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RESOURCE CONSERVATION AND RECOVERY FACILITY INVESTIGATION REPORT ZONE  
K VOLUME 1 OF 5 SECTIONS 1 TO 9 WITH TRANSMITTAL CNC CHARLESTON SC  
6/11/1999  
ENSAFE INC.



DEPARTMENT OF THE NAVY

SOUTHERN DIVISION

NAVAL FACILITIES ENGINEERING COMMAND

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14-Jun-99

Mr. John Litton, P.E.  
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Bureau of Land and Waste Management  
South Carolina Department of Health and Environmental Control  
2600 Bull Street  
Columbia, SC 29201

Subj: SUBMITTAL OF THE FINAL ZONE K RCRA FACILITY INVESTIGATION  
REPORT

Dear Mr. Litton:

The purpose of this letter is to submit the enclosed Final Zone K RFI Report for Naval Base Charleston. The revised report is submitted to fulfill the requirements of condition IV.E.2 of the RCRA Part B permit issued to the Navy by the South Carolina Department of Health and Environmental Control and the U.S. Environmental Protection Agency (USEPA).

The Navy requests that the Department and the USEPA review and provide comment or approval whichever is appropriate. If you should have any questions please contact Billy Drawdy at (843) 743-9985 or myself at (843) 820-5543.

Sincerely,

DAVID P. DODDS  
Remedial Project Manager  
Environmental Department

Encl:

(1) Final Zone K RFI Report, EnSafe, dated 11 June 1999

Copy to:

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**COMPREHENSIVE LONG-TERM  
ENVIRONMENTAL ACTION NAVY  
CHARLESTON NAVAL COMPLEX  
NORTH CHARLESTON, SOUTH CAROLINA  
CTO-029**



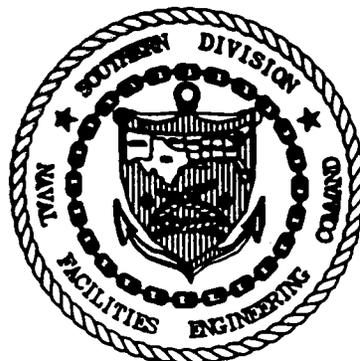
**ZONE K  
RCRA FACILITY INVESTIGATION REPORT**

**VOLUME I OF V  
SECTIONS 1 TO 9**

**SOUTHDIV CONTRACT  
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**Prepared for:**

**DEPARTMENT OF THE NAVY  
SOUTHERN DIVISION  
NAVAL FACILITIES ENGINEERING COMMAND  
NORTH CHARLESTON, SOUTH CAROLINA**



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**June 11, 1999  
Revision: 0**

**Release of this document requires prior notification of the Commanding Officer of the Southern Division, Naval Facilities Engineering Command, North Charleston, South Carolina.**

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## ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR CHARLESTON NAVAL COMPLEX ZONE K

%D	percent difference
%RSD	percent relative standard deviation
AA	Atomic Absorption
AEC	Area of Ecological Concern
ALs	Action Levels
AOC	Area of Concern
AST	Aboveground Storage Tank
AWQC	Ambient Water Quality Criteria
BAFs	Bioaccumulation Factors
B(a)P	Benzo(a)pyrene
BEQs	Benzo(a)pyrene equivalents
BEST	Building Economic Solutions Together
bgs	Below Ground surface
BOS	Bottom of Screened Interval
BOW	Bottom of Well (end cap)
BRA	Baseline Risk Assessment
BRAC	Base Closure and Realignment Act
CAC	Cation Exchange Capacity
CAMU	Corrective Action Management Unit
CAS	Chemical Abstract Service
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity
CLEAN	Comprehensive Long-term Environmental Action Navy
CLP	Contract Laboratory Program
cm/s	Centimeters per second
CMS	Corrective Measures Study
CNC	Charleston Naval Complex
COC	Chemical of Concern
COPC	Chemical of Potential Concern
cPAHs	Carcinogenic Polynuclear Aromatic Hydrocarbons
CPSS	Chemicals Present in Site Samples
Cr III	Trivalent chromium
Cr VI	Hexavalent Chromium
CSAP	Comprehensive Sampling and Analysis Plan
CSI	Confirmatory Sampling Investigation
CSO	Caretaker Site Office
CT	Central Tendency

**ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR  
CHARLESTON NAVAL COMPLEX ZONE K (Continued)**

DAF	Dilution Attenuation Factor
DPT	Direct-push Technology
DQO	Data Quality Objective
DRO	Diesel Range Organics
DTW	Depth to Groundwater
ECPC	Ecological chemicals of Potential Concern
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESA	Ecological Study Area
ESDSOPQAM	Environmental Services Division, Standard Operating Procedures and Quality Assurance Manual
FI/FC	Fraction Ingested/Fraction Contacted
$f_{oc}$	Fraction Organic Content
ft/d	feet per day
g	Gram
gpm	gallons per minute
GRO	Gasoline Range Organics
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HSA	Hollow-Stem Auger
HSWA	Hazardous and Solid Waste Amendments
HTTD	High-Temperature Thermal Desorption
i	Horizontal Hydraulic Gradient
ICAP	Inductively Coupled Argon Plasma
ICM	Interim Corrective Measures
ICP	Inductively Coupled Plasma
ID	Inner Diameter
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
$K_{oc}$	Organic Carbon/Water Partitioning Coefficient
$K_d$	Normalized Partitioning Coefficient
$K_h$	Horizontal Hydraulic Conductivity
$K_v$	Vertical Hydraulic Conductivity (permeability)

**ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR  
CHARLESTON NAVAL COMPLEX ZONE K (Continued)**

LOAEL	Lowest-Observed-Adverse-Effect Level
LTTD	Low-Temperature Thermal Desorption
LWA	Lifetime-weighted Average
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
mg/kg	milligram per kilogram
mg/m <sup>3</sup>	milligrams per cubic meter
MOMAG	Mobile Mine Assembly Group
msl	mean sea level
n	porosity (decimal fraction)
NA	Not applicable/not available
ND	Nondetect/ not determined
n <sub>e</sub>	Effective porosity
NFI	No further investigation
ng/kg	Nanograms per kilogram
ng/mL	Nanograms per milliliter
NOAEL	No-observed-adverse-effect level
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PCBs	Polychlorinated Biphenyls
PCE	Tetrachloroethene
PDE	Potential Dietary Exposure
PE	Performance Evaluation
pg/L	picograms/liter
ppm	parts per million
PQLs	Practical Quantitation Limits
PRG	Preliminary Remediation Goal
psi	Pounds Per Square Inch
PVC	Polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
Qcs	Quaternary Clayey Sand and Clay
Qs	Quaternary Sand

**ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR  
CHARLESTON NAVAL COMPLEX ZONE K (Continued)**

R	Retardation Factor
RAB	Restoration Advisory Board
RBC	Risk-based Concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RfD	Reference Dose
RFI	RCRA Facility Investigation
RGO	Remedial Goal Option
RME	Reasonable Maximum Exposure
RPM	Remedial Project Manager
RRF	Relative Response Factor
RTE	Rare, Threatened, Endangered
SAS	Special Analytical Services
SCDHEC	South Carolina Department of Health and Environmental Control
SCDM	Superfund Chemical Data Matrix
SCWMRD	South Carolina Wildlife and Marine Resources Department
SESE	Shipboard Electronics System Evaluation
SF	Slope Factor
SMCL	Secondary Maximum Contaminant Level
SOUTHDIV	Southern Division Naval Facilities Engineering Command
SQL	Sample Quantitation Limit
SSL	Soil Screening Level
SSV	Sediment Screening Value
SVE	Soil-Vapor Extraction
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
Ta	Ashely Formation
TCE	Trichloroethene
TEC	Toxicity Equivalency Quotients
TEF	Toxicity Equivalency Factor
TEQ	2,3,7,8-TCDD Equivalency Quotients
THQ	Target Hazard Quotient
TOC	Top of Well Casing
TOS	Top of Screened Interval
TPH	Total Petroleum Hydrocarbon
TRV	Toxicity Reference Value
TS	Treatability Study
TTAL	Treatment Technique Action Level
TU	Treatment Units

**ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR  
CHARLESTON NAVAL COMPLEX ZONE K (Continued)**

UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
USF&WS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
UST	Underground Storage Tank
UV	Ultraviolet
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
$\mu\text{g/L}$	microgram per liter
$\mu\text{g/kg}$	micrograms per kilogram

**ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR  
CHARLESTON NAVAL COMPLEX ZONE K (Continued)**

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## **1.0 INTRODUCTION**

The environmental investigation and remediation at Charleston Naval Complex (CNC) are required by the Hazardous and Solid Waste Amendments (HSWA) portion of the Resource Conservation and Recovery Act (RCRA) Part B permit. These conditions are consistent with RCRA Corrective Action Program objectives to evaluate the nature and extent of any hazardous waste or constituent releases and to identify, develop, and implement appropriate corrective measures to protect human health and the environment. The scope of the RCRA Facility Investigation (RFI) includes the entire naval base, which has been divided into Zones A through L to accelerate the RFI process. This Zone K RFI Report, prepared by EnSafe Inc. (EnSafe), is submitted to satisfy the HSWA portion of the Part B permit dated September 1998.

Zone K includes the following noncontiguous CNC properties (Figure 1-1): (1) the Naval Annex, (2) the Clouter Island property, (3) the Short Stay facility, (4) the Sullivans' Island Shipboard Electronics Systems Evaluation (SESE) facility, and (5) the Downtown Degaussing Station.

### **1.1 CNC Description and Background**

#### **Location and History**

The Naval Annex is north/northwest of CNC and is bounded to the north by Airport Road, to the east by I-26, to the south by Air Park Road, and to the west by the Charleston Air Force Base (Figure 1-2). Naval Annex is a flat-lying area, approximately 40 feet above mean sea level (msl). The property now occupied by Naval Annex has a diverse history of occupation. Aerial photographs indicate the Naval Annex area consisted of open spaces and forested areas prior to 1941. During World War II, the Naval Annex was owned by the Air Force and was the location of a weather forecasting facility. According to historical documents provided by the Air Force, it was turned over to the 792nd Squadron of the Tactical Air Command in 1954. From 1954 until 1981, Naval Annex was an operating radar station. In 1981, the radar station was dismantled, and the entire Naval Annex was acquired by Naval Station Charleston. Mobile Mine Assembly Group

11 (MOMAG 11) assumed operations on the property at that time. Aerial photographs and maps indicate that the Naval Annex was fully developed by 1960.

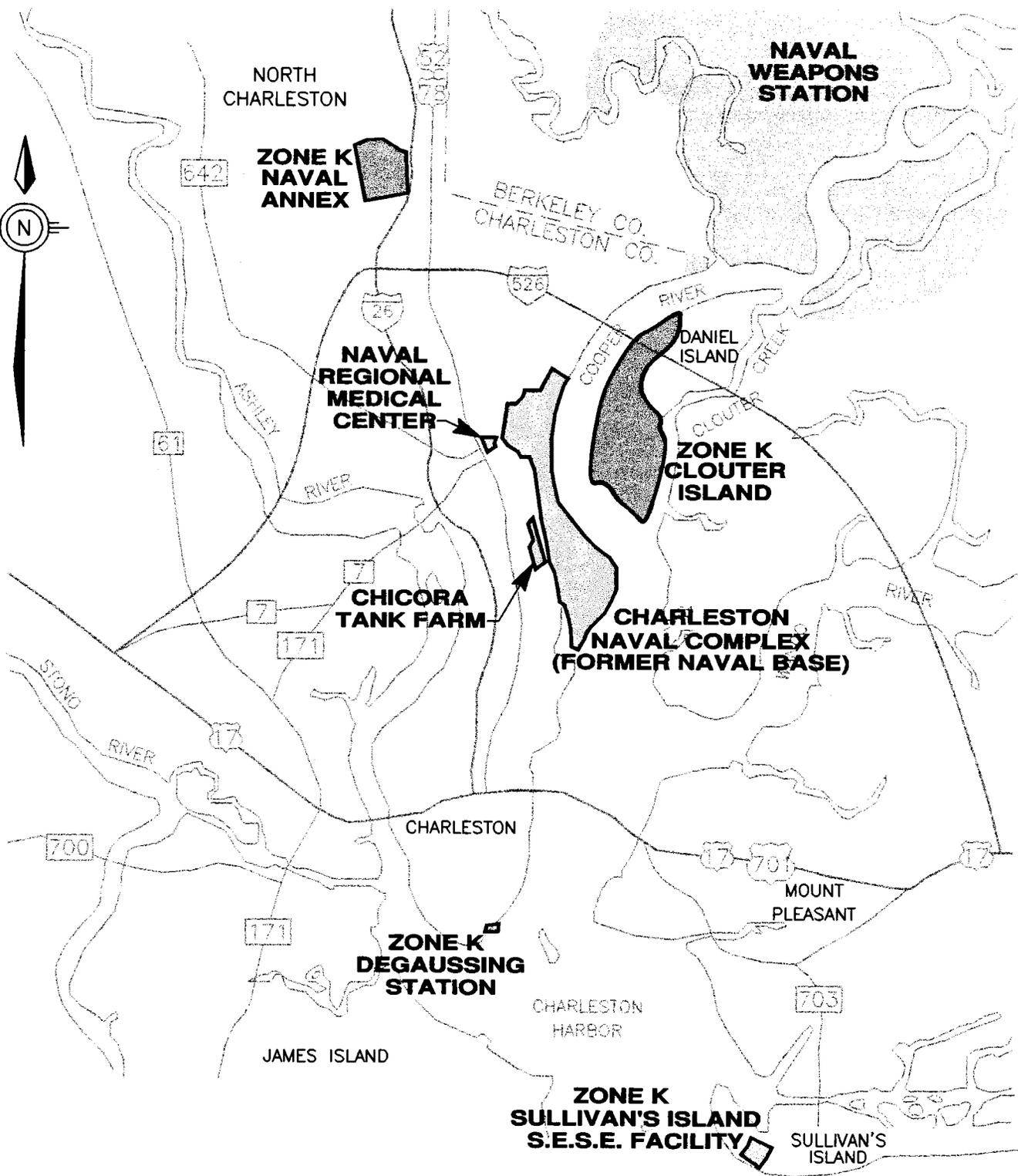
Clouter Island is across the Cooper River from CNC and is bounded by Cooper River and Clouter Creek (Figure 1-3). Clouter Island is undeveloped and is primarily used for dredge spoil disposal. An approximately 1,400-acre portion of Clouter Island on the eastern side of the Cooper River directly across from CNC has been reserved by the U.S. Navy for dredge spoil deposition. Clouter Island is flat, with low elevations, similar to CNC. A portion of Clouter Island has been altered by dredge spoil disposal practices. A dike, designed to retain liquified spoils during deposition and allow spoil dewatering, encloses most of the southern end of Clouter Island. This dike parallels the Cooper River shoreline a short distance toward the interior of the island. The dike has modified the former natural dendritic drainage pattern observed in 1941 aerial photographs of the area. The island's interior drains through constructed dewatering spillways. Ground surface within the dredge spoil area has been raised through spoil deposition.

### **Base Closure**

In 1993, CNC Charleston was added to the list of bases scheduled for closure under the Defense Base Closure and Realignment Act (BRAC), which regulates property closure and transition to the community. Following the April 1, 1996 closure, operations have been scaled back and environmental cleanup has begun to make the property available for redevelopment.

### **1.2 Base Closure Process for Environmental Cleanup**

Section 1.2 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the base closure process for environmental cleanup.



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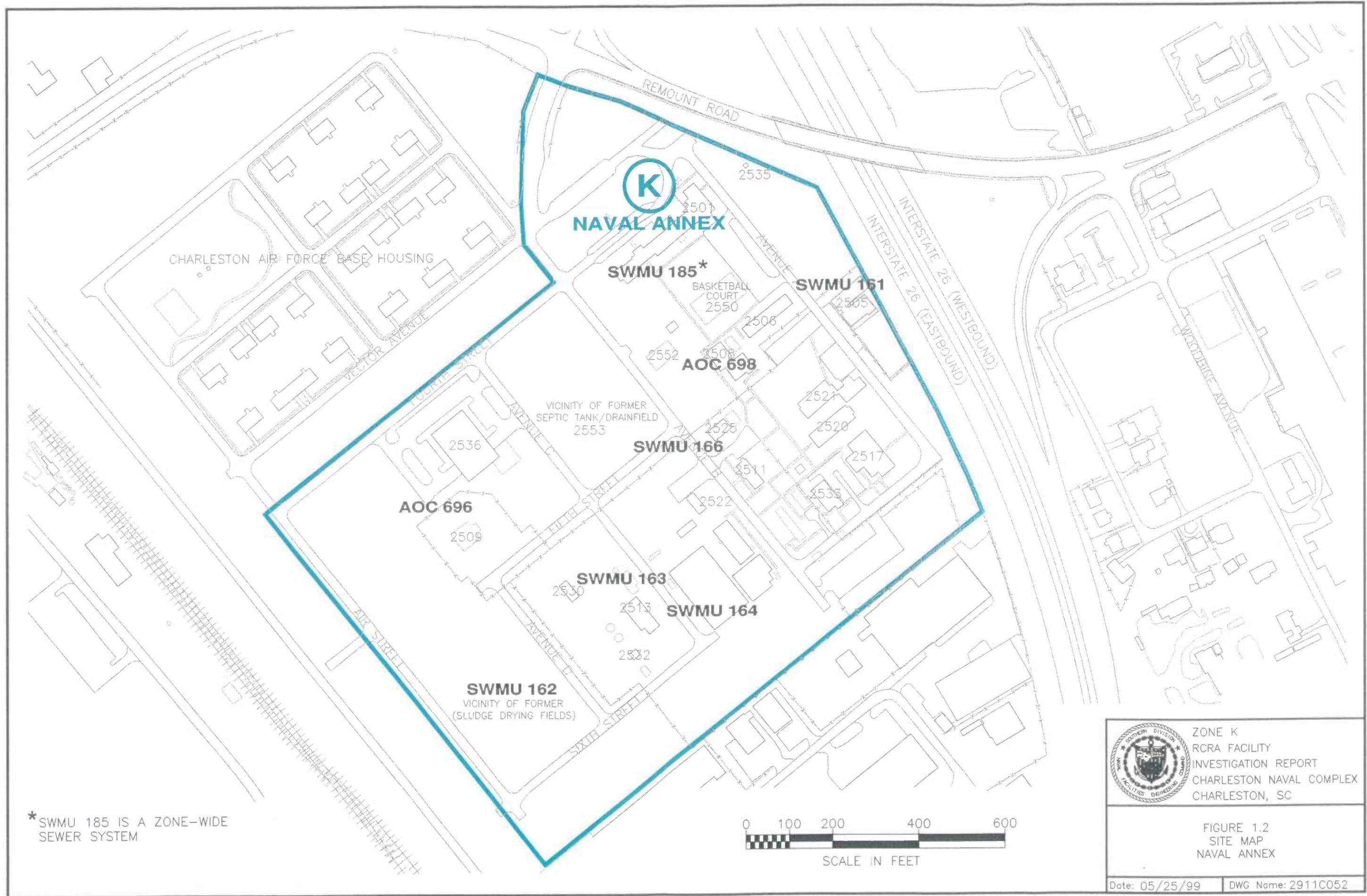
ZONE K  
RCRA FACILITY  
INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX  
CHARLESTON, SC

FIGURE 1.1  
LOCATION OF CHARLESTON NAVAL  
COMPLEX, NAVAL ANNEX  
CLOUTER ISLAND AND  
SURROUNDING AREAS

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**K**

**NAVAL ANNEX**

**SWMU 185\***

BASKETBALL COURT  
2550

**SWMU 161**

**AOC 698**

VICINITY OF FORMER  
SEPTIC TANK/DRAINFIELD  
2553

**SWMU 166**

**AOC 696**

**SWMU 163**

**SWMU 164**

**SWMU 162**  
VICINITY OF FORMER  
(SLUDGE DRYING FIELDS)

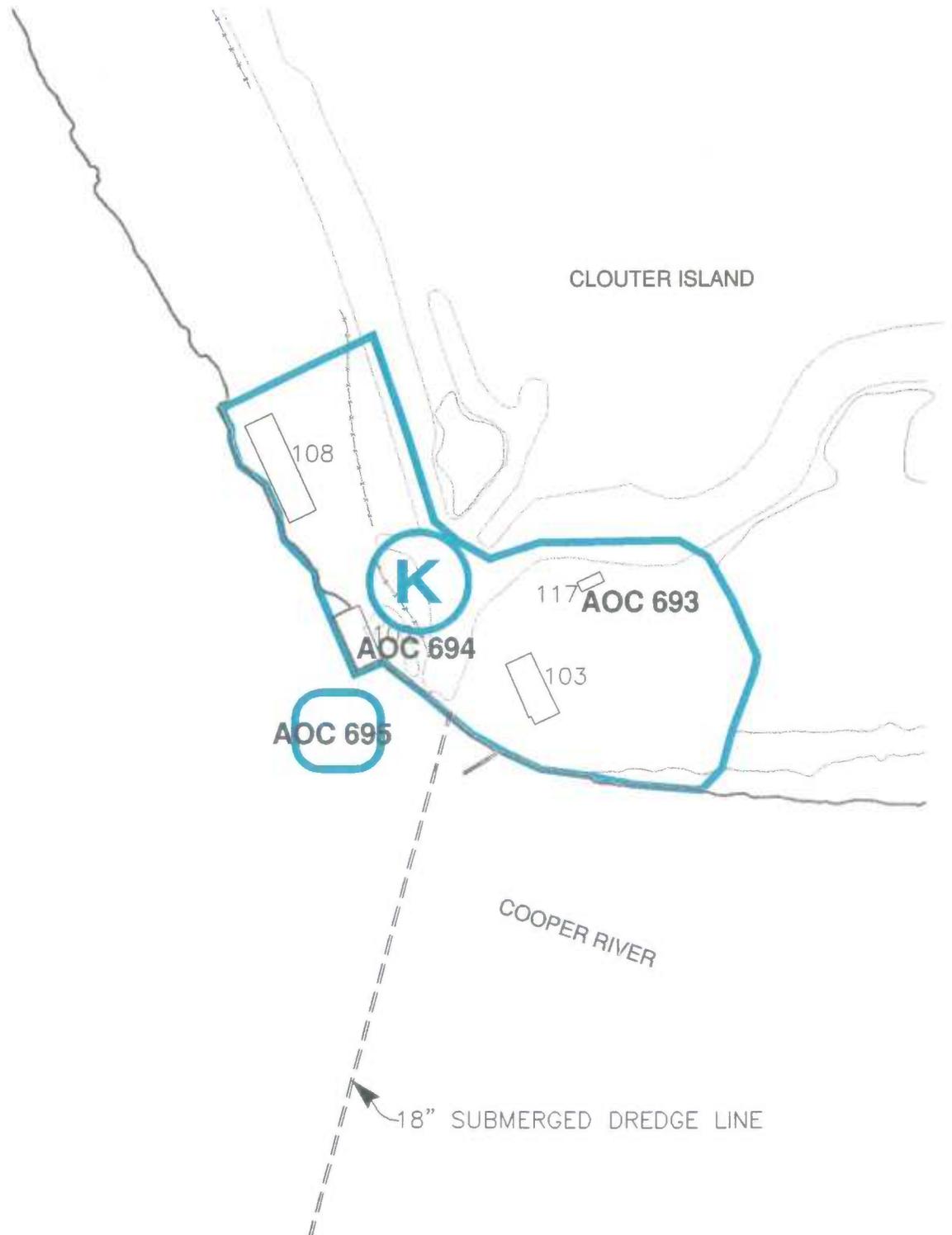
\* SWMU 185 IS A ZONE-WIDE SEWER SYSTEM




**ZONE K**  
 RCRA FACILITY  
 INVESTIGATION REPORT  
 CHARLESTON NAVAL COMPLEX  
 CHARLESTON, SC

**FIGURE 1.2**  
 SITE MAP  
 NAVAL ANNEX

00222 HM012



SCALE IN FEET



ZONE K  
RCRA FACILITY  
INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX  
CHARLESTON, SC

FIGURE 1.3  
SITE MAP  
CLOUTER ISLAND

Date: 05/24/99

DWG Name: 2911C066

### **1.3 Investigative Zone Delineation**

Due to the size of the base and the level of detail required for investigations, CNC has been divided into 12 investigative zones, identified as A through L. The Zone K areas are identified on Figure 1-1.

The zone investigations and cleanups were ranked by the Restoration Advisory Board (RAB) and the Building Economic Solutions Together (BEST) committee (a state-authorized board that studies and reports on the best reuse options for the property being transferred). In 1994, BEST was replaced by the Charleston Naval Complex Redevelopment Authority, which has authority to establish leases for the transferred property.

Of the five noncontiguous CNC properties, only the Naval Annex and the Clouter Island property have sites which require an RFI or confirmatory sampling investigation (CSI) as determined by the *Final RCRA Facility Assessment* (RFA) for Naval Base Charleston (E/A&H, June 1995). Sites at the Short Stay facility, the SESE facility, and the Downtown Degaussing Station were recommended for no further investigation (NFI) (E/A&H, June 1995) and will not be included in this RFI report.

### **1.4 Current Investigation**

#### **Objective**

RFI objectives are to characterize the nature and extent of contaminants associated with releases from solid waste management units (SWMUs) and areas of concern (AOCs), to evaluate contaminant migration pathways, and to identify both actual and potential receptors. The ultimate goal is to determine the need for interim corrective measures (ICMs) or a corrective measures study (CMS). This need will be determined by conducting a baseline risk assessment (BRA) to assess the risks posed to human health and the environment by individual sites or groups of sites within a zone.

## Scope

Fifteen sites (12 at Naval Annex and three on Clouter Island) were identified in Zone K through the RFA process. Each Zone K site is detailed in the *Final RCRA Facility Assessment* (E/A&H, June 1995). Recommendations for the investigative approach to be taken at each site were based on the best information available at that time and are subject to change should more information become available.

The investigatory designations are as follows:

- **No Further Investigation (NFI)** — This designation was applied to an AOC or SWMU if sufficient data were available during the RFA process to thoroughly assess the potential hazards associated with the site and to determine that it does not pose a threat to human health or the environment.
- **Confirmatory Sampling Investigation (CSI)** — This designation was applied to an AOC or SWMU if insufficient data were available during the RFA process to thoroughly assess the potential hazards associated with the AOC or SWMU. Generally, a limited amount of confirmatory samples are needed to determine whether a hazard exists. Confirmatory sampling results will be used to determine whether a NFI designation is appropriate or a full-scale RFI is warranted.
- **RFI** — This approach was used for AOCs or SWMUs if visual evidence, historical information such as spill reports, or analytical data indicate that hazardous substances have been released to the environment. An RFI is used to characterize the site to determine the nature and extent of contamination, to identify migration pathways, to identify actual and potential receptors, and to evaluate ecological and human health risks posed by the site.

Of the 15 SWMUs and AOCs identified in the RFA, 10 required further investigation. The final Zone K RFI work plan outlined an investigative strategy for each of the 10 sites designated for a CSI or RFI. Due to the presence of trichloroethene (TCE) in groundwater, a new SWMU was identified at the Naval Annex, the Automobile Service Shop, (the trichloroethene was discovered during sampling activities for SWMU 166 [the Sewer System and Former Septic Tank and Associated Drainfield]). The Automobile Service Shop has been designated SWMU 166 and the Sewer System and Former Septic System and Associated Drainfield formerly known as SWMU 166 is now SWMU 185. Due to continuing sampling to define the extent of the TCE contaminant plume at SWMU 166, the SWMU 166 and SWMU 185 portion of this final RFI report will be included as an addendum to the Zone K RFI when the investigation is complete. Eight of the sites requiring further investigation are located at Naval Annex (Figure 1-2) and the other three are located at Clouter Island (Figure 1-3). This RFI addresses all 11 sites. Table 1.1 summarizes each Zone K SWMU and AOC requiring further investigation and its investigative approach.

**Table 1.1**  
**Zone K SWMUs and AOCs with Investigatory Designations**

Zone K AOCs and SWMUs	Site Description	Investigative Approach	Investigation Grouping
SWMU 161	Vehicle Maintenance Shop, Naval Annex	CSI	Investigated independently
SWMU 162	Sludge Drying Field and Associated Sewage Treatment Facility	CSI	Investigated independently
SWMU 163	Concrete Pit Area	CSI	Investigated independently
SWMU 164	Blasting Operation	CSI	Investigated independently
SWMU 166	Automobile Service Shop	RFI	Investigated independently
SWMU 185	Sewer System and Former Septic Tank and Associated Drainfield	CSI	Investigated independently
AOC 693	Fuse and Primer House, Former Building 117	CSI	Investigated with 694
AOC 694	Former Naval Ammunition Depot	CSI	Investigated with 693

**Table 1.1**  
**Zone K SWMUs and AOCs with Investigatory Designations**

<b>Zone K AOCs and SWMUs</b>	<b>Site Description</b>	<b>Investigative Approach</b>	<b>Investigation Grouping</b>
AOC 695	Electric Locomotive Shed, Former Building 119	CSI	Investigated independently
AOC 696	Transformer Area Near Building 2509	CSI	Investigated independently
AOC 698	Boiler House, Building 2508	RFI	Investigated independently

### 1.5 Previous Investigations 1

In addition to data generated during this investigation, information from previous Zone K 2  
 investigations was reviewed for this report and incorporated where appropriate. The Zone K sites 3  
 for which previous data were available are discussed as follows. 4

At AOC 696, Transformer Area near Building 2509, samples of the transformer fluid were 5  
 collected in 1991 and determined to contain less than 50 parts per million (ppm) polychlorinated 6  
 biphenyls (PCBs). However, transformer liquid samples collected in 1997 resulted in two of the 7  
 three transformers containing PCB levels exceeding 50 ppm. An Interim Measure for this AOC 8  
 was completed in November 1997 (Environmental Detachment Charleston, 1998) and is discussed 9  
 further in Section 10.8. 10

### 1.6 RFI Report Organization 11

To facilitate review of the RFI report, sections have been organized to discuss zone-wide 12  
 information, overall technical approach, and evaluation methodologies first. These general 13  
 sections are sequenced according to the natural progression of an RFI investigation. 14

The zone-wide sections are:	1
1.0 INTRODUCTION	2
2.0 PHYSICAL SETTING	3
3.0 FIELD INVESTIGATION	4
4.0 DATA VALIDATION	5
5.0 METHODOLOGY FOR DETERMINING NATURE AND EXTENT OF CONTAMINATION	6 7
6.0 FATE AND TRANSPORT	8
7.0 HUMAN HEALTH RISK ASSESSMENT	9
8.0 ECOLOGICAL RISK ASSESSMENT	10
9.0 CORRECTIVE MEASURES	11
 The site-specific sections are:	 12
10.0 SITE-SPECIFIC (SWMU and AOC) EVALUATIONS	13
11.0 CONCLUSIONS	14
 followed by:	 15
12.0 REFERENCES	16
13.0 SIGNATORY REQUIREMENT	17

Section 10 follows the same sequence as Sections 1 through 9 (zone-wide) except on a site-specific basis. The section is subdivided by specific AOCs or SWMUs and includes the actual data summaries, risk calculations, and corrective measures evaluations specific to that site. In this

manner, the entire investigation sequence, including conclusions, is contained within a specific 1  
tabbed section for easy reference. 2

Section 11 summarizes the conclusion from each Section 10 site-specific evaluation. This 3  
organization makes it easy to determine which sites have been recommended for the CMS and 4  
which are recommended for no further action. Section 12 is a compilation of references. 5

<b>2.0</b>	<b>ZONE K PHYSICAL SETTING</b>	1
<b>2.1</b>	<b>Regional Geology</b>	2
<b>2.1.1</b>	<b>Regional Physiographic and Geologic Setting</b>	3
	The regional physiographic and geologic setting for the Charleston area is described in Section 2.1.1 in the Zone A Final RFI report. Local topography of Clouter Island and Naval Annex are presented on Figures 2-1 and 2-2, respectively.	4 5 6
<b>2.1.2</b>	<b>Regional Hydrology and Hydrogeology</b>	7
	The regional hydrology and hydrogeology Charleston area are also described in the Zone A Final RFI report. Major surface water features associated with Clouter Island and Naval Annex are shown on Figures 2-1 and 2-2, respectively.	8 9 10
<b>2.2</b>	<b>Zone K Geologic Investigation</b>	11
	Clouter Island and Naval Annex facilities were investigated separately as part of the Zone K geologic investigation. Geological and stratigraphic information has been obtained from RFI soil and monitoring well borings. Lithologic samples were classified and logged by an EnSafe geologist as described in the <i>Final Comprehensive Sampling and Analysis Plan RCRA Facility Investigation</i> (E/A&H, August 1994) (CSAP). Undisturbed thin-walled Shelby tubes were collected during soil sampling for analysis of geotechnical parameters and soil characteristics by a certified geotechnical laboratory.	12 13 14 15 16 17 18
	<b>Clouter Island</b>	19
	Clouter Island is directly east across the Cooper River from CNC. As a result, the lithology and stratigraphy of the sediments underlying Clouter Island are expected to be similar to those encountered at CNC. Naturally deposited sediments at CNC typically consist of fine to medium sand with varying amounts of silt and clay to a depth of 20 to 105 feet below ground surface (bgs).	20 21 22 23

Below these sediments, the lithology typically changes to a dense, slightly calcareous clayey silt, which is referred to as the Ashley Formation.

### Naval Annex

Based on pre-RFI boring log data obtained from Navy archives (Maps 2505-4 and 2556-27), the sediments underlying Naval Annex consist of a light gray fine sand to a depth of approximately 25 feet to 40 feet. A soft to very stiff inorganic clay is present at a depth of 25 feet to 40 feet (bgs) at Naval Annex. No background lithologic data are available for sediments lower than 40 feet bgs at Naval Annex.

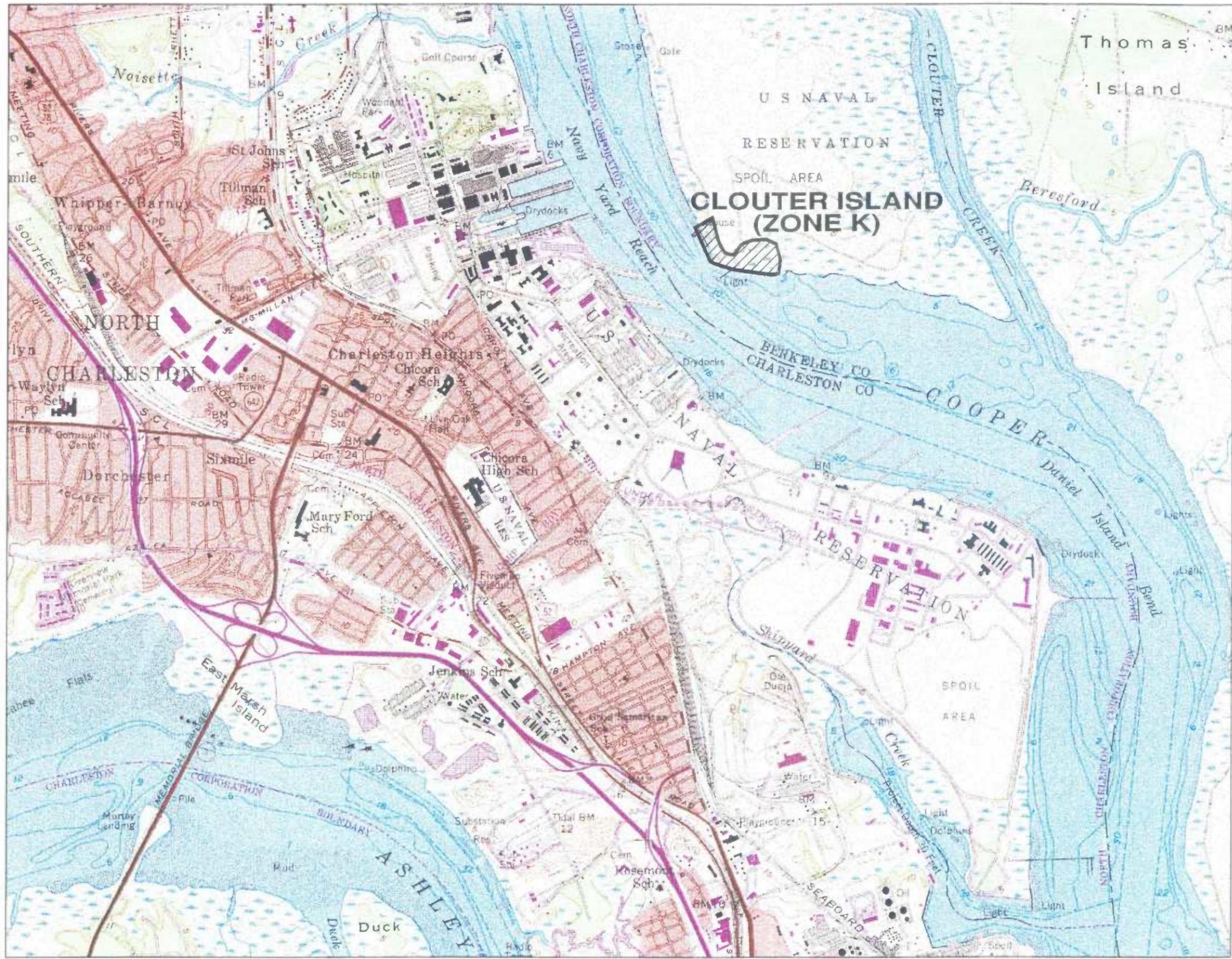
According to the *Final RCRA Facility Investigation Work Plan for Charleston Air Force Base, Charleston, South Carolina* (AFCEE, 1993) the sediments present near Naval Annex are part of the Ten Mile Hill beds. The clean sand facies of the Ten Mile Hill beds is a dark-yellowish-orange, fine- to medium-grained, crossbedded sand which mostly occurs at elevations of 35 to 50 feet mean sea level (msl). The Ten Mile Hill beds unconformably overlie the Ashley Formation.

### 2.2.1 Monitoring Wells

#### 2.2.1.1 Clouter Island

Seven temporary monitoring wells were installed on Clouter Island in April 1997. The temporary wells were installed using a 2.5-inches inner diameter (ID) stainless steel hand auger and bored to depths between 6.5 to 10.5 feet bgs. The screened sections of these wells only penetrated the upper 2 to 3 feet of saturated material.

Construction data for the temporary wells are summarized in Table 2.1. Figure 2-3 identifies the temporary well locations. Lithologic boring logs and construction diagrams for the Clouter Island temporary wells are presented in Appendix A.



ZONE K  
RCRA FACILITY  
INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX  
CHARLESTON, SC

FIGURE 2.1  
TOPOGRAPHY OF  
CLOUTER ISLAND  
AND  
SURROUNDING AREAS

00332 114022



**Table 2.1**  
**Clouter Island Well Construction Data Summary**

Well ID	Installation Date	Drilled Data (bgs)			DTW * (feet)
		TOS	BOS	BOW	
NBCKGDKCL1	4/17/97	4.0	6.5	6.8	4.16
NBCK694002	4/17/97	7.2	9.7	9.8	6.41
NBCK694003	4/17/97	7.9	9.9	10.5	7.02
NBCK694004	4/17/97	4.4	6.4	7.0	4.06
NBCK694005	4/17/97	4.5	5.9	6.5	4.11
NBCK694006	4/17/97	5.2	6.6	7.2	1.63
NBCK694007	4/17/97	4.9	6.3	6.9	1.86

**Notes:**

- bgs = below ground surface
- TOS = Top of screened interval
- BOS = Bottom of screened interval
- BOW = Bottom of well (end cap)
- DTW\* = Depth to groundwater from top of well casing; these depths should only be considered approximate since groundwater depths vary seasonally and diurnally (4/21/97 data presented).

**2.2.1.2 Naval Annex**

The initial phase of the hydrologic investigation at Naval Annex consisted of 31 groundwater samples collected in November 1996 using direct-push technology (DPT) (i.e., Geoprobe). These samples were collected just below the water table as part of the SWMU 166 RFI sampling plan. Sample results indicated one area of TCE contamination.

In December 1996, the first monitoring well drilling phase occurred at SWMUs 161, 162, 163, 166 (185), and AOC 698, and two background locations with the installation of eight shallow wells using hollow-stem auger (HSA) drilling techniques. The shallow wells were installed such that the screened intervals intersected the water table. The TCE contamination detected during the first Geoprobe investigation was further delineated in subsequent DPT phases between February and August 1997 with the collection of groundwater samples from an additional 62 DPT

locations. Shallow, intermediate, and deep groundwater samples were collected at each of these 1  
locations from approximately 10, 20, and 30 feet bgs, respectively. At six of the additional 62 2  
DPT sample locations, soil was continuously sampled to approximately 35 feet bgs to characterize 3  
the lithology. 4

After the extent of TCE contamination in groundwater was defined by DPT screening samples, 5  
11 deep and seven shallow monitoring wells were installed on Naval Annex property during the 6  
second well installation phase in May 1997. Deep wells were installed in the lower portion of the 7  
surficial aquifer, while the seven shallow wells were installed in its upper portion. Rotasonic 8  
drilling was used for both shallow and deep well installation. Figure 2-4 identifies all Naval 9  
Annex monitoring well locations and Geoprobe locations. 10

In December 1997 and January 1998, nine shallow and deep well pairs were installed. Seven were 11  
installed offsite and two were installed on the Naval Annex. 12

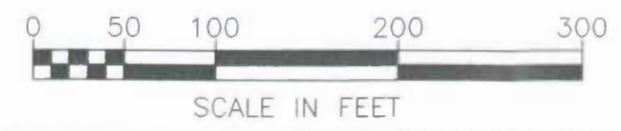
In June 1998, a third phase of monitoring well installation was conducted to provide additional 13  
deep wells upgradient of the TCE plume. Rotasonic drilling techniques were used for these two 14  
deep wells, 16622D and 16623D. 15

Table 2.2 summarizes the monitoring well construction data for Naval Annex. Lithologic and well 16  
construction boring logs from all Naval Annex monitoring wells and deep Geoprobe soil borings 17  
are presented in Appendix A. 18



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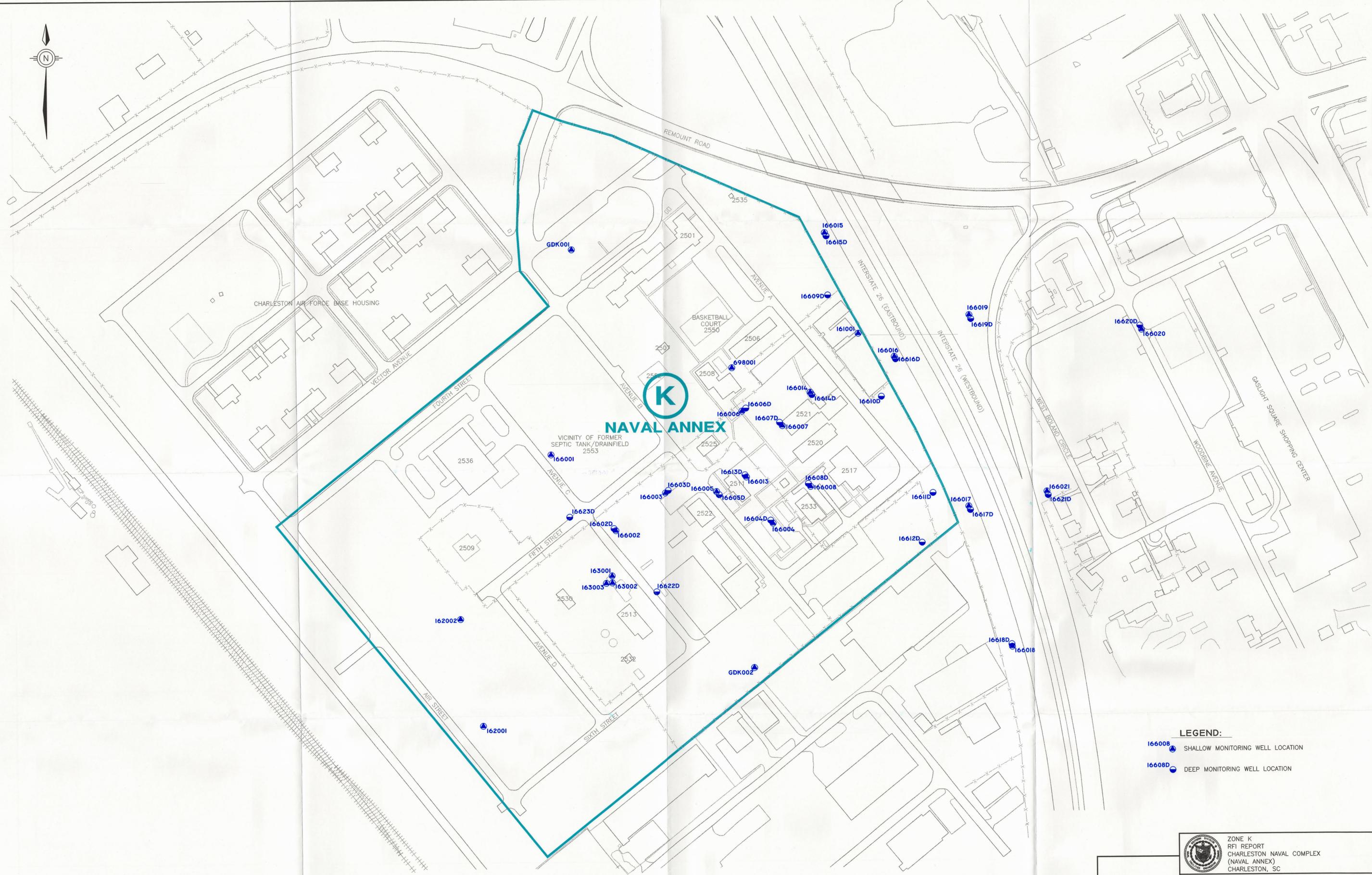
694003 SHALLOW MONITORING WELL LOCATION



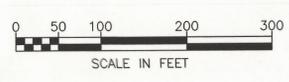
 ZONE K  
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CHARLESTON, SC

FIGURE 2.3  
TEMPORARY WELL LOCATIONS  
CLOUTER ISLAND

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- LEGEND:**
- 166008  SHALLOW MONITORING WELL LOCATION
  - 16608D  DEEP MONITORING WELL LOCATION



REVISIONS		
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 ZONE K RFI REPORT CHARLESTON NAVAL COMPLEX (NAVAL ANNEX) CHARLESTON, SC		
FIGURE 2.4 MONITORING WELL LOCATIONS NAVAL ANNEX		
Dr by: W. FAULK	Tr by: --	
Ck by: S. PARKER	Appr by: T. HAVERKOST	Sheet 1
Date: 05/25/99	DWG Name: 2911C079	Of 1

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**Table 2.2**  
**Naval Annex Well Construction Data Summary**

Well ID	Installation Date	TOC elev. (feet msl)	Ground elev. (feet msl)	Drilled Data (feet bgs)			DTW * (feet)	GW elev. (feet msl)
				TOS	BOS	BOW		
NBCK161001*	12/5/96	41.07	41.2	6.0	15.5	16.0	9.47	31.60
NBCK162001*	12/4/96	38.51	38.5	5.0	14.5	15.0	4.50	34.01
NBCK162002*	12/4/96	42.24	39.8	5.0	14.5	15.0	7.35	34.89
NBCK163001*	12/3/96	42.13	39.6	5.0	14.5	15.0	7.35	34.78
NBCK163002*	1/12/99	43.05	40.0	1.8	11.1	11.8	8.51	34.54
NBCK163003*	1/12/99	42.37	39.8	2.6	11.9	12.6	7.83	34.54
NBCK166001*	12/5/96	41.02	40.8	5.0	14.5	15.0	4.40	36.62
NBCK166002	5/8/97	42.24	41.0	7.0	11.7	12.0	7.43	34.81
NBCK16602D	5/7/97	42.24	40.1	25.1	29.7	31.0	7.42	34.82
NBCK166003	5/9/97	42.51	40.9	7.1	12.1	12.4	7.85	34.66
NBCK16603D	5/8/97	42.51	40.9	28.1	32.7	33.0	7.94	34.57
NBCK166004	5/8/97	42.25	40.5	8.0	12.7	13.0	8.21	34.04
NBCK16604D	5/8/97	42.27	40.7	27.1	31.7	32.0	8.22	34.05
NBCK166005	5/5/97	40.22	41.2	8.0	12.7	13.0	5.71	34.51
NBCK16605D	5/6/97	39.99	41.2	25.0	29.7	30.0	5.60	34.39
NBCK166006	5/12/97	43.21	41.7	7.1	11.7	12.0	9.28	33.93
NBCK16606D	5/12/97	43.11	41.7	25.1	29.7	30.0	9.31	33.80
NBCK166007	5/12/97	43.45	41.8	7.1	11.7	12.0	9.87	33.58
NBCK16607D	5/13/97	41.57	41.8	26.1	30.7	31.0	7.01	34.56
NBCK166008	5/14/97	40.11	41.3	8.1	12.7	13.0	6.59	33.52
NBCK16608D	5/13/97	40.34	41.5	29.1	33.7	34.0	6.81	33.53
NBCK16609D	5/9/97	42.26	40.9	26.1	30.7	31.0	10.37	31.89
NBCK16610D	5/14/97	43.01	41.4	26.1	30.7	31.0	10.94	32.07
NBCK16611D	5/6/97	42.46	40.9	25.1	29.7	30.0	10.31	32.15
NBCK16612D	5/7/97	42.63	41.2	25.1	29.7	30.0	10.02	32.61
NBCK166013	12/17/97	39.41	39.7	9.8	11.2	11.6	4.02	35.39
NBCK16613D	1/14/98	39.61	39.8	29.0	31.1	31.5	4.27	35.34
NBCK166014	1/15/98	40.75	40.9	12.0	13.6	14.0	6.78	33.97
NBCK16614D	12/18/97	40.34	40.9	29.8	31.3	31.7	6.58	34.32
NBCK166015	12/18/97	33.23	33.5	10.0	11.2	11.6	2.05	31.18

**Table 2.2**  
**Naval Annex Well Construction Data Summary**

Well ID	Installation Date	TOC elev. (feet msl)	Ground elev. (feet msl)	Drilled Data (feet bgs)			DTW * (feet)	GW elev. (feet msl)
				TOS	BOS	BOW		
NBCK16615D	1/12/98	33.23	33.5	22.0	23.6	24.0	24.0	31.89
NBCK166016	12/17/97	33.50	33.9	9.5	11.2	11.6	1.01	32.49
NBCK16616D	1/12/98	33.73	34.0	23.3	24.7	25.1	0.04	33.69
NBCK166017	1/6/98	33.95	34.3	9.5	11.2	11.6	6.26	27.69
NBCK16617D	1/13/98	34.22	34.4	23.5	24.8	25.2	0.80	33.42
NBCK166018	1/6/98	35.25	35.6	9.9	11.3	11.7	0.91	34.34
NBCK16618D	1/13/98	35.23	35.5	23.5	25.0	25.4	0.27	34.96
NBCK166019	1/6/98	39.52	40.0	9.9	11.2	11.6	6.26	33.26
NBCK16619D	1/14/98	39.70	40.0	19.9	21.1	21.5	6.39	33.31
NBCK166020	1/6/98	38.00	38.7	9.9	11.4	11.8	1.52	36.48
NBCK16620D	1/14/98	38.37	38.6	24.0	26.1	26.5	3.03	35.34
NBCK166021	1/5/98	39.99	40.4	9.9	11.2	11.6	5.91	34.08
NBCK16621D	1/5/98	40.15	40.4	29.4	30.9	31.3	7.89	32.26
NBCK16622D	6/3/98	42.04	39.8	25.0	29.4	30.0	7.26	34.78
NBCK16623D	6/3/98	40.06	40.3	25.0	29.4	30.0	4.97	35.09
NBCK698001*	12/6/96	43.72	40.9	5.0	14.5	15.0	9.81	33.91
NBCKGDK001*	12/5/96	43.41	40.9	5.0	14.5	15.0	9.00	34.41
NBCKGDK002*	12/3/96	41.66	39.2	5.0	14.5	15.0	7.91	33.75

**Notes:**

- \* = PVC well materials; all others are stainless steel
- msl = mean sea level
- bgs = below ground surface
- TOC = Top of well casing
- TOS = Top of screened interval including sand pack
- BOS = Bottom of screened interval
- BOW = Bottom of well (end cap)
- DTW\* = Depth to groundwater from TOC following construction; these depths should only be considered approximate since groundwater depths vary seasonally and diurnally; they are not synoptic and thus were not used for the construction of potentiometric maps.

**2.2.2 Geotechnical Sampling**

Shelby tube samples, collected as part of the RFI drilling program, were analyzed for porosity, bulk density, grain-size distribution, specific gravity, percent moisture, and vertical permeability. Thin-walled steel tubes were pushed into undisturbed soil using a truck-mounted drill rig. The steel tubes were recovered, sealed, labeled, and retained onsite until transported to the laboratory for analysis. Shelby tube sample intervals were selected for geotechnical analysis based upon areal distribution, lithology type, and sample uniformity. No Shelby tubes were collected during the Clouter Island geologic investigation since the temporary wells were installed by hand. Shelby tube sample laboratory data reports are presented as Appendix B. Table 2.3 summarizes Naval Annex Shelby tube data.

**Table 2.3  
 Geotechnical Data Summary**

Location ID	Depth (ft bgs)	Top elev. (ft msl)	Lith type	K <sub>v</sub> (cm/s)	K <sub>v</sub> (ft/d)	n	% moist	% Sand	% Silt	% Clay
NBCKGDK001	8-10	32.9	Qs	1.20E-03	3.40	43.0	27.6	93.0	4.5	2.5
NBCK161001	10-12	31.2	Qs	1.90E-03	5.39	44.3	28.8	94.0	3.5	2.5
NBCK162001	6-8	32.5	Qs	1.80E-03	5.10	46.9	26.3	94.0	4.0	2.0
NBCK163001	8-10	31.6	Qs	6.30E-04	1.79	45.6	31.1	91.5	1.5	7.0
<i>Mean</i>				<i>1.27E-03</i>	<i>3.59</i>	<i>45.0</i>	<i>28.5</i>	<i>93.1</i>	<i>3.4</i>	<i>3.5</i>
NBCK16610D	30-32	11.4	Qcs	2.70E-04	0.77	40.9	21.8	90	6	4

**Notes:**

- K<sub>v</sub> = vertical hydraulic conductivity (permeability)
  - n = porosity (decimal fraction)
  - cm/s = centimeters per second
  - ft/d = feet per day
  - Qs = Quaternary sand
  - Qcs = Quaternary clayey sand and clay
- All means are arithmetic, except for K<sub>v</sub>, which are geometric means.

### **2.2.3 Zone K Geology**

Only Quaternary and Tertiary-age sediments were encountered during the Zone K RFI. The lowermost stratigraphic unit identified in Zone K is the Ashley Formation member of the Mid-Tertiary age Cooper Group. Overlying the Ashley are primarily younger Quaternary-age stratigraphic units, although some remnant of Upper Tertiary sediments may be present, field identification of these deposits is extremely difficult.

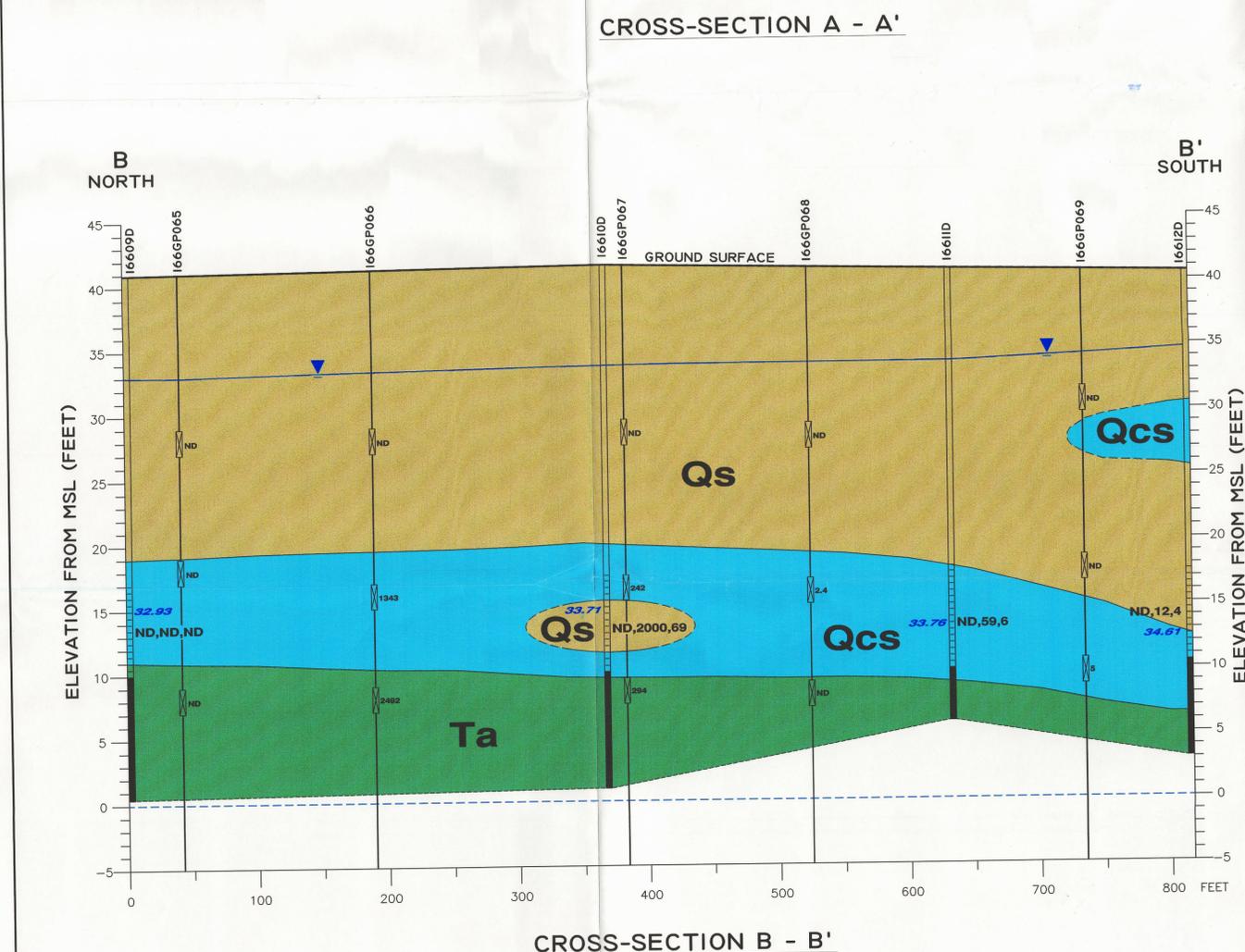
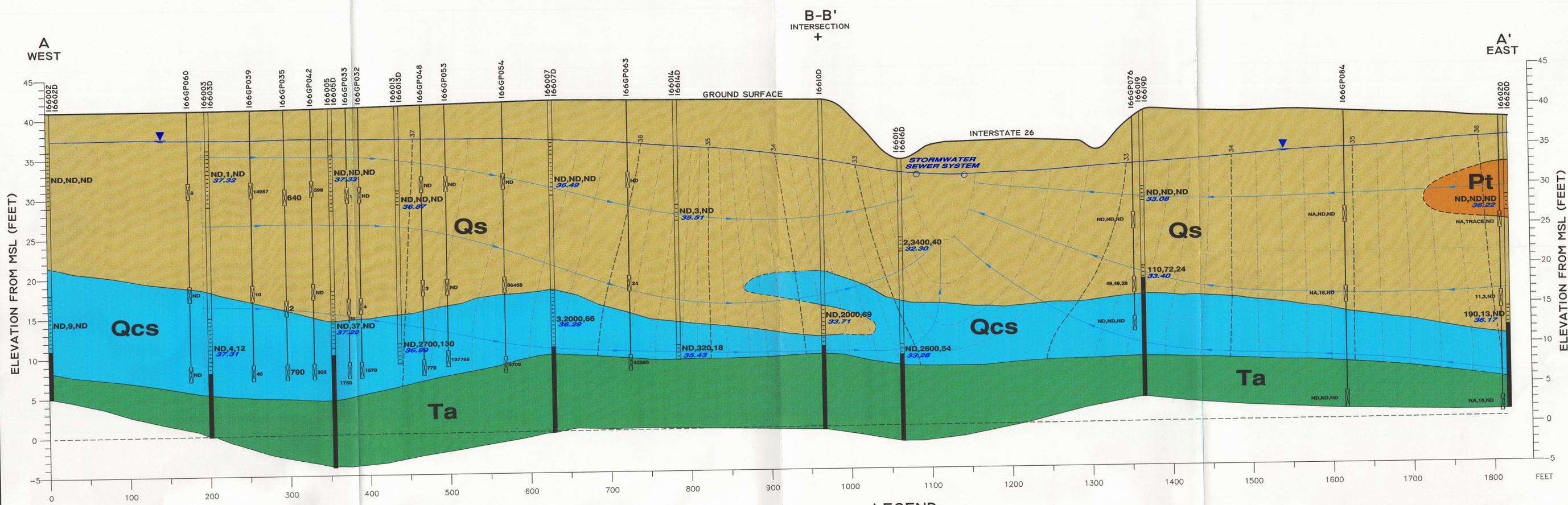
Since the geologic data obtained from the temporary well borings at Clouter Island were limited to the upper 10 feet bgs, no geologic cross sections were prepared for this RFI report. As a result, subsequent discussion of the geologic formations relate to data obtained at Naval Annex.

Stratigraphic units encountered during the RFI are presented in the following sections in ascending order. Geologic cross sections for Naval Annex, developed from split-spoon and rotasonic core sample data, are presented in Figure 2-5.

#### **2.2.3.1 Tertiary-Age Sediments**

##### **Ashley Formation (Ta)**

The oldest sediment encountered during the Zone K RFI investigation has been the Ashley Formation, the youngest member of the Tertiary-age Cooper Group. The Ashley Formation was deposited in an open-marine shelf environment during a rise in sea level in the late Oligocene. Due to successive sea level transgression-regression (rise and fall) sequences during late Tertiary and early Quaternary time, extensive erosion has removed many of the marine and terrigenous deposits overlying the Ashley Formation (Weems and Lemon, 1993).



REVISIONS		
Rev Number	Rev Date	Rev By

Dr by: W. FAULK	Tr by: -
Ck by: T. KAFKA	Appr by: S. PARKER
Date: 05/27/99	DWG Name: 2911C061

FIGURE 2.5  
LITHOSTRATIGRAPHIC  
CROSS-SECTIONS A-A' and B-B'

ZONE K  
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The Ashley Formation is an olive-yellow to olive-brown, tight, slightly calcareous, clayey silt with varying amounts of very fine to fine grained sand that decrease rapidly with depth. It is firm to stiff, low in plasticity, and damp to moist. The Ashley Formation was encountered in most of the deep monitoring wells at the Naval Annex, which were confined to the area associated with SWMU 166 TCE contamination.

Ashley Formation elevations range from 10.9 feet msl at 16609D to 3.8 feet msl at 16622D and were used to construct a contour map of its surface (Figure 2-6). The figure indicates that the unit undulates between slight ridges and troughs at the site. The most notable trough trends generally west to east through deep wells 16603D, 16605D, and 16608D. Elevations increase to the northwest of this central trough to form a slight ridge along the northwestern property boundary adjacent to Interstate-26. Another trough-ridge pattern is visible along the interstate, where low elevations at deep wells 16615D and 16616D rise to the east at 16619D.

### **2.2.3.2 Quaternary-age Sediments**

The Quaternary Period began with the Pleistocene Epoch and continues with the Holocene (Recent) Epoch. During Quaternary time, several marine transgression-regression sequences resulted in a jumbled network of terrace complexes composed of varied coastal depositional environments such as barrier islands, back-barrier lagoons, tidal inlets, and shallow-ocean-marine shelf systems. Due to regional crustal uplift in the Charleston area during the Quaternary, many barrier to back-barrier deposits from high sea level stands are preserved as terraces. However, succeeding transgressions reworked the shallow-marine shelf deposits on the seaward side of each older barrier ridge or island. The result of this erosional and redepositional process of older sediments is that a subsequently younger sequence of deposits may exist on the seaward side, and laterally adjacent to the previous (older) coastal deposit. Therefore, it can be difficult to determine discrete formational units within the Quaternary system. Weems and Lemon (1993) identified and correlated several Quaternary-age formations. However, field identification of these formational units is difficult since many characteristics may only be evident at the microscopic level.

Throughout Naval Annex, Quaternary-age sediments extend from the top of the Ashley Formation to just below ground surface. Based on the 22 deep borings drilled at Naval Annex, these sediments range from approximately 27 feet thick at 16617D to 37 feet thick at 16605D and 16608D. The geologic interpretation of this area in recent reports indicates these deposits to be members of the Ten Mile Hill Beds (Weems and Lemon, 1993; AFCEE, 1993). The Ten Mile Hill Beds are of Pleistocene age and date to approximately 200,000 to 240,000 years ago. Weems and Lemon (1993) used the informal designation of the Ten Mile Hill Beds to differentiate them from the older Ladson Formation, because they represent a younger sea transgression/regression than that recorded by the Ladson Formation. The Ten Mile Hill Beds consist of a sequence of three distinct facies: a clayey sand to sand associated with back-barrier deposits, a clean barrier island sand deposit, and nearshore shelf fossiliferous sand and shell deposit. Due to the difficulty in positively identifying discrete formational units, two Quaternary-age lithostratigraphic units have been correlated for the geologic cross sections presented in this report. They are described as follows:

#### **Quaternary Clayey Sand and Clay (Qcs)**

The Qcs unit typically unconformably overlies the Ashley Formation (Ta) at Naval Annex. This unit generally consists of green to gray-green, fine to coarse, clayey sand with varying amounts of silt. Phosphate nodules from pebble to cobble size and shell hash are often intermixed within the matrix or as distinct basal lenses. Clay lenses, when present, are often green, firm to stiff, and plastic. The deep wells installed at Naval Annex are primarily screened within this unit.

#### **Quaternary Sand (Qs)**

The Qs unit overlies the Qcs unit and extends to ground surface, although smaller Qs lenses may be present at depth. The Qs is a gray, green, brown, and orange fine to medium sand with varying silt content and very distinctive mica content. The unit is marked by a lack of cohesiveness from limited fines content. Shallow wells installed at Naval Annex are screened within the Qs unit.

Figure 2-6 Elevation of Top of Ashley Formation

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Based on geotechnical data obtained from Shelby tube samples, the Qs deposits had an average grain-size composition of 93.1 % sand, 3.4% silt, and 3.5% clay. Porosity estimates ranged from 43.0 to 46.9%.

### **2.2.3.3 Soil**

The Soil Conservation Service of the U.S. Department of Agriculture recently completed the soil mapping of the Charleston Air Force Base area. Fifteen soil types were identified. The surface soils were typically sand and sandy loam, but at depth the clay content generally increases (AFCEE, 1993).

Soils at Clouter Island are expected to be similar to those found at CNC, primarily sandy with varying amounts of silt and clay. As with areas of CNC, Clouter Island soils are heavily influenced by dredge spoil disposal practices.

## **2.3 Zone K Hydrogeologic Investigation**

Zone K's hydrogeology was not assessed using the temporary wells installed on Clouter Island. Hydrogeological information was obtained from slug test analyses and water level measurements during the Naval Annex portion of the RFI. Estimates of vertical permeability, grain-size distribution, and porosity were obtained from laboratory analysis of Shelby tube samples collected during drilling. Only data pertinent to the Quaternary deposits are discussed since they were the only deposits to be sampled and evaluated hydrogeologically at Naval Annex.

### **2.3.1 Local Hydrogeologic Setting**

#### **Clouter Island**

Clouter Island is a north-south trending island bounded on the west by the Cooper River and on the east by Clouter Creek. The interior of Clouter Island near the area considered part of the CNC RFI (southwest corner of the island) is a dredge spoil disposal area. A narrow strip of land

between the spoil disposal area and Cooper River is the location of two of the Clouter Island AOCs. The third AOC is just offshore from the island at the end of a former trestle. There are no perennial surface water drainage features on this part of Clouter Island. The entire area of investigation for Clouter Island is less than 5 feet msl.

Groundwater levels in the temporary wells were from 1 to 5 feet bgs. Given its proximity to the Cooper River, the hydrogeology of the area of Clouter Island sampled during the RFI is expected to be controlled directly by the Cooper River and its tidal fluctuations. Groundwater probably flows in the water table aquifer on Clouter Island toward Cooper River or Clouter Creek. The Ashley Formation, as determined in previous CNC investigations, is expected to be the uppermost, laterally extensive aquitard/confining unit underlying Clouter Island.

### **Naval Annex**

The Naval Annex area is positioned on a surface water drainage divide (Figure 2-2). Surface elevations at Naval Annex are from 40 to 45 feet msl. From this area, surface water would flow south toward Filbin Creek, or north toward Turkey Creek. Filbin Creek flows toward the east and drains into the Cooper River. Turkey Creek flows toward the northeast and drains into Goose Creek, a Cooper River tributary.

Pre-RFI boring log data obtained from Navy archives (Maps 2505-4 and 2556-27) revealed that depth to groundwater at Naval Annex is between 3 feet and 9 feet bgs. Naval Annex is on a topographic high, and groundwater may flow in all directions away from that high. A preliminary United States Geological Survey (USGS) groundwater flow model, which encompasses the Naval Annex area, provided information relative to regional groundwater flow directions at Naval Annex. The model predicted groundwater flow to the north, south, east, and west from Naval Annex. A hydrogeologic cross section presented in the Charleston Air Force Base RFI work plan showed a clay-rich interval of sediment at approximately 20 feet to 30 feet bgs near the South

Carolina Department of Health and Environmental Control (SCDHEC) District Office monitoring well located approximately 750 feet southwest of Naval Annex. Groundwater in this cross section flows toward the west. A potentiometric map included in this same work plan identified groundwater flow in the surficial aquifer toward the west-southwest from Naval Annex (AFCEE, 1993).

### 2.3.2 Surficial Aquifer

The following hydrogeologic data presentation is limited to Naval Annex because Clouter Island's hydrogeology was not assessed.

The unconfined surficial aquifer extends from the water table to the top of the Ashley Formation, the regional confining unit. As shown previously, its elevation varies across Naval Annex at SWMU 166 (Figure 2-6). Table 2.4 summarizes the saturated thicknesses of the surficial aquifer near SWMU 166. Gross aquifer thickness is the potential aquifer thickness from ground surface to the confining unit (Ta).

Saturated thicknesses are highest in the central portion of SWMU 166 near 16603D, 05D, and 08D and decrease to 23 feet near 16609D and 10D. As expected, these greater saturated thicknesses correspond to the NW-SE trending trough in the Ashley Formation shown on Figure 2-6.

**Table 2.4**  
**Aquifer Characteristics at SWMU 166 at the Naval Annex**

Location	Ashley Fm. Elev. (ft msl)	Ground. Elev. (ft msl)	March 1998 Groundwater Elev. (ft msl)	Gross Aquifer Thickness (ft)	Saturated Thickness* (ft)
16602D	7.1	40.1	37.18	33.0	30.0
16603D	4.9	40.9	37.31	36.0	32.4
16604D	7.7	40.7	36.85	33.0	29.2
16605D	4.2	41.2	37.20	37.0	33.0

**Table 2.4**  
**Aquifer Characteristics at SWMU 166 at the Naval Annex**

<b>Location</b>	<b>Ashley Fm. Elev. (ft msl)</b>	<b>Ground. Elev. (ft msl)</b>	<b>March 1998 Groundwater Elev. (ft msl)</b>	<b>Gross Aquifer Thickness (ft)</b>	<b>Saturated Thickness* (ft)</b>
16606D	10.7	41.7	36.79	31.0	26.1
16607D	9.8	41.8	36.29	32.0	26.5
16608D	4.5	41.5	36.22	37.0	31.7
16609D	10.9	40.9	33.95	30.0	23.1
16610D	9.4	41.4	33.71	32.0	24.3
16611D	8.9	40.9	33.76	32.0	24.9
16612D	7.2	41.2	34.61	34.0	27.4
16613D	7.0	39.8	36.99	32.8	30.0
16614D	Blind Drilled	40.9	35.43	Not Determined	
16615D	5.5	33.5	31.11	28.0	25.6
16616D	6.0	34.0	33.28	28.0	27.3
16617D	7.6	34.4	33.52	26.8	25.9
16618D	7.4	35.5	34.33	28.1	26.9
16619D	9.0	40.0	33.40	31	24.4
16620D	6.0	38.6	36.17	32.6	30.2
16621D	Blind Drilled	40.4	31.73	Not Determined	
16622D	3.8	39.8		Not Installed	
16623D	Not Determined	40.3		Not Installed	

**Note:**

\* — Saturated thickness based on 3/6/98 water level measurements.

Table 2.5 lists water level elevations in monitoring wells installed at Naval Annex. It shows that 1  
 water levels have generally risen from May 1997 to March 1998. Water levels were not measured 2  
 during the summer of 1997. Based on monthly precipitation amounts for the Charleston 3

International Airport from the National Climatic Data Center ([www.ncdc.noaa.gov](http://www.ncdc.noaa.gov)), the two-month total for April and May 1997 was 8.65 inches, the two-month total for December 1997 and January 1998 was 12.77 inches and the two-month total for February and March 1998 was 15.68 inches. Each monthly total reflects the month the water level was measured and the preceding month. The May 1997 water level elevations are lower than water levels from the other two measurement events. The precipitation for April and May 1997 is also lower than the amounts for the other two totals. Likewise, the March 1998 water level elevations are generally higher than the others and February and March 1998 precipitation total is higher than the other totals.

**Table 2.5**  
**Groundwater Elevations**  
**Naval Annex, Zone K**

Groundwater Elevation (feet above mean sea level)

Monitoring Well ID	May 21, 1997	Jan. 22, 1998	March 6, 1998
161001	31.62	32.23	32.88
162001	33.90	35.58	35.84
162002	34.83	36.51	36.72
163001	34.67	36.16	36.91
166001	36.30	37.84	39.25
166002	35.92	Not Recorded	37.17
16602D	35.93	Not Recorded	37.18
166003	35.76	36.93	37.32
16603D	35.68	36.89	37.31
166004	35.13	36.51	36.87
16604D	35.15	36.49	36.85
166005	35.51	36.76	37.33
16605D	35.49	36.75	37.20
166006	35.01	36.18	36.96
16606D	34.88	36.04	36.79
166007	34.59	35.79	36.49
16607D	34.56	35.73	36.29
166008	34.62	35.88	36.25

**Table 2.5**  
**Groundwater Elevations**  
**Naval Annex, Zone K**

Groundwater Elevation (feet above mean sea level)

<b>Monitoring Well ID</b>	<b>May 21, 1997</b>	<b>Jan. 22, 1998</b>	<b>March 6, 1998</b>
16608D	34.54	35.75	36.22
16609D	32.96	33.87	33.95
16610D	33.12	33.92	33.71
16611D	33.22	34.19	33.76
16612D	33.69	34.90	34.61
166013	Not Installed	Not Installed	37.06
16613D	Not Installed	Not Installed	36.99
166014	Not Installed	Not Installed	35.51
16614D	Not Installed	Not Installed	35.43
166015	Not Installed	Not Installed	32.93
16615D	Not Installed	Not Installed	31.11
166016	Not Installed	Not Installed	32.30
16616D	Not Installed	Not Installed	33.28
166017	Not Installed	Not Installed	33.15
16617D	Not Installed	Not Installed	33.52
166018	Not Installed	Not Installed	34.13
16618D	Not Installed	Not Installed	34.33
166019	Not Installed	Not Installed	33.08
16619D	Not Installed	Not Installed	33.40
166020	Not Installed	Not Installed	36.22
16620D	Not Installed	Not Installed	36.17
166021	Not Installed	Not Installed	35.11
16621D	Not Installed	Not Installed	31.73
698001	33.91	35.10	Not Recorded
GDK001	34.41	36.20	38.04
GDK002	33.75	35.43	36.31

**Note:**

Deep wells 16622D and 16623D are not included because they were not installed until June 1998

### **2.3.3 Groundwater Flow Direction**

Groundwater levels were measured on March 6, 1998, 16 shallow and 13 deep wells at the Naval Annex and seven shallow and six deep wells east and west of the interstate outside the annex boundary. All wells were first vented and allowed to equilibrate to atmospheric pressure. Water levels were collected within a two-hour period.

Groundwater elevations in the shallow wells represent the water table surface in the surficial aquifer, as shown on Figure 2-7, a piezometric map. High groundwater elevations in the northwestern portion of the annex indicate the presence of a local recharge zone near well 166001. Groundwater flows radially from this high, although its western extent was not defined during this investigation. The presence of the interstate roadcut, which lies approximately 10 feet topographically lower than the annex to the west and 6 feet lower than the land to the east, creates a discharge zone along its axis east of the annex boundary. Groundwater originating east of the interstate flows west toward it before migrating northwest along the interstate axis. Groundwater originating from the annex flows northeast to east toward it before flowing northwest along its axis. The potentiometric low at the interstate is a result of the stormwater sewer system installed as a part of the interstate construction (see Section 10.5.5).

Figure 2-8 depicts the potentiometric contours of the lower portion of the surficial aquifer. The contour pattern for the deep well groundwater elevations is similar, but more subdued than the shallow wells pattern. Groundwater flows southeast to northeast from the annex toward the interstate, where it discharges to the storm sewer system. On the interstate's eastern side, groundwater flows west toward it before discharging to the storm sewer system.

### **2.3.4 Vertical Hydraulic Gradient**

Vertical hydraulic gradients were calculated in the surficial aquifer at 15 shallow/deep well pairs from March 6, 1998 groundwater elevation data. Calculations were made by dividing the

1 difference between groundwater elevations in shallow and deep well pairs by the vertical distance  
2 between the bottom of each respective well screen. Positive values indicate downward vertical  
3 gradients, whereas negative values indicated an upward vertical gradient. Table 2.6 lists each well  
4 pairs calculated vertical hydraulic gradients.

5 Vertical gradients at three of the four well pairs near the interstate indicate an upward hydraulic  
6 gradient. All other vertical gradients at study area well pairs were slightly downward, except for  
7 well pair 002, which was slightly upward.

8 The magnitude of the vertical gradients at locations away from the interstate were small, indicating  
9 that groundwater flow in these areas is primarily horizontal. The magnitude of the vertical  
10 gradients (upward) near the interstate were somewhat higher, indicating a greater vertical  
11 component to the groundwater flow. The magnitude of the upward vertical gradient along the  
12 interstate increases along the interstate in the northerly direction. The upward vertical gradient  
13 is slightest at the 018 well pair and increases to the north at the 017 and 016 well pairs.

14 A flow net based on water level measurements from shallow and deep monitoring wells is  
15 portrayed on the A-A' profile (Figure 2-5). An upward vertical gradient is present near the  
16 interstate; at other locations, the gradient is horizontal or downward.





**(K)**  
**NAVAL ANNEX**

CHARLESTON AIR FORCE BASE HOUSING

BASKETBALL COURT  
2550

VICINITY OF FORMER  
SEPTIC TANK/DRAINFIELD  
2553

VICINITY OF FORMER  
(SLUDGE DRYING FIELDS)

**LEGEND:**

**16603D**  
**37.31** ● DEEP MONITORING WELL W/  
NUMBER AND GROUNDWATER  
ELEVATION (feet MSL)

**— 34 —** GROUNDWATER ELEVATION CONTOUR  
(CONTOUR INTERVAL — 1 FT. MSL)  
DASHED WHERE INFERRED

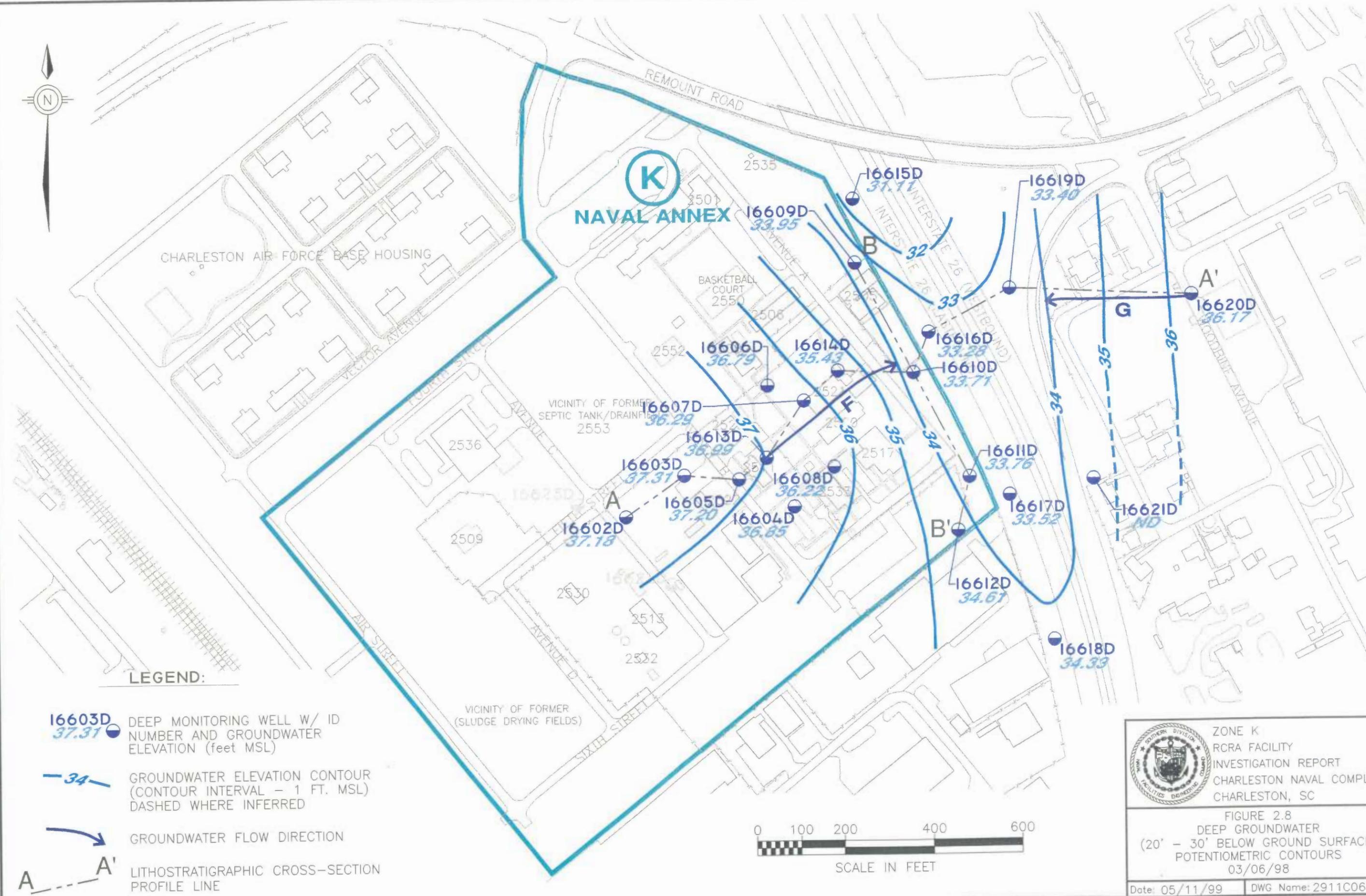
**→** GROUNDWATER FLOW DIRECTION

**A — A'** LITHOSTRATIGRAPHIC CROSS-SECTION  
PROFILE LINE



ZONE K  
RCRA FACILITY  
INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX  
CHARLESTON, SC

FIGURE 2.8  
DEEP GROUNDWATER  
(20' - 30' BELOW GROUND SURFACE)  
POTENTIOMETRIC CONTOURS  
03/06/98



**Table 2.6**  
**Vertical Hydraulic Gradients at Naval Annex**  
**March 6, 1998**

Well Pair	Shallow Well GW Elev. (ft msl)	Deep Well GW Elev. (ft msl)	GW Elev. Diff (ft msl)	Vertical Dist. (ft)	Vertical Hyd. Gradient
166002 and 02D	37.17	37.18	0.01	18.0	-0.0005
166003 and 03D	37.32	37.31	0.01	20.6	0.0005
166004 and 04D	36.91	36.89	0.02	19.0	0.001
166005 and 05D	37.33	37.20	0.13	17.0	0.008
166006 and 06D	36.96	36.79	0.17	18.0	0.009
166007 and 07D	36.49	36.08	0.41	19.0	0.021
166008 and 08D	36.25	36.22	0.03	21.0	0.001
166013 and 13D	37.14	37.07	0.07	19.9	0.004
166014 and 14D	35.51	35.43	0.08	17.7	0.004
166015 and 15D	32.93	31.11	1.82	12.4	0.148
166016 and 16D	32.30	33.28	0.98	13.5	-0.073
166017 and 17D	33.15	33.52	0.37	13.6	-0.027
166018 and 18D	34.13	34.33	0.20	13.7	-0.014
166019 and 19D	33.08	33.40	0.32	10.0	-0.032
166020 and 20D	36.22	36.17	0.05	15.0	0.003
166021 and 21D	35.11	31.73	Deep well potentiometric surface reflective of top of Ashley Formation rather than base of water table aquifer.		

**Note:**

For the vertical hydraulic gradient, a positive number indicates potential for downward flow; a negative number indicates potential for upward flow.

**2.3.5 Horizontal Hydraulic Gradient**

The horizontal hydraulic gradient ( $i$ ) is a measurement of the change in hydraulic head ( $\Delta h$ ) (i.e., change in groundwater elevation) at two points over the distance between them ( $\Delta x$ ). It is a dimensionless value and is generally used to quantitatively determine the magnitude of groundwater flow in a given region.

Because the well locations for the Naval Annex RFI were based solely on SWMU and AOC locations and historical land uses, few monitoring wells are actually located along groundwater flowpaths from one another. As a result, horizontal hydraulic gradients were calculated along several representative groundwater flowpaths, presented in Figure 2-7 (labeled "A" through "E") and Figure 2-8 (labeled "F" and "G"). The results are presented in Table 2.7.

**Table 2.7**  
**Horizontal Hydraulic Gradients**

Flowpath	$\Delta h$ (ft)	$\Delta x$ (ft)	i
<i>Shallow Wells</i>			
A	2.25	275	0.0082
B	4.01	315	0.0127
C	1.33	285	0.0047
D	3.22	435	0.0074
E	1.13	410	0.0028
<i>Deep Wells</i>			
F	2.99	365	0.0082
G	2.17	335	0.0065

In general, the horizontal hydraulic gradient across the water table is greater in the northeastern portion of the annex along the interstate boundary. This is largely a function of the topographic relief related to the interstate roadcut. The range in horizontal hydraulic gradients calculated for the deep well groundwater flowpaths is smaller than that of the shallow wells. Given the relative uniformity of the groundwater flow pattern in Figure 2-8, the hydraulic gradient along the bottom of the surficial aquifer appears fairly consistent at the site.

**2.3.6 Horizontal Hydraulic Conductivity ( $K_h$ )**

**2.3.6.1 Slug Tests**

Slug tests are used to evaluate the horizontal hydraulic conductivity of an aquifer at a single point. A slug test is initiated by inserting a 1.88-inch diameter Teflon cylinder below the static water level in the well, creating an instantaneous rise in the water level. The change in water level is monitored over time as the aquifer attempts to reach equilibrium in response to the perturbation. This procedure is known as a falling head slug test since the water level (hydraulic head) falls from its disturbed, higher position, back to its original static level. After equilibrium is reestablished, the slug is quickly removed, causing the static water level to drop. This procedure is a rising head slug test since the water level in the well rises back to its original static level as the test progresses.

The resulting values of the falling and rising head slug tests for Naval Annex are presented in Tables 2.8 and 2.9 for the shallow and deep wells. The lithologic types listed in these tables are those thought to be primarily responsible for the response during the slug test.

**Table 2.8**  
**Naval Annex Shallow Well Slug Test**  
**Horizontal Hydraulic Conductivity Results in feet/day**

Well	Lith Type	Falling Head Hydraulic Conductivity	Rising Head Hydraulic Conductivity	Geometric Mean <sup>a</sup>
NBCK162002	Qs	30.66 <sup>b</sup>	31.39 <sup>b</sup>	31.03
NBCK166002	Qs	7.12 <sup>b</sup>	5.43 <sup>c</sup>	6.39
NBCK166003	Qs	12.27 <sup>c</sup>	6.79 <sup>c</sup>	9.13
NBCK166004	Qs	6.46 <sup>c</sup>	5.66 <sup>c</sup>	6.05
NBCK166007	Qs	16.07 <sup>c</sup>	16.50 <sup>c</sup>	16.28
NBCKGDK001	Qs	5.62 <sup>b</sup>	6.61 <sup>b</sup>	6.10
NBCKGDK002	Qs	5.60 <sup>b</sup>	10.78 <sup>b</sup>	7.77

**Note:**

- <sup>a</sup> = Average calculated using the falling and rising head values.
- <sup>b</sup> = Geometric mean of three tests.
- <sup>c</sup> = Geometric mean of two tests.
- Qs = Quaternary sand.

**Table 2.9**  
**Naval Annex Deep Well Slug Test**  
**Horizontal Hydraulic Conductivity Results in feet/day**

Well	Lith Type	Falling Head Hydraulic Conductivity	Rising Head Hydraulic Conductivity	Geometric Mean <sup>a</sup>
NBCK16602D	Qcs	1.33 <sup>c</sup>	1.47 <sup>d</sup>	1.39
NBCK16603D	Qcs	0.47 <sup>b</sup>	0.32 <sup>b</sup>	0.39
NBCK16604D	Qcs	0.47 <sup>b</sup>	0.43 <sup>b</sup>	0.45
NBCK16606D	Qs	2.83 <sup>b</sup>	2.74 <sup>b</sup>	2.78
NBCK16607D	Qcs	3.55 <sup>b</sup>	3.89 <sup>b</sup>	3.72
NBCK16609D	Qcs	3.66 <sup>b</sup>	3.77 <sup>b</sup>	3.72
NBCK16610D	Qs	4.54 <sup>b</sup>	4.29 <sup>b</sup>	4.41
NBCK16611D	Qcs	3.18 <sup>c</sup>	3.15 <sup>c</sup>	3.17

**Notes:**

- <sup>a</sup> = Average calculated using the falling and rising head values.
- <sup>b</sup> = Geometric mean of two tests.
- <sup>c</sup> = Geometric mean of four tests.
- <sup>d</sup> = Geometric mean of three tests.
- Qs = Quaternary sand.
- Qcs = Quaternary clayey sand and clay.

Data from the slug tests were first compiled using the computer program AquiferTest v. 2.51 1  
 (Waterloo Hydrogeologic Institute). Rising and falling head slug test data from the shallow and 2  
 deep portions of the surficial aquifer were plotted using an unconfined aquifer solution of Bouwer 3  
 and Rice (1976). This solution assumes that the aquifer is homogeneous, isotropic (meaning 4  
 vertical hydraulic conductivity equals horizontal hydraulic conductivity), in steady-state 5  
 equilibrium, and that flow into the well is solely through the well screen. Adjustments to the 6  
 effective well radius were made for those cases in which the well did not fully penetrate the aquifer 7  
 (i.e., shallow well screens intersecting the water table) as described in an addendum to the original 8  
 method (Bouwer, 1989). While this analysis results in a more reliable estimate of the aquifer's 9  
 true hydraulic conductivity, it is important to recognize that these values are only point estimates 10  
 of aquifer characteristics within a three-dimensional aquifer. As such, these values should be used 11

carefully in discussing overall aquifer characteristics. It is for this reason that slug test results have been reported to two decimal places for this project. The shallow and deep well slug test analyses are presented as Appendix C.

Because hydraulic conductivity data are lognormally distributed, the geometric mean is the best measure of central tendency. Therefore, the average hydraulic conductivity for each well is presented as the geometric mean of the falling and rising head values when applicable.

The geometric means of hydraulic conductivity based upon slug-tested shallow wells vary from 6.05 to 31.03 feet/day with an average of 9.76 feet/day. These values best represent the hydrogeologic characteristics of the Qs unit in which the shallow wells were installed. However, the range of values was greater than expected for the Qs unit considering the deposits visual uniformity.

The geometric means of hydraulic conductivity from slug-tested deep wells vary from 0.39 to 4.41 feet/day with an average of 1.84 feet/day. This ten-fold variation in hydraulic conductivity is understandable, given the variability of silt and clay amounts intermixed within the Qcs matrix.

### **2.3.6.2 Grain-Size Evaluation**

A grain-size evaluation, using empirically derived formulas that calculate the hydraulic conductivity of porous media, was presented in the *Zone E RFI Report (E/A&H, November 1997)*. Four Zone K Shelby tube samples were included in this evaluation. The Zone K samples consist of Qs materials, which is advantageous for use in grain-size evaluations because the empirical methods are based upon sandy and gravelly materials with little fines content.

The methodology, data analysis, and data interpretation of the grain-size evaluation are presented in Section 2 and Appendix D of the *Zone E RFI Report (E/A&H, November 1997)*. Only those results pertinent to the Zone K RFI are presented and discussed here.

Table 2.10 presents the hydraulic conductivity results from the grain-size evaluation of the four Zone K Shelby tube samples. The method names Beyer, Terzaghi, and Hazen are those of the authors who had derived the empirical formulas. These three methods were most reliable and accurate for the deposits analyzed, as discussed in Appendix D of the *Zone E RFI Report (E/A&H, November 1997)*. The raw data results for the Zone K samples are presented in Appendix D of this report.

**Table 2.10**  
**Hydraulic Conductivity (feet/day) Results from Grain-Size Evaluation**  
**of Zone K Undisturbed Shelby Tube Samples**

Location	Sample Depth (feet bgs)	Empirical Methods <sup>1</sup>			Hyd. Cond. Geometric Mean
		Beyer	Hazen	Terzaghi	
NBCK161001	10-12	27.86	43.65	37.42	35.70
NBCK162001	6-8	28.63	44.79	40.25	37.23
NBCK163001	8-10	0.12	0.33	0.30	0.23
NBCKGDK001	8-10	25.34	36.85	29.20	30.10

**Note:**

<sup>1</sup> = The empirical formulas for Beyer (1964), Hazen (1892), and Terzaghi (1925) were taken from VuKovic, M. and Soro, A. 1992. *Determination of Hydraulic Conductivity of Porous Media from Grain-size Composition*. Water Resources Publications, Littleton, CO.

These results are close to the maximum values in the range produced from the slug tests. However, direct comparison of slug test conductivities and grain-size conductivities are expected to be order of magnitude-type comparisons due to the inherent differences in methods. It is important to recognize that conductivities from the grain-size evaluation are the result of analyzing the physical characteristics of the Qs unit at the structural level, which cannot be accomplished using other hydrogeological methods for estimating hydraulic conductivity (i.e., slug tests).

### **2.3.6.3 Specific Capacity Testing**

Hydraulic conductivity estimates may be obtained from specific capacity tests, which are single well pumping tests. Specific capacity tests are often preferred over slug tests for estimating hydraulic conductivity due to the greater overall stress imparted on the aquifer system during a specific capacity test. Another advantage lies in the fact that the tests may be conducted during well development or purging prior to groundwater sampling.

Quantitatively, specific capacity is defined as  $Q/s$  where  $s$  is the drawdown produced at a particular volumetric flow rate,  $Q$ , from a well. The flow rate and drawdown are recorded until the water level stabilizes in the well at a quasi-equilibrium state. Generally, specific capacity tests are conducted at pumping rates high enough to determine well efficiency. However, flow rates greater than 1 or 2 gallons per minute (gpm) are difficult to attain, especially from deep wells set in the lower permeable deposits overlying the Ashley Formation at the Naval Annex. Walton (1970) states that discharge rates less than 25 gpm make it unfeasible to calculate well losses. Furthermore, well loss at such minimal pumping rates should be negligible in newly installed wells.

Specific capacity tests were conducted using a disposable, two-stage, submersible pump. In all, 11 deep wells at SWMU 166 were tested in December 1997 and March 1998. Three wells (16606D, 14D, and 07D) were tested twice.

The specific capacity test procedure began with measuring the initial water level in each well to record static conditions. Next, the pump was submerged and activated momentarily to fill the pump and discharge line. After the water level had equilibrated within 0.03 feet of its original static level, the test was initiated by starting the pump. Drawdown was measured at regular intervals with a water level indicator. Volume measurements were made with a graduated bucket. After drawdown had stabilized within 0.01 to 0.1 feet over 5 to 10 minute period, the pump was

either turned off or the discharge rate was increased (stepped). Tests were stepped only to observe what effect increased discharge had on the saturated thickness at that particular location. Recovery of groundwater levels after pumping had terminated was recorded at three locations to provide additional data for evaluation of pumping stress on the aquifer.

The analytical method of Bradbury and Rothschild (1985) was used to estimate the hydraulic conductivity from specific capacity data. This method uses an iterative computer code to solve for transmissivity in the following expression:

$$T = \frac{Q}{4\pi(s-s_w)} \ln \frac{2.25Tt}{r_w^2 S} + 2s_p$$

**where:**

T = transmissivity (L<sup>2</sup>/t)

Q = discharge (L<sup>3</sup>/t)

s = drawdown in well (L)

s<sub>w</sub> = well loss (L)

t = time (t)

r<sub>w</sub> = radius of well (L)

S = aquifer storage (dimension less)

s<sub>p</sub> = partial penetration factor (L).

Each variable in the expression above may be attained from test parameters or well construction information, except for the well loss coefficient and aquifer storage. Since the surficial aquifer at the Naval Annex is considered unconfined, the low and high estimates from literature values for specific yield were applied (0.01 and 0.3) (Kruseman and deRidder, 1992). The well loss coefficient is an unknown variable, but given the low discharge rates of the tests, considered to

be nominal. A default value of no well loss was used in the program, which results in slightly elevated, and thus more conservative hydraulic conductivity estimates.

The specific capacity test results and input data are summarized in Table 2.11. In the cases where specific capacity tests were stepped, only the first step was used for hydraulic conductivity analysis.

**Table 2.11**  
**Input Data and Results from Specific Capacity Tests**

Well	Lith. Type	Date	b (ft)	L (ft)	Q (gpm)	s (ft)	Q/s (gpm/ft)	K (Sy = 0.01)	K (Sy = 0.3)	% dec in b
16602D	Qcs	12/12/97	25.3	7.0	0.49	5.44	0.09	1.71	1.52	21.5
16603D	Qcs	3/23/98	33.8	6.5	0.14	6.07	0.02	0.46	0.42	18.0
16605D	Qs/Qcs	3/24/98	34.6	8.0	0.58	6.80	0.09	1.44	1.30	19.7
16606D	Qs	3/24/98	27.8	7.0	0.21	1.26	0.17	3.15	2.82	4.5
		3/30/98	27.1		0.92	6.13	0.15	2.89	2.60	22.6
16607D	Qs/Qcs	3/24/98	27.2	7.0	0.37	1.97	0.19	3.47	3.10	7.2
		3/30/98	26.5		0.62	3.80	0.17	3.21	2.88	14.3
16609D	Qcs	12/11/97	22.7	7.0	0.08	0.65	0.12	2.26	1.97	2.9
16610D	Qs	3/25/98	24.5	7.0	0.31	1.30	0.24	4.54	4.02	5.3
16611D	Qcs	3/23/98	26.3	7.5	0.43	2.22	0.19	3.45	3.06	8.4
16612D	Qs/Qcs	3/23/98	29.7	7.5	0.36	1.19	0.30	5.60	5.06	4.0
16613D	Qcs	3/25/98	30.2	4.0	0.58	14.41	0.04	1.21	1.14	47.7
16614D	Qcs	3/25/98	25.0	1.8	0.58	5.77	0.10	5.84	5.63	23.1
		3/30/98	26.7		0.70	8.01	0.09	5.13	4.96	30.0

**Notes:**

- b = saturated thickness
- L = intake length including filter pack
- Q = discharge rate
- Q/s = specific capacity
- s = drawdown
- K = hydraulic conductivity
- Sy = specific yield
- % dec = percent decrease

The results indicate that  $K_h$  estimates do not vary significantly with specific yield estimates. The variation between  $K_h$  and specific yield was greatest at 16609D (~13%) and lowest at 16614D

(~4%). Table 2.11 also indicates how greatly drawdown varied with well location and discharge. For instance, although 16605D and 14D were both pumped at the same 0.58 gpm, drawdown was more than twice as great at 14D. This variation most likely reflects the heterogeneity of the geologic units and their hydraulic characteristics. Other factors that might influence test response are differences in well construction, well development, and test procedure. By evaluating the change in saturated thickness at each location with discharge rate, specific capacity test data become a useful tool in planning for future aquifer testing activities associated with potential remedial alternatives.

**2.3.6.4 Summary**

The horizontal hydraulic conductivity results from slug tests, specific capacity tests, and grain-size evaluations were averaged (geometric mean) to produce a representative effective conductivity value ( $K_{h(eff)}$ ) for the two Quaternary-age lithologic units presented in Section 2.2.3.2. Equal weight was given to each method since each revealed ranges in values among its results that were of the same order of magnitude as the ranges in values between the three methods. Only the specific capacity  $K_h$  values generated using  $S_y = 0.01$  were included in the average since they were higher and more conservative. No grain-size evaluation was conducted on Qcs samples. Table 2.12 presents the  $K_v$  and  $K_{h(eff)}$  values for the Qs and Qcs lithologies. These data are to be used for subsequent evaluations in later sections of this report.

**Table 2.12**  
**Hydraulic Conductivity Summary for Quaternary-age Units**  
**in Zone K**

Lithologic Unit	$K_v$ (feet/day)	$K_{h(eff)}$ (feet/day)
Quaternary Sand (Qs)	3.59	5.9
Quaternary clayey sand and clay (Qcs)	0.77	2.2

### 2.3.7 Horizontal Groundwater Velocity

To estimate the rate at which groundwater and possibly dissolved contaminants are migrating, groundwater velocity was calculated using the following formula:

$$V = \frac{K_h * i}{n_e}$$

where:

V	=	horizontal groundwater velocity	$K_h$	=	hydraulic conductivity
i	=	horizontal hydraulic gradient	$n_e$	=	effective porosity

Groundwater velocities were computed using the shallow and deep groundwater flow paths along which horizontal hydraulic gradients had been calculated, as described in Section 2.3.5. Porosity values from geotechnical data (Table 2.3) were substituted for  $n_e$  (effective porosity) values since no site-specific effective porosity estimates are available. However, it is understood that a site-specific  $n_e$  would be lower than that applied and thus produce higher groundwater flow velocities. As a result, the lowest and highest porosity values from the four Qs samples were used for  $n_e$  in shallow groundwater velocity calculations. The  $K_{h(eff)}$  value computed for Qs deposits was used for  $K_h$  in the calculation (Table 2.12). Since groundwater flow along the bottom of the surficial aquifer is largely within the Qcs deposits (as monitored by the deep wells), the porosity (Table 2.3) and  $K_{h(eff)}$  data (Table 2.12) specific to that lithologic type were used in the deep groundwater velocity calculation.

The estimated minimum and maximum groundwater velocities are presented in Table 2.13.

**Table 2.13  
 Groundwater Velocity Results**

Flowpath*	Porosity		$K_{h(eff)}$ (ft/day)	$i$	GW velocity (ft/day)	
	Min	Max			Max	Min
<b>Shallow Groundwater</b>						
A	0.430	0.469	5.9	0.0082	0.111	0.102
B	0.430	0.469	5.9	0.0127	0.174	0.160
C	0.430	0.469	5.9	0.0047	0.064	0.059
D	0.430	0.469	5.9	0.0074	0.102	0.093
E	0.430	0.469	5.9	0.0028	0.038	0.035
<b>Deep Groundwater</b>						
F	0.409	0.409	2.2	0.0082	0.044	0.044
G	0.409	0.409	2.2	0.0065	0.035	0.035

**Note:**

\* = Refer to Figures 2-7 and 2-8 for locations of groundwater flow paths.

**2.3.8 Continuous Water Level Monitoring**

Water levels were monitored over a 38-day period between January 28 and March 6, 1998, in well pair 166002/02D and in deep wells 16609D and 16610D. To observe how the aquifer system responded to local precipitation, these wells were selected for the study based upon their accessibility, their location with respect to recharge-discharge areas and the predominant NW-SE groundwater flow direction at the site, and the geology corresponding to their screened intervals. Water levels were measured at 15-minute intervals using downhole pressure transducers and Hermit 2000 data loggers, which were started once equilibrium in the wells had been reestablished after insertion of the transducers. The data loggers were programmed to convert pressure readings to groundwater elevations to make it easy to reduce data.

Local weather conditions are monitored at the Charleston International Airport Weather Station (CHS), approximately one half mile west of the site. Hourly precipitation data were obtained from the National Climatic Data Center for the CHS station. Daily precipitation totals are presented in Figure 2-9. During the observation period, 11.84 inches of rain were recorded, of which 8.87 inches were produced in three separate precipitation events 2/3, 2/16-2/17, and 2/22, labeled R<sub>1</sub>, R<sub>2</sub>, and R<sub>3</sub>, respectively, in Figure 2-9.

Groundwater elevations at each well location are plotted against daily precipitation totals in Figure 2-9. Before looking at larger-scale responses to precipitation events, note that the minor oscillations in groundwater elevation that occur as short-term transients in the 166002 and 02D data reflect the higher sensitivity of the 10 pounds per square inch (psi) pressure transducers used at those locations. Comparatively, the 50 psi pressure transducers used at wells 16609D and 10D are less sensitive to small-scale pressure changes, as indicated by the absence of short-term transients in the data. This variability at smaller scale events does not adversely affect the accuracy of the transducer responses to larger-scale changes in groundwater elevation.

Groundwater elevations in all four well locations decreased steadily over the first week of the study period. These decreases likely reflect the drying conditions following rainfall on January 23, 1998 (3.27 inches) and January 27, 1998 (1.52 inches) before the study period. Increases in groundwater elevation at each well location correlate closely to the three primary precipitation events, R<sub>1</sub>, R<sub>2</sub>, and R<sub>3</sub>. Aquifer response to a smaller rainfall event on February 27 (0.39 inches) was clearly evident in groundwater elevations at the 166002/02D well pair, but not in deep wells 09D and 10D.

Figure 2-9 also indicates that the overall increase in groundwater elevation for each precipitation event appears to be greater at the 166002/02D well pair than at deep wells 09D and 10D. Aquifer response to local precipitation is generally similar at all four wells, except for the R<sub>2</sub> event. Deep

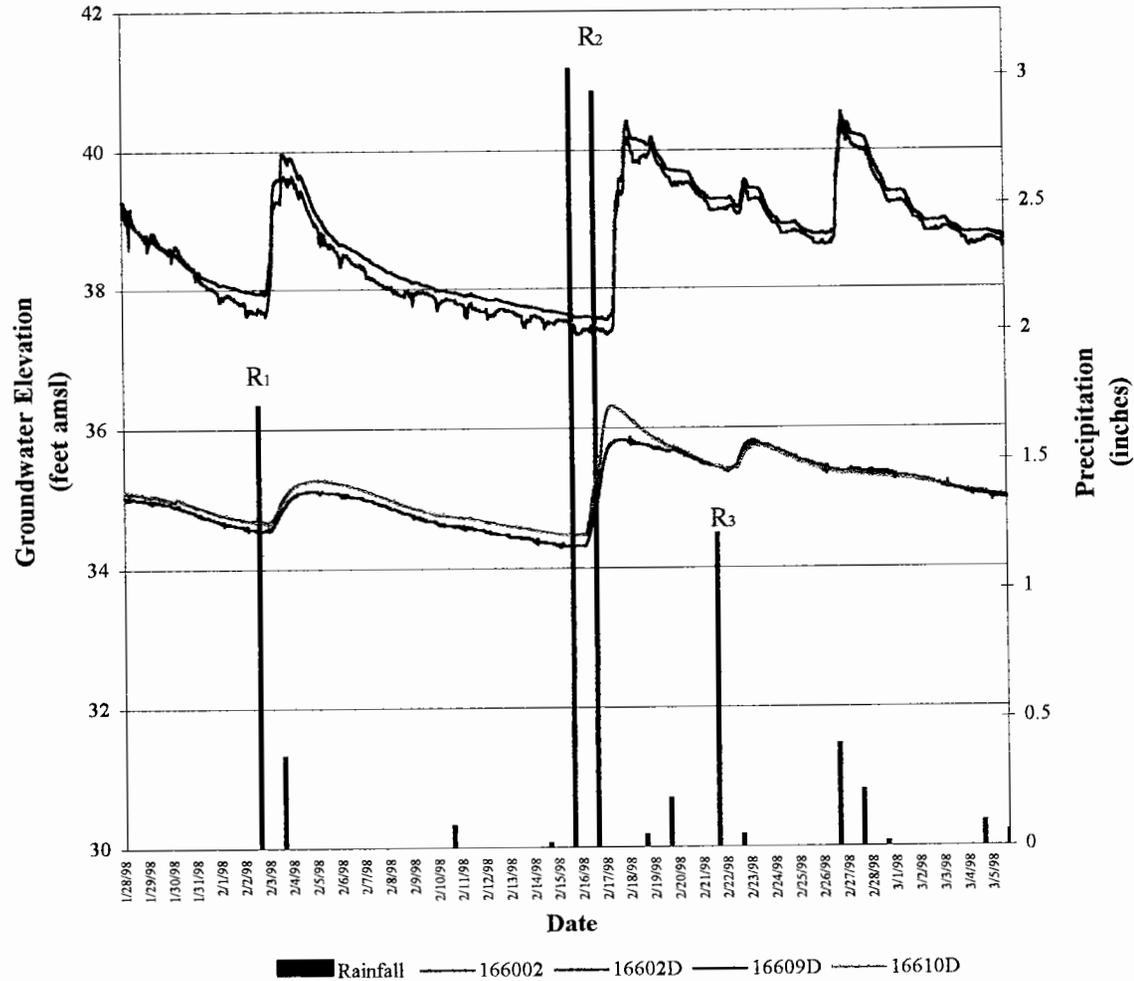
wells 09D and 10D appear to respond earlier to the  $R_2$  event than the 166002/02D well pair. However, a direct comparison is difficult with this plot because the elevation data and precipitation data are presented at different time scales (i.e., 15-minute intervals for groundwater elevations but daily totals for precipitation).

To determine a response time for each well or well location to precipitation events, hourly precipitation data were plotted against the groundwater elevation data during the  $R_2$  precipitation event (Figure 2-10). This rainfall event is significant due to its magnitude over a short period of time, the different responses at 09D and 10D compared to the 002/02D well pair, and its timing after an 11-day dry period during which less than 0.1 inches of precipitation was recorded. Figure 2-10 shows that 1.03-inches of rain fell at 1600 hours on February 16 and 2.05-inches of rain fell on 0300 hours on February 17. Water levels at 09D and 10D began to respond nearly instantaneously on February 16 and continued to rise 12 to 19 hours after the 2.05-inches of rainfall on February 17. Response to this precipitation comes later at the 166002/02D well pair, as shown by the steady elevations to approximately 1700 hours on February 17. However, once recharge is initiated at this location in the aquifer, it occurs quickly, as indicated by the steep slope of increasing groundwater elevations. The delay time in onset of recharge at the 166002/02D well pair is approximately 25 hours after the 1.03-inches event.

Well hydrographs were compared to the maximum hourly precipitation readings during the  $R_2$  event to estimate a delay time for maximum recharge response. The groundwater elevation responses to the 1.03-inch and 2.05-inch rainfalls are labeled on Figure 2-10 for each well hydrograph. Response to the 1.03-inch event is clearly evident at the 166002 and 02D well pair and is labeled "A1" and "B1", respectively. The response to the 2.05-inches of rainfall is labeled "A2" and "B2" for 166002 and 16602D, respectively. Although an increase in groundwater elevation is obvious at 09D and 10D shortly after the 1.03-inches were recorded, a distinct peak

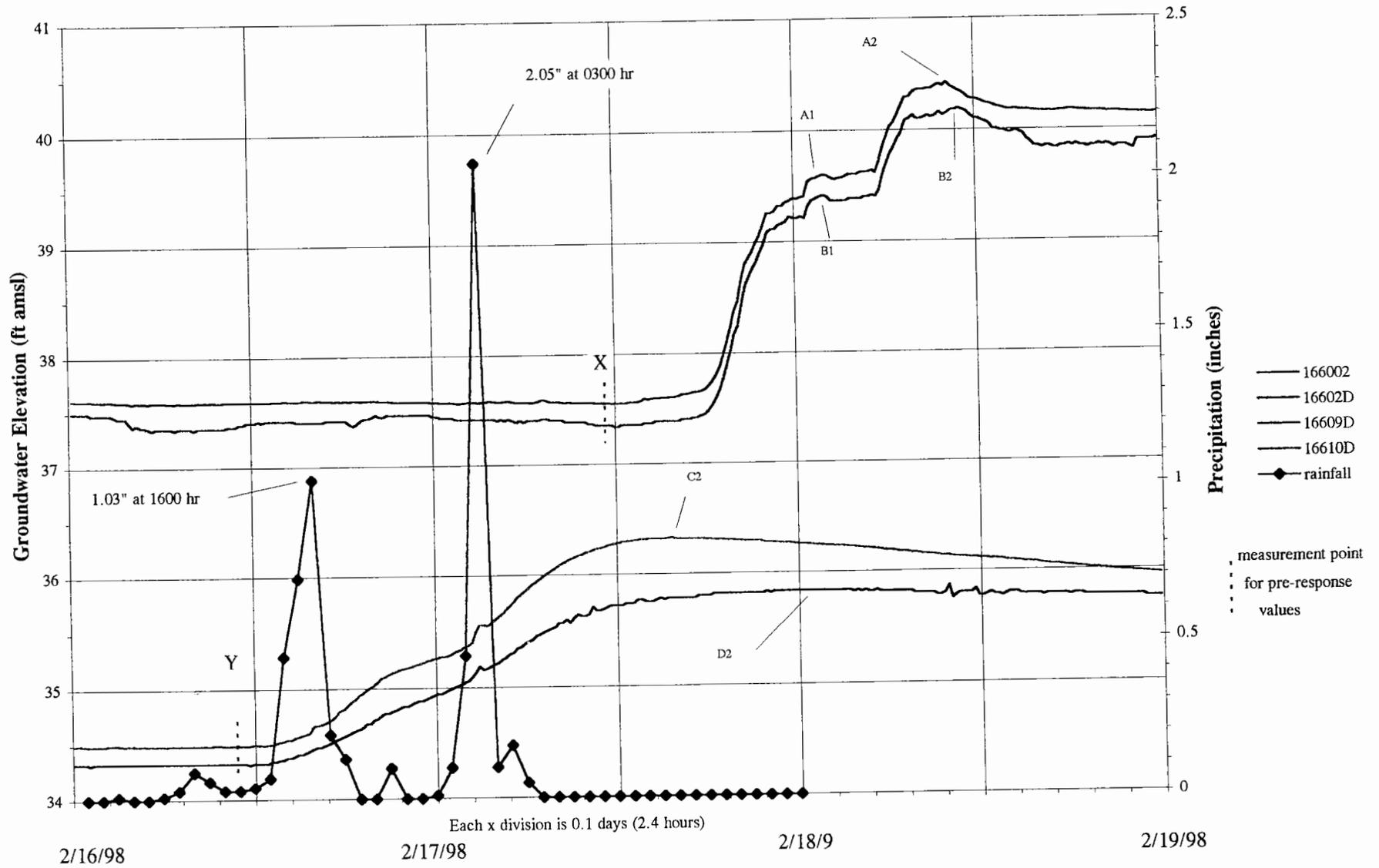
**Figure 2-9**

Groundwater Elevations at the Naval Annex with Daily Precipitation Totals at Charleston International Airport



Note: Rainfall amounts were recorded hourly and totaled daily. Daily totals plotted. Groundwater elevations were recorded once every 0.25 hour using an electronic data logger.

**Figure 2-10**  
 Hourly Precipitation Versus Groundwater Elevation February 16-18, 1998



in groundwater elevation at either well is not evident. The 2.05-inches are also seen immediately in 09D and 10D, as evidenced by the small peaks in groundwater elevation that coincide closely with the 0300 hours. However, groundwater elevations in each well continue to rise well after precipitation slackens. Although the peak in these hydrographs is not as distinct as at the 166002 and 02D well pair, groundwater elevations slowly reach maximum values. These maxima are labeled "C2" and "D2" at 09D and 10D, respectively. Precipitation maxima for the two rainfall events were recorded 11 hours apart. The separation between A1-A2 and B1-B2 is 10.25 hours (the discrepancy lies in the fact that different time scales were used to measure precipitation and groundwater levels). The maximum groundwater elevations A1 and A2, which correlate to the 1.03-inches and 2.05-inches of rainfall are seen approximately 34 and 32 hours, respectively, after each event. At 09D and 10D, the lag times were calculated from points C2 and D2 since response to the 1.03-inch event is not as distinct. This lag time was approximately 12.5 hours in 10D and 18.75 hours in 09D.

A rate of change in groundwater elevation in response to the  $R_2$  event may be calculated by finding the lowest elevation value at each well location prior to recharge and subtracting it from the maximum peak recorded at each well; the result is divided by the amount of time between the low and high values. The pre-response background elevations were taken at the blue dotted lines labeled X for the 166002/02D well pair and Y for wells 09D and 10D in Figure 2-10. At 166002, the lowest groundwater elevation of 37.55 feet was recorded at 1241 on February 17, about 4.5 hours before it began to rise in response to the 1.03-inch rainfall. Peak elevation was determined to be 40.43 feet at point "A2" (Figure 2-10). The difference, 2.88 feet, is divided by 9.5 hours, for a groundwater elevation change of approximately 0.3 ft/hr, or 3.6 inches/hr. Similarly, groundwater elevation change rates for the  $R_2$  precipitation event were calculated at each well as follows: 0.3 ft/hr (3.6 inches/hr) at 16602D; 0.07 ft/hr (0.8 inches/hr) at 16609D; and 0.11 ft/hr (1.3 inches/hr) at 16610D.

The results of this study indicate that the onset of aquifer recharge at each monitored well location ranged from nearly instantaneous to one day. Similarly, peak aquifer recharge in response to hourly precipitation peaks was seen in corresponding hydrographs at lag times ranging from 12.5 to 32 hours. Groundwater elevation rate changes during the high volume event on February 16 to 17 ranged from 0.8 to 3.6 inches/hour at the four monitored locations. It is unclear why recharge on those dates varied significantly at each well location. Two potential factors are thought to be the primary influences: the geologic heterogeneity between locations and depths and the spatial distribution of each well location in relation to the local recharge and discharge areas at the site.

### **2.3.9 Lithologic Unit Summary**

#### **2.3.9.1 Tertiary Age Ashley Formation (Ta)**

The Ashley Formation is a regional confining unit between underlying Tertiary and Cretaceous age aquifer systems and Quaternary-age water-bearing strata that overlie it. Lithologic cross sections presented by Weems and Lemon (1993) show the Ashley Formation to have a laterally consistent overall thickness. Although no samples of the unit were obtained during the Zone K RFI, samples taken for the Zone E RFI indicated that the unit has a high silt and clay content with varying sand percentages based upon depth within the formation. Vertical permeabilities of these samples in Zone E ranged from 1.62E-06 centimeters per second (cm/sec) (4.60E-03 feet/day) to 2.97E-04 cm/sec (0.842 feet/day), with a mean of 1.70E-05 cm/sec (0.048 feet/day). This average  $K_v$  value correlates well with the range reported in Fetter (1988) of units with permeabilities less than or equal to  $10^{-5}$  cm/sec (0.03 feet/day) being considered confining units.

#### **2.3.9.2 Quaternary-age Sediments**

The two Quaternary-age lithologies encountered in the Zone K RFI at Naval Annex are remnants of former sea transgression/regression dating from 200,000 to 240,000 years ago. This change in sea level resulted in the deposition of three diverse facies ranging from clean barrier sand

deposits to fossiliferous sand and shell deposits and to clayey sand and clay back-barrier deposits. 1  
Despite these variabilities, the Quaternary-age sediments are hydraulically connected and behave 2  
as one surficial aquifer under unconfined conditions. 3

#### **Quaternary Sand (Qs)** 4

The Qs lithology comprises the primary aquifer material within Naval Annex. These deposits 5  
extend from ground surface to 20 to 25 feet bgs and range in elevation from 42 to 16 feet msl. 6  
Occasional Qs lenses are interbedded deeper than 16 feet msl, but appear to be isolated and 7  
discontinuous. Horizontal permeability based upon the geometric means of slug test data and 8  
grain-size evaluations for Qs sediments ranged from 6 to 37 feet/day; a geometric mean of all 9  
permeability estimates was approximately 5.9 feet/day. Vertical permeabilities ranged from 10  
6.30E-04 cm/sec (1.8 feet/day) to 1.90E-03 cm/sec (5.4 feet/day). 11

#### **Quaternary Clayey Sand and Clay (Qcs)** 12

The Qcs deposits unconformably overlie Ta deposits and unconformably contact the overlying Qs 13  
deposits. The clayey facies within these sediments are most likely related to their back-barrier 14  
depositional environment. When not interbedded with Qs deposits, the Qcs unit thickness varies 15  
from 8 to 13 feet; lenses of 2 to 4 feet thick are encountered when the unit is interlayered with Qs. 16  
The Qcs unit has significant water-transporting capabilities, although less than that of Qs deposits. 17  
Qcs horizontal permeabilities, based on slug tests and specific capacity tests, range from 0.45 to 18  
5.84 feet/day with a geometric mean of 2.2 feet/day. The vertical permeability of one Qcs sample 19  
was found to be 2.70E-04 cm/s (0.77 feet/day). 20

## **2.4 Climate** 21

Section 2.3 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the climate of Charleston, 22  
SC. 23

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### **3.0 FIELD INVESTIGATION**

The following section lists the field investigation objectives and describes the technical sampling methods, procedures, and protocols implemented for Zone K data collection. Fieldwork was conducted in accordance with the Comprehensive Sampling and Analysis Plan (CSAP) and the USEPA Region IV, Environmental Services Division, *Standard Operating Procedures and Quality Assurance Manual* (February 1991) (ESDSOPQAM). 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 Evaluations.

#### **3.1 Investigation Objectives**

The sampling strategy for each Zone K AOC and SWMU, as detailed in the *Final Zone K RFI Work Plan* (E/A&H, September 1995), was designed to collect sufficient environmental media data to:

- Characterize the Zone K sites
- Define contaminant pathways and potential receptors (on and offsite, where applicable)
- Define the nature and extent of any contamination, at Zone K 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 samples collected during this investigation were identified using the 10-character scheme from Section 11.4 of the CSAP. This scheme identifies the samples by site, matrix, location, and depth. The first three characters identify the site where the sample was collected. The fourth character identifies the sample matrix or quality control (QC) code. The fifth through eighth characters identify the location. The ninth and tenth characters identify the soil sample interval. For

example: sample ID 161SB00602 is a second-interval soil sample from Boring B006 at SWMU 161. For the groundwater samples, the ninth and tenth characters identify the sampling sequence. For example, 166GW00101 would be the first groundwater sample collected from monitoring well W001 at SWMU 166, and 166GW00102 would indicate the second groundwater sample collected.

### 3.2.2 Soil Sampling

Section 4 of the CSAP describes RFI soil sampling procedures and activities which are summarized below.

#### 3.2.2.1 Soil Sample Locations

Soil samples were collected from locations proposed in the *Final Zone K RFI Work Plan* (September 1995), which were based on the investigation strategy outlined in Section 1.2 of that plan. Each SWMU and AOC primary sampling pattern is justified in Sections 2.1 through 2.9 of the work plan. Some proposed sample locations were modified slightly due to utility obstructions.

At some sites, additional samples were required to adequately characterize contaminant distribution. After the analytical data were interpreted for samples collected during the initial round of soil sampling, a second sampling round was proposed in some areas.

Typically, additional sample locations were justified due to relatively high contaminant concentrations identified on the previous sampling pattern's perimeter.

#### 3.2.2.2 Soil Sample Collection

Composite soil samples were collected for laboratory analysis from 0 to 1 foot bgs and from 3 to 5 feet bgs. The 0- to 1-foot bgs interval is referred to in this report as the "first" or "upper interval." At soil sample locations overlain by pavement, the upper interval was collected from

the base of the pavement to 1 foot below the base of the pavement. The 3- to 5-foot bgs interval is referred to as the "second" or "lower interval."

No other intervals were sampled due to the relatively shallow depth to groundwater in Zone K, typically from 5 to 7 feet bgs. No saturated soil samples were retained for laboratory analysis.

Stainless-steel hand augers were used to collect soil samples. At grassy locations, the vegetative root zone (generally less than 2 inches thick) overlying the soil at the upper interval was removed before augering to 1 foot bgs. As the auger filled with soil, it was removed from the hole, and the portion for volatile organic analysis (VOA) was immediately collected with a stainless-steel spoon. The remaining sample was placed in a stainless-steel mixing bowl. This process was repeated until the entire interval had been collected. The hole was then augered to approximately 3 feet bgs, and a new, decontaminated auger bucket was used. The lower interval sample was then collected, following the same procedures after the initial soil was removed from the auger. A coring machine was used at a few locations within Zone K to gain access to soil covered by concrete and/or asphalt.

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

Section 3.2.2.3 of the *Zone A RFI Report* (EnSafe, August 1998) discusses soil sample preparation, packaging, and shipment for CNC.

**3.2.2.4 Soil Sample Analysis**

Section 3.2.2.4 of the *Zone A RFI Report* (EnSafe, August 1998) discusses soil sample analysis for CNC.

### **3.2.3 Monitoring Well Installation and Development**

Section 5 of the CSAP describes monitoring well installation and development methods used. All monitoring wells were installed in accordance with South Carolina Well Standards and Regulations after permits were acquired from the SCDHEC. The following subsections briefly describe the site-specific methods applied in Zone K. Appendix A includes all lithologic boring logs and monitoring well construction diagrams for Zone K.

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

All shallow monitoring wells were installed so that groundwater samples could be collected from the upper portion of the shallow aquifer. These monitoring wells were installed using the hollow-stem auger drilling method, which involved augering to the total depth of the borehole using hollow-stem auger flights tipped with a lead auger head. The total depth of the shallow wells depended primarily on depth to groundwater. Every effort was made to bracket the water table surface at each shallow monitoring well location.

For each monitoring well borehole, 2-foot split-spoon samples were collected continuously for lithologic characterization. These soil samples were visually classified and screened for organic vapors by the onsite geologist, but were not retained for chemical analysis, unless the location was being used for soil contaminant characterization and delineation.

Shelby tube samples representing the lithology of the typical screened interval for each SWMU/AOC were retained for engineering parameter analysis.

Typical shallow monitoring well construction involved placing a 10-foot section of 2-inch inside diameter polyvinyl chloride (PVC) screen with 0.010-inch slots attached to 10 feet of 2-inch ID PVC riser pipe down the inside of the hollow-stem auger, after drilling to the desired depth. Filter pack material was then poured into the annular space between the hollow-stem auger and PVC to

approximately 2 feet above the top of the screened section. As the sand was added, the level in the annulus borehole was measured with a weighted tape. The hollow-stem auger sections were gradually withdrawn while the sand was added to allow uniform placement of the filter pack and to avoid bridging and inadvertently raising the well screen and riser casing with the augers. Care was taken to not raise the hollow-stem auger sections higher than the filter pack level in the borehole, preventing the formation from collapsing on the well screen. The well was then "swabbed" by raising and lowering a surge block the length of the screened interval. This action settled the sand and would often lower the level of sand as much as a foot. Following swabbing, additional sand was added to the annulus of the well to raise its level to at least 2 feet above the screened interval. Bentonite pellets were placed from the top of the filter pack to ground surface, then hydrated with potable water. After allowing for the bentonite to hydrate for approximately 24 hours, the surface mount was constructed. An expansion locking well cap provided temporary groundwater protection before the surface mount was completed.

### **3.2.3.2 Monitoring Well Protector Construction**

Section 3.2.3.4 of the *Zone A RFI Report* (EnSafe, August 1998) discusses monitoring well protector installation for CNC.

### **3.2.3.3 Monitoring Well Development**

Section 3.2.3.5 of the *Zone A RFI Report* (EnSafe, August 1998) discusses monitoring well development for CNC.

### **3.2.4 Groundwater Sampling**

Groundwater was sampled in accordance with Section 6 of the CSAP. The following subsections briefly summarize the site-specific methods applied in Zone K.

**3.2.4.1 Groundwater Sampling Locations**

Groundwater samples were collected from well locations based on the approved locations identified in the *Final Zone K RFI Work Plan* with the following exceptions. Monitoring well NBCK162001 was moved approximately 75 feet south to the edge of the soccer field. Soil samples associated with the monitoring well were collected at the originally proposed location. Monitoring well NBCK166001 was moved approximately 50 feet south to the edge of the soccer field because the field was still in use. The soil samples associated with that well location were collected at originally proposed locations. Geoprobe location NBCK166S17 was not sampled due to close proximity of monitoring well NBCK163001.

**3.2.4.2 Groundwater Sample Collection**

Section 3.2.4.2 of the *Zone A RFI Report* (EnSafe, August 1998) discusses groundwater sample collection at CNC.

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

Section 3.2.4.3 of the *Zone A RFI Report* (EnSafe, August 1998) discusses groundwater sample preparation, packaging, and shipment for CNC.

**3.2.4.4 Groundwater Sample Analysis**

Section 3.2.4.4 of the *Zone A RFI Report* (EnSafe, August 1998) discusses groundwater sample analysis for CNC.

**3.2.5 Sediment Sampling**

Sediment was sampled in accordance with Section 7 of the CSAP. The following subsections briefly summarize the methods, as applied in Zone K.

**3.2.5.1 Sediment Sample Locations**

Sediment samples were collected from the approved locations identified in the *Final Zone K RFI Work Plan*.

**3.2.5.2 Sediment Sample Collection**

At Naval Annex, composite sediment samples were collected for laboratory analysis from 0 to 6 inches bgs using the scoop sampling method outlined in Section 7.2.3 of the CSAP. The following summarizes that method.

Stainless-steel spoons and bowls were used to collect sediment samples. After the sample location was located, a decontaminated stainless-steel spoon or spatula was used to expose a previously unexposed surface. Using a clean decontaminated stainless-steel spoon, the exposed sediment was then scooped into a decontaminated stainless-steel bowl. For VOC samples, the sample containers were filled directly from the sampling device while filtering out twigs, large rocks, and grass. The remainder was homogenized in the bowl and placed into the appropriate sample containers.

AOC 695 (Electric Locomotive Shed, Former 119, Clouter Island) sediment samples were collected from the Cooper River in the vicinity of the former locomotive shed using the dredge sampling method outlined in Section 7.2.1 of the CSAP. The following is a summary of that method.

The Ponar grab sampler was used to collect underwater dredge sediment samples. The Ponar sampler is a steel, clam-shell type scoop activated by a cantilevered system. The sampler is lowered into the sediment and the jaws of the sampler are closed by releasing the tension on the rope. The sampler is then retrieved, and the jaws are opened, allowing access to the sample. The appropriate sample containers are then filled (VOA samples first). The collection process is repeated until sufficient volume is obtained.

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

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

Sediment samples were identified at the time of collection in accordance with Section 11.4 of the CSAP, and as stated in Section 3.2.1. Appropriate labels and custody seals were completed and affixed to each sample bottle. Immediately after sample collection and identification, sample containers were placed on ice in coolers. Sampling information was recorded in a dedicated field logbook and in a master logbook placed in a fireproof safe in the site trailer.

Sediment sample containers were individually custody-sealed, encased in protective bubble wrap, double-bagged in waterproof reseal able plastic bags, and placed on ice in a cooler to ensure proper preservation at 4°C during shipment. All sample information was entered on a preprinted chain-of-custody form which was then affixed to the top, inside surface of the sample cooler. Temperature blanks were included with each shipment to monitor sample temperature upon arrival.

### **3.2.5.4 Sediment Sample Analysis**

Sediment samples were analyzed per USEPA SW-846 at data quality objectives (DQO) Level III unless otherwise noted, as follows:

- Metals 40 CFR Part 264 Appendix IX
- VOC USEPA Method 8240
- SVOC USEPA Method 8270
- Pesticides/PCBs USEPA Method 8080
- Cyanide USEPA Method 9010

- Organotins Per Triangle Laboratories, Research Triangle Park, 1  
North Carolina Standard Operating Procedure 2
- Dioxins USEPA Method 8290 3
- Hexavalent Chromium USEPA Method 218.4 4
- Organophosphorus pesticides USEPA Method 8140 5

**3.2.6 Geoprobe Sampling** 6

A Geoprobe investigation was completed at two sites within Zone K to investigate/delineate the 7  
extent of groundwater contamination. Sampling was performed in accordance with Section 6.1.3 8  
in Revision No. 01 of the CSAP. The following sections detail the Geoprobe sampling conducted 9  
in Zone K. 10

**3.2.6.1 Geoprobe Sampling Locations** 11

Ninety-nine locations were sampled with the Geoprobe (92 at SWMU 166, six at AOC 698, and 12  
one at SWMU 163). All locations were permitted in accordance with SCDHEC well standards 13  
and regulations. 14

**3.2.6.2 Geoprobe Sample Collection** 15

Subsurface groundwater samples from the water table aquifer were collected at each location. At 16  
the locations associated with the SWMU 166 TCE plume, multiple depths were sampled. The 17  
shallowest depth which produced sufficient yield was approximately 11 to 13 feet bgs. The rods 18  
were pushed to the depth to be sampled and then retracted two feet to open the screened section. 19  
A length of Teflon tubing was inserted to the bottom of the probed interval. Samples for VOC 20  
analysis were collected by allowing the contents of the tubing to gravity drain into the sample 21  
bottles. After sampling, each borehole was abandoned using bentonite pellets. 22

<b>3.2.6.3 Geoprobe Sample Preparation, Packaging, and Shipment</b>	1	
Samples were labeled and placed on ice in a cooler immediately after collection, then delivered to the offsite laboratory for analysis.	2 3	
<b>3.2.6.4 Geoprobe Sample Analysis</b>	4	
Geoprobe samples were analyzed per USEPA SW-846 at DQO Level III as follows:	5	
• VOC	USEPA Method 8260	6
• TPH		7
(diesel range organics – DRO)	USEPA Method Modified 8015	8
(gasoline range organics – GRO)	USEPA Method Modified 8015	9
<b>3.2.7 Vertical and Horizontal Surveying</b>	10	
Section 3.2.7 of the <i>Zone A RFI Report</i> (EnSafe, August 1998) discusses vertical and horizontal surveying for CNC.	11 12	
<b>3.2.8 Aquifer Characterization</b>	13	
Section 3.2.8 of the <i>Zone A RFI Report</i> (EnSafe, August 1998) discusses methods for aquifer characterization for CNC.	14 15	
<b>3.2.9 Decontamination Procedures</b>	16	
Section 3.2.9 of the <i>Zone A RFI Report</i> (EnSafe, August 1998) discusses decontamination procedures for CNC.	17 18	
<b>3.2.9.1 Decontamination Area Setup</b>	19	
Section 3.2.9.1 of the <i>Zone A RFI Report</i> (EnSafe, August 1998) discusses decontamination area setup for CNC.	20 21	

<b>3.2.9.2 Cross-Contamination Prevention</b>	1
Section 3.2.9 of the <i>Zone A RFI Report</i> (EnSafe, August 1998) discusses cross-contamination prevention for CNC.	2 3
<b>3.2.9.3 Nonsampling Equipment</b>	4
Section 3.2.9.3 of the <i>Zone A RFI Report</i> (EnSafe, August 1998) discusses decontamination procedures for nonsampling equipment for CNC.	5 6
<b>3.2.9.4 Sampling Equipment</b>	7
Section 3.2.9 of the <i>Zone A RFI Report</i> (EnSafe, August 1998) discusses decontamination procedures for sampling equipment for CNC	8 9

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<b>4.0 DATA VALIDATION</b>	1
<b>4.1 Introduction</b>	2
DQOs are qualitative and quantitative statements specifying the quality of data required to support decisions during environmental response actions. The level of certainty regarding the precision of the data varies with their intended end use. According to USEPA guidance, <i>Data Quality Objectives for Remedial Response Activities, Development Process</i> , EPA/540/G-87/003 (USEPA, March 1987), the levels of analytical data are as follows:	3 4 5 6 7
<ul style="list-style-type: none"><li>• Level I — Field screening or analysis using portable instruments. Results are often not compound-specific and not quantitative, but results are available in real-time. It is the least costly analytical option.</li></ul>	8 9 10
<ul style="list-style-type: none"><li>• Level II — Field analyses using more sophisticated portable analytical instruments. In some cases the instruments may be set up in a mobile laboratory onsite. The quality of the data generated depends on the use of suitable calibration standards, reference materials, and sample preparation equipment in addition to operator training. Results are available in real-time or in several hours.</li></ul>	11 12 13 14 15
<ul style="list-style-type: none"><li>• Level III — All analyses performed in an offsite analytical laboratory. Level III analyses may use Contract Laboratory Program (CLP) procedures, but do not usually use the validation or documentation procedures required of CLP Level IV analysis. The laboratory need not be a CLP laboratory.</li></ul>	16 17 18 19
<ul style="list-style-type: none"><li>• Level IV — All analyses are performed in an offsite analytical laboratory following rigorous QA/QC protocols and documentation meeting or exceeding CLP requirements.</li></ul>	20 21

- Level V – Analysis by nonstandard methods. All analyses are performed by an offsite analytical laboratory which need not be a CLP laboratory. Method development or method modification may be required for specific constituents or detection limits. CLP special analytical services (SAS) are Level V.

For the RFI at CNC, analytical Level III data with 10% analyses for Appendix IX at Level IV were deemed appropriate for the intended data uses: site characterization, risk assessment, and corrective measure determinations/design. For Zone K, samples from sites 693 and 694 were all analyzed for the Appendix IX parameters.

It should be noted that in September 1993, USEPA replaced this guidance with an updated manual, *Data Quality Objectives Process for Superfund, Interim Final Guidance*, EPA/540/G-93/071 (USEPA, September 1993) which stated, "This guidance replaces the earlier guidance EPA 540/G-87/003, Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-7B and the five analytical levels introduced in that document." As a result, the five analytical data levels were reduced to two – screening data and definitive data.

Definitive data (formerly Levels III and IV) are defined as analytical data generated using rigorous analytical methods, such as approved USEPA reference methods. These data are analyte-specific, with confirmation of analyte identity and concentration. These approved methods produce tangible raw data (e.g., chromatograms, spectra, digital values, etc.) in paper printouts or computer-generated electronic files. Analytical or total measurement error (precision) must be determined for data to be definitive (USEPA, September 1993). As a result, the data collected at CNC are now defined as definitive data per the most recent USEPA guidance but will still be referred to as Level III and Level IV throughout the report to avoid confusion.

## 4.2 Validation Summary

This section presents the QA/QC evaluation of the data produced from the analysis of environmental media samples collected in Zone K during the RFI. This evaluation will verify that the appropriate QA/QC elements were followed and/or completed (e.g., method requirements, documentation, etc.) to identify and/or characterize any problems with the data set, and ultimately to determine the usability of the analytical data for site characterization, risk assessment, and corrective measure determinations.

Examples of definitive data (formerly Level III and IV) QA/QC elements are as follows:

- Sample documentation (verified time of sample receipt, extraction and holding times)
- Chain of custody
- Initial and continuing calibration
- Determination and documentation of detection limits
- Analyte(s) identification
- Analyte(s) quantification
- QC blanks (trip, method, rinsate)
- Matrix spike recoveries
- Performance evaluation (PE) samples (when specified)
- Analytical method precision
- Total measurement error determination

RFI environmental samples were collected at Zone K from November 1996 to September 1997. Zone K is presently under going groundwater monitoring as part of the RFI. The samples were analyzed by Ceimic and Southwest Laboratory of Oklahoma. In accordance with the approved CSAP, sample analyses followed the guidance in the *USEPA Test Methods for Evaluating Solid*

Waste, SW-846 (USEPA, 1992) and Title 40 CFR Part 264. Table 4.1 summarizes the analytical methods and DQO laboratory deliverables.

**Table 4.1  
 CNC Analytical Program**

Full Scan/Appendix IX Analytical Methods	Data Quality Level	Method Reference
Volatile Organic Compounds (VOCs)	III/IV	SW-846 8260
Semivolatile Organic Compounds (SVOCs)	III/IV	SW-846 8270
Pesticides/Polychlorinated biphenyls (PCBs)	III/IV	SW-846 8080
Chlorinated Herbicides	IV	SW-846 8150
Organophosphorous Pesticides (OP Pest)	IV	SW-846 8140
Cyanide	III/IV	USEPA 9012
TAL Metals	III/IV	SW-846 6010/7060/7421/7470/7740/7841
Hexavalent Chromium	IV	USEPA 218.4
Polychlorinated dibenzo-p-dioxins	IV	USEPA 8290
Explosives	III/IV	USEPA 8330
Organotins	III	GC/FPD Wade et al
Total Petroleum Hydrocarbons - Diesel Range	III	SW-846 Modified 8015
Total Petroleum Hydrocarbons- Gasoline	III	SW-846 Modified 8015

**Notes:**

Full Scan parameters include: VOCs, SVOCs, pesticides/PCBs, metals, and cyanide (Level III). Appendix IX parameters include: VOCs, SVOCs, pesticides/PCBs, herbicides, OP pesticides, metals, cyanide, hexavalent chromium, and dioxins (Level IV). TAL Metals includes Tin. Explosives, Organotins, and Total Petroleum Hydrocarbons analyses were site specific.

The methods listed in Table 4.1 are from:

- USEPA OSWER, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Third Edition, revised July 1992.

- USEPA Environmental Monitoring and Support Laboratory, *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, revised March 1983. 1  
2
- *Title 40 Code of Federal Regulations Part 264, Appendix IX (52 Federal Register 25947)*, 3  
July 1987. 4

Third-party independent data validation of all analytical work performed under the CSAP was 5  
conducted by Validata Chemical Services based on the QC criteria developed for CLP. The third- 6  
party validator's function was to assess and summarize the quality and reliability of the data to 7  
determine their usability and to document any factors affecting data usability, such as compliance 8  
with methods, possible matrix interferences, and laboratory blank contamination. 9

#### **4.2.1 Organic Evaluation Criteria** 10

Section 4.2.1 of the Zone A RFI Report discusses the organic evaluation criteria as they apply to 11  
the Zone K RFI. Appendix E includes the complete analytical dataset for Zone K. 12

##### **4.2.1.1 Holding Times** 13

Section 4.2.1.1 of the Zone A RFI Report discusses organic sample holding times as they apply 14  
to the Zone K RFI. 15

##### **4.2.1.2 GC/MS Instrument Performance Checks** 16

Section 4.2.1.2 of the Zone A RFI Report discusses performance standards for VOC and SVOC 17  
analyses as they apply to the Zone K RFI. 18

##### **4.2.1.3 Surrogate Spike Recoveries** 19

Section 4.2.1.3 of the Zone A RFI Report discusses organic surrogate compounds as they apply 20  
to the Zone K RFI. 21

<b>4.2.1.4</b>	<b>Instrument Calibration</b>	1
	Section 4.2.1.4 of the Zone A RFI Report discusses instrument calibration as they apply to organic data evaluation for the Zone K RFI.	2 3
<b>4.2.1.5</b>	<b>Matrix Spike/Matrix Spike Duplicate</b>	4
	Section 4.2.1.5 of the Zone A RFI Report discusses matrix spikes/duplicates as they apply to organic data evaluation for the Zone K RFI.	5 6
<b>4.2.1.6</b>	<b>Laboratory Control Samples and Laboratory Duplicates</b>	7
	Section 4.2.1.6 of the Zone A RFI Report discusses laboratory control samples/duplicates as they apply to organic data evaluation for the Zone K RFI.	8 9
<b>4.2.1.7</b>	<b>Blank Analysis</b>	10
	Section 4.2.1.7 of the Zone A RFI Report discusses blank analysis as they apply to organic data evaluation for the Zone K RFI.	11 12
<b>4.2.1.8</b>	<b>Field-Derived Blanks</b>	13
	Section 4.2.1.8 of the Zone A RFI Report discusses field derived blanks as they apply to organic data evaluation for the Zone K RFI.	14 15
<b>4.2.1.9</b>	<b>Internal Standard Performance</b>	16
	Section 4.2.1.9 of the Zone A RFI Report discusses field derived blanks as they apply to organic data evaluation for the Zone K RFI.	17 18
<b>4.2.1.10</b>	<b>Diluted Samples</b>	19
	A table is provided of diluted samples due to high concentrations of contamination. The practical quantitation limits (PQLs) reported in the diluted sample tables and in the dataset spreadsheets can	20 21

be compared to the method detection limit (MDL) study provided on page 4-15 to determine if PQLs were sufficiently low to be compared with reference concentrations (e.g., Maximum Contaminant Levels [MCLs], Risk-Based Concentrations [RBCs], etc.). Table 4.2 lists the diluted samples for Zone K.

**Table 4.2**  
**Diluted DPT Sample Summary**

Method	Parameter	Sample ID	Results	Units	VQUAL
SW846-VOA	1,2-Dichloroethene (total)	166GP03234	170.00	UG/L	D
SW846-VOA	1,2-Dichloroethene (total)	166GP03534	540.00	UG/L	D
SW846-VOA	1,2-Dichloroethene (total)	166GP04234	570.00	UG/L	D
SW846-VOA	Trichloroethene	166GP03234	1400.00	UG/L	D
SW846-VOA	Trichloroethene	166GP03334	1600.00	UG/L	D
SW846-VOA	Trichloroethene	166GP03434	1800.00	UG/L	D
SW846-VOA	Trichloroethene	166GP03512	640.00	UG/L	D
SW846-VOA	Trichloroethene	166GP03534	250.00	UG/L	D
SW846-VOA	Trichloroethene	166GP03911	3000.00	UG/L	D
SW846-VOA	Trichloroethene	166GP04234	1400.00	UG/L	D
SW846-VOA	Trichloroethene	166GP04926	1400.00	UG/L	D
SW846-VOA	Trichloroethene	166GP05424	1600.00	UG/L	D
SW846-VOA	Trichloroethene	166GP05433	3700.00	UG/L	D
SW846-VOA	Trichloroethene	166GP05811	160.00	UG/L	DJ
SW846-VOA	Trichloroethene	166GP06133	940.00	UG/L	D
SW846-VOA	Trichloroethene	166GP06333	2000.00	UG/L	D
SW846-VOA	Trichloroethene	166GP06726	370.00	UG/L	D

**Table 4.2**  
**Diluted Soil Sample Summary**

Method	Parameter	Sample Id	Results	Units	VQUAL
SW846-PEST	4,4'-DDD	162CB00301	72.70	UG/KG	D
SW846-PEST	4,4'-DDD	162SB00301	87.90	UG/KG	D
SW846-PEST	4,4'-DDD	162SB00501	147.00	UG/KG	D
SW846-PEST	4,4-DDD	ANXM000101	124.00	UG/KG	D
SW846-PEST	4,4'-DDE	162CB00301	144.00	UG/KG	D
SW846-PEST	4,4'-DDE	162SB00101	390.00	UG/KG	D

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**Table 4.2**  
**Diluted Soil Sample Summary**

Method	Parameter	Sample Id	Results	Units	VQUAL
SW846-PEST	4,4'-DDE	162SB00201	336.00	UG/KG	D
SW846-PEST	4,4'-DDE	162SB00301	174.00	UG/KG	D
SW846-PEST	4,4'-DDE	162SB00501	450.00	UG/KG	D
SW846-PEST	4,4'-DDE	698SB01101	990.00	UG/KG	D
SW876-PEST	4,4'-DDE	698SB01301	52.00	UG/KG	D
SW846-PEST	4,4'-DDE	ANXM000101	118.00	UG/KG	D
SW846-PEST	4,4'-DDT	162CB00301	137.00	UG/KG	D
SW846-PEST	4,4'-DDT	162SB00101	596.00	UG/KG	D
SW846-PEST	4,4'-DDT	162SB00201	383.00	UG/KG	D
SW846-PEST	4,4'-DDT	162SB00301	160.00	UG/KG	D
SW846-PEST	4,4'-DDT	162SB00501	600.00	UG/KG	D
SW846-PEST	4,4'-DDT	698SB01101	370.00	UG/KG	D
SW846-PEST	4,4'-DDT	698SB01201	43.00	UG/KG	D
SW846-PEST	4,4'-DDT	698SB01301	68.00	UG/KG	D
SW846-PCB	Aroclor-1260	696SB00301	1780.00	UG/KG	D
SW846-PEST	Heptachlor epoxide	698SB01101	140.00	UG/KG	D
SW846-VOA	Trichloroethene	ASRSB00702	1800.00	UG/KG	D
SW846-VOA	Trichloroethene	ASRSB00801	150.00	UG/KG	D
SW846-VOA	Tetrachloroethene	163SB00301	990.00	UG/KG	D

**Table 4.2**  
**Diluted Groundwater Sample Summary**

Method	Parameter	Sample Id	Result	Units	VQUAL
SW846-VOA	Trichloroethene	166GW07D1A	1000.00	UG/L	D
SW846-VOA	Trichloroethene	166GW10D1A	2200.00	UG/L	D
SW846-VOA	Trichloroethene	166GW13D1A	2700.00	UG/L	D
SW846-VOA	Trichloroethene	166GW14D1A	320.00	UG/L	D
SW846-VOA	Trichloroethene	166GW07D01	930.00	UG/L	D
SW846-VOA	Trichloroethene	166GW07D02	1200.00	UG/L	D
SW846-VOA	Trichloroethene	166GW07D03	2000.00	UG/L	D
SW846-VOA	Trichloroethene	166GW07D04	3800.00	UG/L	D
SW846-VOA	Trichloroethene	166GW10D01	1900.00	UG/L	D
SW846-VOA	Trichloroethene	166GW10D02	3200.00	UG/L	D

**Table 4.2**  
**Diluted Groundwater Sample Summary**

Method	Parameter	Sample Id	Result	Units	VQUAL
SW846-VOA	Trichloroethene	166GW10D04	3400.00	UG/L	D
SW846-VOA	Trichloroethene	166GW13D02	7200.00	UG/L	D
SW846-VOA	Trichloroethene	166GW16D01	2600.00	UG/L	D
SW846-VOA	Trichloroethene	166GW16D02	1700.00	UG/L	D
SW846-VOA	Trichloroethene	166GW01601	3400.00	UG/L	D
SW846-VOA	Trichloroethene	166GW01602	1600.00	UG/L	D
SW846-VOA	Trichloroethene			UG/L	D
SW846-VOA	Trichloroethene			UG/L	D
SW846-VOA	Trichloroethene			UG/L	D
SW846-VOA	Trichloroethene			UG/L	D
SW846-VOA	Trichloroethene			UG/L	D

#### 4.2.2 Inorganic Evaluation Criteria 1

Section 4.2.2 of the Zone A RFI Report discusses inorganic sample holding times as they apply to the Zone K RFI. 2  
3

##### 4.2.2.1 Holding Times 4

Section 4.2.2.1 of the Zone A RFI Report discusses inorganic holding times as they apply to the Zone K RFI. 5  
6

##### 4.2.2.2 Instrument Calibration 7

Section 4.2.2.2 of the Zone A RFI Report discusses instrument calibration as they apply to inorganic data evaluation for the Zone K RFI. 8  
9

##### 4.2.2.3 Blank Analysis 10

Section 4.2.2.3 of the Zone A RFI Report discusses inorganic blank analysis as they apply to inorganic data evaluation for the Zone K RFI. 11  
12

<b>4.2.2.4</b>	<b>Inductively Coupled Argon Plasma Interference Check Samples</b>	1
	Section 4.2.2.4 of the <i>Zone A RFI Report</i> discusses inductively coupled argon plasma interference check samples as they apply to inorganic data evaluation for the Zone K RFI.	2 3
<b>4.2.2.5</b>	<b>Laboratory Control Samples</b>	4
	Section 4.2.2.5 of the <i>Zone A RFI Report</i> discusses laboratory control samples as they apply to inorganic data evaluation for the Zone K RFI.	5 6
<b>4.2.2.6</b>	<b>Spike Sample Analysis</b>	7
	Section 4.2.2.6 of the <i>Zone A RFI Report</i> discusses spike sample analysis as it applies to inorganic data evaluation for the Zone K RFI.	8 9
<b>4.2.2.7</b>	<b>Laboratory Duplicates</b>	10
	Section 4.2.2.7 of the <i>Zone A RFI Report</i> discusses laboratory duplicates as they apply to inorganic data evaluation for the Zone K RFI.	11 12
<b>4.2.2.8</b>	<b>Inductively Coupled Argon Plasma (ICAP) Serial Dilutions</b>	13
	Section 4.2.2.8 of the <i>Zone A RFI Report</i> discusses ICAP serial dilutions as they apply to inorganic data evaluation for the Zone K RFI.	14 15
<b>4.2.2.9</b>	<b>AA Duplicate Injections and Postdigestion Spike Recoveries</b>	16
	Section 4.2.2.9 of the <i>Zone A RFI Report</i> discusses atomic absorption (AA) duplicate injections and postdigestion spike recoveries as they apply to inorganic data evaluation for the Zone K RFI.	17 18
<b>4.3</b>	<b>Zone K Data Validation Reports</b>	19
	The Zone K data validation reports, along with a table of validation qualifiers, are included as Appendix F for review. These reports are the outcome of the evaluations described above and are	20 21

specific to the analytical data collected during the Zone K RFI. During data validation review of Zone K DPT groundwater analytical sample results, the following deficiencies and/or problems were noted in the volatile, semivolatile, and metals methods per site.

**Site 162:** For the soil samples in Site 162, the VOC acetone was detected in the method blank. The metals had aluminum, beryllium, calcium, cobalt, copper, potassium, selenium, sodium, and zinc were detected in the method blank.

The VOC chloroform was detected in the distilled water and equipment blanks for Site 162. The SVOC had phenol was detected in the equipment blank. The metals, iron, magnesium, sodium, and zinc were detected in the distilled water blank. Aluminum, barium, cadmium, calcium, copper, iron, lead, magnesium, manganese, potassium, sodium, vanadium, and zinc were detected in the equipment blank. The metals aluminum, barium, calcium, chromium, cobalt, copper, magnesium, nickel, potassium, silver, sodium, and zinc were detected in the method blank.

**Site 163:** Acetone was detected in the equipment blank. The SVOC phenol was detected in the equipment blank. The metals barium, copper, nickel, sodium, tin and zinc were detected in the method blank.

**Site 164:** Acetone was detected in the trip blank, chloroform was detected in the equipment blank, and 1,2- dichloroethene was detected in the method blank. Phenol was detected in the method blank. The metals aluminum, barium, beryllium, calcium, chromium, cobalt, copper, magnesium, nickel, potassium, silver, sodium, thallium, and zinc were detected in the method blank. Aluminum, barium, sodium, and zinc were detected in the distilled water blank. Aluminum and barium were detected in the equipment blank.

**Site 166:** The VOC vinyl chloride was detected in the method blank and phenol was detected in the method blank. The metals aluminum, barium, beryllium, chromium, cobalt, copper, magnesium, nickel, potassium, silver, and zinc were detected in the method blank.

**Site 693:** The VOCs acetone, 2-hexanone and 1,4-dioxane were detected in the method blank and acetone was detected in the trip blank. The metals aluminum, antimony, barium, calcium, copper, magnesium, sodium, and zinc were detected in the method blank.

**Site 694:** The VOCs acetone and 2-hexanone were detected in the blank and acetone, acetonitrile, and isobutyl alcohol were detected in the method blank. The SVOCs benzo(g,h,i)pyrene and dibenz (a,h)anthracene were detected in the method blank. The metals aluminum, antimony, barium, calcium, copper, magnesium, sodium, and zinc were detected in the method blank.

**Site 694:** The VOCs acetone, 2-hexanone and 1,4-dioxane were detected in the method blank and acetone was detected in the trip blank. The metals aluminum, antimony, barium, calcium, copper, magnesium, sodium, and zinc were detected in the method blank.

**Site 696:** Acetone was detected in the trip blank.

**Site 698:** Aluminum, arsenic, barium, beryllium, calcium, chromium, chromium, cobalt, copper, iron lead, magnesium, nickel, potassium, sodium, silver, tin, vanadium, and zinc were detected in the method blank.

**Auto Service Rack Site:** The VOC acetone was detected in the trip blank and acetone and methylene chloride were detected in the method blank.

**The Grid Samples:** Acetone was detected in the trip and method blanks and acetone and chloroform were detected in the equipment blank. The SVOC phenol was detected in the equipment blank. The metals aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, silver, sodium, vanadium, and zinc were detected in the equipment blank. Magnesium and zinc were detected in the method blank.

**DPT Samples:** In Site 166, trichloroethene was detected in the trip blank, acetone was detected in the method blank, and acetone and chloroform were detected in the equipment blank. The SVOC, bis (2-ethylhexyl)phthalate was detected in the equipment blank. The metals aluminum, arsenic, barium, beryllium, cadmium,, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, nickel, potassium, sodium, thallium, tin, vanadium, and zinc were detected in the equipment blank. Aluminum, barium, beryllium, calcium, chromium, cobalt, copper, cyanide, nickel, potassium, selenium, silver, sodium, thallium, and zinc were detected in the method blank.

**Groundwater Samples:** At site 161, acetone was detected in the trip blank and the method blank. The SVOCs bis (2-ethylhexyl)phthalate and diethylphthalate were detected in the method blank. The metals beryllium, calcium, magnesium, and zinc were detected in the method blank.

**Site 162:** The VOCs chloroform and acetone were detected in the distilled water blank and equipment blank respectively. The metals sodium and zinc were detected in the distilled water blank and lead, selenium, sodium, vanadium, and zinc were detected in the equipment blank. Aluminum, antimony, calcium, cobalt, copper, lead, magnesium, manganese, potassium, sodium, selenium, vanadium, and zinc were detected in the methods blank.

**Site 163:** Acetone and chloroform were detected in the distilled water blank, 1  
bromodichloromethane was detected in the equipment and field blanks, and acetone was detected 2  
in the trip and method blanks. The SVOC bis(2-ethylhexyl)phthalate was detected in the method 3  
blank and diethylphthalate was detected in the distilled water, equipment, and field blanks. The 4  
metals beryllium, chromium, and zinc were detected in the method blank. The metals, aluminum, 5  
barium, magnesium, potassium, sodium, and zinc were detected in the distilled water blank. 6  
Aluminum, barium, calcium, copper, iron, lead, magnesium, potassium, sodium, and zinc were 7  
detected in the equipment blank. Aluminum, barium, calcium, copper, iron, magnesium, 8  
potassium, sodium, tin, and zinc were detected in the field blank. Aluminum, antimony, calcium, 9  
cobalt, copper, lead, magnesium, selenium, thallium, vanadium, and zinc were detected in method 10  
blank. 11

**Site 166:** For the volatiles, acetone was detected in the trip and method blanks, 12  
bromochloroethane and chloroform were detected in the distilled water and equipment blanks, and 13  
acetone was detected in the equipment blank. The semivolatile method had di-n-butylphthalate 14  
detected in the equipment blank and diethylphthalate and bis (2-ethylhexyl)phthalate were detected 15  
in the method blank. The metals antimony, sodium, and zinc were detected in the distilled water 16  
blank; aluminum, antimony, barium, sodium, and zinc were detected in the equipment blank; and 17  
aluminum, calcium, copper, sodium, and zinc were detected in the field blank. Aluminum, 18  
beryllium, calcium, magnesium, thallium, and zinc were detected in the method blanks. 19

**Site 694:** For volatiles, acetone was detected in the field blank and methylene chloride was 20  
detected in the field and trip blanks. For the semivolatiles, Di-n-butylphthalate and 21  
diethylphthalate were detected in the method blank. The metals aluminum, barium, cadmium, 22  
calcium, cyanide, iron, magnesium, manganese, selenium, sodium, and zinc were detected in the 23  
field blank. The method blank had detections of antimony, barium, beryllium, calcium, cyanide, 24  
potassium, sodium, and zinc. 25

**Site 698:** The VOC acetone was detected in the trip and method blanks. The SVOC Bis(2-ethylhexyl)phthalate was detected in the method blank. The metals beryllium, calcium, magnesium, and zinc were detected in the method blank.

**Groundwater Grid Samples:** The VOC acetone was detected in the distilled water, field, and method blanks.

For SVOCs, Bis(2-ethylhexyl)phthalate was detected in the distilled water and method blanks and diethylphthalate was detected in the method blank. The metals aluminum, barium, calcium, copper, iron, magnesium, manganese, nickel, potassium, sodium, and zinc were detected in the distilled water blank. In the equipment blank, aluminum, barium, calcium, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, and zinc were detected. The field blank had detections of aluminum, antimony, barium, calcium, copper, iron, magnesium, manganese, nickel, potassium, sodium, and zinc. The method blanks had detections of aluminum, antimony, calcium, cobalt, copper, cyanide, lead, magnesium, manganese, potassium, selenium, sodium, thallium, vanadium, and zinc.

Review of the analytical data showed elevated detection limits for sample 166GP05333 due to trichloroethene concentrations of 15000  $\mu\text{g}/\text{l}$ .

Method detection limits (MDLs), the lowest concentration seen by the laboratory with 99% accuracy, are provided below as a comparison to RBCs and MCLs of reported contaminants.

Southwest Laboratory of Oklahoma's Method Detection Limit Study	1
Test Code	2
Method	3
Matrix	4
Extract Volume	5
Initial Calibration	6
Continuing Calibration	7

Tetra-Octa Dioxin/Furans-High Res Mass Spec  
 MS790  
 SW846/8290, High Resolution Method  
 Water-Soil  
 1000 mL - 10g  
 1.0/2.5/5 - 200/500/1000 ng/mL  
 10/25/50 ng/mL

Compound	MDL's CAS Number	Water pg/L	Soil ng/Kg	
2378-TCDD	1746-01-6	6.79	0.17	10
12378-PeCDD	40321-76-4	6.64	0.74	11
123478-HxCDD	39227-28-6	17.63	0.82	12
123678-HxCDD	57653-85-7	13.56	0.89	13
123789-HxCDD	19408-74-3	15.35	0.96	14
1234678-HpCDD	35822-39-4	14.44	0.41	15
OCDD	3268-87-9	21.46	0.59	16
2378-TCDF	51207-31-9	2.96	0.39	17
12378-PeCDF	57117-41-6	5.58	0.27	18
23478-PeCDF	57117-31-4	13.26	0.60	19
123478-HxCDF	70648-26-9	7.96	0.54	20
123678-HxCDF	57117-44-9	8.68	0.57	21
123789-HxCDF	72918-21-9	17.87	0.69	22
234678-HxCDF	60851-34-5	16.00	0.88	23
1234678-HpCDF	67562-39-4	10.99	0.26	24
1234789-HpCDF	55673-89-7	17.98	0.53	25
OCDF	39001-02-0	10.63	0.32	26

	<b>Volatiles</b>	1
Test Code	MS300	2
Method	SW846 8240, 3rd Edition, Nov. 1986/Sept. 1994	3
Matrix	Soil-Water	4
Sample Volume	5 g - 5 mL	5
Initial Calibration	5-20-50-100-200 ppb , %RSD < 30% for CCC compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100	6
Continuing Calibration	50 ppb, %D < 20% for CCC Compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100	7
		8
		9

<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil µg/kg</b>	
Chloromethane	74-87-3	0.96	1.6	10
Vinyl Chloride	75-01-4	1.4	1.8	11
Bromomethane	74-83-9	1.8	2.0	12
Chloroethane	75-00-3	1.4	2.1	13
1,1-Dichloroethene	75-35-4	1.4	1.8	14
Acetone	67-64-1	1.6	2.6	15
Carbon Disulfide	75-15-0	1.5	2.0	16
Methylene Chloride	75-09-2	3.0	1.8	17
1,2-Dichloroethene (total)	540-59-0	0.97	2.1	18
trans-1,2-Dichloroethene	156-60-5	0.97	2.1	19
1,1-Dichloroethane	75-34-3	0.97	2.0	20
Vinyl Acetate	108-05-4	0.92	1.6	21
cis-1,2-Dichloroethene	156-59-2	0.93	1.9	22
2-Butanone	78-93-3	0.88	1.6	23
Chloroform	67-66-3	0.85	1.9	24
1,1,1-Trichloroethane	71-55-6	1.3	1.8	25
Carbon Tetrachloride	56-23-5	1.2	1.9	26
Benzene	71-43-2	15	1.7	27
1,2-Dichloroethane	107-06-2	0.44	2.0	28
Trichloroethene	79-01-6	1.0	1.9	29
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Compound	MDL's CAS Number	Water µg/L	Soil µg/kg	
1,2-Dichloropropane	78-87-5	0.76	1.9	1
Bromodichloromethane	75-27-4	0.68	1.9	2
2-Chloroethyl Vinyl Ether	110-75-8	0.54	4.4	3
cis-1,3-Dichloropropene	10061-01-5	0.58	2.0	4
4-Methyl-2-Pentanone	108-10-1	1.8	1.9	5
Toluene	108-88-3	1.0	1.7	6
trans-1,3-Dichloropropene	10061-02-6	0.60	1.8	7
1,1,2-Trichloroethane	79-00-5	0.45	1.9	8
Tetrachloroethene	127-18-4	1.2	2.2	9
2-Hexanone	591-78-6	0.62	2.4	10
Dibromochloromethane	124-48-1	0.78	1.6	11
Chlorobenzene	108-90-7	0.83	1.9	12
Ethylbenzene	100-41-4	1.2	1.9	13
m,p-Xylene	13-302-07	2.2	3.9	14
Xylene (Total)	1330-20-7	2.2	3.9	15
o-Xylene	95-47-6	0.93	1.9	16
Styrene	100-42-5	0.8	2.1	17
Bromoform	75-25-2	1.0	1.7	18
1,1,2,2-Tetrachloroethane	79-34-5	1.3	1.7	19
	<b>Semivolatile</b>			20
Test Code	MS500			21
Method	SW846 8270, 3rd Edition, Nov. 1986, PQL Table II, Rev.0, Sept. 1986			22 23
Matrix	Water-Soil			24
Extract Volume	1000 mL - 30g			25
Initial Calibration	20-50-100-120-160 ng, %RSD for CCC compounds = 30%, SPCC = RF > 0.05			26 27
Continuing Calibration	50 ng, %D = 25% for CCC Compounds, SPCC = RF > 0.05			28

Compound	MDL's CAS Number	Water µg/L	Soil µg/Kg	
Phenol	108-95-2	3.3	100	1
bis(2-Chloroethyl)ether	111-44-4	3.4	100	2
2-Chlorophenol	95-57-8	3.3	97	3
1,3-Dichlorobenzene	541-73-1	2.6	100	4
1,4-Dichlorobenzene	106-46-7	2.8	120	5
Benzyl alcohol	100-51-6	3.6	82	6
1,2-Dichlorobenzene	95-50-1	3.0	100	7
2-Methylphenol	95-48-7	2.9	130	8
bis(2-Chloroisopropyl)ether	108-60-1	3.5	89	9
4-Methylphenol	106-44-5	3.4	94	10
N-Nitroso-di-n-propylamine	621-64-7	2.8	87	11
Hexachloroethane	67-72-1	2.3	94	12
Isophorone	78-59-1	3.0	100	13
Nitrobenzene	98-95-3	3.5	100	14
2-Nitrophenol	88-75-5	3.4	99	15
2,4-Dimethylphenol	105-67-9	3.9	160	16
bis(2-Chloroethoxy)methane	111-91-1	3.3	99	17
2,4-Dichlorophenol	120-83-2	2.6	110	18
Benzoic acid	65-85-0	9.2	150	19
1,2,4-Trichlorobenzene	120-82-1	2.9	94	20
Naphthalene	91-20-3	2.6	110	21
4-Chloroaniline	106-47-8	3.3	210	22
Hexachlorobutadiene	87-68-3	3.0	90	23
4-Chloro-3-methylphenol	59-50-7	2.6	90	24
2-Methylnaphthalene	91-57-6	2.4	85	25
Hexachlorocyclopentadiene	77-47-4	NA	75	26
2,4,6-Trichlorophenol	88-06-2	2.6	110	27

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Compound	MDL's CAS Number	Water µg/L	Soil µg/Kg	
2,4,5-Trichlorophenol	95-95-4	2.7	110	1
2-Chloronaphthalene	91-58-7	2.1	110	2
2-Nitroaniline	88-74-4	2.8	110	3
Dimethylphthalate	131-11-3	0.8	120	4
Acenaphthylene	208-96-8	2.4	120	5
2,6-Dinitrotoluene	606-20-2	4.0	110	6
3-Nitroaniline	99-09-2	3.6	150	7
Acenaphthene	83-32-9	2.2	100	8
2,4-Dinitrophenol	51-28-5	2.9	100	9
4-Nitrophenol	100-02-7	2.6	93	10
Dibenzofuran	132-64-9	1.9	110	11
2,4-Dinitrotoluene	121-14-2	3.9	100	12
Diethylphthalate	84-66-2	1.2	120	13
Fluorene	86-73-7	1.8	100	14
4-Chlorophenyl-phenylether	7005-72-3	2.2	120	15
4-Nitroaniline	100-01-6	2.8	150	16
4,6-Dinitro-2-methylphenol	534-52-1	2.4	100	17
N-nitrosodiphenylamine	86-30-6	2.4	110	18
4-Bromophenyl-phenylether	101-55-3	2.3	86	19
Hexachlorobenzene	118-74-1	2.6	84	20
Pentachlorophenol	87-86-5	2.3	76	21
Phenanthrene	85-01-8	2.6	110	22
Anthracene	120-12-7	2.6	100	23
Di-n-butylphthalate	84-74-2	2.0	110	24
Fluoranthene	206-44-0	1.9	100	25
Pyrene	129-00-0	1.2	120	26
Butylbenzylphthalate	85-68-7	1.1	120	27

Compound	MDL's CAS Number	Water µg/L	Soil µg/Kg	
Benzo(a)anthracene	56-55-3	1.0	100	1
3,3'-Dichlorobenzidine	91-94-1	2.4	120	2
Chrysene	218-1-9	0.9	100	3
bis(2-Ethylhexyl)phthalate	117-81-7	3.5	140	4
Di-n-octylphthalate	117-84-0	2.0	110	5
Benzo(b)fluoranthene	205-99-2	1.8	120	6
Benzo(k)fluoranthene	207-08-9	2.1	100	7
Benzo(a)pyrene	50-32-8	1.6	83	8
Indeno(1,2,3-cd)pyrene	193-39-5	1.6	110	9
Dibenz(a,h)anthracene	53-70-3	1.6	120	10
Benzo(g,h,i)perylene	191-24-2	1.6	130	11

	<b>Pesticide/PCB</b>			12
Test Code	GC800			13
Method	SW846 8080A, 3rd Edition, Nov. 1986			14
Matrix	Water-Soil			15
Extract Volume	1000 mL - 30g			16
Initial Calibration	5 point calibration, %RSD=20%			17
Continuing Calibration	Single point calibration, %D = 15%			18

Compound	MDL's CAS Number	Water µg/L	Soil µg/Kg	
alpha-BHC	319-84-6	0.002	0.130	19
beta-BHC	319-85-7	0.001	0.120	20
delta-BHC	319-86-8	0.006	0.086	21
gamma-BHC(Lindane)	58-89-9	0.002	0.068	22
Heptachlor	76-44-8	0.019	0.095	23
Aldrin	309-00-2	0.001	0.062	24
Heptachlor epoxide	1024-57-3	0.004	0.051	25

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<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil µg/Kg</b>	
Endosulfan I	959-98-8	0.003	0.098	1
Dieldrin	60-57-1	0.004	0.170	2
4,4'-DDE	72-55-9	0.006	0.150	3
Endrin	72-20-8	0.008	0.120	4
Endosulfan II	33213-65-9	0.006	0.110	5
4'4'-DDD	72-54-8	0.004	0.100	6
Endosulfan sulfate	1031-07-8	0.002	0.250	7
4'4'-DDT	50-29-3	0.009	0.250	8
Methoxychlor	72-43-5	0.021	0.390	9
Endrin ketone	53494-70-5	0.004	0.110	10
Endrin aldehyde	7421-36-3	0.008	0.220	11
alpha-Chlordane	5193-71-9	0.002	0.250	12
gamma-Chlordane	5103-74-2	0.002	0.130	13
Toxaphene	8001-35-2	0.016	2.000	14
Aroclor-1016	12674-11-2	0.210	2.600	15
Aroclor-1221	11104-28-2	0.062	2.300	16
Aroclor-1232	11141-16-5	0.280	1.800	17
Aroclor-1242	53469-21-9	0.024	1.600	18
Aroclor-1248	12672-29-6	0.096	2.200	19
Aroclor-1254	11097-69-1	0.140	3.200	20
Aroclor-1260	11096-82-5	0.170	2.700	21
	<b>Pesticides, Organophosphorus</b>			22
Test Code	GC880			23
Method	SW846-8140, EPA methodology			24
Matrix	Water-Soil			25
Extract Volume	1000 mL - 30g			26
Initial Calibration	5 point calibration, %RSD = 20%			27
Continuing Calibration	Single point calibration, %D = 15%			28

Compound	MDL CAS Number	Water µg/L	Soil µg/Kg	
Dichlorvos	62-73-7	0.29	17.0	1
Mevinphos	7786-34-7	0.47	30.0	2
Demeton S	8065-48-3	0.27	19.0	3
Ethoprop	13194-48-4	0.23	17.0	4
Naled	300-76-5	0.50	60.0	5
Phorate	298-02-2	0.18	11.0	6
Diazinon	333-41-5	0.33	19.0	7
Disulfoton	298-04-4	0.22	12.0	8
Parathion-methyl	298-00-0	0.04	3.5	9
Ronnel	299-84-3	0.41	22.0	10
Fenthion	55-38-9	0.20	6.9	11
Chlorpyrifos	2921-88-2	0.20	9.9	12
Trichloroanate	327-98-0	0.20	9.5	13
Stirophos	22248-79-9	0.57	79.0	14
Tokuthion	34643-46-4	0.34	16.0	15
Merphos	150-50-5	0.29	15.0	16
Fensulfothion	115-90-2	0.60	78.0	17
Bolstar	35400-43-2	0.20	9.2	18
Azinphos-methyl	86-50-0	0.26	85.0	19
Coumaphos	56-72-4	0.41	100.0	20
	<b>Acid Herbicides</b>			21
Test Code	GC570			22
Method	SW846-8150, EPA methodology			23
Matrix	Water-Soil			24
Extract Volume	1000 mL - 30g			25
Initial Calibration	5 point calibration, %RSD=20%			26
Continuing Calibration	Single point calibration, %D = 15%			27

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Compound	MDL's CAS Number	Water µg/L	Soil µg/Kg	
Dalapon	75-99-0	1.30	24	1
Dicamba	1918-00-9	0.11	4.89	2
MCPPP	93-65-2	7.4	535	3
MCPA	94-74-6	12.0	627	4
Dichloroprop	120-36-5	0.19	8.26	5
2,4-D	94-75-7	0.29	9.51	6
2,4,5-TP (Silvex)	93-72-1	0.088	6.15	7
2,4,5-T	93-76-5	0.18	2.28	8
2,4-DB	94-82-6	0.70	12.46	9
Dinoseb	88-85-7	0.49	2.76	10

	<b>Metals reporting limits by Low-level Inductively Coupled</b>			12
	<b>Plasma (ICP)</b>			13
Method	SW846 Third Edition, Nov. 1986, Method 6010A			14
Matrix	Water-Soil			15
Extract Volume	100mL - 1g			16
Initial Calibration	0-500µg/L - varies			17
Continuing Calibration	1/2 high std			18

Compound	MDL's CAS Number	Water µg/L	Soil mg/kg	
Aluminum	7429-90-5	8.0	1.30	19
Antimony	7440-36-0	1.6	0.27	20
Arsenic	7440-38-2	2.1	0.31	21
Barium	7440-39-3	0.3	0.06	22
Beryllium	7440-41-7	0.2	0.03	23
Boron	7440-42-8	11.0	2.60	24
Cadmium	7440-43-9	0.3	0.05	25
Calcium	7440-70-2	43.0	1.90	26

Compound	MDL's CAS Number	Water µg/L	Soil mg/kg	
Chromium	7440-47-3	1.0	0.07	1
Cobalt	7440-48-4	0.8	0.06	2
Copper	7440-50-8	1.4	0.26	3
Iron	7439-89-6	20.0	1.60	4
Lead	7439-92-1	0.9	0.18	5
Magnesium	7439-95-4	43.0	4.70	6
Manganese	7439-96-5	0.3	0.04	7
Molybdenum	7439-98-7	0.9	0.18	8
Nickel	7440-02-0	0.7	0.12	9
Potassium	7440-09-7	55.0	7.00	10
Selenium	7782-49-2	3.4	0.24	11
Scandium	440-20-2	0.1	0.02	12
Strontium	7440-24-6	0.2	0.07	13
Silicon	7440-21-3	35.0	15.00	14
Silver	7440-22-4	1.0	0.17	15
Sodium	7440-23-5	19.0	4.90	16
Thallium	7440-28-0	5.0	0.46	17
Tin	7440-31-5	14.0	0.45	18
Titanium	7440-32-6	0.7	0.05	19
Vanadium	7440-62-2	1.1	0.13	20
Zinc	7440-66-6	5.8	1.10	21
	<b>Metals reporting limits by ICP</b>			22
Method	SW846 Third Edition, Nov. 1986, Method 6010			23
Matrix	Water-Soil			24
Extract Volume	100mL - 1g			25
Initial Calibration	0-1000 µg/L - varies			26
Continuing Calibration	1/2 high std			27

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<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil mg/kg</b>	
Aluminum	7429-90-5	14	2.8	1
Antimony	7440-36-0	12	1.7	2
Arsenic	7440-38-2	32	3.1	3
Barium	7440-39-3	1.0	0.19	4
Beryllium	7440-41-7	1.0	0.10	5
Boron	7440-42-8	17	2.5	6
Cadmium	7440-43-9	1.3	0.11	7
Calcium	7440-70-2	39	23.0	8
Chromium	7440-47-3	1.9	0.38	9
Cobalt	7440-48-4	2.8	0.46	10
Copper	7440-50-8	8.3	0.73	11
Iron	7439-89-6	18	1.7	12
Lead	7439-92-1	12	1.5	13
Magnesium	7439-95-4	25	6.1	14
Manganese	7439-96-5	1.2	0.10	15
Molybdenum	7439-98-7	5.7	25	16
Nickel	7440-02-0	6.5	0.59	17
Potassium	7440-09-7	560	57.0	18
Selenium	7782-49-2	28	3.1	19
Silicon	7440-21-3	70	23.0	20
Silver	7440-22-4	1.4	0.25	21
Sodium	7440-23-5	27	50.0	22
Thallium	7440-28-0	48	4.6	23
Tin	7440-31-5	17	2.1	24
Titanium	7440-32-6	1.0	0.14	25
Vanadium	7440-62-2	2.2	0.27	26
Zinc	7440-66-6	11	1.1	27

	<b>Mercury by Cold Vapors</b>	1
Test Code	MT310	2
Method	SW846 Third Edition, Nov. 1986	3
Matrix	Water-Soil	4
Extract Volume	100mL - 0.6g	5
Initial Calibration	0 - 10.0 µg/L	6
Continuing Calibration	1/2 HIGH STD	7

<b>Compound</b>	<b>MDL's CAS number</b>	<b>Water µg/L</b>	<b>Soil mg/kg</b>	8
Mercury	7439-97-6	0.12	0.030	9

	<b>Micellaneous Inorganic Analyses</b>	10
Test Code	Methods various	11
Method		12
Matrix	Water-Soil	13
Extract Volume		14
Initial Calibration		15
Continuing Calibration		16

<b>Compound</b>	<b>MDL Method</b>	<b>Water mg/L</b>	<b>Soil mg/kg</b>	17
Chloride (IC)	EPA300.0	0.07	0.7	18
Cyanide (Total)	SW846-9010	2.0	0.5	19
Hexavalent Chromium	SW846-7196	0.005	0.20	20
Sulfate (IC)	EPA300.0	0.1	0.9	21
Total Dissolved Solids	EPA160.1	4	—	22

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

This section describes the approach and technical methods to determine the nature and extent of all chemicals present in site samples (CPSSs) of soil and groundwater at Zone K SWMUs and AOCs, and to compare inorganics concentrations in site samples to naturally occurring background concentrations. Nature and extent were evaluated to determine the overall distribution of constituents detected on micro (site-specific), and macro (zonewide) scales. In addition, these data will be used to assess basewide conditions and the relationship of contaminants between zones across CNC.

Types of compounds detected in Zone K are: VOCs, SVOCs, pesticides, PCBs, dioxins, TPH, and inorganics. Detected concentrations were compared to corresponding RBCs listed in the USEPA Region III *Risk-Based Concentration Table* (April 1998) to: (1) evaluate the significance of the detections; (2) determine the need for any additional sampling to define the extent of contamination; and (3) develop investigative endpoints. Detected inorganic chemical concentrations were also compared to corresponding background reference concentrations. Comparisons to RBCs in the nature and extent sections pertain only to the protection of human health and do not address protection of ecological receptors. Excess risk to the ecosystem from the contaminants onsite is assessed in Section 8.

The following subsections present methods and screening values used to assess analytical results for organic and inorganic chemicals in Zone K samples. Site-specific evaluations of the nature and extent of contamination, fate and transport of contaminants, and corresponding human health risk and hazard for AOCs and SWMUs in Zone K are detailed in Section 10 of this report.

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

Concentrations of organic compounds detected in Zone K soil and groundwater samples were compared to RBCs. Each compound's frequency of detection and its mean 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 final *Zone A RFI Report* (EnSafe, 1998) details the guidance and procedures followed during the Zone K RFI.

## **5.2 Inorganic Analytical Results Evaluation**

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

Many chemicals, particularly carcinogenic inorganics such as arsenic, 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 specific site parameter must be before it is of concern. USEPA Region IV guidance on this subject recommends using twice the mean of the background data values as an upper bound, considering any site-related values higher than this bound to represent contamination. Although more

sophisticated statistical tests can be used when larger datasets are available, the smaller site and background datasets of Zone K mandated use of the “twice the mean” approach for comparing site values to background.

Where possible, EnSafe used a dual testing procedure to compare site-specific values for inorganics to those of the grid-based background datasets. “Twice the mean” reference concentrations were used in combination with Wilcoxon rank sum tests to make the comparisons for surface soil, subsurface soil, and shallow groundwater. Background reference values were calculated according to established procedures for CNC, in consultation with the project team technical subcommittee at meetings and in subsequent memos and telephone conferences during 1997 and 1999.

Because conditions at the two areas were markedly different, background reference values for surface soil, subsurface soil, and shallow groundwater at the Naval Annex and at Clouter Island were calculated separately.

### **5.2.1 Background Datasets**

The background dataset for Naval Annex upper-interval soil consisted of nine samples (GDKSB00101 to GDKSB00901). The Naval Annex lower-interval soil dataset also consisted of nine samples (GDKSB00102 to GDKSB00902). The background dataset for shallow groundwater at the Naval Annex consisted of seven samples derived from two monitoring wells (NBCKGDK001 and NBCKGDK002). First-round results from well NBCKGDK001 were not used in the calculations due to elevated concentrations caused by high turbidity.

At Clouter Island, the background dataset for soils consisted of three upper-interval samples (GDKSBCL101, GDKSBCL301, and GDKSBCL401), one lower-interval sample (GDKSBCL102), and one upper-interval duplicate sample from the Dredge Spoil Area

(GDKSBCL201 and GDKCBCL201). The desired number of lower-interval soil samples for background calculation could not be collected due to shallow depth to groundwater. One background monitoring well was installed at Clouter Island (NBCKGDKCL1). The background dataset for shallow groundwater from this well consisted of four rounds of sample results.

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, means 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 (ND) values of inorganics 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 samples from the AOCs and SWMUs were assembled into datasets for each chemical of interest from surface and subsurface soils and from shallow groundwater, for comparison to background. Other than at SWMU 166, no deep groundwater monitoring wells were installed at AOCs or SWMUs in Zone K.

### 5.2.4 Comparing Site Values to Background

Section 5.2.4 of the final *Zone A RFI Report* discusses statistical hypothesis testing for comparing site concentrations to background. It presents EPA's suggested "twice the mean" 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 (comparable to the “twice the mean” test) and the Wilcoxon rank sum test.

### **5.2.5 Reference Concentration Test**

As discussed above, background reference values were determined for each inorganic in each environmental medium by calculating twice the mean of the background sample concentrations. Analytical results for each site sample were then compared to the corresponding reference concentrations to identify individual samples in which concentrations significantly exceeded background. If the test results were positive (i.e., significantly exceeding 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.

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

At some sites, sample concentrations may be consistently higher than average background concentrations without ever exceeding calculated background reference values. In these cases, it may be possible to identify onsite contamination by showing that concentrations in site samples, as a group, significantly exceed background concentrations, as a group.

The most commonly prescribed method for comparing two populations is the Student's *t*-test, which determines whether the two population means differ significantly. The *t*-test was not used in this investigation to compare site values to background because it is parametric. A nonparametric counterpart to the *t*-test is the Wilcoxon rank sum test, also known as the Mann-Whitney U test. Since it is nonparametric, the two datasets that are compared need not be drawn from normal or even symmetric distributions, and the test can accommodate a moderate

number of nondetect values by treating them as ties (Gilbert, 1987). The Wilcoxon test was used where justified by the number of samples (at least four in each dataset) and the percentage of detections (normally, at least 20 to 25 %). Section 5.2.6 of the final *Zone A RFI Report* additionally describes the Wilcoxon rank sum test and the justification for its use.

### 5.2.7 Summary of Statistical Techniques Used

Techniques that allow the use of statistical inference were chosen wherever possible. Methods used can detect situations where: (a) individual site values are much higher than background, or (b) overall site values are higher than background. For situation (a), twice the mean concentrations of soil and groundwater background data values served as the background reference values. To account for situation (b), the Wilcoxon rank sum test was applied to both soil and groundwater results, where appropriate, to compare each group of site values to its corresponding background group. Where the Wilcoxon test could not be run due to an insufficient number (fewer than four) of site and/or background samples, only the “twice the mean” test was performed; where no more than one background sample was collected, no background reference value was determined.

### 5.2.8 Combined Results of the Reference Concentration and Wilcoxon Rank Sum Tests

Methods described in Section 5.2.5 identify individual site samples with concentrations significantly exceeding background, while the method in Section 5.2.6 identifies entire sites. If the outcome of either test was positive (i.e., significantly exceeded background), sample values were compared to the corresponding USEPA RBCs for soil and tap-water and, where appropriate, carried forward into a detailed human health risk assessment (HHRA). 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:

- Following procedures in Section 5.2.1, high values were removed from the background datasets whether or not they were true outliers in the conventional sense, thereby lowering the total background concentrations to which site values were compared.
- The use of two complementary tests wherever possible increased the likelihood that any contamination would be identified and addressed further, since a positive result from either test triggered a detailed HHRA whenever site concentrations exceeded corresponding USEPA RBC values.
- The use of twice the mean of background sample concentrations as reference concentrations generally results in lower (more conservative) background values than are justified by more sophisticated statistical tests.

The effect of these factors is to increase the rate of false-positive test results while minimizing the rate of false negatives, as explained in Section 5.2.4 of the final *Zone A RFI Report*. In other words, some samples will be identified as contaminated when they reflect nothing more than the high end of the range of background concentrations, and will trigger a detailed HHRA if their concentrations also exceed corresponding USEPA RBC values.

**5.3 Screening Values**

**5.3.1 Background Reference Values**

Tables 5.1 through 5.5 present concentrations of inorganic chemicals detected in non-site-related surface soil, subsurface soil, and shallow groundwater samples from the Naval Annex and Clouter

**Table 5.1**  
**Inorganic Element Background Calculations for Surface Soils (mg/kg)**  
**Zone K, Naval Annex**

Analyte	Frequency of Detection	Range of Concentrations Detected	Arithmetic Mean <sup>1</sup>	2 x Mean
Aluminum	9/9	4,050 - 8,320	5,580	11,200
Antimony	1/9	0.59	0.23	0.45
Arsenic	9/9	0.60 - 2.50	1.50	3.00
Barium	9/9	6.6 - 20.	12.8	25.6
Beryllium	5/9	0.06 - 0.32	0.08	0.17
Cadmium	1/9	0.08	0.06	0.13
Chromium	9/9	2.8 - 6.3	4.2	8.4
Cobalt	3/9	0.16 - 0.46	0.17	0.34
Copper	6/9	0.90 - 4.80	1.93	3.86
Cyanide	0/9	ND	NA	NA
Iron	9/9	1,200 - 7,990	3,530	7,060
Lead	8/8 <sup>2</sup>	8.9 - 32.5	19.8	39.6
Manganese	9/9	3.2 - 45.0	13.2	26.4
Mercury	0/9	ND	NA	NA
Nickel	5/9	0.39 - 2.00	0.85	1.70
Selenium	3/9	0.63 - 0.71	0.42	0.84
Silver	2/9	0.24 - 0.88	0.22	0.44
Thallium	0/9	ND	NA	NA
Tin	3/9	10.5 - 32.0	9.7	19.4
Vanadium	9/9	5.3 - 12.5	7.9	15.8
Zinc	1/9	23.8	7.4	14.8

**Notes:**

- <sup>1</sup> Arithmetic mean was calculated using one-half of SQL for nondetects.
- <sup>2</sup> One lead result (259.00 mg/kg in sample GDKSB00101) was removed from the dataset as an outlier.

**Table 5.2**  
**Inorganic Element Background Calculations for Subsurface Soils (mg/kg)**  
**Zone K, Naval Annex**

Analyte	Frequency of Detection	Range of Concentrations Detected	Arithmetic Mean <sup>1</sup>	2 x Mean
Aluminum	9/9	3,090 - 12,000	5,270	10,500
Antimony	0/9	ND	NA	NA
Arsenic	9/9	0.34 - 3.1	0.99	1.98
Barium	9/9	1.8 - 7.2	3.42	6.83
Beryllium	6/9	0.03 - 0.2	0.06	0.12
Cadmium	0/9	ND	NA	NA
Chromium	9/9	2.4 - 8.5	4.38	8.76
Chromium (hexavalent)	0/2	ND	NA	NA
Cobalt	4/9	0.4 - 1.0	0.31	0.62
Copper	3/9	0.23 - 0.51	0.17	0.34
Cyanide	0/9	ND	NA	NA
Iron	9/9	795 - 10,900	2,570	5,130
Lead	9/9	2.5 - 4.4	3.22	6.43
Manganese	9/9	1.5 - 6.8	2.97	5.93
Mercury	0/9	ND	NA	NA
Nickel	8/9	0.23 - 4.7	1.32	2.64
Selenium	1/9	0.51	0.26	0.52
Silver	2/9	0.41 - 0.57	0.21	0.42
Thallium	0/9	ND	NA	NA
Tin	0/9	ND	NA	NA
Vanadium	9/9	3.5 - 15.7	6.09	12.2
Zinc	0/9	ND	NA	NA

**Note:**

<sup>1</sup> Arithmetic mean was calculated using one-half of SQL for nondetects.

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**Table 5.3**  
**Inorganic Element Background Calculations for Shallow Groundwater ( $\mu\text{g/L}$ )**  
**Zone K, Naval Annex<sup>1</sup>**

Analyte	Frequency of Detection	Range of Concentrations Detected	Arithmetic Mean <sup>2</sup>	2 x Mean
Aluminum	1/7	391	236	471
Antimony	0/7	ND	NA	NA
Arsenic	0/7	ND	NA	NA
Barium	6/7	6.7 - 28.8	15.6	31.2
Beryllium	0/7	ND	NA	NA
Cadmium	0/7	ND	NA	NA
Chromium	0/7	ND	NA	NA
Cobalt	0/7	ND	NA	NA
Copper	1/7	1.3	1.41	2.81
Cyanide	0/7	ND	NA	NA
Iron	4/7	64.3 - 239	118	235
Lead	1/7	1.9	0.97	1.94
Manganese	4/7	1.3 - 13.8	4.66	9.33
Mercury	0/7	ND	NA	NA
Nickel	0/7	ND	NA	NA
Selenium	0/7	ND	NA	NA
Silver	0/7	ND	NA	NA
Thallium	0/7	ND	NA	NA
Tin	2/7	53.8 - 196	51	102
Vanadium	1/7	0.76	0.40	0.80
Zinc	0/7	ND	NA	NA

*Notes:*

- <sup>1</sup> Due to high turbidity in the first-round sample from well NBCKGDK001, first-round results from this well were not included in background calculations.
- <sup>2</sup> Arithmetic mean was calculated using one-half of SQL for nondetects.

**Table 5.4**  
**Inorganic Element Background Calculations for Surface Soils (mg/kg)**  
**Zone K, Clouter Island**

Analyte	Frequency of Detection	Range of Concentrations Detected	Arithmetic Mean <sup>1</sup>	2 x Mean
Aluminum	3/3	5,020 - 24,700	16,100	32,100
Antimony	3/3	0.48 - 2.2	1.08	2.16
Arsenic	3/3	7.2 - 13.8	11.5	23.0
Barium	3/3	16.5 - 51.3	33.6	67.1
Beryllium	3/3	0.31 - 0.99	0.68	1.35
Cadmium	2/3	0.29 - 0.42	0.28	0.55
Chromium	3/3	21.3 - 45.9	34.6	69.1
Chromium (hexavalent)	0/3	ND	NA	NA
Cobalt	3/3	0.35 - 4.5	2.85	5.7
Copper	3/3	39.8 - 94.5	59.5	119
Cyanide	0/1	ND	NA	NA
Iron	3/3	10,400 - 23,400	17,600	35,200
Lead	3/3	37.7 - 70.8	49.1	98.3
Manganese	3/3	368 - 1,050	605	1,210
Mercury	3/3	0.17 - 0.52	0.32	0.63
Nickel	3/3	4.6 - 16.1	12.2	24.5
Selenium	2/3	0.51 - 1.1	0.62	1.24
Silver	1/3	0.31	0.21	0.41
Thallium	0/3	ND	NA	NA
Tin	1/3	46	19.5	39.1
Vanadium	3/3	18.8 - 51.2	38.0	75.9
Zinc	3/3	84.4 - 145	118	236

**Note:**

<sup>1</sup> Arithmetic mean was calculated using one-half of SQL for nondetects.

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**Table 5.5  
 Inorganic Element Background Calculations for Shallow Groundwater (µg/L)  
 Zone K, Clouter Island<sup>1</sup>**

Analyte	Frequency of Detection	Range of Concentrations Detected	Arithmetic Mean <sup>2</sup>	2 x Mean
Aluminum	0/4	ND	NA	NA
Antimony	0/4	ND	NA	NA
Arsenic	4/4	5.8 - 9.4	7.53	15.1
Barium	4/4	29.1 - 61.9	48.0	95.9
Beryllium	0/4	ND	NA	NA
Cadmium	1/4	0.36	0.20	0.40
Chromium	0/4	ND	NA	NA
Cobalt	0/4	ND	NA	NA
Copper	2/4	4.6 - 5.9	2.89	5.78
Cyanide	0/4	ND	NA	NA
Iron	4/4	2,580 - 6,250	4,590	9,170
Lead	0/4	ND	NA	NA
Manganese	4/4	311 - 976	607	1,210
Mercury	0/4	ND	NA	NA
Nickel	1/4	3.5	1.42	2.84
Selenium	0/4	ND	NA	NA
Silver	0/4	ND	NA	NA
Thallium	0/4	ND	NA	NA
Tin	1/4	39.8	17.3	34.6
Vanadium	4/4	3.3 - 5.9	4.55	9.1
Zinc	0/4	ND	NA	NA

**Notes:**

- <sup>1</sup> Background values are based on results from four samples from one well (NBCKGDKCL1).  
<sup>2</sup> Arithmetic mean was calculated using one-half of SQL for nondetects.

Island. Background reference concentrations were calculated for 18 inorganic chemicals in surface soil, 14 inorganics in subsurface soil, and 8 inorganics in shallow groundwater at the Naval Annex; and for 19 inorganics in surface soil and 9 inorganics in shallow groundwater at Clouter Island. Because only one subsurface soil grid sample was recovered at Clouter Island, no background reference values could be calculated. In all of the background calculations, ND values were treated as discussed above in Section 5.2.2.

### **5.3.2 Other Screening Values**

Tables 5.6, 5.7, and 5.8 present all of the screening values used to evaluate nature and extent, fate and transport, and HHRA for organics and inorganics in Zone K media. Separate screening tables were created for inorganics at the Naval Annex and Clouter Island because background concentrations are different in the two areas. Concentrations of chemicals detected in site samples were compared to residential soil and tap-water RBCs; soil-to-groundwater and soil-to-air SSLs; MCLs; saltwater surface water chronic screening values; and background reference values for surface soil, subsurface soil, and shallow groundwater (Section 5.3.1).

Table 5.6  
Organic Screening Values Used for Nature and Extent, Fate and Transport, and Human Health Risk Assessments  
Organic Compounds Detected in Surface Soil, Subsurface Soil, Sediment, Shallow Groundwater, and Deep Groundwater  
Charleston Naval Complex, Zone K  
Charleston, South Carolina

Parameter	Residential	Soil to	Soil to	Tap Water	MCL	Saltwater	Soil	Water
	Soil RBC (THQ=0.1)	GW SSL	Air SSL	RBC (THQ=0.1)		Surface Water Chronic		
<b>Volatile Organic Compounds</b>								
Acetone	780000	8000	100000000	370	NA	NA	UG/KG	UG/L
Benzene c	22000	15	800	0.36	5	109	UG/KG	UG/L
Bromodichloromethane c	10000	300	3000000	0.17	0.1	NA	UG/KG	UG/L
2-Butanone (MEK)	4700000	3900 a	10000	190	NA	NA	UG/KG	UG/L
Carbon disulfide	780000	16000	720000	100	NA	NA	UG/KG	UG/L
Chloroform c	100000	300	300	0.15	0.1	815	UG/KG	UG/L
Chloromethane (methyl chloride) c	49000	3.7 a	63	1.5	NA	2700	UG/KG	UG/L
1,2-Dichloroethane (EDC) c	7000	10	400	0.12	5	1130	UG/KG	UG/L
1,1-Dichloroethene c	1100	30	70	0.044	7	2240	UG/KG	UG/L
cis-1,2-Dichloroethene	78000	200	1200000	6.1	70	NA	UG/KG	UG/L
trans-1,2-Dichloroethene	160000	350	3100000	12	100	NA	UG/KG	UG/L
1,2-Dichloroethene (total)	70000	200 j	1200000	5.5	NA	NA	UG/KG	UG/L
Ethylbenzene	780000	6500	400000	130	700	4.3	UG/KG	UG/L
2-Hexanone	310000	3700 a	10000	150	NA	NA	UG/KG	UG/L
Methylene chloride c	85000	10	13000	4.1	NA	2560	UG/KG	UG/L
4-Methyl-2-pentanone (MIBK)	630000	6700 a	NA	290	NA	NA	UG/KG	UG/L
1,1,2,2-Tetrachloroethane c	3200	1.5	600	0.053	NA	90.2	UG/KG	UG/L
Tetrachloroethene (PCE) c	12000	30	11000	1.1	5	45	UG/KG	UG/L
Trichloroethene (TCE) c	58000	30	5000	1.6	5	NA	UG/KG	UG/L
Vinyl chloride c	340	5	30	0.019	2	NA	UG/KG	UG/L
Xylene (total)	16000000	70000 a	410000	1200	10000	NA	UG/KG	UG/L
<b>Semivolatile Organic Compounds</b>								
Acenaphthene	470000	290000	NA	220	NA	9.7	UG/KG	UG/L
Acenaphthylene	160000 d	47000 a	NA	73 d	NA	NA	UG/KG	UG/L
Anthracene	2300000	6000000	NA	1100	NA	NA	UG/KG	UG/L
Benzoic acid	31000000	200000	NA	15000	NA	NA	UG/KG	UG/L
Benzo(g,h,i)perylene	1600000 d	5.7E+07 a	NA	73 d	NA	NA	UG/KG	UG/L
Benzo(a)pyrene equivalents (BEQs) c	87	NA	NA	0.0092	0.2	NA	UG/KG	UG/L
Benzo(a)anthracene c	870	800	NA	0.092	NA	NA	UG/KG	UG/L
Benzo(a)pyrene c	87	4000	NA	0.0092	0.2	NA	UG/KG	UG/L
Benzo(b)fluoranthene c	870	2300 a	NA	0.092	NA	NA	UG/KG	UG/L
Benzo(k)fluoranthene c	8700	25000	NA	0.92	NA	NA	UG/KG	UG/L
Chrysene c	87000	80000	NA	9.2	NA	NA	UG/KG	UG/L
Dibenzo(a,h)anthracene c	87	800	NA	0.0092	NA	NA	UG/KG	UG/L
Indeno(1,2,3-cd)pyrene c	870	7000	NA	0.092	NA	NA	UG/KG	UG/L
Butylbenzylphthalate c	1600000	930000	930000	7300	NA	29.4	UG/KG	UG/L
Carbazole c	32000	300	NA	3.3	NA	NA	UG/KG	UG/L

Table 5.6  
Organic Screening Values Used for Nature and Extent, Fate and Transport, and Human Health Risk Assessments  
Organic Compounds Detected in Surface Soil, Subsurface Soil, Sediment, Shallow Groundwater, and Deep Groundwater  
Charleston Naval Complex, Zone K  
Charleston, South Carolina

Parameter	Residential	Soil to	Soil to	Tap Water	MCL	Saltwater	Soil	Water
	Soil RBC (THQ=0.1)	GW SSL	Air SSL	RBC (THQ=0.1)		Surface Water Chronic		
Dibenzofuran	31000	6800 a	120000	2.4	NA	NA	UG/KG	UG/L
Di-n-butylphthalate	780000	2300000	2300000	370	NA	3.4	UG/KG	UG/L
bis(2-Ethylhexyl)phthalate (BEHP) c	46000	1800000	3.1E+07	4.8	NA	NA	UG/KG	UG/L
Fluoranthene	310000	2100000	NA	150	NA	1.6	UG/KG	UG/L
Fluorene	310000	280000	NA	150	NA	NA	UG/KG	UG/L
2-Methylnaphthalene	160000	18000 a	NA	12	NA	23.5	UG/KG	UG/L
4-Methylphenol (p-cresol)	39000	670 a	NA	18	NA	NA	UG/KG	UG/L
Naphthalene	160000	31000 a	NA	73	NA	23.5	UG/KG	UG/L
N-Nitroso-di-n-propylamine c	91	0.024 a	NA	0.0096	NA	NA	UG/KG	UG/L
Phenanthrene	160000 d	660000 a	NA	110 e	NA	NA	UG/KG	UG/L
Phenol	4700000	50000	NA	2200	NA	58	UG/KG	UG/L
Pyrene	230000	2100000	NA	110	NA	NA	UG/KG	UG/L
<b>Pesticides/PCB Compounds</b>								
Aldrin c	38	200	3000	0.004	NA	0.13	UG/KG	UG/L
Aroclor-1254 c	320	1000	1000	0.033	0.5	0.03	UG/KG	UG/L
Aroclor-1260 c	320	1000	1000	0.033	0.5	0.03	UG/KG	UG/L
alpha-BHC (alpha-HCH) c	100	0.5	800	0.011	NA	1400	UG/KG	UG/L
delta-BHC (delta-HCH) c	350 f	1.8 a	NA	0.037 f	NA	NA	UG/KG	UG/L
alpha-Chlordane c	1800 g	5000 g	20000	0.19 g	2 g	0.004 g	UG/KG	UG/L
gamma-Chlordane c	1800 g	5000 g	20000	0.19 g	2 g	0.004 g	UG/KG	UG/L
4,4'-DDD c	2700	8000	NA	0.28	NA	0.025	UG/KG	UG/L
4,4'-DDE c	1900	27000	NA	0.2	NA	0.14	UG/KG	UG/L
4,4'-DDT c	1900	16000	1.0E+09	0.2	NA	0.001	UG/KG	UG/L
Dieldrin c	40	2	1000	0.0042	NA	0.0019	UG/KG	UG/L
Endosulfan II	47000 h	9000 h	NA	22 h	NA	0.0087	UG/KG	UG/L
Endosulfan sulfate	47000 h	4600 a	NA	22 h	NA	NA	UG/KG	UG/L
Endrin	2300	500	NA	1.1	2	0.0023	UG/KG	UG/L
Endrin aldehyde	2300 i	340 a	NA	1.1 i	2 i	NA	UG/KG	UG/L
Endrin ketone	2300 i	340 a	NA	1.1 i	2 i	NA	UG/KG	UG/L
Heptachlor c	140	11000	100	0.0023	0.4	0.0036	UG/KG	UG/L
Heptachlor epoxide c	70	330	5000	0.0012	0.2	0.0036	UG/KG	UG/L
<b>Dioxin Compounds</b>								
2378-TCDD Equivalents (TEQs) c	4.3 *	1600 a	NA	0.45	30	NA	NG/KG	PG/L
2378-TCDD c	4.3	1600 a	NA	0.45	30	10	NG/KG	PG/L
12378-PeCDD c	8.5	61 a	NA	0.89	NA	NA	NG/KG	PG/L
123478-HxCDD c	43	4100 a	NA	4.5	NA	NA	NG/KG	PG/L
123678-HxCDD c	43	4100 k	NA	4.5	NA	NA	NG/KG	PG/L

Table 5.6  
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Organic Compounds Detected in Surface Soil, Subsurface Soil, Sediment, Shallow Groundwater, and Deep Groundwater  
Charleston Naval Complex, Zone K  
Charleston, South Carolina

Parameter	Residential	Soil to	Soil to	Tap Water	MCL	Saltwater	Soil	Water
	Soil RBC (THQ=0.1)	GW SSL	Air SSL	RBC (THQ=0.1)		Surface Water Chronic		
123789-HxCDD c	43	4100 k	NA	4.5	NA	NA	NG/KG	PG/L
1234678-HpCDD c	430	110000 a	NA	45	NA	NA	NG/KG	PG/L
OCDD c	4300	1100000 a,l	NA	450	NA	NA	NG/KG	PG/L
2378-TCDF c	43	240 a	NA	4.5	NA	NA	NG/KG	PG/L
12378-PeCDF c	85	770 a	NA	8.9	NA	NA	NG/KG	PG/L
23478-PeCDF c	8.5	120 a	NA	0.89	NA	NA	NG/KG	PG/L
123478-HxCDF c	43	220000 a	NA	4.5	NA	NA	NG/KG	PG/L
123678-HxCDF c	43	220000 m	NA	4.5	NA	NA	NG/KG	PG/L
123789-HxCDF c	43	220000 m	NA	4.5	NA	NA	NG/KG	PG/L
234678-HxCDF c	43	220000 m	NA	4.5	NA	NA	NG/KG	PG/L
1234678-HpCDF c	430	54000 a	NA	45	NA	NA	NG/KG	PG/L
1234789-HpCDF c	430	54000 n	NA	45	NA	NA	NG/KG	PG/L
OCDF c	4300	540000 a,n	NA	450	NA	NA	NG/KG	PG/L
<b>TPH - Diesel Range Organics</b>								
Diesel	NA	NA	NA	NA	NA	NA	UG/KG	UG/L
<b>TPH - Gasoline Range Organics</b>								
Gasoline	NA	NA	NA	NA	NA	NA	UG/KG	UG/L

**Notes:**

**Screening Concentrations:**

Residential Soil RBC and Tap Water RBC - From USEPA Region III Risk-Based Concentration Table, October 1998 (Table values for noncarcinogens divided by 10 to reflect THQ=0.1)

Soil to GW - Generic SSLs based on DAF = 10, adapted from USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or calculated using values from Table 6.4

Soil to Air - From USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or USEPA Region III RBC Table, October 1998; values for 2-butanone and 2-hexanone were estimated.

MCL - From USEPA Drinking Water Regulations and Health Advisories, October 1996

Saltwater Surface Water Chronic - From USEPA Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment, November 1995; Table 2

\* - 4.3 ng/kg RBC used as screening concentration for nature and extent discussions, however, 1.0 µg/kg (1000 ng/kg) used as a project screening concentration for risk assessment evaluation.

a - Calculated soil to groundwater SSL value (See Table 6.4)

c - Carcinogen

d - Naphthalene used as surrogate

e - Pyrene used as surrogate

f - beta-BHC used as surrogate

g - Chlordane used as surrogate

h - Endosulfan used as surrogate

i - Endrin used as surrogate

j - cis-1,2-Dichloroethene used as surrogate

k - 123478-HxCDD used as surrogate

l - 1234678-HpCDD used as surrogate

m - 123478-HxCDF used as surrogate

n - 1234678-HpCDF used as surrogate

GW - Groundwater

NA - Not available/Not applicable

ND - Not detected

RBC - Risk-based concentration

SSL - Soil screening level

THQ - Target hazard quotient

NG/KG - Nanograms per kilogram

UG/KG - Micrograms per kilogram

PG/L - Picograms per liter

UG/L - Micrograms per liter

Table 5.7

Inorganic Screening Values Used for Nature and Extent, Fate and Transport, and Human Health Risk Assessments  
 Inorganic Chemicals Detected in Surface Soil, Subsurface Soil, Sediment, Shallow Groundwater, and Deep Groundwater  
 Charleston Naval Complex, Zone K, Naval Annex  
 Charleston, South Carolina

Parameter	Residential Soil RBC (THQ=0.1)	Surface Soil Backgroun Reference	Subsurface Soil Background Reference	Soil to GW SSL	Soil to Air SSL	Tap Water RBC (THQ=0.1)	Shallow GW Background Reference	Deep GW Background Reference	MCL	Saltwater Surface Water Chronic	Soil Units	Water Units
<b>Inorganic Chemicals</b>												
Aluminum (Al)	7800	11200	10500	560000 a	NA	3700	471	NA	NA	NA	MG/KG	UG/L
Antimony (Sb)	3.1	0.45	NA	2.7	NA	1.5	NA	NA	6	NA	MG/KG	UG/L
Arsenic (As) c	0.43	3	1.98	15	750	0.045	NA	NA	50	36	MG/KG	UG/L
Barium (Ba)	550	25.6	6.83	820	690000	260	31.2	NA	2000	NA	MG/KG	UG/L
Beryllium (Be)	16	0.17	0.12	32	1300	7.3	NA	NA	4	NA	MG/KG	UG/L
Cadmium (Cd)	7.8	0.13	NA	4	1800	1.8	NA	NA	5	9.3	MG/KG	UG/L
Chromium (Cr) (total)	23 f	8.4	8.76	19 f	270	11 f	NA	NA	100 f	50 f	MG/KG	UG/L
Cobalt (Co)	470	0.34	0.62	990 a	NA	220	NA	NA	NA	NA	MG/KG	UG/L
Copper (Cu)	310	3.86	0.34	5600 a	NA	150	2.8	NA	1300 e	2.9	MG/KG	UG/L
Cyanide	160	NA	NA	20	NA	73	NA	NA	200	1	MG/KG	UG/L
Iron (Fe)	2300	7060	5130	NA	NA	1100	235	NA	300	NA	MG/KG	UG/L
Lead (Pb)	400 d	39.6	6.43	400 d	400	15 e	1.9	NA	15 e	8.5	MG/KG	UG/L
Manganese (Mn)	160	26.4	5.93	480 a	NA	73	9.3	NA	NA	NA	MG/KG	UG/L
Mercury (Hg)	2.3 b	NA	NA	1	10	1.1 b	NA	NA	2	0.025	MG/KG	UG/L
Nickel (Ni)	160	1.7	2.64	65	13000	73	NA	NA	100	8.3	MG/KG	UG/L
Selenium (Se)	39	0.84	0.52	2.6	NA	18	NA	NA	50	71	MG/KG	UG/L
Silver (Ag)	39	0.44	0.42	17	NA	18	NA	NA	NA	0.23	MG/KG	UG/L
Thallium (Tl)	0.55	NA	NA	0.36	NA	0.26	NA	NA	2	21.3	MG/KG	UG/L
Tin (Sn)	4700	19.4	NA	5500 a	NA	2200	102	NA	NA	NA	MG/KG	UG/L
Vanadium (V)	55	15.8	12.2	3000	NA	26	0.8	NA	NA	NA	MG/KG	UG/L
Zinc (Zn)	2300	14.8	NA	6200	NA	1100	NA	NA	NA	86	MG/KG	UG/L

**Notes:**  
 Screening Concentrations:  
 Residential Soil RBC and Tap Water RBC - From USEPA Region III Risk-Based Concentration Table, October 1998 (Table values for noncarcinogens divided by 10 to reflect THQ = 0.1)  
 Soil to GW - Generic SSLs based on DAF = 10, adapted from USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or calculated using values from Table 6.4  
 Soil to Air - From USEPA Soil Screening Guidance: Technical Background Document, May 1996 or USEPA Region III RBC Table, October 1998.  
 MCL - From USEPA Drinking Water Regulations and Health Advisories, October 1996  
 Salt Water Surface Water Chronic - From USEPA Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment, November 1995, Table 2  
 Background reference values revised April 1999

a - Calculated soil to groundwater SSL value (See Table 6.4)  
 b - Mercury RBCs from October 1997 RBC Table  
 c - Carcinogen  
 d - USEPA de facto residential soil level

e - USEPA treatment technique action level  
 f - Assumes hexachrome  
 GW - Groundwater  
 NA - Not available/Not applicable  
 ND - Not detected

RBC - Risk-based concentration  
 SSL - Soil screening level  
 THQ - Target hazard quotient  
 MG/KG - Milligrams per kilogram  
 UG/L - Micrograms per liter

Table 5.8  
 Inorganic Screening Values Used for Nature and Extent, Fate and Transport, and Human Health Risk Assessments  
 Inorganic Chemicals Detected in Surface Soil, Subsurface Soil, Sediment, and Shallow Groundwater  
 Charleston Naval Complex, Zone K, Clouter Island  
 Charleston, South Carolina

Parameter	Residential Soil RBC (THQ=0.1)	Surface Soil Background Reference	Subsurface Soil Background Reference	Soil to GW SSL	Soil to Air SSL	Tap Water RBC (THQ=0.1)	Shallow GW Background Reference	Deep GW Background Reference	MCL	Saltwater Surface Water Chronic	Soil Units	Water Units
<b>Inorganic Chemicals</b>												
Aluminum (Al)	7800	32100	NA	560000 a	NA	3700	NA	NA	NA	NA	MG/KG	UG/L
Antimony (Sb)	3.1	2.16	NA	2.7	NA	1.5	NA	NA	6	NA	MG/KG	UG/L
Arsenic (As) c	0.43	23	NA	15	750	0.045	15.1	NA	50	36	MG/KG	UG/L
Barium (Ba)	550	67.1	NA	820	690000	260	95.9	NA	2000	NA	MG/KG	UG/L
Beryllium (Be)	16	1.35	NA	32	1300	7.3	NA	NA	4	NA	MG/KG	UG/L
Cadmium (Cd)	7.8	0.55	NA	4	1800	1.8	0.4	NA	5	9.3	MG/KG	UG/L
Chromium (Cr) (total)	23 f	69.1	NA	19 f	270	11 f	NA	NA	100 f	50 f	MG/KG	UG/L
Cobalt (Co)	470	5.7	NA	990 a	NA	220	NA	NA	NA	NA	MG/KG	UG/L
Copper (Cu)	310	119	NA	5600 a	NA	150	5.78	NA	1300 e	2.9	MG/KG	UG/L
Cyanide	160	NA	NA	20	NA	73	NA	NA	200	1	MG/KG	UG/L
Iron (Fe)	2300	35200	NA	NA	NA	1100	9170	NA	300	NA	MG/KG	UG/L
Lead (Pb)	400 d	98.3	NA	400 d	400	15 e	NA	NA	15 e	8.5	MG/KG	UG/L
Manganese (Mn)	160	1210	NA	480 a	NA	73	1210	NA	NA	NA	MG/KG	UG/L
Mercury (Hg)	2.3 b	0.63	NA	1	10	1.1 b	NA	NA	2	0.025	MG/KG	UG/L
Nickel (Ni)	160	24.5	NA	65	13000	73	2.84	NA	100	8.3	MG/KG	UG/L
Selenium (Se)	39	1.24	NA	2.6	NA	18	NA	NA	50	71	MG/KG	UG/L
Silver (Ag)	39	0.41	NA	17	NA	18	NA	NA	NA	0.23	MG/KG	UG/L
Thallium (Tl)	0.55	NA	NA	0.36	NA	0.26	NA	NA	2	21.3	MG/KG	UG/L
Tin (Sn)	4700	39.1	NA	5500 a	NA	2200	34.6	NA	NA	NA	MG/KG	UG/L
Vanadium (V)	55	75.9	NA	3000	NA	26	9.1	NA	NA	NA	MG/KG	UG/L
Zinc (Zn)	2300	236	NA	6200	NA	1100	NA	NA	NA	86	MG/KG	UG/L

Notes:  
 Screening Concentrations:  
 Residential Soil RBC and Tap Water RBC - From USEPA Region III Risk-Based Concentration Table, October 1998 (Table values for noncarcinogens divided by 10 to reflect THQ = 0.1)  
 Soil to GW - Generic SSLs based on DAF = 10, adapted from USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or calculated using values from Table 6.4  
 Soil to Air - From USEPA Soil Screening Guidance: Technical Background Document, May 1996 or USEPA Region III RBC Table, October 1998.  
 MCL - From USEPA Drinking Water Regulations and Health Advisories, October 1996  
 Salt Water Surface Water Chronic - From USEPA Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment, November 1995, Table 2  
 Background reference values revised April 1999

a - Calculated soil to groundwater SSL value (See Table 6.4)  
 b - Mercury RBCs from October 1997 RBC Table  
 c - Carcinogen  
 d - USEPA de facto residential soil level

e - USEPA treatment technique action level  
 f - Assumes hexachrome  
 GW - Groundwater  
 NA - Not available/Not applicable  
 ND - Not detected

RBC - Risk-based concentration  
 SSL - Soil screening level  
 THQ - Target hazard quotient  
 MG/KG - Milligrams per kilogram  
 UG/L - Micrograms per liter

## **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 the processes that govern their interaction 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 constituents' chemical and physical properties, govern the processes that move constituents between or within media, that is infiltration, advection, diffusion, dispersion, erosion, and volatilization. A discussion of fate and transport will help to identify potential receptors that may be impacted by constituents moving the environment.

The AOCs and SWMUs at the Zone K Naval Annex are on flat, low-lying land; a portion is covered with buildings and pavement. Precipitation falling on impervious surfaces drains into a storm water drainage system of pipes and ditches and eventually leaves the property near SWMU 162. No impervious surfaces are present at the Clouter Island AOCs. Rainwater that infiltrates the soil percolates into the water table aquifer at both the Naval Annex and Clouter Island. Groundwater at the Naval Annex flows northward or southward toward tributaries of the Cooper River, as discussed in Section 2.3.1. At Clouter Island, groundwater is expected to flow toward the Cooper River and Clouter Creek. After evaluating Zone K for the characteristics discussed in the previous paragraph, three 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
- Air emissions resulting from volatilization or fugitive particulates released from surface soil

**Definitions:**

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

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

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

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

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

*Volatilization* is the process whereby contaminants dissolved in water or present as nonaqueous phase liquids evaporate into soil gas in the vadose zone and/or into the atmosphere. Volatilization of solutes is described by their vapor pressures and Henry's law constants.

## 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 provides an overview of chemical properties and expected behavior in environmental media based on these properties.

**Table 6.1**  
**Constituent Characteristics Based On**  
**Chemical and Physical Properties**

Property	Critical Value <sup>a</sup>	High (>)	Low (<)
Vapor pressure	10 <sup>-3</sup> mm Hg	volatile	nonvolatile
Density	1.0 g/cm <sup>3</sup>	sinks/falls	floats/rises
Solubility	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	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	biologically dependent	does not degrade readily	degrades readily
Organic Carbon/water partitioning coefficient (K <sub>oc</sub> )	10 to 10,000 L <sub>water</sub> /kg <sub>oc</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	400 g/mole	difficult to predict chemical's behavior relative to the properties listed above	exhibits predictable behavior relative to the properties listed above

**Notes:**

- <sup>a</sup> - Critical values were based on literature review and professional judgment.
- mm Hg - Millimeters of mercury
- atm-m<sup>3</sup>/mole - Atmosphere cubic meters per mole
- L<sub>water</sub>/kg<sub>oc</sub> - Liters of water per kilogram of organic carbon
- g/cm<sup>3</sup> - Grams per cubic centimeters
- mg/L - Milligrams per liter
- g/mole - Grams per mole

Compounds with similar chemical and physical properties display similar fate and transport behavior, which makes it easier to group them into categories. Section 6.1.1 of the *Zone A RFI Report* (EnSafe August 1998) details characteristics affecting fate and transport for the following groups of chemicals:

- VOCs
- SVOCs
- Pesticides/PCBs
- 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 total organic carbon, normalized partitioning coefficient, cation exchange capacity (CEC), redox conditions, pH, soil type, and retardation factor. The following briefly discusses these properties.

#### Total Organic Carbon

Total organic carbon indicates the soil's sorptive capabilities. The higher the Total organic carbon, the higher the potential for a given chemical to sorb to soil particles, particularly for organic compounds. Total organic carbon 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 Total organic carbon:  $K_d = K_{oc}$  1  
 $f_{oc}$ . 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. Soils with high CEC values have 6  
the potential to adsorb inorganic ions and organic compounds with dipole moments. CEC varies 7  
directly with clay content, depending on the type of clay. The amount of cation exchange also 8  
depends on soil pH. 9

### **Redox Conditions**

 10

Redox is the process which includes oxidation (the loss of electrons), and reduction (the gain of 11  
electrons). Changes in oxidation state generate products differ from the reactants in their 12  
solubilities, toxicities, reactivities, and mobilities. Extreme redox conditions tend to mobilize 13  
chemicals, especially transition metals. 14

### **pH**

 15

The pH value is a negative inverse logarithmic measure of hydrogen ion concentration in the soil 16  
or groundwater, indicating the medium's acidity or alkalinity. Chemicals react differently under 17  
changing pHs. Low pH conditions tend to mobilize chemicals, especially inorganics, while high 18  
pH conditions may lead to the formation of immobile metal hydroxides. 19

### **Soil Type**

 20

The mineralogical composition, particle-size distribution, and organic content of soil affect 21  
chemical fate and transport. Soil characteristics influence or determine hydraulic conductivity, 22  
effective porosity, and hydraulic gradient which, in turn, dictate groundwater flow. 23

## Retardation Factor (R)

The retardation factor measures 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

$K_d$  = Normalized partitioning coefficient (L/kg)

$\rho_b$  = Dry soil bulk density (kg/L)

n = Soil total porosity

As presented in Table 6.2, the average total porosity of the Qs deposits that primarily compose the surficial aquifer in the Naval Annex portion of Zone K is 45%, as determined through analysis of four Shelby tube samples collected from depths ranging from 6 feet to 12 feet bgs. In Section 2.3.6.4, an effective horizontal hydraulic conductivity  $K_{h(eff)}$  was calculated for each lithostratigraphic unit (Qs or Qcs) using the hydraulic conductivity data generated from slug tests, grain-size evaluations, and specific capacity testing. The  $K_{h(eff)}$  value for the Qs deposits was determined to be 5.9 feet/day; the Qcs  $K_{h(eff)}$  value was calculated at 2.2 feet/day. Data used to calculate the Qcs  $K_{h(eff)}$  were confined to SWMU 166.

Horizontal hydraulic gradients were calculated for shallow and deep groundwater at the Naval Annex. For shallow groundwater, measured gradients varied from 0.0026 feet/feet to 0.0137 feet/feet. For deep groundwater, measured gradients were 0.0065 feet/feet and 0.0094 feet/feet (Table 2.7).

**Table 6.2**  
**Soil and Aquifer Parameters Used to Evaluate**  
**Fate and Transport: Naval Annex**

Parameter	Number of Samples	Zone K Minimum Value	Zone K Maximum Value	Zone K Geometric Mean Value	Units
Total Porosity <sup>a</sup>					
Qs	4	0.430	0.469	0.450	—
Qcs	1	0.409	0.409	0.409	
Horizontal Hydraulic Conductivity					
Shallow Wells <sup>b</sup>	7 wells	6.05	31.0	9.76	
Deep Wells <sup>b</sup>	8 wells	0.39	4.41	1.84	feet/day
Grain-Size <sup>c</sup>	4 Shelby tubes	0.23	37.2	9.79	
Qs <sup>d</sup>	2 wells	2.89	4.54	3.62	
Qcs <sup>d</sup>	6 wells	0.46	5.84	1.87	
Overall Geometric Mean $K_{h(eff)}$					
Qs <sup>e</sup>	All			5.9	
Qcs <sup>e</sup>	All			2.2	

**Notes:**

- <sup>a</sup> — Values are from Zone K Shelby tube samples collected from the vadose zone and surficial aquifer (Table 2.3).
- <sup>b</sup> — Values are geometric means of rising head and falling head slug test results (Tables 2.8 and 2.9).
- <sup>c</sup> — Values are from grain-size evaluation using empirically derived formulas (Table 2.10).
- <sup>d</sup> — Values are from specific capacity tests, assuming  $S_y=0.01$  (Table 2.11).
- <sup>e</sup> — Derivation of overall mean values is explained in Section 2.3.6.4.
- — Porosity values are unitless.

Table 6.3 lists the approximate time of travel for advective groundwater flow in offsite directions from various SWMUs/AOCs at the Naval Annex, depending on direction of flow, local groundwater gradient, and lithology. The flowpaths presented in Table 2.7 and shown in Figures 2-7 and 2-8 were used as the basis of travel time estimates for shallow and deep groundwater.

Maximum and minimum estimated groundwater velocities along each flowpath were presented in Table 2.13. As discussed in Section 2.3.7, total porosity values from geotechnical analysis (Table 6.2) were used as effective porosity ( $n_e$ ) estimates for the groundwater velocity calculations in Table 2.13. Effective porosity, however, represents drainable porosity. USEPA (1989) provides methods for estimating  $n_e$  for various aquifer materials. Where  $n_e$  is unknown, specific

yield may be substituted into the velocity equation. A specific yield of 28%, representative of medium sand (Johnson, 1967), was used for Qs, which is a fine to medium-grained sand with limited fines. A lower specific yield of 20% was estimated for the more heterogeneous Qcs unit, a clayey sand with varying silt content. As discussed in Section 2.3.7, lower estimated values of  $n_e$  yield higher estimated groundwater velocities for a given hydraulic conductivity. For maximum conservatism, the lower set of  $n_e$  values (yielding higher velocities) was used to calculate travel times, which are the quotients of distance traveled divided by the groundwater velocities.

Table 6.3  
 Estimated Advective Groundwater Travel Times  
 at Naval Annex

Flowpath	Horizontal Gradient <sup>c</sup> (-)	Effective Porosity <sup>d</sup> (-)	Horizontal Velocity (ft/day)	Horizontal Velocity (ft/year)	Horizontal Distance <sup>e</sup> (feet)	Travel Time (years)
<i>Shallow Groundwater</i>						
A	0.0082	0.28	0.173	63.1	275	4.4
B	0.0137	0.28	0.289	105	365	3.5
C	0.0036	0.28	0.076	27.7	355	13
D	0.0070	0.28	0.147	53.8	460	8.6
E	0.0026	0.28	0.055	20.0	440	22
<i>Deep Groundwater<sup>b</sup></i>						
F	0.0094	0.20	0.103	37.7	325	8.6
G	0.0065	0.20	0.072	26.1	335	13

**Notes:**

- <sup>a</sup> Calculated using hydraulic conductivity of 5.9 feet/day, assuming Qs lithology.
- <sup>b</sup> Calculated using hydraulic conductivity of 2.2 feet/day, assuming Qcs lithology.
- <sup>c</sup> From Table 2.7.
- <sup>d</sup> Estimated, from textural classes of aquifer samples (USEPA 1989).
- <sup>e</sup> Distance measured perpendicular to equipotential lines.

Shallow groundwater flow (Figure 2-7) is separated by the groundwater flow divide trending west to east across the Naval Annex. North of the flow divide, groundwater flows toward the north or northeast; south of the flow divide, groundwater flows to the south. Deep groundwater flows roughly west to east across SWMU 166 (Figure 2-8).

Groundwater flow at Clouter Island is expected to be toward the Cooper River and Clouter Creek. Information is limited because of the small number and shallow depths of the wells. A river gauging station at the Army Depot in North Charleston at mile 10.5 of the Cooper River, upstream from CNC, reported a mean river stage of 1.06 feet for the year October 1992 to September 1993. Downstream from CNC at the gauging station at Charleston Harbor (mile 0.6), mean river stage is roughly zero. Calculation of travel times for locations at Clouter Island should be based on an assumption of one-half foot local elevation for water in the Cooper River.

## **6.2 Fate and Transport Approach for Zone K**

Each site-specific fate and transport discussion in Section 10 begins with a description of site characteristics that can affect constituent migration. As presented earlier in this section, three potential routes of constituent migration have been identified for Zone K. Each SWMU or AOC has been evaluated for site conditions that promote these migration pathways. In some cases, it is logical to evaluate fate and transport for a combination of sites based on their proximity.

Evaluation of an individual constituent's ability to migrate considers three cross-media transfer mechanisms: (1) soil-to-groundwater, (2) groundwater to surface water, and (3) surface soil-to-air. 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 K fate and transport phenomena were evaluated using constituent-specific chemical and physical properties, calculated soil and aquifer properties, USEPA risk-based screening concentrations and maximum contaminant levels, and approved background reference concentrations (Tables 5.6, 5.7, 5.8, and 6.2).

The following sections describe the methods used to evaluate the potential migration of constituents identified at each SWMU/AOC. Where a specific migration pathway could not be

identified for a site, that pathway was not formally assessed or screened. Fate and transport were not evaluated for essential nutrients (calcium, iron, magnesium, potassium, and sodium) or for chlorides or sulfates, which are abundant in shallow coastal/estuarine environments. Section 10 discusses site-specific fate and transport, migration pathways, and potential receptors.

### 6.2.1 Soil-to-Groundwater Cross-Media Transport

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 to impact 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 K. However, all soil constituents were evaluated for their potential threat to groundwater whether they were detected in groundwater or not. The screening process may be summarized as follows:

#### *Quantitative*

Maximum soil constituent concentrations for each SWMU/AOC (or group thereof) were compared to leachability-based generic soil-to-groundwater screening levels as presented in the USEPA *Soil Screening Guidance: Technical Background Document*, May 1996. SSLs were modified from those in the *Technical Background Document* or calculated independently, as described below, assuming a dilution attenuation factor (DAF) of 10 for soils at both the Naval Annex and Clouter Island.

Soil background reference values for Zone K inorganics were determined after consultation with the project team technical subcommittee; separate sets of values were determined for the Naval Annex and Clouter Island because of their physical separation and distinct soil characteristics. At the request of SCDHEC, however, background reference values were not considered during initial

comparisons of maximum soil concentrations with SSLs. The theoretical effect of this exclusion during the screening process was to identify all possible threats to groundwater as naturally occurring or anthropogenic soil constituents regardless of their sources. Since arsenic and manganese at Clouter Island are the only inorganics in Zone K soil samples with background reference values exceeding their SSLs, the practical effect of the exclusion was limited.

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

- Tap-water risk-based screening concentrations, as presented in the USEPA Region III RBC table, October 1998, assuming a target hazard quotient of 1.0.
- Groundwater background reference values for Zone K inorganics, determined in consultation with the project team technical subcommittee and selected as described below.

Theoretically, soil at a site would be screened from further investigation when the true mean of the population of contaminant concentrations falls below the SSL. To allow for uncertainty in the data and to minimize Type I and Type II errors, EPA recommends comparing the contaminant concentrations in composite surface soil site samples to two times the SSL when data quantity and quality are high; for more limited data sets, the 95% UCL on the mean should be compared to SSLs using the Land method (*User's Guide*, Section 2.6). For subsurface soil, mean contaminant concentrations from each soil boring (i.e., from composite samples) should be compared to SSLs. This RFI's fate and transport screening comparisons were much more conservative than those recommended by EPA: the maximum contaminant concentrations from individual grab samples (rather than composite samples) were compared to the corresponding SSLs, making it much more likely that results from a single "hot spot" would exceed one of the screening standards.

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 releases or immobile constituents may not yet 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. No significant threat to groundwater via leachate migration was assumed if soil concentrations do not exceed conservative leachability-based screening levels. Likewise, if current groundwater concentrations do not exceed risk-based screening values or background, existing soil/groundwater equilibria were considered to sufficiently protect human health relative to potential groundwater ingestion exposure pathways.

The soil-to-groundwater migration pathway was assessed using generic SSLs that assume a DAF of 10 for both the Naval Annex and Clouter Island, rather than site-specific SSLs. DAFs higher than 10 would be justified for Zone K SWMUs and AOCs, based on site-specific values of hydraulic conductivity, hydraulic gradient, aquifer thickness, and estimated infiltration rate (to estimate dilution), as well as soil type and organic content (to estimate attenuation). Section 6.3 compares assumptions underlying the fate and transport screening process with site-specific and zonewide conditions, including factors affecting dilution and attenuation of contaminants. Item 4 of Section 6.3 presents the input variables used to estimate the Zone K DAFs. Higher DAF values would translate into higher, less conservative SSLs. As a screening tool, generic SSLs are used to compile a conservative, inclusive list of potential fate and transport concerns. The detailed fate and transport assessments then evaluate the identified concerns to facilitate risk management decisions.

Table 6.4 lists physical site characteristics along with chemical and physical properties and regulatory standards for each constituent detected in Zone K soil and groundwater samples at the Naval Annex and Clouter Island, enabling calculation of soil screening levels for protection of

groundwater. If generic SSLs for organics were not listed in the *Technical Background Document* or the Region III RBC table, they were calculated using the chemical property values shown in Table 6.4. Values of Henry's law constant,  $K_{oc}$ , and  $K_d$  not available in the *Technical Background Document* or the USEPA *Soil Screening Guidance: User's Guide*, April 1996, were obtained from the Superfund Chemical Data Matrix (SCDM), September 1997, which is the source of the values presented in the two *Soil Screening Guidance* documents. Values of  $K_d$  for inorganics not available in the EPA documents were taken from the TERRA model (Baes, et al., 1984), which is considered a standard reference source.

Where calculated SSLs in Table 6.4 differed from EPA's generic values, the EPA values prevailed, except in cases where EPA had revised the underlying risk-based values subsequent to issuing the *Soil Screening Guidance*. Differences between the generic listed SSLs and EnSafe's calculated SSLs were generally due to EPA's use of nonstandard target leachate concentrations as starting points for their calculations: rather than starting with their own listed RBCs or MCLs, EPA often rounds their calculated values off to one significant figure. EPA's starting-point values are listed in Attachment D, "Regulatory and Human Health Benchmarks for SSL Development," of the *User's Guide*.

The SSL used for total chromium in Naval Annex soil samples was 19 mg/kg, as recommended in the *Technical Background Document* (after adjusting for DAF=10). EPA's prescribed (adjusted) value of 19 mg/kg is equal to the SSL for hexavalent chromium, on the conservative assumption that any detected chromium may be hexachrome. Although hexachrome was not detected in any of the 11 Naval Annex soil samples for which it was analyzed, the number of hexachrome analyses was not considered large enough to eliminate the possibility of hexachrome as a contributor to reported total chromium concentrations. At Clouter Island, 39 soil samples were analyzed for hexachrome with no reported detections. The larger number of negative hexachrome analyses made it possible to rule out hexavalent chromium as a component of detected

Table 6.4  
Soil to Groundwater Soil Screening Levels  
Charleston Naval Complex, Zone K, Naval Annex  
Charleston, South Carolina

Site-Specific Parameters:								
Fraction Organic Carbon (→) :	0.002	Dimension- less Henry's Law Constant [H] (→)	Organic Carbon Water Part. Coeff. [Koc] (L/kg)	Tap Water RBC (mg/L)	Acceptable Ground- water MCL/ MCLG (mg/L)	Target Leachate Conc. (mg/L)	Calculated Zonewide 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	NL	3.7	37	7.4	
Benzene c	2.28E-01	5.89E+01	0.00036	0.005	0.005	0.05	0.0169	
Bromodichloromethane c	6.56E-02	5.50E+01	0.00017	0.1	0.1	1	<b>0.316</b>	
2-Butanone (MEK)	2.30E-03	1.90E+00	1.9	NL	1.9	19	<b>3.88</b>	
Carbon disulfide	1.24E+00	4.57E+01	1	NL	1	10	3.99	
Chloromethane c	3.60E-01	6.50E+00	0.0015	NL	0.0015	0.015	<b>0.00366</b>	
1,2-Dichloroethane (EDC) c	4.01E-02	1.74E+01	0.00012	0.005	0.005	0.05	0.0119	
1,1-Dichloroethene c	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	2.40E+01	1.5	NL	1.5	15	<b>3.81</b>	
Methylene chloride c	8.98E-02	1.17E+01	0.0041	0.005	0.005	0.05	0.0116	
1,1,1,2-Tetrachloroethane c	1.41E-02	9.33E+01	5.3E-05	NL	5.3E-05	0.00053	0.000206	
Tetrachloroethene (PCE) c	7.54E-01	1.55E+02	0.0011	0.005	0.005	0.05	0.0288	
Trichloroethene (TCE) c	4.22E-01	1.66E+02	0.0016	0.005	0.005	0.05	0.0284	
Vinyl chloride c	1.11E+00	1.86E+01	1.9E-05	0.002	0.002	0.02	0.00667	
Xylene (total)	2.48E-01	2.40E+02	12	10	10	100	<b>70.1</b>	
Semivolatile Organic Compounds								
Acenaphthene	6.36E-03	7.08E+03	2.2	NL	2.2	22	316	
Acenaphthylene	4.50E-03	3.10E+03	0.73	NL	0.73	7.3	<b>46.7</b>	
Anthracene	2.67E-03	2.95E+04	11	NL	11	110	6512	
Benzo(g,h,i)perylene	5.70E-06	3.90E+06	0.73	NL	0.73	7.3	<b>56941</b>	
Benzo(a)pyrene equivalents (BEQs) c								
Benzo(a)anthracene c	1.37E-04	3.98E+05	9.2E-05	NL	9.2E-05	0.00092	0.733	
Benzo(a)pyrene c	4.63E-05	1.02E+06	9.2E-06	0.0002	0.0002	0.002	4.08	
Benzo(b)fluoranthene c	4.55E-03	1.23E+06	9.2E-05	NL	9.2E-05	0.00092	2.26	
Benzo(k)fluoranthene c	3.40E-05	1.23E+06	0.00092	NL	0.00092	0.0092	22.6	
Chrysene c	3.88E-03	3.98E+05	0.0092	NL	0.0092	0.092	73.3	
Dibenzo(a,h)anthracene c	6.03E-07	3.80E+06	9.2E-06	NL	9.2E-06	9.2E-05	0.699	
Indeno(1,2,3-cd)pyrene c	6.56E-05	3.47E+06	9.2E-05	NL	9.2E-05	0.00092	6.38	
Butylbenzylphthalate c	5.17E-05	5.75E+04	7.3	NL	7.3	73	8410	
Carbazole c	6.26E-07	3.39E+03	0.0033	NL	0.0033	0.033	0.230	
Dibenzofuran	5.30E-04	1.40E+04	0.024	NL	0.024	0.24	<b>6.77</b>	
Di-n-butylphthalate	3.85E-08	3.39E+04	3.7	NL	3.7	37	<b>2516</b>	
bis(2-Ethylhexyl)phthalate (BEHP) c	4.18E-06	1.51E+07	0.0048	0.006	0.006	0.06	1812	
Fluoranthene	6.60E-04	1.07E+05	1.5	NL	1.5	15	3213	
Fluorene	2.61E-03	1.38E+04	1.5	NL	1.5	15	417	
2-Methylnaphthalene	2.10E-02	7.50E+03	0.12	NL	0.12	1.2	<b>18.2</b>	
4-Methylphenol (p-cresol)	3.20E-05	8.50E+01	0.18	NL	0.18	1.8	<b>0.666</b>	
Naphthalene	1.98E-02	2.00E+03	0.73	NL	0.73	7.3	<b>30.7</b>	
N-Nitroso-di-n-propylamine c	9.23E-05	2.40E+01	9.6E-06	NL	9.6E-06	9.6E-05	<b>2.38E-05</b>	
Phenanthrene	9.40E-04	3.00E+04	1.1	NL	1.1	11	<b>662</b>	
Phenol	1.63E-05	2.88E+01	22	NL	22	220	<b>56.7</b>	
Pyrene	4.51E-04	1.05E+05	1.1	NL	1.1	11	2312	
Pesticide/PCB Compounds								
Aldrin c	6.97E-03	2.45E+06	4.0E-06	NL	4E-06	4E-05	0.196	
Aroclor-1254 c	1.10E-01	3.09E+05	3.3E-05	0.0005	NA	NA	<b>1</b>	
Aroclor-1260 c	1.10E-01	3.09E+05	3.3E-05	0.0005	NA	NA	<b>1</b>	
delta-BHC c	1.80E-05	2.30E+03	3.7E-05	NL	3.7E-05	0.00037	<b>0.00178</b>	

Table 6.4  
Soil to Groundwater Soil Screening Levels  
Charleston Naval Complex, Zone K, Naval Annex  
Charleston, South Carolina

Site-Specific Parameters:								
Fraction Organic Carbon (--) :	0.002	Dimension- less Henry's Law Constant [H'] (--)	Organic Carbon Water Part. Coeff. [Koc] (L/kg)	Tap Water RBC (mg/L)	Acceptable Ground- water MCL/ MCLG (mg/L)	Target Leachate Conc. (mg/L)	Calculated Zonewide 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							
alpha-Chlordane c		1.99E-03	1.20E+05	0.00019	0.002	0.002	0.02	4.80
gamma-Chlordane c		1.99E-03	1.20E+05	0.00019	0.002	0.002	0.02	4.80
4,4'-DDD c		1.64E-04	1.00E+06	0.00028	NL	0.00028	0.0028	5.60
4,4'-DDE c		8.61E-04	4.47E+06	0.0002	NL	0.0002	0.002	17.9
4,4'-DDT c		3.32E-04	2.63E+06	0.0002	NL	0.0002	0.002	10.5
Dieldrin c		6.19E-04	2.14E+04	4.2E-06	NL	4.2E-06	4.2E-05	0.00181
Endosulfan		4.59E-04	2.14E+03	0.22	NL	0.22	2.2	9.86
Endosulfan II		4.59E-04	2.14E+03	0.22	NL	0.22	2.2	9.86
Endosulfan sulfate		8.60E-02	9.50E+02	0.22	NL	0.22	2.2	4.64
Endrin		3.08E-04	1.23E+04	0.011	0.002	0.002	0.02	0.496
Endrin aldehyde		NDA	8.50E+03	0.011	0.002	0.002	0.02	0.344
Endrin ketone		NDA	8.50E+03	0.011	0.002	0.002	0.02	0.344
Heptachlor c		6.07E+01	1.41E+06	2.3E-06	0.0004	0.0004	0.004	11.3
Heptachlor epoxide c		3.90E-04	8.32E+04	1.2E-06	0.0002	0.0002	0.002	0.333
<b>Polychlorinated dibenzodioxins/dibenzofurans</b>								
2378-TCDD Equivalents (TEQs) c		3.20E-03	2.70E+06	4.5E-10	3E-08	3E-08	3E-07	0.00162
2378-TCDD c		3.2E-03	2.7E+06	4.5E-10	3E-08	3E-08	3E-07	0.00162
12378-PeCDD c		3.2E-03	3.4E+06	8.9E-10	NL	8.9E-10	8.9E-09	6.05E-05
123478-HxCDD c		3.2E-03	4.6E+07	4.5E-09	NL	4.5E-09	4.5E-08	0.00414
123678-HxCDD c		3.2E-03	4.6E+07	4.5E-09	NL	4.5E-09	4.5E-08	0.00414
123789-HxCDD c		3.2E-03	4.6E+07	4.5E-09	NL	4.5E-09	4.5E-08	0.00414
1234678-HpCDD c		3.2E-03	1.2E+08	4.5E-08	NL	4.5E-08	4.5E-07	0.108
OCDD c		3.2E-03	1.2E+08	4.5E-07	NL	4.5E-07	4.5E-06	1.08
2378-TCDF c		3.2E-03	2.7E+06	4.5E-09	NL	4.5E-09	4.5E-08	0.000243
12378-PeCDF c		3.2E-03	4.3E+06	8.9E-09	NL	8.9E-09	8.9E-08	0.000765
23478-PeCDF c		3.2E-03	6.5E+06	8.9E-10	NL	8.9E-10	8.9E-09	0.000116
123478-HxCDF c		3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.216
123678-HxCDF c		3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.216
234678-HxCDF c		3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.216
123789-HxCDF c		3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.216
1234678-HpCDF c		3.2E-03	6.0E+07	4.5E-08	NL	4.5E-08	4.5E-07	0.0540
1234789-HpCDF c		3.2E-03	6.0E+07	4.5E-08	NL	4.5E-08	4.5E-07	0.0540
OCDF c		3.2E-03	6.0E+07	4.5E-07	NL	4.5E-07	4.5E-06	0.540
<b>Inorganic Compounds</b>								
<i>Kd (6.8 pH)</i>								
Aluminum		NA	1.50E+03	37	NL	37	370	5.55E+05
Antimony		NA	4.50E+01	0.015	0.006	0.006	0.06	2.71
Arsenic c		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	0.073	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	55	NL	55	550	9.90E+08
Chromium (VI)		NA	1.90E+01	0.11	0.1	0.1	1	19.2
Cobalt		NA	4.50E+01	2.2	NL	2.2	22	994
Copper		NA	4.30E+02	1.5	1.3	1.3	13	5593
Lead		NA	NA	0.015	NL	0.015	0.15	400
Manganese		NA	6.50E+01	0.73	NL	0.73	7.3	476
Mercury		4.67E-01	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	NL	0.18	1.8	15.3

Table 6.4  
Soil to Groundwater Soil Screening Levels  
Charleston Naval Complex, Zone K, Naval Annex  
Charleston, South Carolina

Site-Specific Parameters:		Dimension- less Henry's Law Constant [H] (--)	Organic Carbon Water Part. Coeff. [Koc] (L/kg)	Tap Water RBC (mg/L)	MCL/ MCLG (mg/L)	Acceptable Ground- water Conc. (mg/L)	Target Leachate Conc. (mg/L)	Calculated Zonewide 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							
Thallium		NA	7.10E+01	0.0026	0.0005	0.0005	0.005	0.356
Tin		NA	2.50E+01	22	NL	22	220	5544
Vanadium		NA	1.00E+03	0.26	NL	0.26	2.6	2601
Zinc		NA	6.20E+01	11	NL	11	110	6842

**Notes:**

Henry's Law Constant (H) and Organic Carbon Water Partitioning Coefficient (Koc) - From USEPA Soil Screening Guidance: User's Guide, Attachment C, April 1996 (first preference); Superfund Chemical Data Matrix (SCDM) - User Version, September 1997 (second preference); Texas Risk Reduction Program Concept Document 2, Volume 1, Appendix VII, December 1996; or TERRA model, Oak Ridge National Laboratory, 1984 (for Kd values for inorganics)

Tap Water RBC - From USEPA Region III Risk-Based Concentration Table, October 1998

MCL/MCLG - From USEPA Drinking Water Regulations and Health Advisories, October 1996

Acceptable groundwater concentration - MCL/MCLG if available, otherwise tap water RBC

Target Leachate Concentration - Acceptable groundwater concentration multiplied by dilution factor

Soil to Groundwater SSL - Calculated using Equation 10 from USEPA Soil Screening Guidance: User's Guide, April 1996

c - Carcinogen

Kd - Normalized partitioning coefficient

NA - Not applicable

NDA - No data available

NL - Not listed

kg/L - Kilograms per liter

L/kg - Liters per kilogram

mg/kg - Milligrams per kilogram

mg/L - Milligrams per liter

total chromium in Clouter Island soil samples. Consequently, the SSL used for total chromium in Clouter Island soil samples was 1,000,000 mg/kg. According to the *Technical Background Document*, Appendix A, Table A-1, trivalent chromium as a contaminant in soil is not considered a threat to groundwater at any concentration.

As explained above, background reference values were not considered during initial comparisons of maximum soil concentrations with SSLs. For comparison of groundwater concentrations with risk-based standards at the Naval Annex, the greater of the background reference values for shallow and deep groundwater was used as the screening alternative to inorganic tap-water RBCs. The lithology of the surficial aquifer at Naval Annex is mostly sand, with no 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. Because no deep monitoring wells were installed at Clouter Island, only shallow background values were considered in screening comparisons there.

Because unique risk assessment procedures are mandated by USEPA for the chlorinated dibenzodioxins/dibenzofurans, these compounds were treated uniquely in the fate and transport screening assessment. The lowest value of  $K_{oc}$  from the component congeners was used along with  $H'$  and the MCL for 2,3,7,8-TCDD to calculate a conservative SSL of 1,600 ng/kg. Although the value of  $H'$  for 2,3,7,8-TCDD is the only dioxin  $H'$  value available in SCDM,  $H'$  has virtually no effect on the calculated SSL since  $K_{oc}$  values for dioxin congeners are so high. SSLs were also calculated for individual congeners, using data available in SCDM. For congeners without listed  $K_{oc}$  values, SSL calculations used surrogate  $K_{oc}$  values from congeners with similar chemical structures. Some of the calculated SSLs for individual congeners are more conservative (lower) than that for TEQs because they are based on multiples of 2,3,7,8-TCDD's RBC (0.45 pg/L) rather than its much higher MCL (30 pg/L), since there are no MCLs listed for congeners other

than 2,3,7,8-TCDD. The calculated SSLs for TEQs should be used as “pre-screening” values. 1  
If total TEQs in a soil sample exceed 1,600 ng/kg, then the concentrations, distribution, and 2  
transport characteristics of the individual congeners should be examined to gauge the potential 3  
threat to groundwater. 4

### *Detailed Assessment* 5

Upon completion of the quantitative screening process, site constituent concentrations exceeding 6  
the screening values were examined to delineate the magnitude, number, and areal extent of soil 7  
impacts potentially affecting groundwater. Maximum constituent concentrations in surface soil 8  
were compared to those in subsurface samples to estimate the extent of downward migration. The 9  
number and spatial distribution of exceedances were noted. Relative concentrations in soil and 10  
groundwater were compared. If relevant, corresponding exceedances in nearby SWMUs/AOCs 11  
were examined as possible contaminant sources or as indicators of lateral migration. 12

Detailed assessments helped determine the significance of soil impacts relative to the surficial 13  
aquifer. In some instances, isolated areas of soil contamination exceeding leachability-based 14  
concentrations may have the potential for localized shallow groundwater impacts, but not of a 15  
magnitude that would pose a long-term or widespread threat to the aquifer. The detailed 16  
assessment was used to identify these cases and to decide which areas of soil contamination may 17  
require supplemental investigation and/or modeling applications during the CMS as part of the 18  
remedial alternatives development process. 19

### **6.2.2 Groundwater-to-Surface Water Cross-Media Transport** 20

Groundwater in the surficial aquifer at both areas of Zone K moves generally toward the Cooper 21  
River, as described in Section 6.0. Much of the groundwater in the surficial aquifer at the Naval 22  
Annex flows into the I-26 stormwater sewer system, which drains into open ditches leading to 23  
Turkey Creek. Groundwater at Clouter Island is expected to flow into Clouter Creek or directly 24

into the Cooper River. The principal focus of this evaluation was determining whether constituents identified in groundwater have the potential to extend their impacts to different locations within the surficial aquifer or to surface water in Turkey Creek, Clouter Creek, and the Cooper River. Other than three samples each from one location at an offsite drainage ditch (166GSW03) and one location at Turkey Creek (166GSW05), surface water was not sampled as part of the Zone K RFI. Therefore, potential impacts on surface water were evaluated by comparing groundwater constituent concentrations to surface water screening standards, as described below. The screening process may be summarized as follows:

***Quantitative***

Chemicals present in groundwater were compared to appropriate screening values. Relative to human health evaluation, maximum groundwater analytical results for each SWMU/AOC (or group thereof) at the Naval Annex and Clouter Island were compared to the greater of:

- Tap-water risk-based screening levels as presented in USEPA Region III RBC tables (October 1998), assuming a target hazard quotient of 1.0.
- Background reference values for inorganics in Zone K shallow groundwater, determined in consultation with the project team technical subcommittee and selected as described above in Section 6.2.1 and in Section 5.

To evaluate potential impact on ecological receptors, maximum shallow groundwater analytical results for each AOC (or group thereof) at Clouter Island 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 K RFI, no background values for surface water constituents could be determined for use as alternatives to surface water screening standards.

Maximum groundwater constituent concentrations from Naval Annex sites were not compared to saltwater surface water screening levels for the following reasons:

- *Distance:* Within the stormwater drainage system, water travels more than 3,100 feet from Junction Box 1, downgradient of the Naval Annex, to where it discharges into Turkey Creek, with numerous other groundwater and drainage inputs from varied sources along the route.
- *Dilution:* VOCs are the primary groundwater contaminant concern at the Naval Annex, but VOC concentrations decrease dramatically between the annex and Turkey Creek. Downgradient from Junction Box 2 of the stormwater drainage system, VOCs were detected in samples from one location at a drainage ditch (PCE and TCE) and from one at Turkey Creek (TCE), as mentioned above. A dye trace study indicated that water constituents are diluted by a factor of 58 between the ditch and the Turkey Creek sample location, and by a factor of 245 between Junction Box 2 and the Turkey Creek location. Additional dilution occurs between the Naval Annex and Junction Box 2. Maximum Naval Annex groundwater concentrations of PCE (at SWMU 166) were 58 times higher than maximum concentrations in the two surface water samples; maximum TCE concentrations (also at SWMU 166) were 1,940 times higher.
- *Relative concentrations:* The maximum concentration of PCE in SWMU 166 groundwater samples was six times higher than in samples from other Naval Annex sites; the maximum TCE concentration was 57 times higher. If the relatively high VOC concentrations in SWMU 166 groundwater are being diluted and attenuated to the extremely low levels seen in downstream surface water samples, then the much lower concentrations at the other Naval Annex sites can be expected to have an insignificant effect on downstream surface water concentrations. Groundwater constituent concentrations from SWMU 166 will be screened against surface water standards in the addendum covering that site.

The 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 representative groundwater chemical concentrations do not exceed tap-water risk-based screening levels and background concentrations, there is no significant threat of offsite groundwater contamination via migration. If reported chemical concentrations in groundwater do not exceed published ambient water quality criteria, it is assumed that those chemicals present no risk to ecological receptors resulting from groundwater discharge to surface water. This screening assessment does not consider effects of dilution and attenuation on transport between the affected well(s) and the surface water discharge point, nor does it consider the dilutional capacity of the receiving water body. Omitting these factors from the quantitative screening ensures that a conservative list of potential groundwater to surface water concerns is developed.

The RBC used for total chromium in Naval Annex groundwater samples was 110  $\mu\text{g/L}$ , following the logic used for chromium analyses in soil (Section 6.2.1, above). At Clouter Island, all 39 soil samples, two sediment samples, and eight groundwater samples that were tested for hexachrome were nondetect. Although the large number of hexachrome nondetects in soil samples justified assuming that chromium in soil was entirely trivalent, the smaller number of groundwater samples did not justify the same assumption. Consequently, the total chromium RBC used for fate and transport analysis of Clouter Island samples was 110  $\mu\text{g/L}$ , which is the value for hexavalent chromium. Since the highest reported groundwater concentration in Clouter Island samples was less than 110  $\mu\text{g/L}$ , this decision had no practical effect.

### *Detailed Assessment*

Upon completion of the quantitative 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 (where sampled) 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 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-to-Air Cross-Media Transport

To evaluate the potential for soil-to-air migration of contaminants, a screening approach focused on chemicals with the greatest potential to volatilize or become airborne in particulate form 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 all chemicals detected in surface soil at each SWMU/AOC were compared to soil-to-air screening concentrations as presented in the USEPA *Soil Screening Guidance: Technical Background Document*, May 1996 (primary source) or USEPA Region III RBC table, June 1996 (secondary source). Concentrations of organic compounds were compared to generic values representing the inhalation of volatiles pathway; concentrations of inorganics were compared to values representing the fugitive dust pathway, except for mercury, whose concentrations were compared to the inhalation of volatiles pathway.

The quantitative assessment defines the list of chemicals under consideration for formal fate and transport evaluation. If soil concentrations do not exceed soil-to-air volatilization or fugitive particulate screening concentrations, minimal migration potential exists, and current soil conditions are considered protective of human health relative to potential inhalation exposure pathways.

***Detailed Assessment***

Following 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 contaminants into the air.

The outcome of the detailed assessments was used to determine the significance of soil impacts on air. In some instances, isolated areas of soil contamination exceeding soil-to-air screening levels may have the potential for localized ambient air impacts, but not be of a magnitude to pose long-term or widespread threats through inhalation pathways. The detailed assessment identified these cases and determined which areas of soil contamination may require supplemental investigation and/or modeling applications during the CMS as part of remedial alternatives development.

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

The 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 beneath the base and adjoining property and surface water in the Cooper River and its tributaries. 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* (summarized in Exhibit 12 of the *User's Guide*). This section compares some of the assumptions of the screening procedure with actual conditions encountered at Zone K SWMUs and AOCs in

an attempt to demonstrate the conservative nature of the method. The screening assumptions are shown in italics, followed by commentaries on each.

1. *The contaminant source is infinite (i.e., steady-state concentrations are maintained during the exposure period).* At virtually every site, the original sources of soil and/or groundwater contamination have been eliminated; there is no ongoing contamination. As constituent molecules migrate through the system or degrade, they are generally not replaced from the original sources.

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 sample.* Site conditions vary greatly, as seen in sample analytical results. Most often, screening 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.* In reality, 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 CNC soils and lithologic units have moderate to very high clay content. The geometric mean CEC of two Clouter Island sediment samples was 87.6 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 relatively high clay content and corresponding high CEC values of Clouter Island soil and sediment should result in extensive attenuation of migrating site constituents, especially inorganics. Naval Annex soil is much sandier, but moderate attenuation can be expected there as well. The geometric mean total organic carbon of the same two sediment samples at Clouter Island was 5.48% ( $f_{oc} = 0.0548$ ). The default

value of  $f_{oc}$  used by EPA to calculate generic SSLs is 0.002, indicating that Clouter Island soils and sediments may have as much as several hundred 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. Total organic carbon values for Naval Annex soil, to be obtained in connection with CMS work at SWMU 166, are expected to be lower than those at Clouter Island.

EPA's generic SSLs are based on  $K_{oc}$  reference values for ionizing organics and  $K_d$  values for inorganics. The listed reference values assume a soil pH of 6.8. Values of  $K_d$  for most metals would be higher in local areas with higher pHs and lower in areas with lower pHs. The effect of pH variations on ionizing organics is reversed, but is weaker than for inorganics. Additional investigations at SWMU 166 will include determinations of soil pH.

4. *The generic SSLs used in the screening tables are based on a dilution attenuation factor of 10 for both Naval Annex and Clouter Island. Since EPA's methodology unrealistically assumes zero attenuation for migration of leachate through the vadose zone and groundwater through the aquifer, the default DAF of 20 recommended in the 1996 Soil Screening Guidance and the DAF of 10 used in the screening tables are actually dilution factors only. Using Equations 11 and 12 presented in the User's Guide, a dilution factor of 10.5 was calculated for generic sites at the Naval Annex, based on the following input variables:*

*Hydraulic conductivity: 660 m/yr (5.9 ft/day, from Table 2.12)*

*Hydraulic gradient: 0.0075 (typical; from Figure 2-7 and Table 2.7)*

*Aquifer thickness: 8.4 m (27.7 ft: mean saturated thickness of 18 SWMU 166 wells)*

*Source length: 30 m (default value from Soil Screening Guidance)*

*Infiltration rate: 0.061 m (2.4 in/yr: twice the average recharge assigned by the preliminary USGS groundwater modeling study to the main part of CNC and the area around it)*

*Calculated mixing zone depth: 3.52 m (from Equation 12 of the User's Guide)*

The assumed infiltration rate of 2.4 inches per year takes into account: (1) that a significant portion of the Naval Annex is developed, and therefore nearly impervious to the seepage of rainfall, and (2) that a large part of the Annex contains drainage ditches or engineered drains that collect and remove much of the rainfall seepage and runoff. Dilution factors could not be calculated for Clouter Island soil due to lack of data. The value of 10 assigned to Clouter Island is considered very conservative because of the high clay and organic content of the soil — neither is reflected in the DAF formula — and the possibility that at least part of the area is a discharge zone for groundwater.

5. *There is no contaminant attenuation as groundwater moves through the aquifer. Although Zone K aquifer sediments were not sampled for hydrogeochemical parameters, their lithology and the CEC and Total organic carbon values of two Clouter Island sediment samples indicate otherwise, as discussed above in item three:*

- Substantial amounts of clay are present in Clouter Island samples.
- The geometric mean CEC of two sediment samples is similar to those of some clay minerals.
- The geometric mean total organic carbon of two sediment samples is two to four times higher than EPA default values.

Additional hydrogeochemical parameters will be analyzed for aquifer samples from SWMU 166 as part of the CMS study.

6. *The mean contaminant concentration in the theoretical groundwater plume associated with each site is equal to: (a) the concentration of leachate produced by the maximum detected soil concentration and diluted 10:1 by groundwater or (b) the maximum detected 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 (where available). High constituent concentrations in Zone K soil or groundwater samples were generally reported from a few isolated locations rather than across entire sites. The number and spatial distribution of screening exceedances is discussed in the detailed assessment for each site.

7. *An appropriate human health screen for groundwater is EPA's Region III tap-water RBCs using a target hazard quotient of 1.0.* Groundwater was evaluated as if it were potential drinking water, although no water-supply wells are completed in the surficial aquifer at CNC or nearby, and high percentages of Zone K groundwater samples that were analyzed for iron or manganese exceeded USEPA's Secondary MCLs. Because 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. The only exceptions to this approach were for the carcinogenic PAHs, which were evaluated in terms of BEQs, and the chlorinated dibenzodioxins/dibenzofurans, which were evaluated in terms of TEQs.

8. *An appropriate ecological screen for surface water in the Cooper River and its tributaries is USEPA's saltwater surface water chronic screening values for hazardous waste sites (Supplemental Guidance to RAGS, Region 4 Bulletins: Ecological Risk Assessment, November 1995).* The portions of the Cooper River and its tributaries opposite the main part of CNC are tidally influenced streams containing brackish water. The screening values in the USEPA publication noted above include the "Criteria to Protect Aquatic Life" incorporated by reference into SCDHEC's Water Classifications and Standards (Regulation 61-68), plus additional values.

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**7.0 HUMAN HEALTH RISK ASSESSMENT**

**7.1 Introduction**

A human health risk assessment (HHRA) analyzes the potential for adverse effects on actual or hypothetical human receptors who could be exposed to hazardous substances released from a site, assuming that no remedial actions are taken to reduce the environmental contamination currently at a site. The methods used to analyze these effects are discussed in the following text.

Section 7.2 describes the objectives of this assessment and Section 7.3 describes the methods that will be used to implement them for each specific site. The site-specific assessments are detailed in Section 10. Overall, the human health risk assessment was conducted in accordance with the risk assessment and human health evaluation guidance listed below:

- *Risk Assessment Guidance for Superfund (RAGS), Volume I – Human Health Evaluation Manual (Part A)*, (USEPA, 1989a), (RAGS Part A).
- *RAGS, Volume I – Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)*, (USEPA, 1991a), (RAGS Part B).
- *RAGS, Volume I – Human Health Evaluation Manual, Supplemental Guidance – Standard Default Exposure Factors – Interim Final*, (USEPA, 1991b), (RAGS Supplement).
- *Dermal Exposure Assessment: Principles and Applications – Interim Report*, ORD, EPA/600/8.91/011B, January 1992.
- Supplemental Guidance to RAGS: Region IV Bulletin, *Human Health Risk Assessment – Interim*, (USEPA Region IV, 1995a).

- Supplemental Guidance to RAGS: Region IV Bulletin, *Development of Health-Based Preliminary Remediation Goals, Remedial Goal Options (RGO) and Remediation Levels* (Supplemental RGO Guidance) (USEPA Region IV, 1994). 1  
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- Supplemental Guidance to RAGS: Region IV Bulletin, *Provisional Guidance of Quantitative Risk Assessment of PAHs*, (USEPA Region IV, 1993). 4  
5
- *Exposure Factors Handbook*, (USEPA, 1989d). 6
- USEPA Region III *Risk-Based Concentration Table, October 1, 1998*. 7
- *Technical Memorandum Guidance on Estimating Exposure to VOCs During Showering*, (USEPA, 1991c). 8  
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These references are identified fully in Section 12, References. 10

## 7.2 Objectives 11

Chemical contamination at the site must be characterized adequately before a risk assessment can be used to determine whether detected concentrations have the potential for toxic effects or increased cancer incidences and before it can become a basis for making remedial decisions. To characterize the study area, the amount, type, and location of contaminant sources are studied. Variables include the pathways of exposure (media type and migration routes); the type, sensitivities, exposure duration, and dynamics of the exposed populations (receptors); and the toxicological properties of identified contaminants. 12  
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- The objectives of the HHRA are to: 1
- Characterize the source media and determine the chemicals of potential concern (COPCs) for affected environmental media. 2  
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  - Identify potential receptors and quantify potential exposures for those receptors under current and future conditions for all affected environmental media. 4  
5
  - Qualitatively and quantitatively evaluate the adverse effects associated with the site-specific COPCs in each medium. 6  
7
  - Characterize the potential baseline carcinogenic risk and noncarcinogenic hazards associated with exposure to impacted environmental media at Zone K under current and future conditions. 8  
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  - Evaluate the uncertainties related to exposure predictions, toxicological data, and resultant carcinogenic risk and noncarcinogenic hazard predictions. 11  
12
  - Establish RGOs for chemicals of concern (COCs) in each environmental medium based on risk/hazard to facilitate risk management decision-making. 13  
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- The focus of each investigation is detailed in the Site Background and Investigative Approach section (Section 10) for each site. At most SWMUs and AOCs, sampling activities consisted of collecting surface (upper interval) and subsurface (lower interval) soil samples, in addition to groundwater samples from monitoring wells installed in the shallow and deep aquifers underlying the zone. Analytical results from surface soils, shallow groundwater, and deep groundwater were used to assess possible exposure to environmental contaminants. 15  
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**Organization**

A human health risk assessment, as defined by RAGS Part A, includes the following steps:

- **Site characterization:** Evaluation site geography, geology, hydrogeology, climate, and demographics.
- **Data collection:** Analysis of environmental media samples, including background/reference samples.
- **Data evaluation:** Statistical analysis of 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:** Identification of potential receptors under current and predicted conditions, visualization of potential exposure pathways, calculation of exposure point concentrations (EPCs), and quantification of chemical intakes.
- **Toxicity assessment:** Qualitative evaluation of the adverse effects of the COPCs, and quantitative estimate of the relationship between exposure and severity or probability of effect.
- **Risk characterization:** A combination of the outputs of the exposure assessment and the toxicity assessment to quantify the total noncancer and cancer risk to the hypothetical receptors.
- **Uncertainty:** Discussion and evaluation of the areas of recognized uncertainty in human health risk assessments in addition to medium- and exposure pathway-specific influences.

- *Risk/Hazard Summary:* Presentation and discussion of the results of the quantification of exposure (risk and hazard) for the potential receptors and their exposure pathways identified under current and future conditions. 1  
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- *Remedial Goal Options:* Computation of 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. 4  
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This general process was followed in preparing the HHRA for each Zone K SWMU and AOC at CNC. 7  
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### **7.3 Human Health Risk Assessment Methods** 9

When performing a HHRA, environmental media data are analyzed to determine potential site-related chemicals and exposures for each medium as outlined in RAGS Part A. The general process outlined below was used to evaluate human health risks for Zone K. 10  
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#### **7.3.1 Data Sources** 13

Section 7.3.1 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the data sources used to perform the HHRA for Zone K. 14  
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#### **7.3.2 Data Validation** 16

Section 7.3.2 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the data validation procedures for Zone K. 17  
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#### **7.3.3 Management of Site-Related Data** 19

Section 7.3.3 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the management of site-related data for Zone K. 20  
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#### 7.3.4 Selection of Chemicals of Potential Concern

The objective of this step was to screen the available information on the substances detected (CPSS) at each SWMU or AOC to develop a list or group of COPCs. COPCs are chemicals selected by comparison with screening concentrations (risk-based and reference), intrinsic toxicological properties, persistence, fate and transport characteristics, and cross-media transport potential. For a COPC to be considered a COC, and warrant assessment relative to corrective measures, it must meet two criteria. First, the COPC must contribute to an exposure pathway with an incremental lifetime excess cancer risk (ILCR) in excess of  $10^{-6}$  or a hazard index (HI) greater than 1 for any of the exposure scenarios evaluated in the risk assessment. Second, the COPC must have an individual risk projection greater than  $10^{-6}$  or an HQ greater than 0.1. ILCR, HQ, and HI are detailed in Sections 7.3.7 and 7.3.8 of this report.

Before evaluating the potential risks/hazards associated with site media, it was first necessary to delineate onsite contamination. This was accomplished by noting the chemicals detected in environmental media. These chemicals represent the CPSS for each SWMU or AOC. The nature and general extent of CPSS at each site are discussed in detail in Section 10. To reduce the list and focus the risk assessment on COPCs, site-related data were compared to risk-based screening concentrations and background concentrations.

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

The maximum CPSS concentrations detected in samples were compared to risk-based screening values obtained from *Risk-based Concentration Table, USEPA Region III*, October 1, 1998. USEPA recommends a target HQ of 0.1 and a risk goal of  $10^{-6}$  to calculate screening concentrations for noncarcinogens and carcinogens, respectively. As a result, noncarcinogenic chemical values were adjusted to equate with an HQ of 0.1.

Groundwater results were compared to tap-water screening values, and reported soil (and sediment, where applicable) concentrations were compared to residential soil ingestion screening values. The soil screening value for lead was set equal to 400 mg/kg, consistent with current OSWER directives considering protection of a hypothetical child resident; the lead groundwater screening value used was the USEPA Office of Water treatment technique AL of 15 µg/L.

A soil screening value of 1 µg/kg (as 2,3,7,8-TCDD equivalents – total TEQs) was applied to chlorinated dibenzodioxins and dibenzofurans. USEPA has determined this value to be an appropriate starting point for setting cleanup levels for dioxin in soil at RCRA sites (*Approach for Addressing Dioxin in Soil at CERCLA and RCRA Sites*, OSWER April 13, 1998). This cleanup level is pending the release of a comprehensive USEPA report regarding dioxin exposure and risk. For groundwater, the TEQ value computed for each sample was compared to the 2,3,7,8-TCDD tap-water screening level of 4E-07 µg/L.

In accordance with recent cPAH guidance (USEPA Region IV, 1993), BEQs were computed, where appropriate, by multiplying the reported concentration of each cPAH by its corresponding 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 were quantified and risk/hazard was projected for cPAHs in soil and groundwater using total BEQ values for each sampling location rather than individual compound concentrations.

CPSSs with maximum detected concentrations exceeding their corresponding concentrations, 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 USEPA's table. Selection of surrogate compounds was based on structural, chemical, or toxicological similarities.

Groundwater RBC screening relevance is discussed in Sections 7.3.6 and 7.3.8. Because shallow and deep groundwater beneath most Zone K areas contain chlorides and/or TDS exceeding South Carolina potable source criteria, water from these aquifers is not appropriate for domestic use. Consequently, screening the concentrations of compounds detected in groundwater against tap-water RBCs provides a highly conservative assessment of the significance of groundwater impacts.

For CPSS present in all depths of soil and in groundwater, an additional risk-based screening was included as part of assessing fate and transport. Fate and transport methods are explained in Section 6; sites are discussed in Section 10.

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

Because Zone K is discontinuous, soil and groundwater background concentrations were determined separately for the Naval Annex and for Clouter Island. Both sets of background concentrations were calculated using results from the grid-based soil and groundwater background sampling. Surface soil, subsurface soil, and shallow groundwater were all addressed separately for the Naval Annex. Surface soil was the only media with sufficient data to determine background concentrations for Clouter Island. After risk- and hazard-based screening values were compared, CPSS were retained for further consideration as COPCs in the HHRA on a SWMU or AOC specific basis if their maximum detected concentrations exceeded corresponding background concentrations, or if overall site concentrations were significantly greater than corresponding overall background concentrations as determined by Wilcoxon rank sum test procedures. 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 common in nature, such as aluminum, manganese, and arsenic. Based on this process, risk and/or hazard associated with naturally occurring chemicals is not addressed if chemicals did not exceed

corresponding background values. The statistical methods used to determine background concentrations and the rationale used for comparison to site concentrations are discussed in Section 5 of this report.

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 entire background dataset). Ideally, population tests identify general elevations in chemical concentrations, absent definable hot spots. Statistical methods, UTL calculations, Wilcoxon rank sum test outputs, and background sample information are discussed in Section 5. In the RFI, the CPSS was generally not considered further in the risk assessments if its maximum concentration was determined to be less than the risk-based screening value or (via background concentration comparison *and* population test). In some cases, further consideration was 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 not associated with adverse health effects. The following essential nutrients were eliminated from the human health risk assessment, based on RAGS, the lack of risk-related data, and USEPA Region IV's recommendations: calcium, magnesium, potassium, and sodium.

A provisional RfD is available for iron, and as a result, iron data were screened using the appropriate RBC for each media (soil or groundwater). Since iron is considered an essential nutrient, risk-based evaluation of iron in the environment is complex to the point that conclusions based on risk become almost meaningless. Therefore, risk is not formally assessed for iron at Zone K sites. As an alternative to risk-based discussion, a background reference concentration was developed and used to assess iron's significance.

### **Summary of COPCs**

Screening evaluations results 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 that have been critiqued and approved by the scientific and regulatory community (i.e., listed in IRIS and/or HEAST). Risk information was not available for some CPSS; therefore, it was not possible to calculate risk and/or hazard for those chemicals. For each environmental medium sampled at a SWMU or AOC, the data were screened using risk-based and background values. Screening process results are presented in tables in each HHRA. Those 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 risk-based screening values are available for the generic group TPH. As a result, TPH assessment was consistent with the CNC soil action level of 100 mg/kg. If no groundwater impacts were identified, the current soil concentrations were considered sufficiently protective of the underlying aquifer.

**7.3.5 Calculation of Risk and Hazard**

Section 7.3.5 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the calculation of risk and hazard for Zone K.

**7.3.6 Exposure Assessment**

Section 7.3.6 of the *Zone A RFI Report* (EnSafe, August 1998) discusses site worker and residential exposure assessments for Zone K.

**Potentially Exposed Populations**

One Zone K RFI site is currently being used as a soccer field. As a result, a current recreational use scenario was considered for this site. In general, soil matrix-related pathways include incidental ingestion and dermal contact. Exposure to groundwater was considered to consist of ingestion only. Table 7.1 presents the exposure parameters used for the recreational use scenario.

**Table 7.1**  
**Parameters Used to Estimate Chronic Daily Intake**  
**at Reasonable Maximum Exposure**

Pathway Parameters	Recreational User	Units
<b>Surface Soil Ingestion and Dermal Contact</b>		
Ingestion Rate (soil)	200 <sup>a</sup>	mg/day
Exposure Frequency	104 <sup>b</sup>	days/year
Exposure Duration	10 <sup>c</sup>	years
Dermal Contact Area	4,600 <sup>d</sup>	cm <sup>2</sup>
Skin Adherence Factor	1	mg/cm <sup>2</sup>
Absorbance Factor	0.01 (organics) 0.001 (inorganics)	unitless
Dermal Adjustment Factor	0.8 (VOCs) 0.5 (other organic compounds) 0.2 (inorganics)	unitless
Conversion Factor	1E-6	kg/mg
Body Weight	45 <sup>a</sup>	kg

**Table 7.1**  
**Parameters Used to Estimate Chronic Daily Intake**  
**at Reasonable Maximum Exposure**

Pathway Parameters	Recreational User	Units
Averaging Time, Noncancer	3,650 <sup>e</sup>	days
Averaging Time, Cancer	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 = Represents 25% of the 90th percentile total body surface area values for male children 15 to 16 year olds (18,400 cm<sup>2</sup>). Development of statistical distributions of ranges of standard factors used in exposure assessments, Office of Research and Development, Office of Health and Environmental Assessment. USEPA No. 600/8-85-010.
- 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.

**7.3.7 Toxicity Assessment**

Section 7.3.7 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the toxicity assessment procedures for Zone K.

**7.3.8 Risk Characterization**

Section 7.3.8 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the risk characterization procedures for Zone K.

**7.3.9 Risk Uncertainty**

This section presents and discusses the uncertainty and/or variability inherent in the risk assessment process and the medium-specific and exposure pathway-specific influences. Risk assessment sections are discussed separately below; 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 CDI estimates. 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, individual chemical risk is added to determine the incremental excess cancer risk for each exposure pathway. If calculations of 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 "conservatism" 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 on which they are based; they also embody uncertainty about potentially unsampled maxima and minima in the analytes. The exposure

pathways considered for selection in the exposure assessment section of the HHRA are extremely conservative.

Assumptions are made as part of the risk assessment process based on population studies and USEPA guidance. This guidance divides the assumptions into two basic categories: the upper bound (90 to 95th percentile) and the mean or 50th percentile central tendency (CT) exposure assumptions. As discussed in the exposure assessment section, the RME is based on the upper-bound assumptions, and CT exposure is based on mean assumptions. Therefore, risks and hazards calculated using RME exposure assumptions are generally overestimates rather than underestimates. The following paragraphs discuss sources of uncertainty and variability pertinent to each exposure pathway evaluated.

### **Quality of Data**

Data collected during the Zone K investigation are presented in Section 10 of this RFI, which includes results from AOC and SWMU sites and the QA/QC of those data. The purpose of the data evaluation is to verify that the QC requirements of the dataset have been met and to characterize questionable data.

Most analytical results for environmental samples have inherent uncertainty/variability, which is a function of the matrix characteristics and heterogeneity, the precision and accuracy of sampling, and preparation and analysis methods employed. Although data are typically considered to be exact values, they are in reality the laboratory's best estimate within a range defined by method control limits. As a result, reported concentrations for any chemical can be underestimates or overestimates of actual concentrations.

**Identification of COPCs**

Rather than addressing risk/hazard for all chemicals detected, screening values were used to focus the HHRA on the pathways of concern and COPCs that individually exceed  $10^{-6}$  risk or an HQ of 0.1.

***Exposure Pathways and Contaminants***

As discussed in Section 7.3.4, comparisons were made using the most conservative set of screening values (residential land use) provided by USEPA for each exposure medium. Many CPSS 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 with low range risk/hazard goals alleviates much uncertainty. A large number (i.e., greater 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 soil screening values calculated by USEPA. If these pathways were the primary concern (as opposed to ingestion), the screening method could eliminate contaminants that should otherwise be considered COPCs. Zone K surface soil data are compared to soil-to-air cross-media transport via volatilization in the fate and transport discussion of this report. Any constituents omitted based on comparison to residential RBCs that have the potential to significantly contribute to risk via other exposure pathways were added back to the list of COPCs.

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

Because the HHRA's purpose 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 in the Zone K RFI 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, as detailed in Section 7.3.4. 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 the Naval Annex or Clouter Island, they are not individual SWMU-specific 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***

In accordance with RAGS, the following nutrients were eliminated from Zone K HHRA: calcium, sodium, potassium, and magnesium. Toxicity from overexposure to the nutrients listed above is possible only if human receptors are exposed to extremely high doses. USEPA recommends eliminating these compounds 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.

The provisional iron RfD is based on data taken from a study of individuals whose intake of iron was equivalent to or even slightly exceeded the recommended daily allowance as a result of their diet. There were no identifiable adverse health effects associated with the dietary levels of iron to which these individuals were exposed. Because no adverse health effects were observed, the basis for the provisional iron RfD was established. Consequently, it is assumed that a potential site receptor's intake of iron is already equal to the reference dose due to dietary intake. Furthermore, any site-related exposure to iron would result in additional iron intake, causing an unacceptable hazard index for iron. These facts complicate risk-based conclusions regarding

site-related concentrations of iron. Therefore, iron was not carried through the quantitative risk assessment due to the uncertainties associated with the provisional iron RfD. As a result, hazard index estimates could be over estimated or underestimated due to these uncertainties.

#### **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 soils 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 Zone K sites is not likely, based on current site uses, the nature of surrounding buildings, and potential reuse plans. If sites located at the Naval Annex were developed as residential sites, most of the present buildings would be demolished and the surface soil conditions would likely change — soil could be covered with roads, paved driveways, landscaping soil, and/or houses, or parts of the property could be made into playgrounds. Similarly, a considerable amount of fill material and erosion controls would likely be required to make Clouter Island sites suitable for residential redevelopment. 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 K location as a source of potable or process water. 1  
A basewide system provides drinking and process water to buildings throughout the Naval Annex. 2  
This system is to remain in operation under the current base reuse plan. In addition, the aquifers 3  
monitored during the RFI process naturally contain significant concentrations of chlorides and 4  
TDS. As a result, these water-bearing zones' potential as potable water sources is questionable. 5  
Absent potential potable uses, the applicability of tap-water based screening or remedial standards 6  
is questionable. Furthermore, groundwater would not be expected to be used under future site use 7  
scenarios. Therefore, the scenario established to project risk/hazard associated with groundwater 8  
exposure is highly conservative, and associated pathways are not expected to be completed in the 9  
future. 10

#### ***Determination of Exposure Point Concentrations*** 11

Based on the guidance provided by USEPA, EPCs are concentrations used to estimate CDI. The 12  
uncertainty associated with EPCs stems primarily from their statistical determination or the 13  
imposition of maximum concentrations, described below. 14

#### ***Statistical Estimation of Exposure Point Concentrations*** 15

USEPA's *Supplemental Guidance to RAGS: Calculating the Concentration Term* guidance, 16  
(May 1992), outlines a statistical estimation of EPC. These calculated concentrations are 95% 17  
UCLs for the mean, which are based on certain assumptions. USEPA assumes that most (if not 18  
all) environmental data are lognormally distributed. This assumption can lead to over estimates 19  
or underestimation of the concentration term because many environmental data are neither 20  
normally nor lognormally distributed. 21

The UCL calculation method includes the H-statistic, which is based on the number of samples 22  
analyzed for each COPC and the standard deviation of the results. To obtain this number, a table 23  
must be referenced, and the value must be interpolated (an estimation) from the table. The 24

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; 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 points, 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. RAGS specifies using the maximum concentration or the UCL as the EPC, based on which is the smaller value. As reviewed above, summation of risk-based on maximum concentrations leads to exposure overestimation, 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 the standard deviation on EPC, low frequency of detection can cause COPCs to be addressed inappropriately in the risk assessment. More specifically, COPCs detected

above RBCs and background concentrations only once or twice in all samples analyzed would be expected to have relatively higher standard deviations as concentration variability or range widens. A 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 the EPC (or possibly the inclusion of the COPC in question a COC) may not be appropriate when the 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 detection frequency.

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 fraction ingested/fraction contracted (FI/FC) from a 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 relative to 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 K HHRAs.

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

Where chlorinated dibenzodioxins and dibenzofurans (dioxins) were detected in soil, TCDD TEQs were derived by multiplying the concentration of each dioxin congener by its corresponding USEPA TEF. The resulting TCDD TEQs were then summed for each sample, and the total was compared to the 1  $\mu\text{g}/\text{kg}$  cleanup level. If the total TCDD 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 and were not carried through the quantitative risk assessment. A dioxin (as TCDD TEQs) soil concentration of 1  $\mu\text{g}/\text{kg}$  is associated with a risk level of 2.5E-04 based on a residential scenario and reasonable maximum exposure parameters. As a result, the elimination of dioxin from the quantitative risk assessment causes an underestimation of risk. Due to the highly complex nature of estimating exposure to dioxin and due to the evolving nature of dioxin risk assessment, a 1  $\mu\text{g}/\text{kg}$  screening level was considered an appropriate screening level. Groundwater exposure quantification was performed using TCDD TEQ values computed for each monitoring point.

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

In addition to the typical uncertainties inherent in toxicity values, parameters were not included in the CDI calculation data if they did not have corresponding RBCs due to the lack of approved toxicological values. This does not indicate that chemicals lacking approved toxicological values pose no risk/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 is reserved for a discussion of 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. For selected sites, 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 total hazard at sites where data supported such a representation.

Risk and hazard point mapping is useful in risk assessment for determining whether hot spots are present in 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 make it easier to estimate the extent of hot spots relative to the overall site area.

These maps also support preliminary scoping of remedial requirements and assessment of potential cleanup alternatives in the CMS. 1  
2

**7.3.10 Risk Summary** 3

In each site-specific HHRA, this section summarizes the risk and hazard projected for each receptor group, exposure medium, and exposure pathway. 4  
5

**7.3.11 Remedial Goal Options** 6

Section 7.3.11 of the *Zone A RFI Report* (EnSafe, August 1998) discusses the remedial goal options for the HHRA for Zone K. 7  
8

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## **8.0 ECOLOGICAL RISK ASSESSMENT**

The ecological risk assessment (ERA) is a key component of the Zone K baseline risk assessment and develops a qualitative and/or quantitative ecological appraisal of Zone K contamination's actual or potential effects on the surrounding 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 Zone K risk components was based on *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997), *Risk Assessment Guidance for Superfund, Volume II - Environmental Evaluation Manual* (USEPA, 1989b), and *Framework for Ecological Risk Assessment* (USEPA, 1992c).

### **8.1 Zone Rationale**

To identify and define the distribution and geographic boundaries of contiguous habitats and similar ecosystems, the CNC was subdivided into eight large Ecological Study Areas (ESAs; see Figure 8-1) at the beginning of the basewide RFI. Zone K, which includes a small portion of Clouter Island (the former ammunition depot) and the noncontiguous Mobile Operations Mine Assembly Group Unit 11 at the Naval Annex (Annex), was initially identified as ESA VIII. After a thorough ecological site assessment of ESA VIII, several smaller specific Areas of Ecological Concern (AECs) were identified, including an area of bottomland hardwoods and coastal marsh at Clouter Island and the open grassy areas at the Annex, which became the focus of the Zone K ERA. Using a comprehensive ecological survey form adapted from Region IV USEPA ERA guidance, habitat and biota of each AEC were evaluated and characterized. This ecological information, along with contaminant information regarding each Zone K SWMU and AOC, determined the likelihood of potential adverse exposure to receptors from Zone K activities. If a complete exposure pathway existed for an AEC, the specific habitat within that AEC was identified as an *ecological subzone* and became the final assessment objective of the Zone K ERA.

Zone K subzones (shown on Figures 8-2a and 8-2b) are discussed in the following sections. The ecological survey forms that apply to Zone K are also summarized below.

## 8.2 Environmental Setting

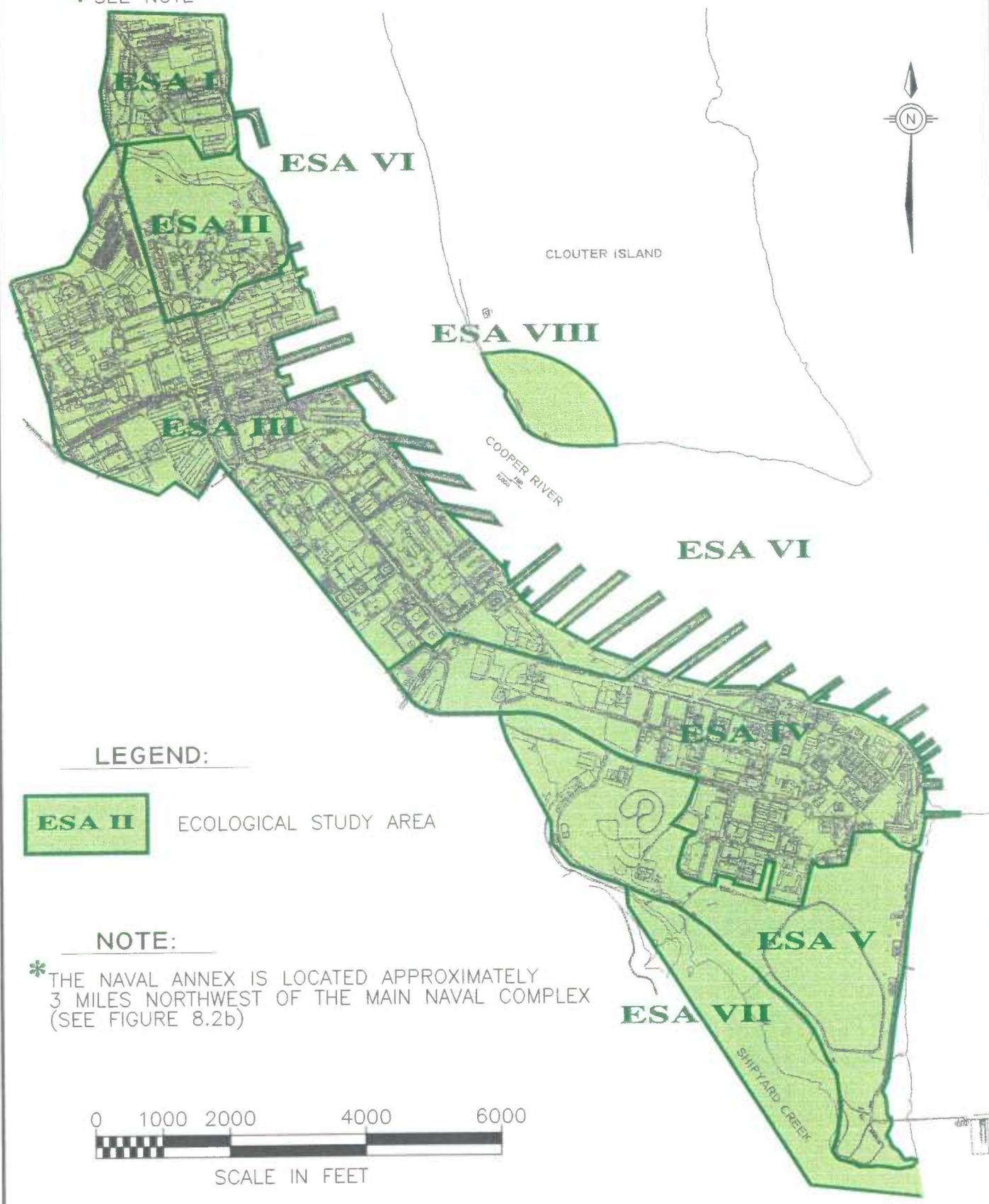
### 8.2.1 Problem Formulation

**Clouter Island/Subzones K-1 and K-2/K-3** – This small parcel on the southern shores of Clouter Island, across the Cooper River from CNC, was once used as a ammunition depot and for the disposal of dredged material. Since this site is isolated from major land areas (access is only via boat), the former depot has been relatively undisturbed and is largely revegetated. The resulting natural areas in this portion of the island have been identified as AEC VIII. The three subzone habitats within this parcel are:

- Subzone K-1 — The littoral zone along the shoreline dominated by smooth cordgrass (*Spartina alterniflora*)
- Subzone K-2/K-3 — The nearly monotypic bottomland hardwood community established across most of the site and dominated by southern hackberry (*Celtis laevigata*) and the narrow but dense, scrub/shrub community with vegetative species such as wax myrtle (*Myrica cerifera*), tallow tree (*Sapium sebiferum*), and red mulberry (*Morus rubra*)

Although the *Final Zone K RFI Work Plan* (E/A&H, September 1996) identified three separate subzones, subsequent site characterizations have shown that Subzone K-2 and K-3 habitats are actually intermixed and have no clear boundaries. With a similar mix of bottomland and scrub-shrub vegetation, it is predicted that terrestrial wildlife species (receptors) associated with these two subzones will be comparable. Therefore, for assessment purposes, Subzones K-2 and K-3 have been combined and will be subsequently referred to as Subzone K-2/K-3.

\* SEE NOTE



**LEGEND:**

**ESA II** ECOLOGICAL STUDY AREA

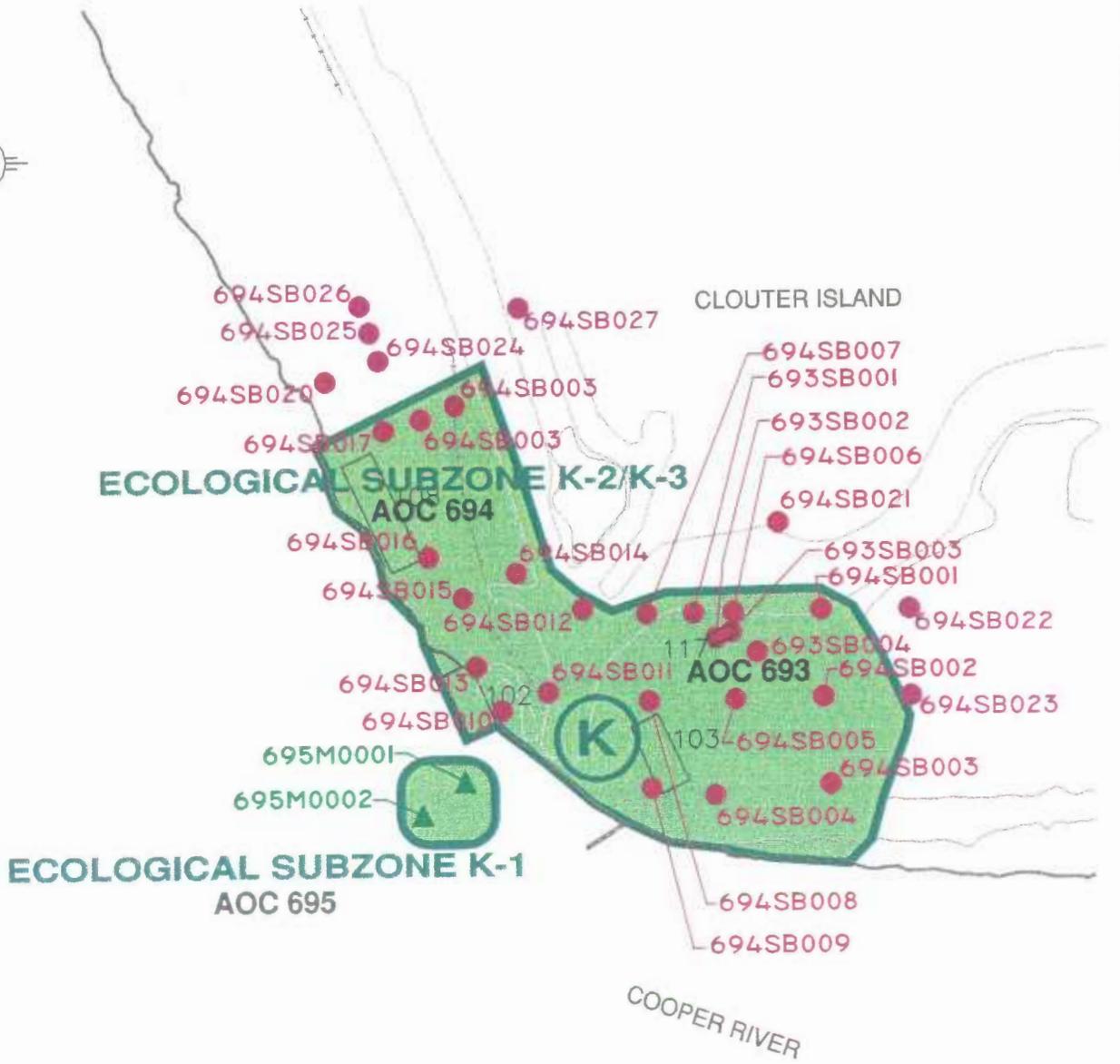
**NOTE:**

\* THE NAVAL ANNEX IS LOCATED APPROXIMATELY 3 MILES NORTHWEST OF THE MAIN NAVAL COMPLEX (SEE FIGURE 8.2b)



ZONE K  
RCRA FACILITY  
INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX  
CHARLESTON, SC

FIGURE 8.1  
ECOLOGICAL  
STUDY AREAS  
LOCATION MAP



**LEGEND:**

- 694SB002 ● SOIL SAMPLE LOCATION
- 695M0002 ▲ SEDIMENT SAMPLE LOCATION



SCALE IN FEET



ZONE K  
RCRA FACILITY  
INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX  
CHARLESTON, SC

FIGURE 8.2a  
ECOLOGICAL SUBZONES K-1 & K-2/K-3  
CLOUTER ISLAND

Date: 05/14/99

DWG Name: 2911C065

**LEGEND:**

- GDKSB002 ● SOIL SAMPLE LOCATION
- ANXM0001 ▲ SEDIMENT SAMPLE LOCATION



ZONE K  
RCRA FACILITY  
INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX  
CHARLESTON, SC

FIGURE 8.2b  
ECOLOGICAL SUBZONE K-4  
NAVAL ANNEX

00222.k1072

Isolated and relatively undisturbed dredge spoil areas with areas of shallow, standing water such as the interior dredge cells of Clouter Island can be important breeding areas for wading birds (Chamberlain, 1991). However, neither a literature review of records of local natural resources nor the AEC and subzone biota surveys noted the presence of breeding colonies of wading birds. This absence may be due to an abundance of a confined population of predatory species such as coyote, racoon, and other more mobile nest predators such as fish crows (*Corvus ossifragus*).

**Clouter Island AOC/SWMUs** – Three AOCs are in or near the ecological subzones at Clouter Island. Historic site maps place the electric locomotive shop (AOC 695) atop a wharf and trestle out over the Cooper River, but the only remnant of this AOC is a partially submerged cement foundation approximately 50 feet offshore. As part of the assessment of the Cooper River, two Zone K sediment samples were collected around the foundation and three Zone J sediment samples were collected within 500 feet of the structure. Potential impacts to aquatic receptors from sediment contaminants will be evaluated as part of the Zone J RFI.

AOC 693, the Fuse and Primer House, is within the larger Former Ammunition Depot (AOC 694); both a source of potential chemical stressors to receptors in Subzone K-2/K-3. Grid-based soil samples were collected throughout AOC 694; therefore most samples used to assess Subzone K-2/K-3 were not biased toward any particular structure or activity. Four biased soil samples were collected in and around AOC 693.

**Naval Annex/Subzone K-4** – The historical uses of the Annex and the associated AOC/SWMUs that may have impacted ecological receptors are described in *Zone K RFI Work Plan* (E/A&H, September 1996) and summarized in Table 8.1. To assess ecological risk to potential receptors at the Naval Annex, habitat at the Annex has been designated Subzone K-4, which consists of maintained grass fields surrounded by a high chain-link fence.

**Table 8.1**  
**AOCs/SWMUs Associated with Subzone K-4**

<b>AOC/SWMU</b>	<b>Description</b>	<b>Materials of Concern</b>
SWMU 161	Vehicle Maintenance Shop	Petroleum products, metals, solvents
SWMU 162	Sludge Drying Field	Paint residue, heavy metals, decomposition gases
SWMU 163	Concrete Pit Area	Solvents, paint wastes, heavy metals
SWMU 164	Blasting Operations	Metals, PAHs, petroleum products
SWMU 166	Automobile Service Shop, Naval Annex	TCE
SWMU 185	Sewer System and Former Septic Tank System	Metals, petroleum products, waste paint and solvents, biodegradation gases
AOC 696	Transformer Area Near Bldg. 2509	PCBs, TPH
AOC 698	Building 2508, Boiler House	Lead, TPH

In addition to the sites listed in Table 8.1, a sediment sample was also collected from a wet weather conveyance, but since the ditch flows only in response to rain and does not support a viable aquatic community, the results from chemical analyses of sediment sample have been incorporated into the terrestrial exposure model.

**Threatened and Endangered Species**

Several rare, threatened, endangered (RTE) species as well as various species of concern could occur at both Clouter Island and the Navy Annex, although given its urban location and disturbed habitats, the Annex is less likely to support any of the listed RTE species. Although not specific to Zone K, Table 8.2 lists those species currently listed by the State or federal agencies as historically or recently identified at CNC. The habitats at the relatively undisturbed Clouter Island are comparable to those found at CNC, particularly ESA V in Zones H and I. These similarities suggest that while on opposite sides of the Cooper River, both areas may have similar occurrences of the listed RTE species.

**Table 8.2**  
**Federal and State Listed Threatened, Endangered and Candidate Species**  
**That Occur or Potentially Occur on CNC**

Common Name	Scientific Name	Residence Status	USF&WS Status	SCWMRD Status
<b>Reptiles and Amphibians</b>				
American Alligator	<i>Alligator mississippiensis</i>	PR	T/SA	T/SA
Flatwoods Salamander	<i>Ambystoma cingulatum</i>	UR	C-2	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 kempii</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

Zone K RCRA Facility Investigation Report  
 Charleston Naval Complex  
 Section 8 — Ecological Risk Assessment  
 Revision No: 0

**Table 8.2**  
**Federal and State Listed Threatened, Endangered and Candidate Species**  
**That Occur or Potentially Occur on CNC**

Common Name	Scientific Name	Residence Status	USF&WS Status	SCWMRD Status
<b>Fish</b>				
Shortnose Sturgeon	<i>Acipenser brevirostrum</i>	LM	E	E
<b>Plants</b>				
Canby's Dropwort	<i>Oxpolis canbyi</i>	UR	E	E
Pondberry	<i>Lindera melissifolia</i>	UR	E	E
Incised Groovebur	<i>Agrimonia incisa</i>	UR	C-2	NC
Sea-Beach Pigweed	<i>Amaranthus pumilus</i>	UR	SR	NC
Cypress Knee Sedge	<i>Carex decomposita</i>	UR	SR	-
Chaff-Seed	<i>Schwalbea americana</i>	UR	SR	NC
Whisk Fern	<i>Pilotun nudum</i>	UR	-	SL
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' 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
			T	=	Threatened
			SL	=	State listed
CR	=	Confirmed resident	RC	=	Of concern, regional
PR	=	Possible resident	NC	=	Of concern, national
UR	=	Unlikely resident	C-2	=	Candidate species for federal listing, Category 2
LM	=	Likely migrant or occasional visitor	T/SA	=	Threatened due to similarity of appearance
PM	=	Possibly migrant or occasional visitor	USF&WS	=	U.S. Fish and Wildlife Service
UM	=	Unlikely migrant or occasional visitor	SCWMRD	=	South Carolina Wildlife and Marine Resources Department
SC	=	Of concern, state			
SR	=	Status review			

**Note:**

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

### **8.3 Conceptual Model**

Figure 8.3 presents a conceptual model of the potential contaminant pathways from Zone K source to the selected ecological receptors at each subzone. For the littoral habitats in Subzone K-1, a preliminary risk evaluation will be conducted using the offshore sediment samples collected around AOC 695. If it is determined that sediment contaminant concentrations exceed the respective effects level (Tables 8.3a and 8.3b), the need for a more extensive ecological risk assessment for aquatic receptors will be evaluated as part of the Zone J RFI’s Ecological Risk Assessment of the water bodies surrounding CNC. The Zone J RFI samples collected in the Cooper River will provide a broader base of data from which a determination can be made about the overall environmental condition of the river and risk estimates for aquatic receptors. Upland Subzones K-2/K-3 and K-4 will be assessed for exposure to terrestrial receptors relating to soil pathways.

### **8.4 Ecological Chemicals of Potential Concern**

Section 10 of this report discusses past activities associated with the SWMUs and AOCs in Zone K. The COCs resulting from these activities have been identified and quantified according to USEPA methods and protocols for analyses of soil and sediment. To determine if these COCs are adversely impacting the surrounding ecosystem, it was necessary to identify ecological chemicals of potential concern (ECPCs). Prior to ECPC selection, several assumptions and consideration were made regarding exposure scenarios and risk calculations.

**Assumptions and Considerations** – Nutrients such as calcium, iron, magnesium, potassium, and sodium were not included in the Zone K ERA since they are naturally occurring. It is also presumed that most biological effects related to soil exposure pathways will be limited to surficial soil (0 to 1 foot bgs). Therefore, in the terrestrial exposure models, only the results from the upper zone are addressed. In addition to restricting exposure modeling to surficial soils, risk calculations were performed using the maximum concentration of each parameter analyzed in each subzone. This conservative approach assumes that receptors are continuously exposed to the

highest concentrations of contaminants, which typically results in an overestimation of actual risk. 1  
To provide a more realistic representation of risk, a discussion of spatial contaminant distribution 2  
will be discussed when necessary. 3

**Resolution of Duplicate Sample Results** — A consistent approach was also necessary to address 4  
the presence of both primary and duplicate sample results in the data sets used in the ERA. For 5  
those samples designated to undergo QA/QC by duplicate analyses, the laboratory reported two 6  
results. Concentrations of compounds detected in both the primary and duplicate sample were 7  
averaged and listed as one concentration. For compounds that were detected in only one of the 8  
primary and duplicate sample, the detected value was used. 9

**Exclusion of Groundwater Sample Results** — Groundwater has been monitored at both Clouter 10  
Island (approximately 2 feet bgs) and the Annex (approximately 3 to 9 feet bgs); however, these 11  
water table depths preclude assessing ecological impacts from this medium to terrestrial receptors. 12  
For aquatic receptors, Zone K groundwater contaminants potentially migrating to the Cooper 13  
River and adversely impacting it will be addressed in the Zone J RFI. 14

#### **ECPCs Selection Criteria** 15

In Zone K screening-level assessment of surficial soil and sediment, analytes were selected as 16  
ECPCs if they met the following criteria: 17

- For inorganics, the maximum concentration exceeded both the corresponding ecological 18  
benchmark recommended in the USEPA's *Ecological Risk Assessment at Military Bases* 19  
and the established Zone K reference concentration. 20



- For organics, the maximum concentrations exceeded both the corresponding ecological benchmark (USEPA, 1998) or was present in more than 5% of the subzone samples collected. 1  
2  
3
  
- Suitable benchmark or reference concentration was unavailable. In sediment, analytes were selected as ECPCs if they met the following criteria: 4  
5
  
- Maximum concentration exceeded its respective USEPA Region IV Sediment Screening Value (SSV) or sediment PRG (Efroymson, 1997a). 6  
7
  
- Suitable benchmark was lacking. 8

The analytes detected in each subzone were compared to the corresponding USEPA ecological benchmark to identify ECPCs. Hazard quotients (HQs) were calculated by dividing the maximum concentration of each analyte by its benchmark to representation potential risk numerically. If an analyte's HQ exceeded one, it's maximum concentration exceeded its respective benchmark and it might pose an adverse impact to the ecological receptor represented by the benchmark (plant, earthworm, mouse, bird, etc.). HQs exceeding 10 indicate moderate risk and HQs exceeding 100, indicate extreme risk. 9  
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Table 8.3 presents the inorganic ECPCs identified for sediments at Subzone K-1, the littoral zone near the Clouter Island AOCs. the parameters which the laboratory did not detect are excluded from the tables. For Subzone K-1 sediments, excluded parameters are all the organic constituents and seven metals (antimony, cadmium, mercury, selenium, silver, tin, and cyanide). Tables 8.4 (a and b) and 8.5 (a and b) present the inorganic and organic ECPCs for Subzone K-2/K-3 and Subzone K-4, respectively. For Subzone K-4, the laboratory did not detect thallium or cyanide in any of the samples. 16  
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Table 8.3  
 Subzone K-1  
 Constituents Detected in Sediment

Parameter	Number of Detections	Range of Concentrations	SSV	SSV HQ	PRG	PRG HQ	ECPC?
<b>Inorganics (N=2; mg/kg)</b>							
Aluminum	2	29,900 - 33,300	NA	NA	NA	NA	Yes
Arsenic	2	15.5 - 17.7	7.24	<b>2.44</b>	42.0	0.42	Yes
Barium	2	30.1 - 53.0	NA	NA	NA	NA	Yes
Beryllium	2	1.5 - 1.6	NA	NA	NA	NA	Yes
Chromium	2	57.7 - 60.3	52.3	<b>1.15</b>	159	0.38	Yes
Cobalt	2	7.2 - 7.3	NA	NA	NA	NA	Yes
Copper	2	9.1 - 9.6	18.7	0.51	77.7	0.12	No
Lead	2	13.9 - 14.8	30.2	0.49	110	0.13	No
Manganese	2	255 - 301	NA	NA	NA	NA	Yes
Nickel	2	17.0 - 17.4	15.9	<b>1.09</b>	38.5	0.45	Yes
Thallium	1	3.3	NA	NA	NA	NA	Yes
Vanadium	2	61.4 - 66.2	NA	NA	NA	NA	Yes
Zinc	2	53.5 - 64.5	124	0.52	270	0.23	No
				<b>SSV HI = 6.20</b>	<b>PRG HI = 1.73</b>		

Notes:

- N - Number of samples collected
- mg/kg - milligrams per kilogram
- SSV - USEPA Region IV Sediment Screening Value
- SSV HQ - Hazard Quotient = Maximum concentration/SSV
- PRG - Sediment PRG (Efroymson, 1997a)
- PRG HQ - Hazard Quotient = Maximum concentration/PRG
- Bold - HQ values which exceed 1.0
- ECPC - Ecological Chemical of Potential Concern (HQ > 1 or could not be calculated)
- NA - SSV or PRG not available and HQ could not be calculated due to lack of benchmark data
- SSV HI - Hazard Index (Sum of SSV HQs)
- PRG HI - Hazard Index (Sum of PRG HQs)

**Table 8.4a**  
**Subzone K-2/K-3**  
**Inorganic Constituents in Surface Soil**

Inorganic Parameter	Number of Detections	Range of Concentrations	Reference Concentration	Ecological Benchmark	HQ	ECPC?
<b>N=31; mg/kg</b>						
Aluminum	31	1,370 - 44,700	32,100	50	<b>894</b>	Yes
Antimony	20	0.48 - 27.9	2.16	3.5	<b>7.97</b>	Yes
Arsenic	29	7.2 - 25.8	23	10	<b>2.58</b>	Yes
Barium	31	4.9 - 131	67.1	165	0.79	No
Beryllium	31	0.10 - 1.6	1.35	1.1	<b>1.45</b>	Yes
Cadmium	25	0.22 - 1.5	0.55	1.6	0.94	No
Chromium	31	4.8 - 77.3	69.1	0.4	<b>193</b>	Yes
Cobalt	31	0.35 - 10.1	5.7	20	0.51	No
Copper	31	4.3 - 1,020	119	60	<b>17</b>	Yes
Lead	31	5.3 - 481	98.3	50	<b>9.62</b>	Yes
Manganese	31	83.5 - 1,050	1,210	100	<b>10.5</b>	No
Mercury	29	0.07 - 1.7	0.63	0.1	<b>17</b>	Yes
Nickel	31	1.7 - 37.1	24.5	30	<b>1.24</b>	Yes
Selenium	12	0.46 - 4.7	1.24	0.81	<b>5.8</b>	Yes
Silver	16	0.31 - 1.2	0.41	2	0.6	No
Tin	16	5.9 - 284	39.1	53	<b>5.36</b>	Yes
Vanadium	31	4.3 - 92.2	75.9	2	<b>46.1</b>	Yes
Zinc	30	37.0 - 792	236	50	<b>15.84</b>	Yes

**Notes:**

- N - Number of samples collected
- mg/kg - milligrams per kilogram
- Ecological Benchmark - Recommended Ecological Screening Value for Soil (USEPA, 1998)
- HQ - Hazard Quotient = maximum concentration/Benchmark
- Bold - HQ values which exceed 1.0
- ECPC - Ecological Chemical of Potential Concern (max conc. > reference conc. and soil benchmark)

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Table 8.4b  
 Subzone K-2/K-3  
 Organic Constituents in Surface Soil

Parameter	Number of Detections	Range of Concentrations	Ecological Benchmark	Frequency of Detection	ECPC?
<b>Volatile Organic Compounds (N=27; µg/kg)</b>					
Acetone	1	2.00	NA	4%	No
Carbon Disulfide	1	4.00	NA	4%	No
<b>Semivolatile Organic Compounds (N=27; µg/kg)</b>					
Anthracene	1	110	100	4%	No
Benzo(a)anthracene	5	87 - 480	NA	19%	Yes
Benzo(a)pyrene	5	89 - 440	100	19%	Yes
Benzo(b)fluoranthene	6	100 - 450	NA	22%	Yes
Benzo(g,h,i)perylene	1	180	NA	4%	No
Benzo(k)fluoranthene	5	130 - 200	NA	19%	Yes
Butylbenzylphthalate	1	680	NA	4%	No
Chrysene	7	96 - 660	NA	26%	Yes
Fluoranthene	6	87 - 710	100	22%	Yes
Indeno (1,2,3-cd) pyrene	2	130 - 160	NA	7%	Yes
Phenanthrene	2	140 - 750	100	7%	Yes
Pyrene	7	91 - 1,100	100	26%	Yes
Bis(2-ethylhexyl)phthalate (BEHP)	3	140 - 620	NA	11%	Yes
<b>Organochlorine Pesticides (N=27; µg/kg)</b>					
4,4'-DDD	3	4.74 - 54.8	2.5	11%	Yes
4,4'-DDE	3	4.72 - 14.0	2.5	11%	Yes
4,4'-DDT	4	14.3 - 70.0	2.5	15%	Yes
Aldrin	2	3.03 - 8.44	2.5	7%	Yes
Dieldrin	3	3.89 - 9.20	0.5	11%	Yes
Endosulfan II	1	10.9	NA	4%	No
Endrin	5	5.20 - 36.2	1.0	19%	Yes
Endrin aldehyde	2	6.00 - 20.9	NA	7%	Yes
Heptachlor epoxide	8	2.56 - 54.7	NA	30%	Yes
Chlordane (alpha)	1	9.91	NA	4%	No
delta-BHC	1	2.62	NA	4%	No
<b>Polychlorinated Biphenyls (N=27; µg/kg)</b>					
Aroclor 1260	15	26.0 - 596	20	55%	Yes

**Table 8.4b**  
**Subzone K-2/K-3**  
**Organic Constituents in Surface Soil**

Parameter	Number of Detections	Range of Concentrations	Ecological Benchmark	Frequency of Detection	ECPC?
<b>Dioxins/Furans (N=31; ng/kg)</b>					
1234678-HpCDD	30	1.20 - 298.9	NA	97%	Yes
1234678-HpCDF	28	0.40 - 27.6	NA	90%	Yes
123478-HxCDD	3	0.89 - 1.72	NA	10%	Yes
123478-HxCDF	19	0.45 - 9.10	NA	61%	Yes
1234789-HpCDF	2	0.38 - 1.03	NA	6%	Yes
123678-HxCDD	20	0.69 - 7.91	NA	65%	Yes
123678-HxCDF	2	2.0 - 5.67	NA	6%	Yes
12378-PeCDF	5	0.58 - 1.72	NA	16%	Yes
123789-HxCDD	19	0.82 - 9.31	NA	61%	Yes
2378-TCDD	1	0.17	3.15	3%	No
2378-TCDF	4	0.77 - 2.37	NA	13%	Yes
OCDD	31	5.76 - 3.312	NA	100%	Yes
OCDF	28	0.40 - 139.9	NA	90%	Yes
Total Hepta-dioxins	29	2.20 - 2,026	NA	94%	Yes
Total Hepta-furans	25	0.47 - 27.6	NA	81%	Yes
Total Hexa-dioxins	27	1.47 - 254.1	NA	87%	Yes
Total Hexa-furans	23	1.55 - 39.37	NA	74%	Yes
Total Penta-dioxins	7	1.13 - 11.9	NA	23%	Yes
Total Penta-furans	20	1.12 - 10.6	NA	65%	Yes
Total Tetra-dioxins	19	0.93 - 9.75	NA	61%	Yes
Total Tetra-furans	13	0.97 - 6.87	NA	42%	Yes

**Notes:**

- N - Number of samples collected
- μg/kg - micrograms per kilogram
- ng/kg - nanograms per kilogram
- Ecological Benchmark - Recommended Ecological Screening Value for Soil (USEPA, 1998)
- NA - Benchmark unavailable
- Bold - HQ values which exceed 1.0
- ECPC - Ecological Chemical of Potential Concern (parameter detected in >5% of the samples)

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Table 8.5a  
 Subzone K-4  
 Inorganic Constituents in Surface Soil

Inorganic Elements	Number of Detections	Range of Concentrations	Reference Concentrations	Ecological Benchmark	HQ	ECPC
<b>N = 58; mg/kg</b>						
Aluminum	58	652 - 11,200	11,200	50	<b>2.24</b>	Yes
Antimony	11	0.38 - 3.3	0.45	3.5	0.94	No
Arsenic (N = 61)	61	0.60 - 32.2	3.00	10	<b>3.22</b>	Yes
Barium	58	5.5 - 105	25.6	165	0.66	No
Beryllium	37	0.03 - 0.65	0.17	1.1	0.59	No
Cadmium	28	0.06 - 4.0	0.13	1.6	<b>2.5</b>	Yes
Chromium	58	0.29 - 21.5	8.4	0.4	<b>53.75</b>	Yes
Cobalt	35	0.16 - 5.4	0.34	20	0.27	No
Copper	53	0.27 - 32	3.86	40	0.80	No
Lead	58	2.6 - 259	39.6	50	<b>5.18</b>	Yes
Manganese	58	3.2 - 70.4	26.4	100	0.70	Yes
Mercury	17	0.06 - 58.2	NA	0.1	<b>58.2</b>	Yes
Nickel	53	0.2 - 6.7	1.70	30	0.22	No
Selenium	10	0.36 - 0.71	0.84	0.81	<b>0.88</b>	No
Silver	3	0.24 - 0.88	0.44	2	0.44	No
Tin	9	1.1 - 32.0	19.4	53	0.60	No
Vanadium	58	1.5 - 16.0	15.8	2	<b>8.0</b>	Yes
Zinc	41	5.0 - 538	14.8	50	<b>10.76</b>	Yes

Notes:

- N - Number of samples collected
- mg/kg - milligrams per kilogram
- Ecological Benchmark - Recommended Ecological Screening Value for Soil (USEPA, 1998)
- HQ - Hazard Quotient = maximum concentration/Benchmark
- Bold - HQ values which exceed 1.0
- ECPC - Ecological Chemical of Potential Concern (max conc. > reference conc. and soil benchmark)

**Table 8.5b**  
**Subzone K-4**  
**Organic Constituents in Surface Soil**

Compound Name	Number of Detections	Range of Concentrations	Ecological Benchmark	Frequency of Detection	ECPC
<b>Volatile Organic Compounds (N=65; <math>\mu\text{g}/\text{kg}</math>)</b>					
Acetone	1	2,700	NA	1.5%	No
Carbon disulfide	1	1.0	NA	1.5%	No
Tetrachloroethene	4	14 - 990	NA	6.2%	Yes
Trichloroethene	17	2 - 59,000	NA	26%	Yes
<b>Semivolatile Organic Compounds (N=64; <math>\mu\text{g}/\text{kg}</math>)</b>					
2-Methylnaphthalene	3	96 - 300	NA	4.6%	No
Acenaphthene	2	46 - 130	20,000	3%	No
Acenaphthylene	1	88	NA	1.6%	No
Anthracene	3	41 - 420	100	4.6%	No
Benzo(a)anthracene	10	39 - 1,700	NA	6.4%	Yes
Benzo(a)pyrene	10	37 - 1,300	100	6.4%	Yes
Benzo(b)fluoranthene	13	52 - 1,700	NA	20%	Yes
Benzo(g,h,i)perylene	7	78 - 1,600	NA	11%	Yes
Benzo(k)fluoranthene	10	56 - 1,700	NA	6.4%	Yes
Bis(2-Ethylhexyl)phthalate (BEHP)	5	41 - 440	NA	8%	Yes
Carbazole (N = 55)	1	180	NA	1.6%	No
Chrysene	13	43 - 1,300	NA	20%	Yes
Di-n-butylphthalate	1	39	NA	1.6%	No
Dibenz(a,h)anthracene	3	130 - 410	NA	5%	No
Dibenzofuran	2	54 - 100	NA	3%	No
Fluoranthene	16	53 - 1,800	NA	25%	Yes
Fluorene	2	42 - 81	100	3%	No
Indeno(1,2,3-cd)pyrene	13	76 - 1,600	NA	20%	Yes
Naphthalene	3	55 - 160	100	5%	No
Phenanthrene	11	90 - 1,300	100	17%	Yes
Phenol	5	100 - 2,100	50	8%	Yes
Pyrene	15	54 - 1,800	100	23%	Yes
<b>Organochlorine Pesticides (N=46; <math>\mu\text{g}/\text{kg}</math>)</b>					
4,4'-DDD	15	4.15 - 147	2.5	33%	Yes
4,4'-DDE	38	3.30 - 990	2.5	83%	Yes
4,4'-DDT	38	5.28 - 600	2.5	83%	Yes

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**Table 8.5b**  
**Subzone K-4**  
**Organic Constituents in Surface Soil**

Compound Name	Number of Detections	Range of Concentrations	Ecological Benchmark	Frequency of Detection	ECPC
Dieldrin	5	6.59 - 33.0	0.5	11%	Yes
Endosulfan II	1	64.8	NA	2%	No
Endosulfan sulfate	2	5.94 - 28.1	NA	4%	No
Endrin	2	27 - 43.4	1.0	4%	No
Endrin aldehyde	3	4.24 - 82.8	NA	7%	Yes
Endrin ketone	3	5.20 - 9.79	NA	7%	Yes
Heptachlor	1	9.5	NA	2%	No
Heptachlor epoxide	9	2.2 - 140	NA	20%	Yes
alpha-Chlordane	14	2.06 - 91.4	NA	30%	Yes
gamma-Chlordane	15	1.7 - 214	NA	33%	Yes
<b>Polychlorinated Biphenyls (N=45; µg/kg)</b>					
Aroclor 1254	1	123	20	2%	No
Aroclor 1260	2	106 - 1,780	20	4%	No
<b>Total Petroleum Hydrocarbons - Diesel Range Organics (N=38; µg/kg)</b>					
Diesel	24	8.76 - 314	NA	63%	Yes

**Notes:**

- N - Number of samples collected
- µg/kg - micrograms per kilogram
- Ecological Benchmark - Recommended Ecological Screening Value for Soil (USEPA, 1998)
- NA - Benchmark unavailable
- ECPC - Ecological Chemical of Potential Concern (exceeds benchmark and detected in >5% of the samples)

## **8.5 Contaminant Fate and Transport**

**Inorganics** — As indicated in Tables 8.4a and 8.5a, the maximum concentration of several inorganic constituents detected in surface soils at Subzones K-2/K-3 and K-4 were below their respective reference concentration. Accordingly, manganese at Subzone K-2/K-3 and aluminum and selenium at Subzone K-4 have been excluded from the subsequent risk assessments. Tables 8.4b and 8.5b also indicates a prevalence of dioxins at Clouter Island and pesticides at the Naval Annex, which were detected in more than half the respective subzone's samples. While there are toxicity equivalency factors (TEFs) for assessing the risks **dioxins** pose to human health, only one ecotoxicity value is available, so these contaminants' total effects cannot be fully assessed.

**Volatile Organics** — It is assumed that impacts to selected assessment endpoint species will be negligible and considered highly unlikely that VOCs will drive any remedial efforts due to the lack of information regarding the impact of VOCs on terrestrial species and the low frequency and concentrations of nearly all the VOCs detected at Subzone K-2/K-3. Therefore VOCs will not be considered further in this ecological assessment. One exception may be trichloroethane, which was detected in more than 25% of the surface soil samples collected at the Naval Annex; however, no ecotoxicological information was available for this VOC.

**Groundwater** — The considerable depth to groundwater at Zone K sites is considered well below any zone capable of supporting terrestrial receptors. There are no surface water bodies at the Naval Annex considered to be influenced by groundwater; therefore, ecological risk from exposure to this media will not be assessed. The Clouter Island sites, however, are adjacent to the Cooper River and impacts from river sediments and the groundwater-surface water interface will be assessed in the ongoing Zone J RFI, which includes the Cooper River, Shipyard Creek, and Noisette Creek.

## Characteristics of ECPCs in Surface Soil

In addition to the USEPA's Recommended Ecological Benchmarks for Military Bases, contaminants are also compared to several other available ecotoxicological benchmarks. These standard screening benchmarks, which are the same as many of the USEPA's benchmarks for military bases, are for terrestrial plants and invertebrates (lower trophic levels) and have been derived from U.S. Department of Energy's *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants* (Efroymson, 1997b), *Toxicological Benchmarks for Potential Contaminants of Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process* (Will and Suter, 1995), and *Preliminary Remediation Goals for Ecological Endpoints* (Efroymson, 1997a).

### *Inorganics*

As indicated in Tables 8.4a and 8.5a, 13 metals in all were retained as ECPCs at Clouter Island Subzone K-2/K-3 and nine metals at the Naval Annex Subzone K-4. Each had a maximum concentration that exceeded both their respective reference concentration and ecological benchmark. These ECPCs indicate the presence of a possible anthropogenic contaminant source and these exceedances may pose ecological risk to receptors in the areas in which they occur.

To conduct a screening-level risk assessment of the background exceedances of metals found at the Zone K subzones, inorganic ECPC stressor characteristics are discussed below. For each metal discussed, the maximum concentration detected for that element (K-2/K-3 max or K-4 max) is presented for comparison.

**Antimony** (K-2/K-3 max = 27.9 mg/kg; K-4 max = 3.3 mg/kg) is considered a non-essential metal; when soluble in soil, it is easily taken up by plants. The maximum concentration at Clouter Island, which was detected in the center of AOC 694, is nearly eight times the 3.5 mg/kg ecological benchmark but the next highest concentration at K-2/K-3 is only 5.1 mg/kg, indicating

a possible anomaly or "hot spot." At the Annex, the maximum antimony concentration is below its respective benchmark.

**Arsenic** (K-2/K-3 max = 25.8 mg/kg; K-4 max = 32.2 mg/kg) occurs naturally and, with respect to cycling in the environment, is constantly changing. Arsenic is not essential for plant growth, yet is actively taken up by roots. The listed ecological benchmark for arsenic is the 10 mg/kg plant benchmark, which was exceeded at both Clouter Island and the Naval Annex, indicating that a potential risk to vegetation is likely at both sites. Soil biota appear to be capable of tolerating and metabolizing relatively high arsenic concentrations (microbiota to 1,600 mg/kg; Wang et al., 1984). The reported earthworm benchmark for arsenic is 60 mg/kg and all Zone K surface soil samples were below this benchmark. Adverse effects to aquatic organisms have been reported at concentrations of 19 to 48  $\mu\text{g}/\text{kg}$  in water but arsenic in soil does not appear to magnify along the aquatic food chain.

**Cadmium** (K-2/K-3 max = 1.5 mg/kg; K-4 max = 4.0 mg/kg) is a relatively rare heavy metal and a known teratogen and carcinogen and probably a mutagen. The ecological benchmark is 1.6 mg/kg. While birds and mammals are comparatively resistant to the biocidal properties of cadmium, it has been implicated as the cause of severe deleterious effects on fish and other wildlife (Eisler, 1985). Freshwater organisms appear to be the most susceptible group to cadmium toxicity, which is modified significantly by water hardness. Adsorption and desorption processes are likely to be major factors in controlling cadmium concentrations in natural waters. Cadmium adsorbs and desorbs rapidly on mud solids and particles of clay, silica, humic material, and other naturally occurring solids.

Cadmium is not essential for plant growth, yet is chemically similar to zinc, which is an essential element, and therefore readily taken up by roots and translocated through the plant and accumulated. Cadmium is toxic to plants at low concentrations, resulting in reduced

photosynthetic rate, poor root system development, and reduced stem conductivity. Since there are more than 50 values from experiments on a variety of plant species, confidence in the 0.1 mg/kg plant benchmark is high.

The less conservative soil PRG is 4.0 mg/kg, which is protective of both plants and terrestrial birds. All detected concentrations at Clouter Island and all but two samples at the Naval Annex are below the ecological benchmark for military bases, but exceed the lower plant benchmark, indicating a potential risk to plants from elevated cadmium concentrations. The 0.55 mg/kg and 0.13 mg/kg reference concentrations for cadmium at these subzones also exceed this benchmark.

An earthworm benchmark of 20 mg/kg has been computed for cadmium using 16 available concentrations causing toxicity (survival and growth, cocoon production, etc.); therefore, the confidence in this benchmark is moderate. The surface soil concentrations of cadmium detected at both sites were well below this benchmark and no risk to earthworms is anticipated.

**Chromium** (K-2/K-3 max = 77.3 mg/kg; K-4 max = 21.5 mg/kg) is not an essential element in plants. Hexavalent chromium (Cr VI) is more soluble and available to plants than the trivalent form (Cr III) and is considered more toxic. Symptoms of chromium plant toxicity include stunted growth, poorly developed roots, and leaf curling, yet confidence in the 1.0 mg/kg plant benchmark is low because it is based on only a few studies. A screening-level benchmark comparison indicates that all but one chromium detection at Zone K subzones exceeded the chromium plant benchmark, indicating risk to plants at both Clouter Island and the Naval Annex. While these exceedances might be considered ecologically significant, the established background values for chromium at Subzones K-2/K-3 and K-4 are 69.1 mg/kg and 8.4 mg/kg, which also exceed the 1.0 mg/kg plant benchmark. Therefore, only the points where the detected concentrations exceed both the chromium plant benchmark and background concentration are therefore considered locations where chromium is an ecological concern to plants.

As with plants, Cr VI produces more adverse effects to wildlife than its trivalent phase. It is 1  
difficult to separate the effects of Cr III and Cr VI without a better understanding of the chromium 2  
transformations in soil, transport across earthworm cell membranes, and reactions within the cell. 3  
Nevertheless, a 0.4 mg/kg ecological benchmark for chromium at military bases (also the 4  
benchmark for terrestrial invertebrates) has been established based on only five reported 5  
concentrations causing toxicity to earthworms. Therefore, confidence in this value is low. This 6  
screening level benchmark comparison indicates significant risk to earthworms at Zone K 7  
subzones, yet the established background value significantly exceeds this benchmark. The samples 8  
exceeding both the established background and the earthworm benchmark justify maintaining 9  
chromium as an ECPC at both Clouter Island and the Naval Annex. 10

The ecological benchmark for **copper** (K-2/K-3 max = 1,020 mg/kg; K-4 max = 32 mg/kg) is 11  
40 mg/kg. Fourteen of the 31 samples collected at Clouter Island exceeded this value and none 12  
at the Annex. Copper is a micronutrient essential for plant nutrition and an essential part of a 13  
copper protein involved in photosynthesis. Toxicity symptoms in plants include reduced growth, 14  
poorly developed root system, and leaf chlorosis. Confidence in the 100 mg/kg plant benchmark 15  
is low because it is derived from fewer than 10 values. Only the three highest concentrations at 16  
Clouter Island exceeded this benchmark and the maximum concentration is five times greater than 17  
the next highest detection (260 mg/kg) indicating a potential "hot spot." The much lower 18  
reference concentration of 119 mg/kg indicates that copper is present across the site at 19  
concentrations which may pose a risk to sensitive wildlife. The plant benchmark at the Naval 20  
Annex was not exceeded. 21

For copper toxicity to terrestrial invertebrates, a benchmark of 60 mg/kg has been established, 22  
which also is the PRG for copper in surface soil. Seven of the 31 copper concentrations at Clouter 23  
Island indicate a potential risk to earthworms at those locations, but the reference concentration, 24

which is nearly twice the benchmark, indicates copper exceedance across the site. There were no earthworm benchmark exceedances at the Naval Annex.

**Lead** (K-2/K-3 max = 481 mg/kg; K-4 max = 259 mg/kg) has an ecological benchmark of 50 mg/kg, which is also the established plant benchmark. It was exceeded at both sites. Compared to other trace elements, lead has a relatively low phytotoxicity. Lead is taken up passively by roots and translocation to shoots is limited and may exist in various forms. It affects plant respiration and photosynthesis by disturbing electron transfer reactions. With 17 values available from experiments conducted with a range of different plant species, moderate confidence is assumed for the 50 mg/kg ecological/plant benchmark. The maximum lead concentration from both subzones significantly exceeded the benchmark value, indicating a potential risk to plants from lead in surface soils, particularly at Clouter Island. The PRG for lead (40.5 mg/kg) is derived from toxicity tests on the woodcock, a terrestrial ground-dwelling bird and is also exceeded at both Zone K subzones.

For earthworms, a benchmark of 500 mg/kg lead has been established based on a study showing inhibition of reproduction at this concentration. No Zone K surface soil samples exceeded this benchmark; therefore no risk to earthworms from lead is anticipated.

The ecological benchmark for **manganese** (K-2/K-3 max = 1,050 mg/kg; K-4 max = 70.4 mg/kg) is 100 mg/kg. The plant benchmark, however, is only 4 mg/kg and confidence in this value is moderate. Manganese is essential for plant growth, yet excess amounts interfere with plant enzymes and decreases respiration. Toxicity symptoms include marginal chlorosis and necrosis of the leaves and root browning. All but one of the 31 detected concentrations at Clouter Island exceeded both the ecological and plant benchmark, indicating what appears to be significant risk to ecological receptors, particularly plants at Clouter Island. While no samples at the Annex exceeded the ecological benchmark, all but two of the 58 detections exceed the plant benchmark.

While these two benchmarks have been exceeded at Clouter Island, it is important to note that the established reference value for manganese at Subzones K-2/K-3 is 1,210 mg/kg, which exceeds both the ecological and plant benchmark. For the Naval Annex, the reference value is 26.4 mg/kg, which is well below the 100 mg/kg ecological benchmark, but still exceeds the 4 mg/kg plant benchmark. Therefore manganese remains an ECPC at Annex locations where both the reference value and plant benchmark have been exceeded.

No benchmark was reported for toxicity of manganese to earthworms, yet the reported benchmark for soil microorganisms is 100 mg/kg (same at the ecological benchmark). As with plants, this screening level benchmark comparison indicates significant risk to microorganisms at Clouter Island, yet the established reference value also significantly exceeds this benchmark. Manganese surface soil concentrations at the Annex are below the benchmark. Since some samples at Subzone K-2/K-3 exceeded both the established reference value and the terrestrial invertebrate benchmark, manganese is retained as an ECPC at Clouter Island.

**Mercury** (K-2/K-3 max = 1.7 mg/kg; K-4 max = 58.2 mg/kg) is a known mutagen, teratogen, and carcinogen. In mammals, it adversely affects reproduction, growth and development, motor coordination, and metabolism (Eisler, 1987a). Mercury has a high potential for bioaccumulation and biomagnification, and is slow to depurate. Organomercury compounds produce more adverse effects than inorganic mercury compounds, but inorganic mercury can be modified to organic mercury compounds through biological transformation processes. The ecological and benchmark for mercury is 0.1 mg/kg, which is derived from the earthworm benchmark (discussed below).

Plant roots take up mercury and its compounds, but translocation is limited, especially for inorganic mercury. The plant benchmark established for inorganic mercury is 0.3 mg/kg; however, confidence in this value is low because it is based on a secondary reference. The

maximum concentrations in both areas exceed the plant benchmark, indicating a potential for excess risk to plants.

A benchmark of 0.1 mg/kg has been established for mercury toxicity to earthworms based on a study showing inhibition of reproduction at this concentration. This value has also been adopted by the USEPA as the recommended ecological screening benchmark for military bases. The maximum mercury concentration from both Clouter Island and the Annex exceeded this benchmark, indicating a potential risk to earthworms.

**Silver** (K-2/K-3 max = 1.2 mg/kg; K-4 max = 0.88 mg/kg) has been assigned an ecological benchmark of 2.0 mg/kg, which is the plant benchmark. When taken up by plants, silver remains in the root system and its toxicity is related to its ionic binding potential. Because this benchmark is based on a report of unspecified toxic effects, confidence is low. Silver was more prevalent at Clouter Island; however, no samples exceeded the plant benchmark, indicating no potential for risk to plants from silver at these locations.

No benchmark was reported for toxicity of silver to earthworms; however, a 50 mg/kg benchmark has been established for soil microorganisms and all surface soil results were well below this benchmark.

**Tin's** ecological benchmark (K-2/K-3 max = 284 mg/kg; K-4 max = 32 mg/kg) is 53 mg/kg, which was exceeded in only three of the samples at Clouter Island. The plant benchmark was established at 50 mg/kg, which is very close to the ecological benchmark concentration, but confidence in this value is low because it is based on a report of unspecified toxic effects. Tin is readily taken up by plants from nutrient solution but it is not essential for plant growth and most of the element remains in the root system. Toxic effects on plants include growth reduction, but no information on specific toxicity mechanisms was identified in the literature. Three of the 16 tin

detections at Clouter Island exceeded the plant benchmark and five samples exceeded the 39.1 mg/kg background concentration; therefore, tin remains an ecological concern at these Subzone K-2/K-3 locations. No screening values were exceeded at the Naval Annex. A benchmark for tin toxicity to earthworms or soil microorganisms was unavailable.

**Vanadium** (K-2/K-3 max = 92.2 mg/kg; K-4 max = 16.0 mg/kg) has no primary reference toxicity data for plants grown in soil, but a USEPA study showed that vanadium added to soil at a concentration of 2.5 mg/kg was toxic to plants; therefore, the USEPA recommends using the plant benchmark (2.0 mg/kg) as the ecological benchmark. Low confidence is assumed for the 2 mg/kg plant benchmark (also the PRG) and one study reported unspecified toxic effects on plants grown in a surface soil with the addition of 500 mg/kg vanadium. The maximum vanadium concentration from both sites exceeds the benchmark value, indicating a potential risk to plants from vanadium in surface soils, particularly at Clouter Island. A benchmark for vanadium toxicity to earthworms or soil microorganisms was unavailable.

**Zinc's** ecological benchmark (K-2/K-3 max = 792 mg/kg; K-4 max = 538 mg/kg) is 50 mg/kg, which is also the plant benchmark. Zinc is an essential element for plant growth and benchmark exceedances result in chlorosis and depressed plant growth and the reported confidence in the benchmark is moderate. The maximum zinc concentration at Clouter Island is nearly 16 times the benchmark and the maximum at the Annex is more than 10 times the benchmark, indicating a potential for significant risk to plants from zinc in surface soil. The established reference value for zinc in soil at Clouter Island is 236 mg/kg, which also significantly exceeds the recommended ecological benchmark. Five samples at Clouter Island also exceeded both the established reference value and benchmark. The reference concentration for zinc at the Annex is only 14.8 mg/kg, and all but seven of the 41 samples containing detectable concentrations of zinc exceeded this value. With these exceedances, zinc is considered a potential stressor for plants at both areas.

The benchmark for zinc's toxicity to earthworms is 200 mg/kg, based on the lowest reported value causing a decrease in cocoon production, yet due to the limited amount of data, confidence in this benchmark is low. Surface soil samples at Clouter Island and the Annex exceed both this benchmark and established reference concentrations, making zinc an ecological concern for earthworms.

In general, heavy metals adversely affect survival, growth, reproduction, development, and metabolism of both terrestrial and aquatic invertebrate species, but effects are substantially modified by physical, chemical, and biological variables. Pascoe et al. (1994) observed that bioavailability of metals in soil to small mammals was generally limited. The study also suggests that metal intake for higher trophic species may be similarly limited. Current toxicological data show that most heavy metals do not biomagnify, and based on contact tests with terrestrial earthworms, the order of toxicity for heavy metals from most toxic to least toxic was copper > zinc > nickel = cadmium > lead.

### *Organics*

Although numerous organics detected in Zone K surface soil were designated as ECPCs, few organic chemicals exist for which toxicity has been adequately measured. Estimating exposure and predicting risk is therefore restricted by the limited availability of toxicity information.

Two volatile organic compounds, tetrachloroethene (PCE) and trichloroethene (TCE), were identified as ECPCs at the Naval Annex since both were detected in more than 5% of surface soil samples. Although there is no ecological benchmark for PCE and TCE, a plant benchmark does exist for PCE based on the growth of lettuce in loam soil and the EC<sub>50</sub> value of 1,000 mg/kg, but no information on the toxicity mechanics of PCE was provided. Since no benchmark for TCE has been established, its toxicity to ecological receptors cannot be calculated as part of this screening-level risk assessment. The remaining two VOCs (acetone and carbon disulfide) were not

considered for this ERA due, in part, to the lack of available benchmarks, but also their low frequency of detection and overall low Zone K concentrations.

Of the SVOCs detected, polycyclic aromatic hydrocarbons (PAHs) were among the most common. Because the major sources of PAHs are attributable to combustion processes (forest fires, residential wood burning, automobile exhaust, etc.), they have become nearly ubiquitous in soil, with concentrations increasing during the last 100 to 150 years, especially in urban areas. There are more than 100 different PAHs, each with a different molecular weight. Since PAH toxicity depends on molecular weight, there is an equally substantial variation in their behavior and distribution in the environment and in their biological effects. Characteristics that differ among PAHs include phototoxicity, solubility, and octanol-water partitioning coefficient ( $\log K_{ow}$ ). This variability in turn affects a PAH's reaction to sunlight, solubility in fats, resistance to oxidation and reduction, and vapor pressure (Eisler, 1987b).

In water, PAHs either evaporate, disperse into the water column, become incorporated in sediments, or degrade through photooxidation, chemical oxidation, and biological transformation by bacteria and animals (Neff, 1979).

Generally, PAHs show little tendency to biomagnify in food chains because most are rapidly metabolized (Eisler, 1987b) and like other petroleum hydrocarbons, they break down fairly rapidly in many wildlife groups. Very little information is available on adverse effects to the food chain as a result of soil PAH contamination. Some studies have shown that PAHs may be translocated in plants and may accumulate in plants grown in contaminated soil, and therefore may impact herbivorous species of wildlife.

Very few ecological benchmarks have been established for SVOCs, but those available are compared to concentrations at Zone K below.

**Acenaphthene** (K-2/K-3 max = ND; K-4 max = 130  $\mu\text{g}/\text{kg}$ ) has a ecological (plant) benchmark of 20,000  $\mu\text{g}/\text{kg}$ , which is well exceeds the concentrations detected at the Annex. **Anthracene** (K-2/K-3 max 110  $\mu\text{g}/\text{kg}$ ; K-4 max = 420  $\mu\text{g}/\text{kg}$ ) exceeds its 100  $\mu\text{g}/\text{kg}$  benchmark at both sites, but was detected in less than 5% of the samples. The recommended benchmark for **benzo(a)pyrene** (K-2/K-3 max = 440  $\mu\text{g}/\text{kg}$ ; K-4 max = 1,300  $\mu\text{g}/\text{kg}$ ) which is also 100  $\mu\text{g}/\text{kg}$ , is exceeded at both sites and was detected in more than 5% of the samples. While there is no USEPA ecological benchmark for **di-n-butyl phthalate** (K-2/K-3 max = ND; K-4 max = 39  $\mu\text{g}/\text{kg}$ ), a plant benchmark of 200,000  $\mu\text{g}/\text{kg}$  has been established and it is well above the maximum concentration detected at K-4. Two benchmarks were reported for **fluorene**. A soil concentration exceeding 30,000  $\mu\text{g}/\text{kg}$  fluorene would indicate potential risk to terrestrial invertebrates and a concentration above 100  $\mu\text{g}/\text{kg}$  would exceed the USEPA's ecological benchmark; however, no concentration exceeded these values. **Naphthalene** (K-2/K-3 max = ND; K-4 max = 160  $\mu\text{g}/\text{kg}$ ) was detected in surface soil at concentrations well below the plant benchmark of 100,000  $\mu\text{g}/\text{kg}$ , but the highest concentration slightly exceeded the more conservative 100  $\mu\text{g}/\text{kg}$  ecological benchmark. Naphthalene's detection frequency was only 5%; therefore, it was not considered an ECPC. The ecological benchmark for **phenanthrene**, also 100  $\mu\text{g}/\text{kg}$ , was significantly exceeded at both sites. **Phenol**, present at the Annex at a maximum concentration of 2,100  $\mu\text{g}/\text{kg}$ , well exceeds the 50  $\mu\text{g}/\text{kg}$  ecological benchmark, but is below both its plant benchmark of 70,000  $\mu\text{g}/\text{kg}$  and earthworm benchmark of 30,000  $\mu\text{g}/\text{kg}$ . **Pyrene** (K-2/K-3 max = 1,100; K-4 max = 1,800  $\mu\text{g}/\text{kg}$ ) was also present in samples collected at both Zone K sites at concentrations well exceeding its ecological benchmark of 100  $\mu\text{g}/\text{kg}$ .

**Organochlorine pesticides** have been used extensively in the United States since the 1940s and appear to be ubiquitous in the environment, being found in surface water, sediment, and biological tissues. They are readily absorbed by warm-blooded species and degradatory products are frequently more toxic than the parent form. In soil invertebrates, organochlorine pesticides can accumulate to concentrations higher than those in the surrounding soil, and residues may, in turn,

be ingested by birds and other animals feeding on earthworms (Beyer and Gish, 1980). Most environmental effects studies have been directed at mammals and birds and no suitable screening-level benchmarks have been established for plants or terrestrial invertebrates.

Few ecological benchmarks have been established for pesticides. As presented in Tables 8.4b and 8.5b, **DDD**, **DDE**, and **DDT** were detected at both sites at concentrations which exceed their respective ecological benchmark of 2.5  $\mu\text{g}/\text{kg}$  and were more abundant at the Annex. **Aldrin** was detected in two samples at Clouter Island; both exceeded the 2.5  $\mu\text{g}/\text{kg}$  benchmark. **Dieldrin** and **endrin** were also present at both sites, with all detected concentrations exceeding the 0.5  $\mu\text{g}/\text{kg}$  and 1.0  $\mu\text{g}/\text{kg}$  benchmark, respectively.

**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 birth defects, a wasting syndrome, tumors, and death. In terrestrial environments, PCBs are rapidly metabolized from the soil into the terrestrial food chain (McKee, 1992). Subsoil-dwelling organisms may directly absorb PCBs, which may transfer to lower-level vertebrate species through the food chain.

Few ecological benchmarks have been established for the screening-level assessment of risk from PCB soil contamination. **Aroclor 1260** (K-2/K-3 max = 596  $\mu\text{g}/\text{kg}$ ; K-4 max = 1,780  $\mu\text{g}/\text{kg}$ ) and **Aroclor 1254** (K-2/K-3 max = ND; K-4 max = 123  $\mu\text{g}/\text{kg}$ ) were the only PCBs detected in Zone K. Both the PCBs detected at the Annex were in fewer than 5% of the samples and well below the reported plant benchmark of 40,000  $\mu\text{g}/\text{kg}$ ; therefore, they were not considered to be ECPCs. The USEPA's recommended benchmark for total PCBs is 20  $\mu\text{g}/\text{kg}$ . The maximum concentration of Aroclor 1260 at Clouter Island is well above this value and has been detected in more than half the samples. Therefore, this PCB is retained as an ECPC for Subzone K-2/K-3.

Neither a PRG nor a benchmark for terrestrial invertebrates has been established for PCB constituents.

**Dioxins** are trace compounds in some commercial herbicides and chlorophenols (Eisler, 1986). The most toxic and most extensively studied dioxin is 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (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. In soil, microbial decomposition of TCDD is slow (Ramel, 1978) and uptake by vegetation is considered negligible (Blair, 1973). Only one sample at Clouter Island (3% of the samples) contained detectable amounts of TCDD (0.17 ng/kg). This detection is well below the 3.15 ng/kg PRG reported for TCDD, which is based on the LOAEL for the short-tailed shrew. No USEPA, plant, or earthworm benchmark was available; therefore, it should not be assumed that this PRG protects either plants or terrestrial invertebrates. Numerous other dioxin/furans were detected in nearly all Subzone K-2/K-3 samples, but no ecological benchmarks were available for these parameters to conduct a screening-level risk assessment.

## 8.6 Exposure Pathways and Assessment

### Benthic Organisms

Exposure to aquatic wildlife in the littoral Subzone K-1 is assessed by considering exposure to benthic organisms. The assessment endpoint selected for this location is a well-balanced benthic community based on chronic exposure to ECPCs detected in sediments. The potential for adverse effects to benthic species will be determined by comparing observed sediment concentrations to those reported in the literature known to change or impair reproduction, growth, or survival (USEPA, November, 1995b).

### **Infaunal Invertebrates**

The primary exposure pathway evaluated for infaunal invertebrates in terrestrial Subzones K-2 and K-4 will be via direct contact with surface soil. An assessment endpoint of a well-balanced soil infaunal community will be qualitatively measured by comparing literature effect level data to actual soil concentrations.

### **Terrestrial Wildlife**

Wildlife measurement endpoint species selected for this ERA are the short-tailed shrew (*Blarina brevicauda*), Eastern cottontail rabbit (*Sylvilagus floridanus*), American robin (*Turdus migratorius*), and red-tailed hawk (*Buteo jamaicensis*). All of these species are likely to occur at each Zone K subzone. Exposure would include direct dermal contact, ingestion of soil particles, and food-chain transfer. As a measure of risk to the endpoint species selected, results were used from laboratory toxicity studies in literature that relate the oral dose of a contaminant to adverse response to growth, reproduction, or survival (Sample et al., 1996).

Small mammals such as the rabbit and shrew could directly contact contaminated soil if the area is used as a migratory corridor or if animals burrow into it. The contact time, and thus exposure, will be limited when animals are crossing the area, but could be lengthy if burrows are established. Dermal contact by small reptiles and amphibians would be similar to that for mammals. For insect populations, direct exposure to ground-dwelling species could link contaminant transfer to higher-level predators. Although dermal contact may represent a significant exposure pathway, a lack of toxicological response information limits its use in the risk evaluation. Thus, exposure related to dermal contact is not evaluated because it is assumed that fur, feathers, and chitinous exoskeleton limit the transfer of contamination across the dermis. Also, inhalation has not been evaluated. Except in atypical circumstances, such as a spill or release, inhalation exposure is considered negligible.

To assess biotransfer of contaminants along food chains, a total potential dietary exposure (PDE) 1  
 has been modeled for each measurement endpoint species based on predicted concentrations of the 2  
 ECPC in food items that the species would consume, the amount of soil it would ingest, the 3  
 relative amount of different food items in its diet, body weight, and total food ingestion rate. The 4  
 equation used for PDE calculations is: 5

$$PDE = \frac{A}{HR} \left[ \sum_{i=1}^m \sum_{k=1}^n p_{ik} (I_i + C_{ijk}) \right] \quad 6$$

where: 7

- PDE = potential dietary exposure (total) 8
  - A = Area of suspected contamination (in acres) 9
  - HR = Species home range (in acres) 10
  - m = total number of ingested media (e.g., food, water, or soil) 11
  - n = number of types of medium (i) consumed (unitless) 12
  - P<sub>ik</sub> = proportion of type (k) of medium (i) consumed (% diet; unitless) 13
  - I<sub>i</sub> = ingestion rate for medium (i) (kg/body weight/d) 14
  - C<sub>ijk</sub> = concentration of contaminant (j) in type (k) of medium (i) (mg/kg) 15
- (Adapted from *Methods and Tools for Estimation of Exposure of Terrestrial Wildlife to Contaminants*, Sample, 1997) 16

Estimated concentrations (C<sub>ijk</sub>) of ECPCs in food items are based on literature-reported 17  
 bioaccumulation factors (BAFs), which are a ratio of the ECPC concentration in dietary items to 18  
 the concentration in soil. The BAFs reported for avian and mammalian species are reported ratios 19  
 of ECPCs in the tissue of the animals to the concentrations of ECPCs in their diets. 20

Since each subzone is heterogenous with respect to both contamination and wildlife use, movement 21  
 of wildlife is also an important factor in estimating exposure. Wildlife species travel various 22  
 distances to find food, water, and shelter and the area covered by these travels is defined as the 23  
 home range. For those endpoint species with a home range larger than the area being investigated, 24  
 such as birds of prey, it was assumed that exposure is proportional to the ratio of the size of the 25  
 contaminated area to the home range size (A/HR). For endpoint species with home ranges small 26

enough to be contained within a subzone, the conservative exposure model assumes an equivalent home range ( $A/HR = 1$ ).

### **Vegetation**

Woody and herbaceous vegetation in the terrestrial subzones could incorporate certain detected constituents through processes such as uptake/accumulation, translocation, adhesion, or biotransformation. Terrestrial herbivores could ingest plant-borne constituents. No studies directed at accretion of ECPCs by plants through sediment were available. Therefore, effects to aquatic plants could not be assessed.

## **8.7 Ecological Effects Assessment**

### **Benthic Organisms**

Potential adverse ecological effects to aquatic species from identified ECPCs were predicted based on the sediment screening values and sediment PRGs. Effects are predicted using a preliminary screening approach. Maximum sediment concentrations for ECPCs are divided by both the SSV and PRG to produce a corresponding HQ (Table 8.3). HQs with a result greater than 1 may produce adverse risk. Values higher than 10 are considered to present moderately high risk and above 100, extreme risk. This is not to suggest, however, a linear relationship between HQs and potential effects to representative wildlife species. Instead, HQs represent the ratio of the highest concentration detected to the adverse effects levels reported in literature and should be viewed only as they relate to these values. The level of risk is based on the assumption that exposure to contaminant concentrations one and two orders of magnitude higher than the effects level is more likely to cause adverse effects.

### **Infaunal Invertebrates**

Predicted potential adverse ecological effects to soil invertebrates from identified ECPCs are based on effects level information in available literature (Table 8.6). Screening benchmarks from

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Table 8.6  
 Summary of Chemical Effects Studies on Terrestrial Infaunal Invertebrates

Parameter	Effects Level	Test Organisms	Measured Response	Study	Confidence Level
<b>Inorganics</b>					
Aluminum	600 mg/kg	soil microbes	Reduced enzyme activity	Will & Suter (1995)	Low
Arsenic	60 mg/kg	earthworm	Decrease in cocoon production	Will & Suter (1995)	Low
	100 mg/kg	soil microbes	Reduced enzyme activity	Will & Suter (1995)	Low
Barium	3,000 mg/kg	soil microbes	Reduced enzyme activity	Will & Suter (1995)	Low
Cadmium	10 - 100 $\mu\text{g}/\text{cm}^2$	earthworm	LC <sub>50</sub>	Roberts & Dorough (1984)	
	20 mg/kg	earthworm/soil microbes	Decrease in growth/reproduction/respiration	Will & Suter (1995)	Mod. - High
	> 128 mg/kg	Mites	Population decrease	Van Straalen et al. (1989)	
	250 mg/kg	earthworm	Reduced growth	Malecki et al. (1982)*	
	1,843 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1986)	
Chromium	0.4 mg/kg	earthworm	75% decrease in survival	Will & Suter (1995)	Low
	10 mg/kg	soil microbes	Reduced enzyme activity	Will & Suter (1995)	High
Cobalt	1,000 mg/kg	microflora	Reduced respiration	Will & Suter (1995)	Low
Copper	10 - 100 $\mu\text{g}/\text{cm}^2$	earthworm	LC <sub>50</sub>	Roberts & Dorough (1984)	
	0.28 - 0.42 mg/kg	Microtox (15 min.)	Photo reduction	Miller et al. (1985)	
	50 mg/kg	earthworm	Reduced cocoon production	Will & Suter (1995)	Moderate
	85 mg/kg	earthworm	Gradual decline of population	Van Rhee (1967)	
	100 mg/kg	soil microbes	Reduced enzyme activity	Will & Suter (1995)	High
	100 - 150 mg/kg	<i>L. rubellus</i>	Reduced cocoon production	Ma (1984)	
	150 mg/kg	earthworm	Population reduced to 50%	Nielson (1951)	
	200 mg/kg	nematode/microarthropods	Population decrease	Parmelee, et al. (1993)	
200 mg/kg	Mite <i>Platynothrus peltifer</i>	Population decrease	Strait (1984)		

**Table 8.6**  
**Summary of Chemical Effects Studies on Terrestrial Infaunal Invertebrates**

Parameter	Effects Level	Test Organisms	Measured Response	Study	Confidence Level
Copper (Continued)	260 mg/kg	earthworm	Population eliminated	Nielson (1951)	
	300 mg/kg	<i>L. rubellus</i>	Mortality	Ma (1984)	
	643 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1986)	
	644 mg/kg	earthworm	EC <sub>50</sub>	Miller et al. (1985)	
	1,000 mg/kg	<i>L. rubellus</i>	6-wk LC <sub>50</sub>	Ma (1982)	
	1,320 mg/kg	earthworm	Reduced growth	Malecki et al. (1982)*	
Lead	10 - 100 µg/cm <sup>2</sup>	earthworm	LC <sub>50</sub>	Roberts & Dorough (1984)	
	500 mg/kg	earthworm	Reduced cocoon production	Will & Suter (1995)	Low
	900 mg/kg	soil microbes/microflora	Reduced enzyme activity/respiration	Will & Suter (1995)	High
	6,000 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1986)	
	21,600 mg/kg	earthworm	Reduced growth	Malecki et al. (1982)*	
Mercury	0.1 mg/kg	earthworm	Reduced survival/cocoon production	Will & Suter (1995)	Low
	0.79 mg/kg	earthworm	50% Mortality	Abbassi & Soni (1985)	
	5 mg/kg	earthworm	21% Mortality	Beyer et al. (1985)	
	5 mg/kg	<i>Octochaetus pattoni</i>	100% Mortality		
	25 mg/kg	earthworm	100% Mortality		
	30 mg/kg	soil microbes/microflora	Reduced enzyme activity/respiration	Will & Suter (1995)	High
Nickel	90 mg/kg	soil microbes	Reduced enzyme activity	Will & Suter (1995)	High
	200 mg/kg	earthworm	Reduced cocoon production	Will & Suter (1995)	Low
	440 mg/kg	earthworm	Reduced growth	Malecki et al. (1982)*	
	757 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1986)	

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**Table 8.6**  
**Summary of Chemical Effects Studies on Terrestrial Infaunal Invertebrates**

Parameter	Effects Level	Test Organisms	Measured Response	Study	Confidence Level
Selenium	70 mg/kg	earthworm	Reduced growth/reproduction	Will & Suter (1995)	Low
	100 mg/kg	soil microbes/microflora	Reduced enzyme activity/respiration	Will & Suter (1995)	Moderate
Silver	50 mg/kg	soil microbes/microflora	Reduced enzyme activity/respiration	Will & Suter (1995)	Moderate
Tin	2,000 mg/kg	soil microbes	Reduced enzyme production	Will & Suter (1995)	Low
Vanadium	20 mg/kg	soil microbes/microflora	Reduced enzyme activity/respiration	Will & Suter (1995)	Moderate
Zinc	1.6 mg/kg	Microtox (15 min.)	Photo reduction	Miller et al. (1985)	
	100 mg/kg	soil microbes	Reduced enzyme production	Will & Suter (1995)	High
	200 mg/kg	earthworm	Reduced survival and growth	Will & Suter (1995)	Low
	628 mg/kg	earthworm	EC <sub>50</sub>	Miller et al. (1985)	
	662 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1986)	
	2,800 mg/kg	earthworm	Reduced growth	Malecki et al. (1982)*	
<b>Semivolatiles</b>					
4-Nitrophenol	7 mg/kg	earthworm	LC <sub>50</sub>	Will & Suter (1995)	Low
	38 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1986)	
Fluorene	30 mg/kg	earthworm	LC <sub>50</sub>	Will & Suter (1995)	Low
	174 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1986)	
Phenol	30 mg/kg	earthworm	LC <sub>50</sub>	Will & Suter (1995)	Low
	100 mg/kg	heterotrophic processes	Reduced CO <sub>2</sub> production	Will & Suter (1995)	Low
	188 mg/kg	earthworm	LC <sub>50</sub>	Neuhauser, et al. (1990)	
<b>Pesticide/PCBs</b>					
DDT	400 µg/kg	earthworm	No detectable concentration in tissue from soil concentrations	Callahan, et al. (1991)	
	1,000 [4,000] µg/kg	earthworm	Survival; no effect for LC <sub>50</sub> test	Menzies, et al. (1992)	

**Table 8.6**  
**Summary of Chemical Effects Studies on Terrestrial Infaunal Invertebrates**

Parameter	Effects Level	Test Organisms	Measured Response	Study	Confidence Level
DDD	700 µg/kg	earthworm	No detectable concentration in tissue from soil concentrations	Callahan, et al. (1991)	
	1,000 [12,000] µg/kg	earthworm	Survival; no effect for LC <sub>50</sub> test	Menzies, et al. (1992)	
DDE	200 µg/kg	earthworm	No detectable concentration in tissue from soil concentrations	Callahan, et al. (1991)	
	1,000 [2,000] µg/kg	earthworm	Survival; no effect for LC <sub>50</sub> test	Menzies et al. (1992)	
PCBs	240 mg/kg	earthworm	LC <sub>50</sub>	Rhett et al. (1988)	
	1,200 mg/kg	Crickets <i>Acheta domesticus</i>	LC <sub>50</sub>	Paine et al. (1993)	
	120,000 mg/kg	Terrestrial epigeic <sup>b</sup> invertebrates	No community structure effects.	McKee (1992)	
<b>Dioxins</b>					
Dioxin	<5 mg/kg	earthworm	No mortality	Reinecke & Nash (1984)	
	<5 mg/kg	<i>Allotobophora caliginosa</i>	No mortality		
	<5 mg/kg	<i>L. rubellus</i>	No mortality		
	> 10 mg/kg	<i>L. rubellus</i>	Lethality		

**Notes:**

a = Growth effects levels are average of at least five of six compounds: metal acetate; metal carbonate; metal chloride; metal nitrate; metal oxide.

b = Aboveground species including Carabidae, Entobeyidae, Formicidae, Gryllidae, and Staphylinidae.

c = Average soil concentration levels [maximum values].

LC<sub>50</sub> = Concentration lethal to 50% of the test organisms.

EC<sub>50</sub> = Effective concentration for producing a specified effect in 50% of the test organisms.

Values presented by Will and Suter (1995) are standard benchmarks derived from a compilation of toxicity tests. Based on their review of the existing toxicological data for each parameter, confidence values (low, moderate, high) have also been assigned to each benchmark.

*Toxicological Benchmarks for Potential Contaminants of Concern for Effects on Soil and Litter* 1  
*Invertebrates and Heterotrophic Process* from Will and Suter (1995) were also included. 2

**Terrestrial Wildlife** 3

Potential adverse effects associated with the identified ECPCs to bird and mammal species are 4  
based on food uptake potential. Available toxicity reference values (TRVs) were determined for 5  
each measurement endpoint species selected. The TRV relates the dose of an ECPC in an oral 6  
exposure with an adverse effect. The lowest observed adverse effects level (LOAEL), the lowest 7  
concentration at which adverse effects to growth, reproduction, and/or survival are reported for 8  
test species and then extrapolated to representative wildlife species, are used to predict potential 9  
chronic effects to species. No observed adverse effects level (NOAEL), obtained either through 10  
experimental data or by convention (one-tenth of the LOAEL), is used to predict sub-chronic 11  
effects concentrations of ECPCs which exceed the NOAEL but are less than the LOAEL. 12

As with soils, HQs for sediments were obtained by calculating the ratio of the greatest ECPC 13  
concentration to its respective effects level. 14

**Vegetation** 15

Toxicity to terrestrial plants from soil contaminants detected within the subzones is qualitatively 16  
evaluated. Risk potentials are discussed relative to literature studies and general information on 17  
phytotoxic mechanisms by selected ECPCs. 18

**8.8 Risk Characterization** 19

Little information exists on the toxic effects to wildlife from VOCs. Primarily, the only 20  
information available are effects studies related to human health from inhalation of specific 21  
compounds by laboratory animals. Impact from the limited occurrence and relatively low 22

concentrations of volatile compounds observed in soil is difficult to assess but little to no effect to terrestrial species is predicted.

### **8.8.1 Benthic Organisms**

Two sediment samples associated with AOC 695 were collected from the Cooper River to assess potential for risks to aquatic species within the littoral zone along Clouter Island (Subzone K-1). No organic compounds exceeded detection limits for their respective methods but 10 metals were determined to be ECPCs. Of these, three SSV-HQs, calculated using USEPA Region IV sediment screening values (SSVs), exceeded one: arsenic (HQ = 2.44), chromium (HQ = 1.15), and nickel (HQ = 1.09). The cumulative HI for the SSV-HQs was only 6.20, which indicates a low risk to benthic organisms. Comparing Zone K sediment concentrations to the less conservative PRGs, however, resulted in no HQs greater than 1 and a cumulative HI of only 1.73, which indicates little or no risk to benthic receptors. The other seven metals were designated ECPCs because no screening values were available. Because SSVs are derived from statistical interpretation of effects databases obtained from literature, actual risks to receptors in the Cooper River may be lower than that implied by using the SSV in the screening assessment.

### **8.8.2 Infaunal Invertebrates**

Most toxicological information reviewed for the infaunal invertebrates dealt with earthworms and other infaunal species. It is important to note that soil found on Clouter Island is predominately sand and may not support these specific organisms. Although infaunal species found in the sandy environment may not be the same as those dealt with in the literature, the ecological niche which they occupy should be similar and, therefore, comparison to toxicological concentrations should apply.

**Inorganic Compounds** — Most studies on metals toxicity to terrestrial receptors have been directed at infaunal ecosystems or avian biology. Relative metal toxicities to infaunal invertebrates (earthworms, soil microbes, microflora, etc.) are also summarized in Table 8.6.

Roberts and Dorough (1984) tested three metal salts (cadmium chloride, copper sulfate, and lead nitrate) and determined that these heavy metal salts fell into the "very toxic" category, with LC<sub>50</sub> values in the 10 to 100 µg/cm<sup>2</sup> range. Although these concentrations (more specifically, application doses) may be relative to earthworms, it is improper to apply them to upper-level trophic species. Studies indicate that although some degradation products become increasingly toxic to earthworms, they are less toxic to upper-level vertebrates.

In a study performed by Neuhauser et al. (1986), metal nitrate compounds were relatively toxic to earthworms in the following order: copper > zinc > nickel > cadmium > lead. Malecki et al., (1982) chose six chemical forms of each metal to cover a broad range of solubility and to represent the forms likely to be found in the soil. Overall, cadmium was most toxic, followed by nickel, copper, zinc, and lead. It appears obvious from the conflicting results of these two studies that the metal form in soil is a major consideration in judging effects of its concentration on soil biota.

Ma (1984) investigated sublethal effects soil copper to growth, cocoon production, and litter breakdown activity for *L. rubellus*. Cocoon and litter breakdown activity were significantly reduced at 131 mg/kg copper and mortality was first observed at concentrations near 300 mg/kg.

Parmelee et al. (1993) concluded that total nematode/microarthropod numbers (mostly of mites) declined in soil in which copper concentrations exceed 200 mg/kg; omnivore-predator nematodes and specific microarthropods groups were significantly reduced at 100 mg/kg copper.

**Semivolatile Organic Compounds** — Although some semivolatiles in soil are considered 1  
carcinogenic to mammals, few field studies address their toxicity to earthworms or other terrestrial 2  
infauna (refer to Table 8.6). In general, SVOCs such as benzo(a)anthracene and benzo(a)pyrene 3  
and other PAHs break down in natural systems via photodegradation and microbial transformation. 4  
Neuhauser et al. (1986) determined that specific phenol compounds (4-nitrophenol, 2,4,6- 5  
trichlorophenol, and phenol) were somewhat toxic to earthworms, with PAHs being relatively less 6  
toxic than other semivolatile compounds studied. As shown in Table 8.6, artificial soil tests 7  
produced lethal concentration ( $LC_{50}$ ) values for fluorene and phenol near 175 mg/kg and 8  
400 mg/kg, respectively. It is important to note that field variability and soil chemical matrices 9  
can greatly influence toxicological effects of PAH compounds. 10

**Pesticide/PCBs** — Numerous studies have measured pesticide's effects on terrestrial infaunal 11  
organisms. Earthworm toxicology and response information is the most prevalent. Beyer and 12  
Gish (1980) observed the persistence of DDT, dieldrin, and heptachlor in earthworms and 13  
determined that earthworms can accumulate pesticides to concentrations present in residence soil. 14  
Callahan et al. (1991), showed very good soil-to-tissue correlation ( $R=0.725$ ), with accumulation 15  
of DDT in single earthworms up to 22 mg/kg. Beyer and Gish (1980) determined that earthworms 16  
accumulated RDDT to 32 mg/kg. Barker (1958) associated poisoning (lethality) of robins with 17  
60 mg/kg DDT in earthworms, and Collett and Harrison (1968) noted that blackbirds and thrushes 18  
were impacted at residues near 20 mg/kg. At concentrations observed in their study, Callahan et 19  
al., (1991) suggested that a feeding rate by robins of 10 to 12 earthworms in as many minutes (as 20  
observed by McDonald, 1983) could provide a sufficient concentration of contamination for 21  
impacts to robins. Callahan et al., (1991), also concluded that chlordane, like other pesticides, 22  
was taken up rapidly by earthworms. Total DDT concentrations exceeding 1,000 mg/kg in soil, 23  
along with documented long half-life information (5.7-years DDT), indicated a long-term 24  
significant risk to receptors. 25

Risk factors associated with PCBs are similar to those for pesticides. After acute mortality, food chain biomagnification and transfer are the most important issues to be considered when assessing long-term risk. Paine et al. (1993) suggested a benchmark value between 100 to 300 mg/kg PCB for mortality in terrestrial insects. Also, Rhett et al. (1988) observed LC<sub>50</sub> values for earthworms treated with PCBs at 240 mg/kg. McKee (1992) reported that soil invertebrate community structure was not reduced by exposure to PCB-contaminated soil (maximum concentrations to 120,000 mg/kg wet weight), based on family-level classification of invertebrates.

**Dioxins** — Reinecke and Nash (1984) studied the toxic effects of dioxin (2,3,7,8-TCDD) in soil to earthworms. For two species, *Allolobophora caliginosa* and *Lumbricus rubellus*, concentrations of 5 mg/kg or less had no acute effect, but concentrations of at least 10 mg/kg were lethal.

Soil contaminants detected in each terrestrial subzone are compared to the range of available infaunal effect levels Table 8.7. Comparisons could not be made for those parameters lacking an effect levels or those with incompatible units (dose vs. concentration), therefore these parameters have been excluded. This information is presented to assist risk managers decide to either proceed with a more detailed risk assessment or conclude the Zone K ERA after only the preliminary assessment. Note that the concentrations of organic effect levels have been converted to units comparable to the Zone K soil results reported by the laboratory.

Table 8.7  
 Comparison of Zone K Soil Contaminants to Infaunal Effect Levels

Parameter	Concentrations Detected in Subzone K-2/K-3	Concentrations Detected in Subzone K-4	Range of Effect Levels	Subzone w/ Potential Risk to Infauna
<b>Inorganics (mg/kg)</b>				
Aluminum	1,370 - 44,700	652 - 11,200	600	K2/K3, K4
Antimony	0.48 - 27.9	0.38 - 3.3	NA	??
Arsenic	7.2 - 25.8	0.60 - 32.2	60 - 100	None
Barium	4.9 - 131	5.5 - 105	3,000	None

**Table 8.7**  
**Comparison of Zone K Soil Contaminants to Infaunal Effect Levels**

Parameter	Concentrations Detected in Subzone K-2/K-3	Concentrations Detected in Subzone K-4	Range of Effect Levels	Subzone w/ Potential Risk to Infauna
Beryllium	0.10 - 1.6	0.03 - 0.65	NA	??
Cadmium	0.22 - 1.5	0.06 - 4.0	20 - 1,843	None
Chromium	4.8 - 77.3	0.29 - 21.5	0.4 - 10	K2/K3, K4
Cobalt	0.35 - 10.1	0.16 - 5.4	1,000	None
Copper	4.3 - 1,020	0.27 - 32.0	0.28 - 1,320	K2/K3, K4
Lead	5.3 - 481	2.6 - 259	500 - 21,600	None
Manganese	83.5 - 1,050	3.2 - 70.4	NA	??
Mercury	0.07 - 1.7	0.06 - 58.2	0.1 - 30	K2/K3, K4
Nickel	1.7 - 37.1	0.2 - 6.7	90 - 757	None
Selenium	0.46 - 4.7	0.36 - 0.71	70 - 100	None
Silver	0.31 - 1.2	0.24 - 0.88	50	None
Tin	5.9 - 284	1.1 - 32.0	2,000	None
Vanadium	4.3 - 92.2	1.5 - 16.0	20	K2/K3
Zinc	37 - 792	5.0 - 538	1.6 - 2,800	K2/K3, K4
<b>Semivolatile Organic Compounds (<math>\mu\text{g}/\text{kg}</math>)</b>				
Fluorene	ND	42 - 81	30,000 - 174,000	None
Phenol	ND	100 - 2,100	30,000 - 188,000	None
<b>Pesticides/PCBs (<math>\mu\text{g}/\text{kg}</math>)</b>				
DDD	4.74 - 54.8	4.15 - 147	700,000 - 1,000,000	None
DDE	4.72 - 14.0	3.30 - 990	200,000 - 1,000,000	None
DDT	14.3 - 70.0	5.28 - 600	400,000 - 1,000,000	None
PCBs	26.0 - 596	106 - 1,780	240,000 - 123,000,000	None
<b>Dioxins (<math>\text{ng}/\text{kg}</math>)</b>				
Dioxins (TEF)	0.63 - 4.76	ND	< 5,000,000 - > 10,000,000	None

**Notes:**

Sources of Effect Levels are presented in Table 8-6 or supporting text.

ND - Not Detected

?? - Could not be determined due to lack of toxic effect information

Dioxin results for Subzone K-2/K-3 are adjusted using Toxicity Equivalent Factors

### Subzone K-2/K-3

As shown in Table 8.7, eight inorganic compounds at the Clouter Island sites exceeded their lowest respective infaunal effect level. At least one subzone sample contained concentrations of aluminum, chromium, copper, mercury, vanadium, and/or zinc at concentrations exceeding their most conservative effect value. The most significant exceedance was for aluminum, which was detected at a concentration nearly 75 times the single benchmark observed to reduce the enzyme production in soil microbes. Chromium was in a site sample at a concentration nearly 200 times the lowest level shown to decrease the survival of earthworms and still seven times the highest (least conservative) effect level shown to adversely affect soil microbes. Copper's maximum concentration (1,020 mg/kg) is 20 times more than the 50 mg/kg set by Will and Suter (1995) as the concentration which decreases earthworm cocoon production. This concentration is below the benchmark of 1,320 mg/kg at which Malecki et al. (1982) observed reduced earthworm growth. Mercury, at a maximum concentration of 1.7 mg/kg, was nearly 20 times the concentration observed to cause reduced survivability and cocoon production in earthworms (Will and Suter, 1995) but well below the 30 mg/kg upper benchmark noted to affect soil microbes and microflora. Zinc concentrations were 100 times than the concentration determined by Miller et al. (1985) to produce adverse effects to soil microbes, but well below the 2,800 mg/kg soil concentration Malecki et al. (1982) observed to reduce the growth in earthworms. These values represent significant risk to infauna in the surface soil at Subzone K-2/K-3.

### Subzone K-4

Five inorganic compounds at the Naval Annex subzone exceeded their lowest infaunal effect level. At least one subzone sample contained concentrations of aluminum, chromium, copper, mercury, and/or zinc at concentrations exceeding their most conservative effect value. The most significant exceedance was for aluminum, which was detected at a concentration nearly 19 times the single benchmark observed to reduce the enzyme production in soil microbes. Chromium was in a site sample at a concentration nearly 54 times the lowest level shown to decrease the survival of

earthworms and still two times greater than the highest (least conservative) effect level shown to adversely affect soil microbes. The maximum concentration of copper (32 mg/kg) exceeds the 0.28 mg/kg effect level showing adverse effects to soil microbes, well below the 50 mg/kg at which Will and Suter (1995) saw decreased earthworm cocoon production and well below the upper benchmark of 1,320 mg/kg at which Malecki et al. (1982) observed reduced earthworm growth. The maximum concentration of mercury is 58.2 mg/kg, which is nearly 12 times the concentrations Abbassi and Soni (1984) saw 100% mortality in earthworms and one order of magnitude above the level at which reduced survivability and cocoon production were observed in earthworms (Will and Suter, 1995). This mercury detection is also nearly twice the 30 mg/kg upper benchmark noted to affect soil microbes and microflora. The highest zinc concentration was 300 times more than the lowest concentration observed by Miller et al. (1985) to produce adverse effects in Microtox tests, but well below the 2,800 mg/kg soil concentration at which Malecki et al. (1982) saw reduced growth in earthworms. These values represent significant risk to infauna at in the surface soil at Subzone K-4.

### **8.8.3 Terrestrial Wildlife**

Risks for the representative wildlife species associated with ingestion of surface soil and food are also quantitatively evaluated using HQs, which are calculated for each identified ECPC by dividing the estimated dietary exposure concentration (PDE) by the corresponding toxicological benchmark (TRV). When the estimated PDE is less than the TRV ( $HQ < 1$ ), the contaminant exposure is assumed to fall below the range considered to be associated with adverse effects for growth, reproduction, and survival and no risk to the wildlife populations is assumed. When the HQ exceeds 1, the ecological significance is discussed and risk is assumed. As with benthic organisms, cumulative risk to terrestrial wildlife at each subzone is represented by a hazard index (HI).

For representative wildlife species, PDEs were calculated using the formula presented in Section 8.6., available bioaccumulation data (Table 8.8) and exposure assumptions (Table 8.9) for

**Table 8.8**  
**Bioaccumulation Data**  
**Ecological Risk Assessment**  
**Zone K**

Analyte	Log K <sub>ow</sub>	Plant	Bioaccumulation or Biotransfer Factor (unitless)		
			Terrestrial Invertebrate	Mammal	Bird
<b>Semivolatiles</b>					
Anthracene	4.4 [c]	NA	0.005 [d]	6.30E-04 [a]	1 [ab]
Benzo(a)anthracene	5.74 [c]	0.019 [e]	0.0125 [d]	1.38E-02 [a]	1 [ab]
Benzo(a)pyrene	6.07 [c]	0.012 [e]	0.0342 [d]	2.95E-02 [a]	1 [ab]
Benzo(b)fluoranthene	6.32 [c]	0.008 [e]	0.032 [d]	5.25E-02 [a]	1 [ab]
Benzo(g,h,i)perylene	7 [c]	0.003 [e]	0.024 [d]	2.50E-01 [a]	1 [ab]
Benzo(k)fluoranthene	6.45 [c]	0.007 [e]	0.025 [d]	7.08E-02 [a]	1 [ab]
Bis(2-ethylhexyl)phthalate (BEHP)	5.3 [f]	0.033 [e]	0.022 [aj]	5.00E-03 [a]	1 [ab]
Butylbenzylphthalate	4.78 [g]	0.049 [e]	0.022 [aj]	1.50E-03 [a]	1 [ab]
Chrysene	5.71 [c]	0.019 [e]	0.031 [d]	1.29E-02 [a]	1 [ab]
Dibenzo(a,h)anthracene	6.42 [c]	0.008 [e]	0.022 [aj]	6.61E-02 [a]	1 [ab]
Di-n-butylphthalate	4.8 [h]	NA	0.022 [aj]	1.60E-03 [a]	1 [ab]
Fluoranthene	5.25 [c]	0.036 [e]	0.007 [d]	4.50E-03 [a]	1 [ab]
Indeno(1,2,3-cd)pyrene	7.7 [c]	0.0014 [e]	0.042 [d]	1.26E+00 [a]	1 [ab]
Phenanthrene	4.43 [c]	NA	0.012 [d]	6.70E-04 [a]	1 [ab]
Pyrene	5.09 [c]	0.044 [e]	0.018 [d]	3.10E-03 [a]	1 [ab]

**Table 8.8**  
**Bioaccumulation Data**  
**Ecological Risk Assessment**  
**Zone K**

Analyte	Log K <sub>ow</sub>	Bioaccumulation or Biotransfer Factor (unitless)			
		Plant	Terrestrial Invertebrate	Mammal	Bird
<b>Pesticides/PCBs/Dioxins</b>					
Aroclor-1248	6 [c]	0.013 [e]	1.2 [i]	1.00E+00 [ak]	1 [ab]
Aroclor-1254	6.02 [c]	0.013 [e]	1.2 [i]	1.00E+00 [ak]	1 [ab]
Aroclor-1260	6 [c]	0.013 [e]	1.2 [i]	1.00E+00 [ak]	1 [ab]
alpha-Chlordane	2.78 [f]	0.027 [ac]	0.8 [j]	7.10E-01 [ak]	0.71 [ai]
gamma-Chlordane	3.32 [f]	0.027 [ac]	0.8 [j]	7.10E-01 [ak]	0.71 [ai]
4,4'-DDE	5.69 [f]	0.02 [e]	0.98 [v]	2.91E+00 [ak]	2.91 [l]
4,4'-DDT	4.48 [f]	0.027 [ac]	0.98 [v]	2.91E+00 [ak]	2.91 [l]
Dieldrin	4.95 [f]	0.049 [e]	1.2 [m]	7.10E-01 [ak]	0.71 [n]
2,3,7,8 TCDD	6.80 [am]	0.005 [e]	5.0 [b]	8.40E-01 [an]	1 [ab]
<b>Inorganics</b>					
Arsenic	NA	0.3 [p]	0.77 [ae]	3.60E-01 [ag]	0.45 [ah]
Barium	NA	0.56 [ag]	0.77 [ae]	3.40E-01 [af]	0.45 [ah]
Cadmium	NA	33 [q]	1.4 [k]	2.06E+00 [r]	0.38 [s]
Copper	NA	0.78 [t]	0.16 [i]	6.00E-01 [q]	0.45 [ah]
Lead	NA	0 [q]	0.22 [u]	5.40E-01 [w]	0.45 [ah]

Table 8.8  
 Bioaccumulation Data  
 Ecological Risk Assessment  
 Zone K

Analyte	Log K <sub>ow</sub>	Bioaccumulation or Biotransfer Factor (unitless)			
		Plant	Terrestrial Invertebrate	Mammal	Bird
<b>Inorganics (continued)</b>					
Manganese	NA	0.56 [ag]	0.77 [ae]	3.40E-01 [ag]	0.45 [ah]
Mercury	NA	0.56 [ag]	0.34 [x]	1.00E-02 [aa]	2.33 [aa]
Selenium	NA	0.009 [y]	0.77 [ae]	3.40E-01 [af]	0.51 [z]
Zinc	NA	0.61 [t]	1.77 [i]	2.06E+00 [w]	0.45 [ah]

**Notes::**

- [a] = Calculated using the following equation (Travis and Arms, 1988), unless otherwise noted:  $\log \text{BAF} - \log K_{ow} - 7.6$ ; result multiplied by average of ingestion rates for nonlactating and lactating test animals. There is an uncertainty involved in using this equation for PAHs because this study did not use any PAHs in the regression analysis.
- [b] = Reinecke and Nash (1984).
- [c] = Geometric mean of values from USEPA (1986).
- [d] = Marquerie et al. (1987) as cited in Beyer (1990). Mean of values. Converted to wet weight assuming 90% body weight as water.
- [e] = Calculated using the following equation in Travis and Arms (1988) for analytes with  $\log K_{ow} > 5$ :  $\log (\text{Plant Uptake Factor}) = 1.588 - 0.578 \log K_{ow}$ .
- [f] = From USEPA (1986).
- [g] = Value from Verschueren (1983).
- [h] = Value from Howard (1990).
- [i] = BCF for earthworms from Diercxsens, et al. (1985).
- [j] = Value from Gish (1970).
- [k] = Mean of values reported for soil invertebrates in Macfadyen (1980) converted from dry weight to wet weight.
- [l] = Whole body pheasant BAF for 4,4'-DDT presented in USEPA (1985), derived from Kenaga (1973).
- [m] = Average of values reported for soil invertebrates in Edwards and Thompson (1973).
- [n] = Jeffries and Davis (1968).

**Notes: (continued):**

- [o] = Value reported for endrin from Gish (1970).
- [p] = Average of BAF values reported from Wang et al. (1984), Sheppard et al. (1985) and Merry et al. (1986).
- [q] = Levine et al. (1989).
- [r] = Mean of values reported for *Sorex araneus* in Macfadyen (1980).
- [s] = Based on accumulation of cadmium in kidneys of European quail in Pimentel et al. (1984).
- [t] = Median of values reported from Levine et al. (1989).
- [u] = Geometric mean of BAF values (fresh st. worm/dry st. soil) for worms and woodlice (USEPA, 1985). Fresh weight tissue concentrations calculated assuming 90% body water content.
- [v] = Beyer and Gish (1980) reported dry weight to wet weight ratio.
- [w] = Mean of values for *Microtus agrestis* and *Apodemus sylvaticus* in Macfadyen (1980).
- [x] = Value from USEPA (1985) sludge document.
- [y] = Based on reported ratio of selenium in plant tissue and iron fly ash amended soil (Stoewsand et al., 1978).
- [z] = Based on average of reported ratio of selenium in diet to liver, kidney, and breast tissue of chickens (Ort and Latshaw, 1978).
- [aa] = USEPA, 1985.
- [ab] = Assumption.
- [ac] = Assumed value based on average of BAFs calculated for other pesticides and PCBs.
- [ad] = Assumed value based on average of BAFs for Aroclor 1260, alpha-chlordane, 4,4'-DDE, Dieldrin and endrin ketone.
- [ae] = Assumed value based on average of BAFs reported for other metals.
- [af] = Assumed value based on average of reported BAFs for Cd, Cu, Pb and Hg.
- [ag] = Assumed value based on average of reported BAFs for As, Cu, Hg and Zn.
- [ah] = Assumed value based on average of reported BAF values for Cd and Se.
- [ai] = Assumed value based on reported BAF for dieldrin.
- [aj] = Assumed value based on average of BAFs for semivolatiles.
- [ak] = Value for mammal unavailable. Bioaccumulation assumed to be the same as values reported for birds.
- [am] = Polder et al. (1995).
- [an] = Rose et al. (1976).
- NA = Not available

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Table 8.9  
 Exposure Parameters and Assumptions for Representative Wildlife Species at Terrestrial Subzones

Prey in Diet (%)

Representative Wildlife Species	Trophic Status	Inverts	Plants	Small Mammals	Herpeto-fauna	Small Birds	Incidental Soil Ingestion (%)	Home Range (acres)	Site Acreage/ Home Range	Food Ingestion Rate (kg/day)	Body Weight (kg)
American Robin <sup>a</sup>	Carnivorous Bird	83	7	0	0	0	10	1.04	0.913	0.10	0.077
Eastern Cottontail <sup>b</sup>	Herbivorous Mammal	0	0.97	0	0	0	3	9.3	0.102	0.08	1.2
Short-tailed Shrew <sup>c</sup>	Carnivorous Mammal	78	12	0	0	0	10	0.96	1.00	0.0025	0.018

Site Areas: K-2/K-3 = 10 acres; K-4 = 36 acres

Notes:

- a = Diet assumptions based on data from Hamilton, 1943 and Wheelwright, 1986.  
 Food ingestion rate (FI) formula:  $FI(kg/day) = 0.0582 \times Wt^{0.651}$  (kg) (Nagy, 1987).  
 Body weight from Clench & Leberman, 1978.  
 Home range reflects interpolated values from Howell, 1942; and Weatherhead & McRae, 1990.
- b = Diet assumptions based on data from Dusi, 1952; and Spencer & Chapman, 1986.  
 FI from formula:  $FI(kg/day) = 0.0687 \times Wt^{0.822}$  (kg) (Nagy, 1987).  
 Body weight reflects interpolated values from Chapman & Morgan, 1973; and Pelton & Jenkins, 1970.  
 Home range reflects interpolated values from Althoff & Storm, 1989; and Dixon et al., 1981.
- c = Diet assumptions based on data from Dusi, 1952; and Whitaker & Ferraro, 1963.  
 FI from formula:  $FI(kg/day) = 0.0687 \times Wt^{0.822}$  (kg) (Nagy, 1987).  
 Body weight from Lomolino, 1984.  
 Home range value from Buckner, 1966.

ECPCs presented in Tables 8.4 (a and b) and 8.5 (a and b). PDEs could not be calculated for those compounds without an associated BAF, as was the case with dioxins. Exposure parameters and assumptions for representative species at Subzones K-2 and K-4 were used to calculate food contaminant concentrations. HQs for both chronic and subchronic effects for ECPCs at Subzone K-2 and K-4 were determined and are presented in Tables 8.10 (a and b) and 8.11 (a and b). If an HQ or HI value is near but below 1.0, it is important to note that potential risks may still be indicated if the TRV value used in the hazard calculation is based on a LOAEL value, as opposed to a NOAEL value. LOAELs represent the concentration below which adverse effects are not likely to occur. It is conceivable that a cumulative risk to wildlife may still be present, even if the reported concentrations are near but do not exceed the LOAEL-based TRV.

### **Subzone K-2/K-3**

As indicated by the HQ and HI values for LOAEL-based chronic effects presented in Table 8.10a, potential risk exists for only the rabbit (HI = 4.68). Slight risk to the rabbit is predicted from the detected concentrations of copper (HQ = 2.32) and arsenic (HQ = 1.14). Due to the overall low concentrations, the cumulative risk to the representative species is considered to be minimal, as indicated by the low HI values.

Estimating the risk for NOAEL-based subchronic effects from exposure to site concentrations at Clouter Island resulted in a greater number and magnitude of TRV exceedances (see Table 8.10b). As with the chronic effects, subchronic risk was from the detected inorganic parameters. The most significant risk, however, was for adverse effects to the rabbit from arsenic (HQ = 11.4, which indicates moderate risk). Copper, cadmium, and lead concentrations produced HQs exceeding 1, indicating potential for low risk to the rabbit. The cumulative risk to the rabbit is estimated to be moderate (HI = 19.99). Low risk is also predicted for the shrew (HI = 1.81, primarily from arsenic) and the robin (HI = 4.34, primarily from cadmium).

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**Table 8.10a**  
**Hazard Quotients for Potential Chronic Effects (LOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentrations of ECPCs in Surface Soil at Subzone K-2/K-3**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Inorganics (mg/kg)</b>										
Aluminum	44,700	NC	7.674	NC	NC	22.952	NC	NC	NA	NC
Antimony	27.9	NC	0.497	NC	NC	1.487	NC	NC	NA	NC
Arsenic	25.8	0.57	0.501	1.14	0.185	1.50	0.124	0.32	12.8	2.49e-02
Barium	131	5.0	14.6	0.34	0.981	43.5	2.26e-02	2.81	41.7	6.73e-02
Beryllium	1.6	NC	NA	NC	NC	NA	NC	NC	NA	NC
Cadmium	1.5	1.20	7.089	0.17	0.08	21.200	3.78e-03	1.73	20.00	8.65e-02
Chromium	77.3	NC	NA	NC	NC	NA	NC	NC	5.00	NC
Cobalt	10.1	NC	NA	NC	NC	NA	NC	NC	NA	NC
Copper	1,020	34.16	14.7	2.32	3.77	44.0	8.56e-02	29.68	61.7	4.81e-01
Lead	481	7.215	58.79	0.12	1.49	175.83	8.48e-03	0.914	11.30	8.09e-02
Manganese	1,050	29.6	209	0.14	7.87	624	1.26e-02	22.52	NA	NC
Mercury	1.7	0.0481	NA	NC	7.22e-03	NA	NC	3.64e-02	0.9	4.05e-02
Nickel	37.1	NC	58.79	NC	NC	175.83	NC	NC	107.00	NC
Selenium	4.7	7.15e-02	0.243	0.29	3.20e-02	0.73	4.42e-02	1.04e-02	1.0	1.04e-02
Silver	1.2	NC	NA	NC	NC	NA	NC	NC	NA	NC
Tin	284	NC	13.9	NC	NC	41.6	NC	NC	16.9	NC
Vanadium	92.2	NC	1.433	NC	NC	4.285	NC	NC	NA	NC
Zinc	792	23.33	235.2	0.10	12.51	703.3	1.78e-02	18.36	131.0	1.40e-01

**Table 8.10a**  
**Hazard Quotients for Potential Chronic Effects (LOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentrations of ECPCs in Surface Soil at Subzone K-2/K-3**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Semivolatile Organic Compounds (<math>\mu\text{g}/\text{kg}</math>)</b>										
Benzo(a)anthracene	480	7.42e-03	3.98	1.86e-03	6.20e-04	11.89	5.21e-05	1.23e-03	NA	NC
Benzo(a)pyrene	440	6.72e-03	3.98	1.69e-03	6.36e-04	11.89	5.35e-05	1.01e-03	NA	NC
Benzo(b)fluoranthene	450	7.98e-03	3.98	2.01e-03	7.04e-4	11.89	5.92e-05	2.53e-03	NA	NC
Benzo(k)fluoranthene	180	3.05e-03	3.98	7.66e-04	2.82e-04	11.89	2.37e-05	4.50e-04	NA	NC
Chrysene	660	NC	NA	NC	NC	NA	NC	NC	NA	NC
Fluoranthene	710	NC	NA	NC	NC	NA	NC	NC	NA	NC
Indeno(1,2,3-cd)pyrene	160	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenanthrene	750	NC	NA	NC	NC	NA	NC	NC	NA	NC
Pyrene	1,100	1.75e-02	14.7	1.19e-03	1.50e-03	44.0	3.83e-05	3.78e-03	61.7	6.12e-05
BEHP	620	9.33e-03	7.3	1.28e-03	8.25e-04	218	3.78e-06	1.22e-03	NA	NC
<b>Organochlorine Pesticides (<math>\mu\text{g}/\text{kg}</math>)</b>										
4,4'-DDD	54.80	8.31e-4	2.94	2.83e-04	5.56e-04	8.79	6.33e-05	1.17e-04	2.8e-02	4.18e-03
4,4'-DDE	14.00	2.12e-04	2.94	7.21e-05	1.42e-04	8.79	1.62e-05	2.99e-05	2.8e-02	1.07e-03
4,4'-DDT	70.00	1.06e-03	2.94	3.61e-04	7.10e-04	8.79	8.08e-05	1.50e-04	2.8e-02	5.34e-03
Aldrin	8.40	NC	0.735	NC	NC	2.198	NC	NC	NA	NC
Dieldrin	9.20	1.44e-04	0.15	9.82e-04	9.62e-05	0.44	2.11e-04	2.69e-05	NA	NC
Endrin	36.20	NC	3.66e-01	NC	NC	1.094	NC	NC	1.00e-01	NC
Endrin Aldehyde	20.90	NC	3.66e-01	NC	MC	1.094	NC	NC	1.00e-01	NC
Heptachlor Epoxide	547.00	1.03e-03	0.96	1.08e-03	4.50e-04	2.86	1.57e-04	4.20e-04	NA	NC

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**Table 8.10a**  
**Hazard Quotients for Potential Chronic Effects (LOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentrations of ECPCs in Surface Soil at Subzone K-2/K-3**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Polychlorinated Biphenyls (<math>\mu\text{g}/\text{kg}</math>)</b>										
Aroclor 1260	596.00	9.12e-03	0.22	4.09e-02	6.14e-03	0.67	9.19e-03	1.40e-03	1.8	7.79e-04
			<b>HI =</b>	<b>4.68</b>		<b>HI =</b>	<b>0.33</b>		<b>HI =</b>	<b>0.94</b>

**Notes:**

- Max. Conc. = Maximum concentration of analyte.
- NA = Data not available.
- NC = Not able to calculate data.
- PDE = Potential Dietary Exposure (mg/kgBW/day) is based on equation in Section 8.6.
- TRV = Toxicity Reference Value (mg/kgBW/day) is derived from Sample, et al (1996) except for Aroclor 1260, derived from ATDSR, 1987.
- HQ = Hazard Quotient - PDE/TRV
- HI = Hazard Index ( $HQ_1 + HQ_2 + \dots HQ_n$ )
- Bold Values = HQs or HIs exceeding 1.0

**Table 8.10b**  
**Hazard Quotients for Potential Subchronic Effects (NOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentrations of ECPCs in Soil at Subzone K-2/K-3**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Inorganics (mg/kg)</b>										
Aluminum	44,700	NC	7.67e-01	NC	NC	2.295	NC	NC	109.7	NC
Antimony	27.9	NC	5.0e-02	NC	NC	1.49e-01	NC	NC	NA	NC
Arsenic	25.8	0.57	5.0e-02	<b>11.4</b>	0.185	1.50e-01	<b>1.24</b>	0.319	5.10	6.25e-02
Barium	131	3.70	4.0	0.93	0.981	11.8	8.32e-02	2.81	20.8	1.35e-01
Beryllium	1.6	NC	NA	NC	NC	NA	NC	NC	NA	NC
Cadmium	1.5	1.20	<b>0.709</b>	<b>1.69</b>	0.08	2.120	3.78e-02	1.73	1.45	<b>1.19</b>
Chromium	77.3	NC	2,011	NC	NC	6015	NC	NC	1.00	NC
Cobalt	10.1	NC	NA	NC	NC	NA	NC	NC	NA	NC
Copper	1,020	34.16	11.2	<b>3.05</b>	3.77	33.4	1.13e-01	29.68	47.0	6.32e-01
Lead	481	7.22	5.88	<b>1.23</b>	1.49	17.58	8.48e-02	0.914	1.13	8.09e-01
Manganese	1,050	29.6	65	4.57e-01	7.87	193	4.08e-02	22.5	997	2.26e-02
Mercury	1.7	<b>4.81e-02</b>	0.96	5.01e-02	7.22e-03	2.86	2.52e-03	<b>3.64e-02</b>	0.45	8.10e-02
Nickel	37.1	NC	29.40	NC	NC	87.91	NC	NC	77.40	NC
Selenium	4.7	7.15e-02	1.47e-01	4.86e-01	3.20e-02	4.40e-01	7.27e-02	1.04e-02	5.00e-01	2.08e-02
Silver	1.2	NC	NA	NC	NC	NA	NC	NC	NA	NC
Tin	284	NC	9.3	NC	NC	27.8	NC	NC	6.8	NC
Vanadium	92.2	NC	1.43e-01	NC	NC	4,28e-01	NC	NC	11.400	NC
Zinc	792	23.3	117.6	1.98e-01	12.51	351.7	3.56e-02	18.35	14.5	<b>1.27</b>

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Table 8.10b  
 Hazard Quotients for Potential Subchronic Effects (NOAELs) for Wildlife Species Associated with  
 Maximum Exposure Concentrations of ECPCs in Soil at Subzone K-2/K-3

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Semivolatile Organic Compounds (<math>\mu\text{g}/\text{kg}</math>)</b>										
Benzo(a)anthracene	480	7.42e-03	0.4	1.85e-02	6.20e-04	1.19	5.21e-04	1.23e-03	NA	NC
Benzo(a)pyrene	440	6.72e-03	0.4	1.62e-02	6.36e-04	1.19	5.34e-04	1.01e-03	NA	NC
Benzo(b)fluoranthene	450	7.98e-03	0.4	1.97e-02	7.04e-04	1.19	5.92e-04	2.53e-03	NA	NC
Benzo(k)fluoranthene	180	3.05e-03	0.4	7.62e-03	2.82e-04	1.19	2.37e-04	4.50e-04	NA	NC
Chrysene	660	NC	NA	NC	NC	NA	NC	NC	NA	NC
Fluoranthene	710	NC	NA	NC	NC	NA	NC	NC	NA	NC
Indeno(1,2,3-cd)pyrene	160	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenanthrene	750	NC	NA	NC	NC	NA	NC	NC	NA	NC
Pyrene	1,100	1.75e-02	11.2	1.58e-03	1.50e-03	33.4	4.45e-05	3.78e-03	47	8.04e-05
BEHP	620	256e-03	7.3	3.51e-04	1.04e-02	21.8	4.77e-04	9.71e-03	1.10	8.93e-03
<b>Organochlorine Pesticides (<math>\mu\text{g}/\text{kg}</math>)</b>										
4,4'-DDD	54.80	8.31e-4	0.59	1.41e-03	5.56e-04	1.76	3.16e-04	1.17e-04	3e-03	3.90e-02
4,4'-DDE	14.00	2.12e-04	0.59	3.60e-04	1.42e-04	1.76	8.07e-05	2.99e-05	3e-03	9.97e-03
4,4'-DDT	70.00	1.06e-03	0.59	1.80e-03	7.10e-04	1.76	4.03e-04	1.50e-04	3e-03	4.90e-02
Aldrin	8.44	NC	1.47e-01	NC	NC	0.04	NC	NC	NA	NC
Dieldrin	9.20	1.44e-04	0.02	9.63e-03	9.25e-05	0.04	2.11e-03	2.69e-05	0.077	3.49e-04
Endrin	36.20	NC	3.7e-02	NC	NC	0.109	NC	NC	1.0e-02	NC
Endrin Aldehyde	20.90	NC	3.7e-02	NC	NC	0.109	NC	NC	1.0e-02	NC
Heptachlor Epoxide	54.70	1.03e-03	0.10	1.08e-02	4.50e-04	0.29	1.57e-03	4.20e-04	NA	NC

**Table 8.10b**  
**Hazard Quotients for Potential Subchronic Effects (NOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentrations of ECPCs in Soil at Subzone K-2/K-3**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin			
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ	
<b>Polychlorinated Biphenyls (<math>\mu\text{g}/\text{kg}</math>)</b>											
Aroclor 1260	596.00	9.12e-03	0.02	4.15e-01	6.14e-03	0.07	9.16e-02	1.40e-03	0.18	7.79e-03	
			<b>HI =</b>	<b>19.99</b>				<b>HI =</b>	<b>1.81</b>		
								<b>HI =</b>	<b>4.34</b>		

**Notes:**

- Max. Conc. = Maximum concentration of analyte
- NA = Data not available
- NC = Not able to calculate data
- PDE = Potential Dietary Exposure (mg/kgBW/day) is based on equation in Section 8.6.
- TRV = Toxicity Reference Value (mg/kgBW/day) is derived from Sample, et al. (1996) except for Aroclor 1260, derived from ATDSR, 1987
- HQ = Hazard Quotient = PDE/TRV
- HI = Hazard Index ( $HQ_1 + HQ_2 + \dots HQ_n$ )
- Bold Values = HQs or HIs exceeding 1.0

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Table 8.11a  
 Hazard Quotients for Potential Chronic Effects (LOAELs) for Wildlife Species Associated with  
 Maximum Exposure Concentration of ECPCs in Soil at Subzone K-4

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Inorganics (mg/kg)</b>										
Aluminum	11,200	NC	7.674	NC	NC	22.952	NC	NC	NA	NC
Antimony	3.3	NC	0.497	NC	NC	1.487	NC	NC	NA	NC
Arsenic	32.2	7.12e01	0.5	1.42e-01	0.231	1.5	0.154	0.40	12.8	3.11e-02
Barium	105	2.97	14.6	2.03e-01	0.79	43.5	1.81e-02	2.25	41.7	5.40e-02
Beryllium	0.65	NC	NA	NC	NC	NA	NC	NC	NA	NC
Cadmium	4.0	3.19	7.089	4.50e-01	0.214	21.2	1.01e-02	4.61	20.00	2.31e-01
Chromium	21.5	NC	NA	NC	NC	NA	NC	NC	NA	NC
Cobalt	5.4	NC	NA	NC	NC	NA	NC	NC	NA	NC
Copper	32.0	1.07	14.7	7.29e-02	0.118	44.0	2.69e-03	0.93	61.7	1.51e-02
Lead	259	3.89	58.79	6.61e-02	0.80	175.83	4.57e-03	0.49	11.30	4.35e-02
Manganese	70.4	1.99	209	9.52e-03	0.53	624	8.45e-04	1.51	NA	NC
Mercury	58.2	1.65	NA	NC	0.25	NA	NC	1.25	0.90	1.39
Nickel	6.7	NC	58.79	NC	NC	175.83	NC	NC	107.00	NC
Selenium	0.71	1.08e-02	2.43e-01	4.42e-02	4.83e-03	7.25e-01	6.67e-03	1.57e-03	1.0	1.57e-03
Vanadium	16.0	NC	1.433	NC	NC	4.285	NC	NC	NA	NC
Zinc	538	15.85	235.2	6.74e-02	8.50	703.3	1.21e-02	12.47	131.0	9.52e-02
<b>Volatile Organic Compounds (µg/kg)</b>										
Tetrachloroethene	990	NC	2.78	NC	NC	8.32	NC	NC	NA	NC
Trichloroethene	59,000	NC	2.783	NC	NC	8.324	NC	NC	NA	NC

**Table 8.11a**  
**Hazard Quotients for Potential Chronic Effects (LOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentration of ECPCs in Soil at Subzone K-4**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Semivolatile Organic Compounds (<math>\mu\text{g}/\text{kg}</math>)</b>										
Benzo(a)anthracene	1,700	2.63e-02	3.98	6.60e-03	2.20e-03	11.89	1.85e-04	4.36e-03	NA	NC
Benzo(a)pyrene	1,300	1.99e-02	3.98	4.99e-03	1.88e-03	11.89	1.58e-04	2.99e-03	NA	NC
Benzo(b)fluoranthene	1,700	2.98e-02	3.98	7.49e-03	2.66e-03	11.89	2.24e-04	9.57e-03	NA	NC
Benzo(g,h,i)perylene	1,600	2.42e-02	3.98	6.08e-03	2.44e-03	11.89	2.05e-04	3.33e-03	NA	NC
Benzo(k)fluoranthene	1,700	2.59e-02	3.98	6.51e-03	2.39e-03	11.89	2.01e-04	3.82e-03	NA	NC
BEHP	440	6.62e-03	73.0	9.07e-05	5.85e-04	218	2.68e-06	8.72e-04	NA	NC
Chrysene	1,300	NC	NA	NC	NC	NA	NC	NC	NA	NC
Fluoranthene	1,800	NC	NA	NC	NC	NA	NC	NC	NA	NC
Indeno(1,2,3-cd)pyrene	1,600	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenanthrene	1,300	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenol	2,100	NC	NA	NC	NC	NA	NC	NC	NA	NC
Pyrene	1,800	2.89e-02	14.7	1.96e-03	2.43e-03	44	5.53e-05	6.18e-03	61.7	1.00e-04
<b>Organochlorine Pesticides (<math>\mu\text{g}/\text{kg}</math>)</b>										
4,4'-DDD	147	2.23e-03	2.94	7.58e-04	1.49e-03	8.79	1.70e-04	3.14e-04	2.8e-02	1.12e-02
4,4'-DDE	990	1.50e-02	2.94	5.11e-03	1.00e-02	8.79	1.14e-03	2.11e-03	2.8e-02	7.55e-02
4,4'-DDT	600	9.10e-03	2.94	3.09e-03	6.09e-03	8.79	6.92e-04	1.28e-03	2.8e-02	4.58e-02
Dieldrin	33.0	5.18e-04	1.47e-01	3.52e-03	3.33e-04	4.40e-01	7.58e-04	9.64e-05	NA	NC
Endosulfan II	64.8	1.23e-03	NA	NC	5.33e-04	NA	NC	4.96e-04	NA	NC

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Table 8.11a  
 Hazard Quotients for Potential Chronic Effects (LOAELs) for Wildlife Species Associated with  
 Maximum Exposure Concentration of ECPCs in Soil at Subzone K-4

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
Endosulfan sulfate	28.1	NC	NA	NC	NC	NA	NC	NC	NA	NC
Endrin aldehyde	82.8	NC	3.66e-01	NC	NC	1.094	NC	NC	1.00e-01	NC
Endrin ketone	9.79	NC	3.66e-01	NC	NC	1.094	NC	NC	1.00e-01	NC
Heptachlor epoxide	140	2.65e-03	0.96	2.77e-03	1.15e-03	2.86	4.03e-04	1.07e-03	NA	NC
Chlordane (alpha and gamma)	305.4	4.68e-03	3.7	2.60e-03	2.23e-03	10.9	2.04e-04	7.19e-04	10.7	6.72e-05
<b>Polychlorinated Biphenyls (µg/kg)</b>										
Aroclor 1260	1,780	2.72e-02	0.22	1.22e-01	1.83e-02	0.67	2.74e-02	4.19e-03	1.8	2.33e-03
<b>Total Organic Hydrocarbons/Diesel Range Organics (µg/kg)</b>										
Diesel	314	NC	NA	NC	NC	NA	NC	NC	NA	NC
		<b>HI = 5.60</b>			<b>HI = 0.24</b>			<b>HI = 2.00</b>		

Notes:

- Max. Conc. = Maximum concentration of analyte
- NA = Data not available
- NC = Not able to calculate data.
- PDE = Potential Dietary Exposure (mg/kgBW/day) is based on equation in Section 8.6.
- TRV = Toxicity Reference Value (mg/kgBW/day) is derived from Sample, et al, (1996) except for Aroclor 1260 which is derived from ATDSR, 1987
- HQ = Hazard Quotient = PDE/TRV
- HI = Hazard Index (HQ<sub>1</sub> + HQ<sub>2</sub> + ...HQ<sub>n</sub>)
- Bold Values = HQs or HIs exceeding 1.0

**Table 8.11b**  
**Hazard Quotients for Potential Subchronic Effects (NOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentration of ECPCs in Soil at Subzone K-4**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Inorganics (mg/kg)</b>										
Aluminum	11,200	NC	0.767	NC	NC	2.295	NC	NC	NA	NC
Antimony	3.3	NC	5.0e-02	NC	NC	0.149	NC	NC	NA	NC
Arsenic	32.2	7.12e01	5.0e-02	<b>14.2</b>	0.231	1.50e-01	<b>1.54</b>	0.40	5.1	7.81e-02
Barium	105	2.97	4.0	0.742	0.79	11.8	6.67e-02	2.25	41.7	1.08e-01
Beryllium	0.65	NC	NA	NC	NC	NA	NC	NC	NA	NC
Cadmium	4.0	3.19	7.09e-01	<b>4.50</b>	0.214	2.120	1.01e-01	4.61	20.00	<b>3.18</b>
Chromium	21.5	NC	2011	NC	NC	6015	NC	NC	NA	NC
Cobalt	5.4	NC	NA	NC	NC	NA	NC	NC	NA	NC
Copper	32.0	1.07	11.2	9.57e-02	0.118	33.4	3.54e-03	0.93	47.0	1.98e-02
Lead	259	3.89	5.88	6.61e-01	0.80	17.58	4.57e-02	0.49	1.13	4.35e-01
Manganese	70.4	1.99	65	3.06e-02	0.53	193	2.73e-03	1.51	997	1.51e-03
Mercury	58.2	1.65	0.96	<b>1.71</b>	0.25	2.86	8.64e-02	1.25	0.45	<b>2.77</b>
Nickel	6.7	NC	29.40	NC	NC	87.91	NC	NC	107.00	NC
Selenium	0.71	1.08e-02	1.47e-01	7.35e-02	4.83e-03	4.40e-01	1.10e-02	1.57e-03	0.5	3.14e-03
Vanadium	16.0	NC	1.43e-01	NC	NC	4.28e-01	NC	NC	NA	NC
Zinc	538	15.85	117.6	1.35e-01	8.50	351.7	2.42e-02	12.47	14.5	8.60e-01
<b>Volatile Organic Compounds (µg/kg)</b>										
Tetrachloroethene	990	NC	0.56	NC	NC	1.66	NC	NC	NA	NC
Trichloroethene	59,000	NC	0.278	NC	NC	0.832	NC	NC	NA	NC

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**Table 8.11b**  
**Hazard Quotients for Potential Subchronic Effects (NOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentration of ECPCs in Soil at Subzone K-4**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
<b>Semivolatile Organic Compounds (<math>\mu\text{g}/\text{kg}</math>)</b>										
Benzo(a)anthracene	1,700	2.63e-02	0.40	6.57e-02	2.20e-03	1.19	1.84e-03	4.36e-03	NA	NC
Benzo(a)pyrene	1,300	1.99e-02	0.40	4.96e-02	1.88e-03	1.19	1.58e-03	2.99e-03	NA	NC
Benzo(b)fluoranthene	1,700	2.98e-02	0.40	7.45e-02	2.66e-03	1.19	2.24e-03	9.57e-03	NA	NC
Benzo(g,h,i)perylene	1,600	2.42e-02	0.40	6.05e-02	2.44e-03	1.19	2.05e-03	3.33e-03	NA	NC
Benzo(k)fluoranthene	1,700	2.59e-02	0.40	6.48e-02	2.39e-03	1.19	2.01e-03	3.82e-03	NA	NC
BEHP	440	6.62e-03	7.30	9.07e-04	5.85e-04	21.80	6.28e-05	8.72e-04	1.10	7.93e-04
Chrysene	1,300	NC	NA	NC	NC	NA	NC	NC	NA	NC
Fluoranthene	1,800	NC	NA	NC	NC	NA	NC	NC	NA	NC
Indeno(1,2,3-cd)pyrene	1,600	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenanthrene	1,300	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenol	2,100	NC	NA	NC	NC	NA	NC	NC	NA	NC
Pyrene	1,800	2.89e-02	11.2	2.58e-03	2.43e-03	33.4	7.92e-05	6.18e-03	47	1.32e-04
<b>Organochlorine Pesticides (<math>\mu\text{g}/\text{kg}</math>)</b>										
4,4'-DDD	147	2.23e-03	0.59	3.78e-03	1.49e-03	1.76	8.47e-04	3.14e-04	2.8e-02	1.05e-01
4,4'-DDE	990	1.50e-02	0.59	2.54e-02	1.00e-02	1.76	5.71e-03	2.11e-03	2.8e-02	7.05e-01
4,4'-DDT	600	9.10e-03	0.59	1.54e-02	6.09e-03	1.76	3.46e-03	1.28e-03	2.8e-02	4.27e-01
Dieldrin	33.0	5.18e-04	1.5e-02	3.45e-02	3.33e-04	4.4e-02	7.58e-03	9.64e-05	7.70e-02	1.25e-03
Endosulfan II	64.8	1.23e-03	0.11	1.11e-02	5.33e-04	3.3e-01	1.61e-03	4.96e-04	10.0	4.96e-05
Endosulfan sulfate	28.1	NC	NA	NC	NC	NA	NC	NC	NA	NC

**Table 8.11b**  
**Hazard Quotients for Potential Subchronic Effects (NOAELs) for Wildlife Species Associated with**  
**Maximum Exposure Concentration of ECPCs in Soil at Subzone K-4**

Analyte	Max. Conc.	Eastern Cottontail Rabbit			Short-tailed Shrew			American Robin			
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ	
Endrin aldehyde	82.8	NC	3.7e-02	NC	NC	1.09e-01	NC	NC	1.00e-01	NC	
Endrin ketone	9.79	NC	3.7e-02	NC	NC	1.09e-01	NC	NC	1.00e-01	NC	
Heptachlor epoxide	140	2.65e-03	0.10	2.76e-02	1.15e-03	0.29	4.02e-03	1.07e-03	NA	NC	
Chlordane (alpha and gamma)	305.4	4.68e-03	1.8	2.60e-03	2.23e-03	5.5	4.05e-04	7.19e-04	2.1	3.42e-04	
<b>Polychlorinated Biphenyls (µg/kg)</b>											
Aroclor 1260	1,780	2.72e-02	0.02	<b>1.24</b>	1.83e-02	0.07	2.74e-01	4.19e-03	0.18	2.33e-02	
<b>Total Organic Hydrocarbons/Diesel Range Organics (µg/kg)</b>											
Diesel	314	NC	NA	NC	NC	NA	NC	NC	NA	NC	
			<b>HI =</b>	<b>23.83</b>				<b>HI =</b>	<b>2.19</b>		
									<b>HI =</b>	<b>8.72</b>	

**Notes:**  
 Max. Conc. = Maximum concentration of analyte  
 NA = Data not available  
 NC = Not able to calculate data.  
 PDE = Potential Dietary Exposure (mg/kgBW/day) is based on equation in Section 8.6.  
 TRV = Toxicity Reference Value (mg/kgBW/day) is derived from Sample, et al, (1996) except for Aroclor 1260 which is derived from ATDSR, 1987.  
 HQ = Hazard Quotient = PDE/TRV  
 HI = Hazard Index (HQ<sub>1</sub> + HQ<sub>2</sub> + ...HQ<sub>n</sub>)  
 Bold Values = HQs or HIs exceeding 1.0

Overall, the preliminary risk estimates of Subzone K-2/K-3 indicate moderate risk to the rabbit. To be conservative, these risk estimates assume that each species feeds exclusively at the location where the maximum concentration of each parameter was detected. The actual risk to any of the three representative wildlife species is probably much lower.

#### **Subzone K-4**

The primary risk to wildlife from chronic exposure to contaminants in surface soil at the Naval Annex comes from the single mercury detection of 58.2 mg/kg (see Table 8.11a). The highest chronic exposure HQ for mercury was 1.39 for the American robin, which was the major contributor to the cumulative HI of 2.00, indicating a low risk potential to small carnivorous birds.

Although elevated concentrations of trichloroethene (TCE; 59,000  $\mu\text{g}/\text{kg}$ ) were detected at the Annex, an HQ could not be calculated because no BAF for TCE was available. However, this sample was collected from beneath a concrete pad and with such limited exposure, TCE is not considered to be a likely source for uptake by resident wildlife species.

No other compounds produced chronic HQs greater than 1; however, there were numerous inorganics with HQs near 1 which resulted in the rabbit's HI exceeding 5.0. This indicates only a slight risk to these small herbivorous mammals.

As expected, the predicted risk for NOAEL-based subchronic effects at Subzone K-4 is considerably higher than risk for chronic effects. Metals are still the primary ECPCs with notable HQs ranging from 1.54 for risk from arsenic to the shrew up to 14.2 for risk from arsenic to the rabbit. These HQ values indicate only moderate risk for observable effects. In addition to arsenic, the concentrations of cadmium and mercury also contribute to the overall risk which were both present in surface soil at concentrations which may pose low risk to both the rabbit and robin.

One additional compound, Aroclor 1260, produced a subchronic HQ of 1.24 for effects to rabbits. The HIs calculated for the three terrestrial species range from 2.19 for the shrew to 23.83 for the rabbit, which indicates low to moderate risk from exposure to surface soil at Subzone K-4, mostly from the presence of arsenic.

#### **8.8.4 Vegetation**

Limited information exists on toxic effects of soil contamination to plants in natural environments. Screening benchmarks for chemical phytotoxicity in soil from *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants* (Efroymsen, 1997). are presented in Table 8.12, along with the level of confidence each value has been assigned based on the type of experiment and the number of studies which had similar findings. It is also important to note that effects concentrations vary depending on specific soil physicochemical conditions such as pH, organic content, and cation exchange capacity (CEC). Some particular characteristics of a compound's plant toxicity are discussed below.

Arsenic's availability to plants is typically highest in coarse-textured soil having little CEC and lowest in clay that contains organic material, iron, calcium, and phosphate (NRCC, 1978). Cadmium appears to be taken up by plants in soil that has abnormally high cadmium residues. Towill et al.'s (1978) study showed no phytotoxic effects to plants for elevated chromium concentrations.

Like other metals, lead's bioavailability to plants is enhanced by reduced soil pH, organic matter, and iron oxides; and phosphorus content (NRCC, 1973). Studies have shown no convincing evidence that terrestrial vegetation is important in food-chain lead biomagnification (USEPA, 1980). Chang et al. (1983) observed that zinc uptake was lower in coarse, loamy soil than in fine loamy soil. The phytotoxic nature of copper to crop production has been studied relative to

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Table 8.12  
 Comparison of Phytotoxic Responses to Maximum Soil Concentrations  
 of ECPCs at Zone K Subzones

Parameter	Maximum Concentration (mg/kg)		Effects Level (mg/kg)	Organism	Measured Response	Study
	K-2/K-3	K-4				
Aluminum	44,700	11,200	50	white clover	Reduced seed establishment	Efroymsen (1997b) - Low
Antimony	27.9	3.3	5	Unspecified organism	Unspecified toxic effect	Efroymsen (1997b) -- Low
Arsenic	25.8	32.2	10	Spruce	Reduction in height	Efroymsen (1997b) - Moderate
			25 - 85	Canadian crops	Depressed crop yield	NRCC (1978)
			50	<i>Oryza sativum</i> , rice	75% decreased yield	NRCC (1978)
Barium	131	105	500	Barley and bush beans	Reduced growth	Efroymsen (1997b) - Low
Beryllium	1.6	0.65	10	Unspecified organism	Unspecified toxic effect	Efroymsen (1997b) - Low
Cadmium	1.5	4.0	4	Various wild and cultivated plants	Reduced growth	Efroymsen (1997b) - High
Chromium	77.3	21.5	1	Soybean, lettuce, tomato, oats	Reduced shoot weight	
Cobalt	10.1	5.4	20	Unspecified organism	Unspecified toxic effect	Efroymsen (1997b) - Low
Copper	1,020	32.0	47	Radish (seed germination)	EC <sub>50</sub>	Miller, et al. (1985)
			55	cucumber (seed germination)	EC <sub>50</sub>	Miller, et al. (1985)
			100	little bluestem/bush beans	Reduced growth/leaf weight	Efroymsen (1997b) - Low
Lead	481	259	50	seedlings/grasses	Reduced transpiration, leaf weight, growth	Efroymsen (1997b) - Moderate
			500	<i>Cassia</i> spp., weeds	90% reduced pollen germination	Krishnayya and Bedi (1986)
			800	corn plant	No elevated concentration in plants	Sadiq (1985)
Manganese	1,050	70.4	500	Bush beans	Reduced stem weight	Efroymsen (1997b) - Low

**Table 8.12**  
**Comparison of Phytotoxic Responses to Maximum Soil Concentrations**  
**of ECPCs at Zone K Subzones**

Parameter	Maximum Concentration (mg/kg)		Effects Level (mg/kg)	Organism	Measured Response	Study
	K-2/K-3	K-4				
Mercury	1.7	58.2	0.3	Unspecified organism	Unspecified toxic effect	Efroymsen (1997b) – Low
			34.9	Barley	Reduced germination	Panda et al. (1992)
Nickel	37.1	6.7	30	seedlings/crops	Reduced growth	Efroymsen (1997b) – Low
Selenium	4.7	0.71	1	grass/crops	Reduced growth	Efroymsen (1997b) – Low
Silver	1.2	--	2	Unspecified organism	Unspecified toxic effect	Efroymsen (1997b) – Low
Tin	284	--	50	bush beans	Reduced shoot weight	Efroymsen (1997b) – Low
Vanadium	92.2	16.0	2	Unspecified organism	Unspecified toxic effect	Efroymsen (1997b) – Low
Zinc	792	538	50	Seedlings/crops	Reduced growth	Efroymsen (1997b) – Moderate
			53	Radish (seed germination)	EC <sub>50</sub>	Miller, et al. (1985)
			61	cucumber (seed germination)	EC <sub>50</sub>	Miller, et al. (1985)
			100	<i>Acer rubrum</i> , red maple	Lethal to seedlings	USEPA (1987)
			100	<i>Quercus rubra</i> , red oak	Lethal to seedlings	USEPA (1987)

application rates (Hirst, et al. 1961). Little information is available on mercury's effects to herbaceous or woody plants (Eisler, 1987a).

Studies by USEPA (1980), Lee and Grant (1981), Wang and Meresz (1982), and Edwards (1983) generally conclude five points for PAH's effects to plants. First, plants can absorb PAHs from soil through roots to other parts. Second, lower molecular weight compounds are absorbed more readily than higher weight compounds. Third, aboveground parts have higher residue concentrations which are most likely attributable to airborne deposition. Fourth, PAH-induced phytotoxic effects are rare and fifth, higher plants can catabolize benzo(a)pyrene and possibly other PAH compounds. Plant uptake of PAHs is therefore not likely to be a significant pathway to terrestrial vertebrate species.

For PCBs, Klekowski (1982) suggested that there was no evidence of genetic damage to terrestrial plants at a PCB-contaminated site in Massachusetts.

For dioxins, Isensee and Jones (1971) indicated that isomer uptake by terrestrial plants was less readily comparable to uptake by aquatic plants, and studies by Blair (1973) and Ramel (1978) considered uptake of 2,3,7,8-TCDD in soil by vegetation to be negligible.

Eisler (1990) noted that there was little information available on phytotoxicity of chlordane and that there was little evidence to indicate accumulation by crop plants. In soil, chlordane is mostly immobile with only a limited capacity for translocation into edible portions of food crops (NRCC, 1975).

**Subzone K-1**

No data are available to determine the effects of contaminants to hydrophytic vegetation. As a qualitative assessment, it appears that the vegetation within this subzone differs little from plants found in similarly saline regimes throughout the Charleston Harbor estuary.

**Subzone K-2/K-3**

The maximum levels of arsenic, copper, and zinc (25.8 mg/kg, 1,020 mg/kg, and 792 mg/kg, respectively) detected in this subzone exceed concentrations reliably found to cause such effects as lethality to woody seedlings, EC<sub>50</sub> (various effects) to herbaceous plant seed germination, and depressed crop yield. These findings are summarized in Table 8.12. Phytotoxic effects from organics were not available but a survey of the area showed no observable effects to vegetation.

**Subzone K-4**

The maximum levels of arsenic, cadmium, and zinc (32.2 mg/kg, 4.0 mg/kg, 538 mg/kg) detected in this subzone exceed the reliable effects levels from Table 8.12. The possible adverse effects from these metals includes both lethality to woody seedlings and EC<sub>50</sub> (various effects) to herbaceous vegetation. Again, phytotoxic effects from organics were not available but there no stressed vegetation (maintained grass) was observed.

**8.9 Uncertainty**

General inherent uncertainties are associated with risk assessments at the screening level. Table 8.13 provides information on the types of uncertainties that could impact final risk calculations. To provide a quantitative perspective, a plus (+) or minus (-) is associated with each uncertainty. A plus suggests that the uncertainty has most likely resulted in an overestimation of risk. A minus suggests it has most likely resulted in an underestimation of risk. When both signs are given, the uncertainty has the potential to either underestimate or overestimate ecological risk.

**Table 8.13**  
**Uncertainties Associated with the Ecological Risk Assessment**  
**Zone K**

<b>Uncertainty Issue</b>	<b>Affect on ERA</b>
Chemical degradation for selected ECPCs	+
Specific effects to biota within study area	+ or -
Effects data not available on some ECPCs	-
Synergistic or antagonistic effect of ECPCs	+ or -
Assumption for effects from similar compounds	+ or -
Use of related species for risk to selected receptor species	-
Dermal or inhalation pathways not evaluated	-
Maximum concentrations used in exposure model	+
Assumed BAFs due to lack of information	+ or -
Actual occurrence of wildlife species within contaminated area	+
Use of literature generated ingestion rates	+ or -
Exposure assumed to be 100%	+
Actual bioavailability not measured (assumed to be 100%)	+
Use of LOAEL as basis of risk determination	+ or -
The most bioavailable form of a chemical was used in the screening assessment	+

**Notes:**

+ = May result in overestimate of risk.

- = May result in underestimate of risk.

Both signs indicate issue may result in either an overestimate or underestimate of risk.

**8.10 Risk Summary**

Potential risks for ecological receptors were evaluated for ECPCs in Zone K surface soil and sediments. Risks associated with exposure to ECPCs in surface soil were evaluated for terrestrial wildlife based on a model that predicts the amount of contaminant exposure via the diet and incidental ingestion of soil. Comparison of predicted doses for representative wildlife species with doses representing thresholds for both chronic and subchronic TRVs is the basis of the risk evaluation. Evaluation of risks for soil invertebrates and plants was based on qualitative

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comparisons to literature effects-levels for taxonomic groups similar to those potentially occurring at Zone K. Risks for aquatic organisms were evaluated by calculating HQs from both SSVs and PRGs that are either promulgated or proposed by federal and state regulatory agencies.

### **Benthic Organisms**

No organic constituents exceeded detection limits in sediments at Subzone K-1. Because no background data are available to determine inorganic ECPCs, all were compared to effects levels for inclusion in the ERA. When compared to SSVs, three metals (arsenic, chromium, and nickel) produced HQs between one and three, resulting in an SSV HI of 6.20. No PRG HQs exceeded 1, and the cumulative PRG HI was only 1.73. The sediments at K-1 are constantly shifting and the concentrations of contaminants and physicochemical parameters affecting bioavailability may vary significantly (SCDHEC, 1990). The SCDHEC report states that their sediment sampling point located directly in front of CNC exhibited "...erratic changes in surficial sediments from one sampling event to the next." Also, this report states that the salinity regime at this location is variable due to weather conditions and, to a lesser degree, tidal influence (vertical stratification). This variability may be responsible for fluctuations in bioavailability due to "salting-out" effect, that is, as dissolved chemicals flow into higher salinity conditions, they precipitate out of the water column and tend to bind to organic matter in the sediments. They therefore become less bioavailable. Following this trend, any risk from CNC would be expected to decrease proportionally with river-mile as the Cooper River advances to the Atlantic Ocean.

### **Infaunal Invertebrates**

The qualitative assessment for terrestrial infauna indicates that risk may be present at both terrestrial subzones. Potential adverse effects, including decrease in cocoon production and lethality to earthworms, are predicted, based on the concentrations of aluminum, chromium, copper, mercury, vanadium, and zinc at Subzone K-2/K-3. Except for vanadium, the same metals pose potential risk to terrestrial invertebrates at Subzone K-4. Mercury concentrations reported at Subzone K-4 indicate significant risk, particularly at the sewage drying pits.

## **Terrestrial Wildlife**

Numerous compounds, both inorganic and organic, have been identified as potentially contributing to adverse effects to ecological receptors as summarized in Tables 8.4 (a and b) and 8.5 (a and b). A low level of chronic risk is predicted for the cottontail rabbit at Subzone K-2/K-3, based on exposure to arsenic and copper. In addition to arsenic and copper, subchronic effects to the rabbit are also predicted for cadmium and lead. With HQs only slightly exceeding 1, arsenic and cadmium pose minimal subchronic effects to both the shrew and robin, respectively.

Subzone K-4 presents a low level of chronic risk to the American robin due to elevated mercury concentrations. While no HQs for any one metal exceeds 1, the cumulative effect of several HQs near 1 result in an overall low chronic risk to the cottontail rabbit. Arsenic, cadmium, mercury, lead, and Aroclor 1260 each pose low to moderate subchronic risk to one or more selected representative species.

## **Vegetation**

Potential adverse effects, including lethality to woody seedlings and  $EC_{50}$  to herbaceous plant seed germination have been identified at Subzone K-2. The maximum concentrations of several inorganic compounds in the surface soil at Subzone K-4 exceed their respective effects level and may cause death to woody seedlings and  $EC_{50}$ -effects to herbaceous vegetation. It should be noted, however, that no evidence of stressed vegetation has been identified during frequent trips to these sites.

**9.0 RECOMMENDATIONS FOR CORRECTIVE MEASURES**

According to Permit Condition IV.E., Corrective Action Plan, SCDHEC will review the final RFI report and notify CNC if further investigations, corrective actions, or a corrective action study or plan are needed to meet R.61-79.264.101 requirements for corrective actions at SWMUs or AOCs. This section on recommendations and a subsequent section on conclusions are in response to SCDHEC’s comment that the RFI report should address whether the extent of contamination has been defined and then propose recommended actions for the SWMUs and AOCs. The extent of contamination, as determined by the formal risk assessment process, is delineated in figures in Section 10, Site-Specific Evaluations. Recommended actions for the SWMUs and AOCs are summarized in a table in Section 11, Conclusions.

The CNC project team established initial action levels (ALs) at 1E-6 residential risk and/or 100 ppm TPH to assess whether a hypothetical Corrective Measures Study would be required. In lieu of these initial ALs, industrial cleanup levels are acceptable if CNC can demonstrate that appropriate and effective institutional controls could be maintained at the site. In addition, any unacceptable ecological risk, as determined by the ERA and defined by the SCDHEC, could also be used to initiate and drive CMS efforts.

The following discussions, in conjunction with Sections 10 and 11, address each site relative to the initial ALs and the need for additional investigation and/or CMS. The potential remedies are based on current data and remedies presented in the RFI work plan, yet final remedies will be evaluated and proposed in the CMS report. The steps to be conducted during a typical CMS are also reviewed.

**9.1 Introduction**

Any CNC CMS will be conducted according to standard methods presented in the USEPA guidance document *RCRA Corrective Action Plan* (USEPA, 1994g). The standard methodology

has been presented in the comprehensive CMS work and project management plans, and will facilitate collecting necessary data, identifying and evaluating potential alternatives, and presenting the final remedial alternative(s) by establishing a set procedure for evaluation and assessment.

The results of risk management decisions by the project team will determine which sites actually become candidates for the CMS process. However, as a result of risk management efforts, it is possible that some sites at which contamination exceed CNC ALs will not be elevated into the CMS process. Cleanup objectives, reuse scenarios, and risk management issues will be instrumental in defining the course of the CMS.

For sites that may require remedial action, it will be the Navy’s responsibility, in conjunction with SCDHEC and USEPA, to select the final cleanup method from the options presented by the CMS. Public participation and input will be solicited during the CMS.

To establish this procedure, the CMS work plan will outline basic elements of the CMS report, which are listed below:

<b>CMS Report Outline</b>	14
1.0. Introduction	15
2.0 Site Description	16
3.0 Remedial Objectives	17
4.0 Identification and Screening of Technologies	18
5.0 Development and Evaluation of Alternatives	19
6.0 Recommendation	20
7.0 Public Involvement Plan	21
8.0 References	22
9.0 Signatory Requirement	23

Each required element of the CMS effort will be detailed in the CMS work plan to define the: 1

- Remedial technology identification and screening process 2
- Base "pool" of technologies to be screened and evaluated for each adversely impacted 3  
medium 4
- Nine evaluation criteria for the assembled remedial alternatives 5
- Minimum requirements of the CMS report 6

Issues to be described under each element are: 7

- The overall purpose of the CMS for CNC. 8

*SWMUs and AOCs at CNC will be discussed in the CMS work plan on a zone-wide basis, 9  
where possible. Activities, contaminants, and issues specific to each zone will be 10  
discussed. The CMS work plan will identify: specific sites to be addressed in the CMS, any 11  
focused approach (such as naming a primary technology in lieu of the full screening), 12  
additional data requirements, and the subsequent cleanup goals. 13*

- Corrective action objectives for CNC, including how target media cleanup standards, 14  
points of compliance, or risk assessments will be established and achieved for each site, 15  
zone, and activity. 16

*Cleanup standards will be developed for each site, zone, or activity using the designated 17  
exposure scenario (residential, commercial, or industrial) for that area and relative to 18  
receptor type, human or ecological. BRAs, conducted in conjunction with the RFI for each 19  
zone, will be used to identify areas as defined by the project team with unacceptable 20  
risk/hazard per the designated exposure scenario. During the CMS, areas with 21*

*unacceptable risk to human and ecological receptors 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 CNC RFI work plans will be used in the CMS work plan to present the "pool" of technologies initially evaluated in a 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, and areal extent of contamination, number and type of contaminants, remedial goals, future land use scenarios, and adjacent remedial activities. In addition, if advantageous to the CMS effort, the CMS work plan will present the requirements for implementing Corrective Action Management Units (CAMUs).*

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

- The general approach to investigating and evaluating potential corrective action measures.

*Corrective measures alternatives will be evaluated using four primary and five secondary criteria:* 1  
2

***Primary*** 3

- *Protect human health and the environment.* 4  
5
- *Attain media cleanup standards set by the implementing agency.* 6
- *Control the source of releases to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment.* 7  
8
- *Comply with all applicable standards for management of wastes.* 9

***Secondary*** 10

- *Long-term reliability and effectiveness.* 11
- *Reduction in waste toxicity, mobility, or volume.* 12
- *Short-term effectiveness.* 13
- *Implementability.* 14
- *Cost.* 15

*Alternatives will be discussed and compared according to these criteria, which are used to gauge the alternatives' effectiveness and implementability.* 16  
17

- If warranted, a separate treatability study (TS) work plan will detail how pilot, laboratory, and/or bench-scale studies will be selected, performed, evaluated, reported, and transferred to full scale. 18  
19  
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*Treatability studies will be implemented when complex or innovative treatment alternatives are being considered. For example, air stripping technologies usually do not require treatability studies to determine optimal processes for treating groundwater. However, ultraviolet (UV)/oxidation, an innovative technology, may require extensive treatability testing to determine oxidant dosages and retention times.*

*The basic structure and objectives of a TS will be discussed in a technical memorandum or TS work plan to follow the CMS work plan. Objectives may include dosages, percent reduction in contaminants, 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.*

- How the statement of basis/responses to comments or permit modifications are to be processed.

*The statement of basis and responses to comments will be handled through Southern Division Naval Facilities Engineering Command (SOUTHDIV). The Comprehensive Long-Term Environmental Action Navy (CLEAN) Contractor, EnSafe, Inc., will assist the U.S. Navy in preparing the statement of basis and responses to comments. Permit modifications will be managed through SOUTHDIV and the Caretaker Site Office (CSO). According to the existing RCRA permit (May 4, 1990, Appendix C, Facility Submission Summary), a permit modification is required to prepare and conduct a Corrective Action Study/Plan.*

- Overall project management, including overall approach and levels of authority, lines of communication, project schedules, and personnel.

*The overall project management is the responsibility of SOUTHDIV for the CSO. 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 its amendments. In general, the CSO is responsible for ensuring that conditions of the permit are satisfied with the ultimate responsibility held by the SOUTHDIV Commander.*

*The budget for conducting the CMS is defined by SOUTHDIV and funds are provided by the U.S. Congress. Personnel to conduct the CMS will be assigned by EnSafe, Inc. on an as-needed basis for project- and zone-specific tasks. EnSafe, Inc. will manage the CMS effort through the EnSafe Charleston, South Carolina, office.*

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

*EnSafe, Inc. will use trained, experienced, and qualified registered engineers and geologists 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
- Land use/risk assessment
- Base-wide treatment facilities
- Presumptive remedies

CAMUs and temporary units (TUs) will be used where necessary, and if advantageous, to facilitate storage and treatment during remediation activities. 1  
2

### **9.3 Proposed Remedy** 3

Before selecting and implementing corrective measures for releases, environmental and cost-effectiveness goals must be established. Typically, the environmental goal is to reduce exposure via direct contact with air, groundwater, and surface water pathways to some level of acceptability. The cost-effectiveness goal is usually to achieve the environmental goals using the least costly alternative that is both technically feasible and reliable. 4  
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### **9.4 Development of Target Media Cleanup Goals** 9

Section 9.4 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses the development of target media cleanup goals for CNC. 10  
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#### **9.4.1 Groundwater Cleanup Goals** 12

Section 9.4.1 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses groundwater cleanup goals for CNC. 13  
14

#### **9.4.2 Soil Cleanup Goals** 15

Section 9.4.2 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses soil cleanup goals for CNC. 16  
17

#### **9.4.3 Surface Water and Sediment Cleanup Goals** 18

Section 9.4.1 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses surface water and sediment cleanup goals for CNC. 19  
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**9.4.4 Air Cleanup Goals** 1

Section 9.4.4 of the final Zone A RFI Report (EnSafe, August 1998) discusses air cleanup goals for CNC. 2  
3

**9.5 Identification and Screening of Corrective Measure Technologies** 4

The initial step in assembling corrective measures alternatives is to identify and screen the corrective measures technologies that apply to the site. Technologies are typically screened using waste- and site-specific characteristics. This section addresses the range of technologies to be assessed for each site, the screening process, and screening criteria. 5  
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7  
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**9.5.1 Identification of Corrective Measure Technologies** 9

Each site will be assessed using the cleanup standard methodology described in Section 9.2. An initial list of impacted media and COCs had been identified in the RFI. For each site, the major contaminants present have been grouped into at least one of the following categories: 10  
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- Chlorinated volatiles 13
- Nonchlorinated volatiles 14
- Chlorinated semivolatiles 15
- Nonchlorinated semivolatiles 16
- Pesticides 17
- PCBs 18
- Dioxins 19
- Inorganic compounds (includes metals) 20

These contaminant groupings and the sites at which COCs have been identified are listed in Table 9.1. This table lists *possible* remedial technologies for the sites. These lists of *possible* remedial technologies do not consider potential single site multitechnology interference. Remedial technologies in this table are described in Section 9.5.2 of this document. 21  
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23  
24

*Zone K RCRA Facility Investigation Report  
 Charleston Naval Complex  
 Section 9 – Recommendations for Corrective Measures  
 Revision No: 0*

**Table 9.1  
 Sites Containing COCs, Types of COCs,  
 and Possible Remedial Technologies**

<b>Site</b>	<b>Type of Compounds</b>	<b>Possible Remedial Technologies</b>
SWMU 162 - Soil	Aluminum, arsenic, mercury and BEQs	a) No Action b) Intrinsic remediation and monitoring c) Containment by capping d) Excavation and landfill, if RCRA-nonhazardous waste e) Insitu, chemical and physical treatment f) Exsitu, chemical and physical treatment
SWMU 163 - Soil	Arsenic, and BEQs	a) No Action b) Intrinsic remediation and monitoring c) Containment by capping d) Excavation and landfill, if RCRA-nonhazardous waste e) Insitu, chemical and physical treatment f) Exsitu, chemical and physical treatments
SWMU 163 – Groundwater	Arsenic, bis(2-Ethylhexyl)phthalate trichloroethene, tetrachloroethene, 1,2 Dichloroethene	a) No Action b) Intrinsic, chemical, physical, and biological remediation and monitoring c) Exsitu, chemical, physical and biological treatment
SWMU 164 - Soil	Arsenic, and BEQs	a) No Action b) Intrinsic remediation and monitoring c) Containment by capping d) Excavation and landfill, if RCRA-nonhazardous waste e) Insitu, chemical and physical treatment f) Exsitu, chemical and physical treatment
AOC 693 and AOC 694 - Soil	Aluminum, antimony, arsenic, chromium, vanadium, and BEQs	a) No Action b) Intrinsic remediation and monitoring c) Containment by capping d) Excavation and landfill, if RCRA nonhazardous waste e) Insitu, chemical, physical and biological treatment f) Exsitu, chemical, physical and biological treatment
AOC 693 and AOC 694 - Groundwater	Arsenic, cadmium, and manganese	a) No Action b) Intrinsic remediation and monitoring c) Exsitu, chemical and physical treatment
AOC 696 - Soil	Arsenic and Arochlor-1260	a) No Action b) Intrinsic remediation and monitoring c) Containment by capping d) Excavation and landfill, if RCRA nonhazardous waste e) Insitu, chemical and physical treatment f) Exsitu, chemical and physical treatment

**Table 9.1**  
**Sites Containing COCs, Types of COCs,**  
**and Possible Remedial Technologies**

Site	Type of Compounds	Possible Remedial Technologies
AOC 698 - Soil	Arsenic, BEQs, and heptachlor epoxide	a) No Action b) Intrinsic remediation and monitoring c) Containment by capping d) Excavation and landfill, if RCRA nonhazardous waste e) Insitu, chemical, physical and biological treatment f) Exsitu, chemical, physical and biological treatment
AOC 698 - Groundwater	Benzene, alpha-BHC, and delta-BHC	g) No Action h) Intrinsic remediation and monitoring c) Insitu, chemical, physical and biological treatment d) Exsitu, chemical, physical and biological treatment

Table 9.2 lists nontreatment options for soil, groundwater/leachate, sediment, surface water, and air. These options include removal, containment, and disposal. Table 9.3 lists types of compounds and the types of treatment for each media. These tables supply general waste management options for various situations.

The following example presents a common situation where more than one type of contaminant is identified at a site. The example site contains volatile and semivolatile organic compounds in soil, which have been identified at concentrations slightly exceeding risk-based remediation goals. A containment alternative might include fencing to restrict unauthorized access, aerating the contaminated area, adding fertilizer and enriched soil, seeding to maintain a vegetative cover to control surface water runoff, and monitoring. This containment approach seeks to reduce health risks through land management and natural attenuation.

**Table 9.2**  
**Removal/Containment/Disposal Options**

Action	Soil	Groundwater/Leachate	Sediment	Surface Water	Air
Removal	<ul style="list-style-type: none"> <li>Excavation</li> </ul>	<ul style="list-style-type: none"> <li>Groundwater extraction</li> <li>Leachate collection</li> </ul>	<ul style="list-style-type: none"> <li>Dredging</li> </ul>	<ul style="list-style-type: none"> <li>Diversion</li> <li>Pumping</li> </ul>	NA
Containment	<ul style="list-style-type: none"> <li>Institutional controls</li> <li>Capping</li> <li>Storm water controls</li> <li>Long-term monitoring</li> <li>Intrinsic (natural) bioremediation/attenuation</li> </ul>	<ul style="list-style-type: none"> <li>Slurry wall</li> <li>Gradient controls</li> <li>Long-term monitoring</li> <li>Monitored natural attenuation</li> </ul>	<ul style="list-style-type: none"> <li>Berms/diversion</li> <li>Storm water controls</li> </ul>	<ul style="list-style-type: none"> <li>Diversion</li> </ul>	NA
Disposal	<ul style="list-style-type: none"> <li>Landfill</li> </ul>	<ul style="list-style-type: none"> <li>POTW</li> <li>NPDES discharge</li> <li>Land application</li> </ul>	<ul style="list-style-type: none"> <li>Landfill</li> </ul>	<ul style="list-style-type: none"> <li>POTW</li> <li>NPDES</li> <li>Subsurface Injection</li> </ul>	Discharge via air permit

*Notes:*  
 POTW = Publicly Owned Treatment Works  
 NPDES = National Pollutant Discharge Elimination System  
 NA = Not Applicable

**Table 9.3  
 Treatment Technology Options**

Contaminant Type	Groundwater/ Leachate			
	Soil	Leachate	Sediment	Air
Chlorinated volatiles	Soil washing Incineration Thermal desorption Bioremediation SVE	Chemical oxidation Bioremediation Adsorption Air stripping Air sparging Treatment walls In-well air stripping UV/ozone oxidation	Same as soil	Oxidation
Nonchlorinated volatiles	Soil washing Incineration Thermal desorption SVE Bioremediation Steam extraction	Oxidation Bioremediation Adsorption Air stripping In-well air stripping Air sparging	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 Sorptions	Same as soil	Oxidation Adsorption
Pesticides	Solidification/stabilization Soil washing Bioremediation Incineration Thermal desorption	Oxidation Bioremediation Sorptions	Same as soil	Oxidation
PCBs	Solidification/stabilization Soil washing Dehalogenation Incineration Thermal desorption	Oxidation Dehalogenation Incineration	Solvent extraction Dehalogenation Solidification/stabilization	Oxidation
Dioxins	Incineration Solidification/stabilization	Oxidation	Same as soil	Oxidation
Inorganics	Solidification/stabilization Soil washing Vitrification	Chemical precipitation Adsorption Sedimentation Filtration	Same as soil	Filtration Scrubbers Adsorption

**Notes:**

SVE = Soil Vapor Extraction  
 UV = Ultraviolet

As discussed in previous sections, COCs and cleanup goals may vary between scenarios because 1  
each site may be evaluated under both residential and industrial reuse scenarios. Two lists of 2  
applicable technologies may be developed for each site, one for each scenario. 3

Several treatment technologies such as incineration and low temperature thermal desorption/high 4  
temperature thermal desorption (LTTD/HTTD) for soil or air sparging for groundwater may 5  
produce an offgas that could require additional treatment or control, and could be subject to local 6  
air permitting requirements. 7

### **9.5.2 Description of Prescreened Technologies** 8

The following paragraphs describe some of the demonstrated technologies that appear to be the 9  
most feasible for the CMS. Non-demonstrated, (innovative or emerging), technologies may also 10  
be identified and evaluated in the CMS, as warranted. These potential technologies are divided 11  
into four categories: insitu soil, exsitu soil, insitu groundwater, and exsitu groundwater. 12

Other remedial alternatives not listed may also be presented in the CMS work plan and report. 13

### **Capping** 14

#### ***Insitu Soil*** 15

A layer of clay, synthetic membrane, soil-vegetative cover, or asphalt is applied to prevent human 16  
exposure to contaminants. Capping also helps to prevent rainwater infiltration and water 17  
percolation, which may transport contaminants (via leaching) from the soil to the groundwater. 18  
This solution may be the most economical and most protective of human health for certain sites. 19

**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 introduced to the soil. In many cases, nutrients can be supplemented to enhance this process. Nitrate and phosphate are often the limiting nutrients in the soil at a site. However, an insufficient electron acceptor is the greatest variable limiting bioremediation. The most common electron acceptor is oxygen for aerobic biodegradation. For these sites, it is likely that bioremediation via natural attenuation is a good candidate for some compounds. Typically nonchlorinated VOCs and nonchlorinated SVOCs are good candidates for this technology.

**Solidification/Stabilization**

This technology consists of mixing reagents with soil to prevent contaminants from leaching into the groundwater below. This technology immobilizes contaminants via physical or chemical means, preventing migration. However, this technology does not remove or reduce contaminant mass.

***Exsitu Treatment of Soil***

All exsitu soil treatments require excavation to another location or bringing the material to the surface. Typically heavy equipment is used to move the soil. If contaminated soil is limited in volume and considered RCRA-nonhazardous waste, it may be feasible to dispose of it in a permitted landfill. If sites have a limited area of contaminated soil, it may be feasible to remove the soil with heavy equipment and treat it exsitu.

### **Soil Washing**

Soil washing physically separates soil particles by size, then treats the smaller grains with solutions that desorb the contaminants. The resulting solution containing contaminants requires treatment by another technology. In general, small soil particles such as clay and silt have a higher total organic carbon content, which tends to absorb hydrophobic compounds such as chlorinated contaminants. This technology essentially 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. This technology is combined with incineration or another type of offgas treatment. Soil is excavated and placed into the treatment systems for either high- or low-temperature desorption to separate the contaminants from the soil, not to destroy the chemical. The volatilized contaminants enter an air stream and travel to some type of gas treatment device for contaminant destruction and/or collection. Low-temperature (200 to 600°F) thermal desorption (LTTD) only applies to VOCs, while high-temperature (600 to 1000°F) thermal desorption (HTTD) applies to SVOCs, PAHs, PCBs, and pesticides.

### **Thermal Destruction/Incineration**

This technology is used with exsitu soil technologies. Typically the contaminant is removed from the soil matrix and transferred to an air stream. The air stream is treated with the thermal destruction on a catalyst or burned in an incinerator, or a combination of the two. High temperatures (1,800 to 2,000°F) are required to destroy organics such as PCBs, dioxins, furans, and pesticides.

**Solidification/Stabilization**

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This technology is similar to the insitu methods; however, soil is excavated before being mixed with the chemical reagents or physical binding agents such as concrete.

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**Bioremediation**

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*Insitu Groundwater Treatment*

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Bioremediating contaminants in groundwater may require adding nutrients (phosphate, nitrate, etc.) and an electron acceptor (e.g., oxygen, nitrate) to the groundwater via injection wells. Typical electron acceptor addition comes from either oxygen via air sparging and/or nitrate with the addition of other nutrients.

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**Intrinsic Remediation**

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This technology, also called *monitored natural attenuation*, simply allows naturally occurring bioremediation, oxidation, hydrolysis, dispersion, and advection to occur. No nutrients or electron acceptors are added. The site should be monitored to observe contaminant mass reduction. Many case studies have demonstrated the effectiveness of this technology for TPH and chlorinated solvent-contaminated sites.

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*Exsitu Treatment of Groundwater*

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Any exsitu treatment of groundwater requires a system of extraction wells and pumps to deliver the groundwater to an aboveground treatment location. However, groundwater extraction and subsequent exsitu treatment (i.e., pump and treat) is not a preferred remedial alternative of the Navy.

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### **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, chemical additives can chelate the metal and precipitate it out of the solution. In either case, the contaminants can then be removed by filtration.

### **Air Stripping**

Groundwater can be extracted and pumped to a nearby publicly owned treatment works. While the contaminated groundwater is in the aeration basin of the water treatment plant, volatile compounds with a high Henry's law constant will undergo mass transfer from the water to the air. Steam can be used to heat the groundwater, causing additional organics to volatilize. These air vapors can be treated with an appropriate technology or discharged under an air permit.

### **Chemical Oxidation/UV-Ozone**

Ozone is one of the most effective chemical oxidizers. Most organic compounds can be oxidized. Because ozone can be generated with UV light sources, groundwater can be directed 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 are typically recalcitrant to biological oxidation, such as chlorinated organics, can be successfully oxidized with ozone.

Effective light transmission is essential for this process. Water with high turbidity is not a good candidate for UV ozonation. Filtration and/or gravity-induced sedimentation would probably be required for extracted groundwater at CNC due to the silty soil.

**Activated Sludge**

Activated sludge treatment of wastes typically 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 their limitations to show why certain CMS technologies may prove infeasible to implement, given existing site- and waste-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 primarily include the current and future use of the site or SWMU/AOC unit. Other characteristics include type of 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 more technology lists to be evaluated for residential and/or Navy-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, PCBs, dioxins and inorganic elements. The presence of halogenated compounds, such as chlorinated benzenes or trichloroethylene, is also critical.

Where multiple types of contamination are present at a site (such as PCBs and dioxins, or pesticides and volatiles), certain technologies may be eliminated from consideration due to their inability to treat wastes effectively. For example, soil-vapor extraction typically is not used on pesticide sites or sites with low vadose-zone permeability, although it is usually very effective on most volatiles. If both contaminants must be treated concurrently, soil vapor extraction (SVE) would not be considered further.

Where appropriate, contaminant concentrations will be considered to screen remedial technologies (i.e., concentrations may be too high or too low for a technology to be effective).

## **Technology Limitations**

Technology limitations are used to assess the implementation feasibility of a particular technology and may include technical restrictions on application, including the presence of a shallow water table, clay and fines content, etc. Additional technology limitations include minimum or maximum process volumes, for example technologies that are cost-effective only when contaminated soil volumes are more than 1,000 cubic yards. Other limitations to be assessed include effectiveness in meeting treatment goals and remedial time.

Technologies meeting this screening criterion may differ from residential to Navy-specified use 1  
scenarios due to differences in cleanup goals for each scenario. 2

**9.6 Development of Corrective Measures Alternatives 3**

Section 9.6 of the final Zone A RFI Report (EnSafe, August 1998) discusses the development of 4  
corrective measures alternatives for CNC. 5

**9.7 Evaluation of Corrective Measure Alternatives 6**

Section 9.7 of the final *Zone A RFI Report* (EnSafe, August 1998) evaluates corrective measures 7  
alternatives for CNC. 8

**9.7.1 Protect Human Health and the Environment 9**

Section 9.7.1 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses an alternatives 10  
ability to protect human health and the environment at CNC. 11

**9.7.2 Attain Media Cleanup Standards Set by the Implementing Agency 12**

Section 9.7.2 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses an alternative's 13  
ability to attain media cleanup standards set by the implementing agency for CNC. 14

**9.7.3 Control the Sources of Releases 15**

Section 9.7.3 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses an alternative's 16  
ability to control the source of releases for CNC. 17

**9.7.4 Comply with All Applicable Standards for Management of Wastes** 1

Section 9.7.4 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses an alternative’s 2  
ability to comply with all applicable standards for the management of wastes for CNC. 3

**9.7.5 Other Factors** 4

Section 9.7.5 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses other factors (e.g. 5  
the secondary criteria) to be considered in choosing a remedial alternative for a site at CNC. 6

**9.8 Ranking the Corrective Measure Alternatives** 7

Section 9.8 of the final *Zone A RFI Report* (EnSafe, August 1998) discusses the process of ranking 8  
the assembled corrective measures alternatives for a site at CNC. 9

**COMPREHENSIVE LONG-TERM  
ENVIRONMENTAL ACTION NAVY  
CHARLESTON NAVAL COMPLEX  
NORTH CHARLESTON, SOUTH CAROLINA  
CTO-029**



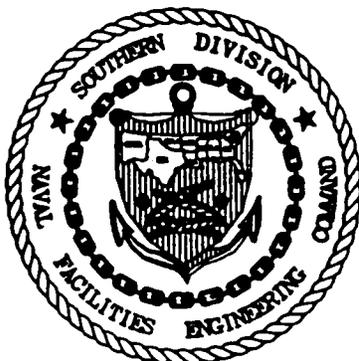
**ZONE K  
RCRA FACILITY INVESTIGATION REPORT**

**VOLUME III OF V  
SECTIONS 11 TO 13**

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SOUTHERN DIVISION  
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**Release of this document requires prior notification of the Commanding Officer of the Southern Division, Naval Facilities Engineering Command, North Charleston, South Carolina.**

**11.0 CONCLUSIONS AND PRELIMINARY RECOMMENDATIONS**

The RFI in Zone K 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 *CNC Comprehensive RFI Work Plan*, regulatory guidance, and as required by the Part B permit. The CNC 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 for no further action, additional evaluation under the CMS, or 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-06 residential ILCR and the hazard index is <1. Potential risk to ecological receptors is low based on the criteria described in Section 11.9.
- 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 a NFA or CMS recommendation.

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. This means some sites currently recommended for CMS may not require any 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.

A summary of the preliminary recommendations for all the sites investigated in Zone K is included in Table 11.1.

**Table 11.1**  
**Zone K Site Conclusions and Preliminary Recommendations**

<b>Site Designation</b>	<b>Conclusion/Recommendations</b>
SWMU 161	No Further Action
SWMU 162	Recommended for inclusion in the CMS
SWMU 163	Recommended for inclusion in the CMS
SWMU 164	Recommended for inclusion in the CMS
SWMU 185	Review of addendum pending
AOC 693/694	Recommended for inclusion in the CMS
AOC 695	RFI Investigatory Designation will be assigned in the Zone J RFI
AOC 696	Recommended for inclusion in the CMS
AOC 698	Recommended for inclusion in the CMS
SWMU 166	Review of addendum pending

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 SWMU 161**

SWMU 161 consists of a gravel parking lot, a vehicle maintenance and wash bay with parts washer, oil-water separator and waste oil tank, and Building 2505 (Figure 10.1.1).

Based on the analytical results for samples collected at SWMU 161 and the resulting human health risk assessment, no COCs requiring further evaluation through the CMS process were identified for the upper soil interval or shallow groundwater. Although low concentrations of VOCs and SVOCs were detected in subsurface soil samples, these detections were localized and well below their respective SSLs. Furthermore, none of these compounds were detected in the numerous groundwater samples collected in the area, particularly downgradient shallow well 166016. As a result, no further action is recommended for SWMU 161.

**11.2 SWMU 162**

SWMU 162 consists of a former sludge drying field at Naval Annex. This site was used for dewatering wastewater treatment sludge from an Air Force-operated sewage treatment plant.

The site is recommended for additional evaluation under the CMS based on risk greater than 1E-06 and a cumulative HI greater than 1.0 in surface soil. Table 11.2 identifies the affected media, the risk/hazard, and the chemicals driving the risk/hazard.

**Table 11.2  
 SWMU 162  
 Conclusion Summary**

Affected Media	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk/Hazard
Surface soil	Yes - ILCR = 2E-05 Yes - HI = 3.0	BEQs, aluminum, arsenic and mercury

BEQs were detected at three sample locations in only the upper-interval samples (162SB001, 002, and 003). The highest concentration was at 162SB002 in the vicinity of the former sewage treatment facility. Arsenic exceeded both its screening concentrations at only one location (162SB00901). Mercury was present at concentrations above its screening concentrations at two locations in the upper-interval samples (162SB001 and 002). Aluminum did not exceed its RBC or background concentration, although it was included as a contributor to risk-based Wilcoxon rank sum test results.

### 11.3 SWMU 163

SWMU 163 consists of a 10-foot x 10-foot x 2-foot uncovered concrete pit, approximately 100 feet north of Building 2513 at Naval Annex (Figure 10.3.1). The pit was used as a less-than-90-day accumulation area for hazardous waste generated at the facility.

The site is recommended for additional evaluation under the CMS based on risk greater than 1E-06 in surface soil and groundwater and a cumulative HI greater than 1.0 in groundwater. Table 11.3 lists the affected medium, the risk/hazard, and the chemical(s) that drive the risk/hazard.

**Table 11.3**  
**SWMU 163**  
**Conclusion Summary**

<b>Affected Medium</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk</b>
Surface soil	Yes - ILCR = 2E-05 No - HI = 0.4	BEQs and Arsenic
Shallow Groundwater	Yes - ILCR = 1E-04 Yes - HI = 11	Arsenic, BEHP, TCE, PCE, and 1,2 Dichloroethene

BEQs were detected in only one sample collected at SWMU 163 (163SB00101). Arsenic was detected at its highest concentration in the upper-interval sample at location 163SB002.

Arsenic was not detected in the second through fourth round groundwater samples. TCE, PCE, BEHP, and 1,2 Dichloroethene were detected in the fourth (March 1999) sampling round.

**11.4 SWMU 164**

SWMU 164 consists of an abrasive blasting booth formerly located in Building 2556 at Naval Annex. Blasting was conducted to remove paint from various types of equipment.

The site is recommended for additional evaluation under the CMS based on risk greater than 1E-06. Table 11.4 lists the affected medium, the risk/hazard, and the chemical(s) that drive the risk/hazard.

**Table 11.4  
 SWMU 164  
 Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk/Hazard
Surface soil	Yes - ILCR = 5E-05 No - HI = 0.56	BEQs and Arsenic

BEQs exceeded the RBC in three upper-interval soil samples (164SB004, 005, and 008). The 164SB004 sample contained the highest BEQ concentration. None of the upper-interval detections of arsenic were over one order of magnitude greater than the screening concentrations. Arsenic was at its highest concentration at 164SB002.

**11.5 SWMU 185**

SWMU 185, originally identified in the work plan as SWMU 166, consists of the sanitary sewer, and septic tank system, serving the Naval Annex excluding the Air Force housing area. The RFI for SWMU 185 has been submitted as an addendum along with SMU 166 and will be incorporated into this document upon review and revision of the addendum.

**11.6 AOC 693 and AOC 694**

AOC 693 consists of former Building 117, a fuse and primer house, which operated from 1930 until 1939. It is located in a wooded area adjacent to the Clouter Creek Dredge Area on Clouter Island. AOC 694, a Naval Ammunition Depot in operation from the 1920s until the 1940s, consists of the area surrounding former Building 117.

AOC 693/694 surface soil is recommended for CMS based on risk greater than 1E-06 and a HI of 2 (resident child). AOC 693/694 shallow groundwater is recommended for CMS based on residential-based risk of 2E-03 and a HI greater than 1. Table 11.5 lists the affected medium, the risk/hazard, and the chemical(s) that drive the risk.

**Table 11.5  
 AOC 693 and AOC 694  
 Conclusion Summary**

<b>Affected Medium</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk</b>
Surface soil	Yes - ILCR = 5E-05 Yes - HI = 2	Aluminum, Antimony, Arsenic, Chromium, Vanadium, and BEQs
Shallow Groundwater	Yes - ILCR = 2E-03 Yes - HI = 22	Arsenic, cadmium, and manganese

Five upper-interval soil samples contained BEQs above the RBC for benzo(a)pyrene (694SB003, 009, 013, 016, and 018). Only one upper-interval arsenic detection exceeded both of its screening concentrations (694SB005). Aluminum concentrations exceeded both the RBC and background in five surface soil samples. Five surface samples had antimony detections exceeding its RBC and four upper-interval chromium detections exceeded both its RBC and background concentration. Vanadium exceeded both of its screening concentrations in three surface samples.

### **11.7 AOC 695**

AOC 695 consists of former Building 119, an electric locomotive shed, which operated from approximately 1922 until 1925. The original location of Building 119 was determined to be on a railroad trestle which extended over the Cooper River. The location of AOC 695 is now approximately 50 to 100 feet offshore.

Assessment of AOC 695 data relative to human health, ecological risk, and fate and transport of chemicals will be addressed as part of the Zone J RFI.

### **11.8 AOC 696**

AOC 696 consists of five former transformers that were located immediately north of Building 2509 at the Naval Annex.

The site is recommended for CMS based on risk greater than 1E-06 in surface soil. Table 11.6 lists the affected medium, the risk/hazard, and the chemical(s) that drive the risk/hazard.

**Table 11.6**  
**AOC 696**  
**Conclusion Summary**

<b>Affected Medium</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk/Hazard</b>
Surface soil	Yes - ILCR = 2E-05  No - HI = 0.2	Arsenic and Aroclor-1260

Arsenic was originally detected in a duplicate sample from Round 1 exceeding its RBC and background concentration. Aroclor-1260 was detected in first round sample 696SB003 exceeding its screening levels. Aroclor-1260 was not detected in follow-up sampling in February 1997. An Interim Measure to remove the upper 1 foot of soil in the transformer area was performed by the CEERD in October 1997. Arsenic was detected in third round samples (February 1998) 696SB010 and 011 exceeding its RBC and background concentrations.

**11.9 AOC 698**

AOC 698 consists of Building 2508 at Naval Annex. The unit is designated as an AOC due to the presence of peeling lead-based paint which is on both the interior and exterior of the building. The site is recommended for additional evaluation under the CMS based on risk greater than 1E-06 in surface soil and shallow groundwater. Table 11.7 lists the affected medium, the risk/hazard, and the chemical(s) that drive the risk/hazard.

**Table 11.7**  
**AOC 698**  
**Conclusion Summary**

<b>Affected Medium</b>	<b>Unacceptable Risk/Hazard in Future Residential Scenario</b>	<b>Chemicals Driving Risk/Hazard</b>
Surface soil	Yes - ILCR = 6E-05  No - HI = 0.7	Arsenic, BEQs, and heptachlor epoxide

**Table 11.7**  
**AOC 698**  
**Conclusion Summary**

Affected Medium	Unacceptable Risk/Hazard in Future Residential Scenario	Chemicals Driving Risk/Hazard
Shallow Groundwater	Yes - ILCR = 3E-05  No - HI = 0.7	Benzene, alpha-BHC, and delta-BHC

Heptachlor epoxide exceeded its RBC in two samples, 698SB002 and 698SB011. Arsenic concentrations were within one order of magnitude of their screening concentrations. The highest arsenic concentration was at 698SB004. The RBC for BEQs was exceeded in sample 698SB020.

Benzene was detected in the monitoring well installed at the site during all four sampling rounds but not in the groundwater screening samples collected in the vicinity of the well. Delta-BHC was detected only in the first round groundwater sample. Alpha-BHC was detected only in the fourth round sample.

#### 11.10 SWMU 166

During the November 1996 groundwater screening sampling effort performed for SWMU 185 (formerly SWMU 166), one sample (166GP011) was collected that contained TCE at 53 µg/L. As a result of this detection, a series of groundwater screening sample collection, soil sampling, monitoring well installation, and groundwater sampling events were performed. To differentiate this effort from the investigation of the sewer system, the NAVBASE Project Team assigned SWMU 166 to the TCE investigation associated with the Automobile Service Shop and reassigned the original sewer investigation as SWMU 185. The *Final Zone K RFI Work Plan* did not include the investigation of the Automotive Service Shop.

The RFI for SWMU 166 has been submitted as an addendum along with SWMU 185 and will be incorporated into this document upon review and revision of the addendum.

### 11.11 Ecological Risk Summary

As described in Section 8.0, Zone K was segregated into three "subzones" for purposes of the ERA. Table 11.8 identifies sites associated with each subzone which were illustrated on Figures 8.2a and 8.2b found in Section 8.1, and chemicals driving ecological risk at each of the sites. Risk to ecological receptors was evaluated for ECPCs in sediment in Subzone K-1 and surface soil for Subzones K-2 and K-4. Risk associated with exposure to ECPCs in sediment at Subzone K-1 was quantified by comparing the maximum concentrations detected to EPA Region IV sediment screening values (SSVs). The risk evaluation for terrestrial wildlife was based on a model that predicts contaminant exposure via the diet and incidental soil ingestion. The model predicts doses for representative wildlife species to doses representing thresholds for chronic and subchronic effects (LOAELs and NOAELs). Risks for soil invertebrates and plants were evaluated based on qualitative comparisons of soil concentrations to effects levels in literature for taxonomic groups similar to those potentially inhabiting Zone K.

Table 11.8  
 AOCs/SWMUs Associated with Zone K Subzones

AOC/SWMU	Description	Ecological Risk Drivers	
		Chronic Exposure	Subchronic Exposure <sup>1</sup>
<b>Subzone K-1</b>			
AOC 695	Electric locomotive shop	Arsenic Chromium Nickel <sup>2</sup>	
<b>Subzone K-2/K-3</b>			
AOC 693	Fuse and primer house	None	Arsenic Lead Zinc 4,4'-DDE 4,4'-DDT

**Table 11.8**  
**AOCs/SWMUs Associated with Zone K Subzones**

AOC/SWMU	Description	Ecological Risk Drivers	
		Chronic Exposure	Subchronic Exposure <sup>1</sup>
AOC 694	Former ammunition depot	Arsenic Copper Lead Zinc	Cadmium 4,4'-DDD 4,4'-DDT
<b>Subzone K-4</b>			
SWMU 161	Vehicle maintenance shop	None	4,4'-DDT
SWMU 162	Sludge drying field	Mercury 4,4'-DDD 4,4'-DDE 4,4'-DDT	Arsenic Lead Zinc
SWMU 163	Concrete pit area	None	Arsenic Cadmium Lead Zinc 4,4'-DDE 4,4'-DDT
SWMU 164	Blasting operations	Arsenic	Cadmium Lead Zinc 4,4'-DDT
SWMU 185	Sewer system	None	None
AOC 696	Transformer area near Building 2509	4,4'-DDT	Arsenic Cadmium Lead Zinc 4,4'-DDE Aroclor 1260
AOC 698	Building 2508, boiler house	4,4'-DDE 4,4'-DDT	Arsenic Cadmium Lead Zinc 4,4'-DDD
SWMU 166	Automobile Service Shop	4,4'-DDE 4,4'-DDT	4,4'-DDD

**Notes:**

- <sup>1</sup> Chemicals listed for subchronic exposure are in addition to those listed for chronic exposure  
<sup>2</sup> Subchronic and chronic exposure scenarios could not be calculated for sediment exposure.

<b>11.11.1 Subzone K-1</b>	1
<b>Aquatic Wildlife</b>	2
A potential risk exists to aquatic receptors proximal to AOC 695 based on detected concentrations of arsenic, chromium, and nickel, which produced hazard quotients (HQs) of 2.44, 1.15, and 1.09, respectively. It is uncertain, however, if these contaminants are attributable to AOC contribution or if they represent background concentrations. Specific bioavailability of the contaminants identified is unknown.	3 4 5 6 7
<b>11.11.2 Subzone K-2/K-3</b>	8
<b>Terrestrial Wildlife</b>	9
A potential for chronic effects to cottontail rabbits and American robins exists based on the maximum detected concentrations of arsenic, copper, lead and zinc at AOC 694. Potential subchronic effects also is predicted from exposure to cadmium, DDE, DDD, and DDT.	10 11 12
<b>Infaunal Invertebrates</b>	13
Potential adverse effects, including decrease in cocoon production and lethality to earthworms, are predicted, based on the concentrations of aluminum, chromium, copper, mercury, vanadium, and zinc at Subzone K-2/K-3.	14 15 16
<b>Vegetation</b>	17
Comparison of the concentration of contaminants detected in Subzone K-2/K-3 to published effects levels indicates a potential for adverse effects to both herbaceous and woody vegetation. However, an examination of the site has reveal no stressed vegetation.	18 19 20

**11.11.3 Subzone K-4**

1

**Terrestrial Wildlife**

2

Subzone K-4 presents a low level of chronic risk to the American robin due to elevated mercury concentrations. While no HQs for any one metal exceeds 1, the cumulative effect of several HQs near 1 result in an overall low chronic risk to the cottontail rabbit. Arsenic, cadmium, mercury, lead, and Aroclor 1260 each pose low to moderate subchronic risk to one or more selected representative species.

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**Infaunal Invertebrates**

8

Aluminum, chromium, copper, mercury, and zinc pose potential risk to terrestrial invertebrates at Subzone K-4. Mercury concentrations reported at Subzone K-4 indicate significant risk, particularly at the sewage drying pits.

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**Vegetation**

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Potential adverse effects, including lethality to woody seedlings and EC<sub>50</sub> to herbaceous plant seed germination have been identified at Subzone K-2. The maximum concentrations of several inorganic compounds in the surface soil at Subzone K-4 exceed their respective effects level and may cause death to woody seedlings and EC<sub>50</sub>-effects to herbaceous vegetation. It should be noted, however, that no evidence of stressed vegetation has been identified during frequent trips to these sites.

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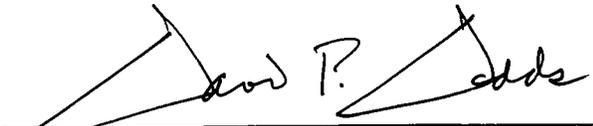
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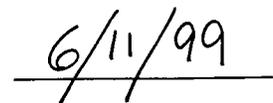
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### 13.0 SIGNATORY REQUIREMENT

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 by 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 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.*

  
\_\_\_\_\_  
David P. Dodds for  
Commanding Officer

  
\_\_\_\_\_  
6/11/99

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