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DRAFT ZONE L RESOURCE CONSERVATION AND RECOVERY FACILITY INVESTIGATION  
REPORT VOLUME 1 OF 12 SECTIONS 1 TO 9 CNC CHARLESTON SC  
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ENSAFE

**DRAFT ZONE L  
RCRA FACILITY INVESTIGATION REPORT  
CHARLESTON NAVAL COMPLEX**

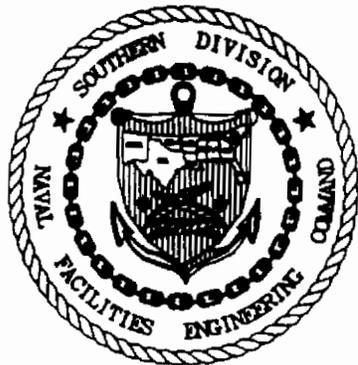


**VOLUME 1 OF 12  
SECTIONS 1 TO 9**

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Appendix E	Chain of Custodies
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## **ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR CHARLESTON NAVAL COMPLEX - ZONE L**

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

AA	Atomic Absorption
ABF	Absorption Factor
AEC	Area of Ecological Concern
AF	Adherence Factor
AOC	Area of Concern
AT	Averaging Time
AWQC	Ambient Water Quality Criteria
BEQ	Benzo(a)pyrene Equivalent
BEST	Building Economic Solutions Together
BRA	Baseline Risk Assessment
BW	Body Weight
CA	Contact Area
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
CMS	Corrective Measures Study
CNC	Charleston Naval Complex
COC	Chemical of Concern
COPC	Chemical of Potential Concern
cPAH	Carcinogen Polynuclear Aromatic Hydrocarbon
CPSS	Chemical Present in Site Samples
CR	Confirmed Resident
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CSAP	Comprehensive Sampling and Analysis Plan
CSI	Confirmatory Sampling Investigation
CSP	Caretaker Site Officer
CT	Central Tendency
D	Diluted Result
DAF	Dilution Attenuation Factor
DJ	Estimated Diluted Result
DPT	Direct Push Technology
DQO	Data Quality Objectives

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

E/A&H	EnSafe/Allen & Hoshall
ECAO	Environmental Criteria and Assessment Office
ECPC	Ecological Chemical of Potential Concern
ED	Exposure Duration
EF	Exposure Frequency
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 Contracted
ft	feet
GC/MS	Gas Chromatography/Mass Spectrometry
GW	Groundwater
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMW	High Molecular Weight
HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments
HTTD	High-Temperature Thermal Desorption
ICM	Interim Corrective Measure
ICAP	Inductively Coupled Argon Plasma
ID	Inside Diameter
ILCR	Incremental Lifetime Excess Cancer Risk
IR	Ingestion Rate
IRIS	Integrated Risk Information System
$K_d$	Partitioning Coefficient
$K_{oc}$	Organic Carbon
LDRs	Land Disposal Restrictions
LM	Likely Migrant
LMW	Low Molecular Weight
LR	Likely Resident
LTDD	Low-Temperature Thermal Desorption

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

MCL	Maximum Contaminant Level
MSL	Mean Sea Level
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
MO	Sediment
NA	Not Available
N/A	Not Applicable
NAVBASE	Naval Base Charleston
NC	Not Calculated
NCEA	National Center for Environmental Assessment
ND	Not Detected
NFI	No Further Investigation
ng/mL	Nanogram per milliliter
NOAEL	No Observed Adverse Effect Level
NPDES	National Pollutant Discharge Elimination System
NRL	Naval Research Lab
NTU	Nephelometric Turbidity Unit
OP Pest	Organophosphorous Pesticide
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PE	Performance Evaluation
Pest/PCB	Pesticide/Polychlorinated Biphenyl
PM	Possibly migrant
POTW	Publicly Owned Treatment Works
ppb	Parts per billion
PR	Possible resident
PRPs	Potentially Responsible Parties
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RAB	Restoration Advisory Board
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RC	Reference Concentration
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Daily Allowance
RFA	RCRA Facility Assessment

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

RfD	Reference Dose
RFI	RCRA Facility Investigation
RGO	Remedial Goal Option
RME	Reasonable Maximum Exposure
ROC	Run of Crusher
RRF	Relative Response Factor
SAS	Special Analytical Services
SB	Soil Boring
SCDHEC	South Carolina Department of Health and Environmental Control
SCWMRD	South Carolina Wildlife and Marine Resources Department
SF	Slope Factor
SOUTHDIV	Southern Division Naval Facilities Engineering Command
SQL	Sample Quantitation Limit
SR	Status Review
SSL	Soil Screening Levels
SSV	Sediment Screening Value
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
T/SA	Threatened due to Similarity of Appearance
TCDD	Tetrachlorodibenzo-p-dioxin
TDS	Total Dissolved Solids
TEF	Toxic Equivalency Factor
THQ	Target Hazard Quotient
TOC	Total Organic Carbon
UCL	Upper Confidence Limit
UR	Unlikely Resident
USDOT	U.S. Department of Transportation
USEPA	United States Environmental Protection Agency
UTL	Upper Tolerance Limit
VOC	Volatile Organic Compound
VQUAL	Validation Qualifer
μg/kg	Microgram per kilogram
μg/L	Microgram per liter

## 1.0 INTRODUCTION 1

The environmental investigation and remediation at Charleston Naval Complex (CNC) are 2  
required by the Hazardous and Solid Waste Amendments (HSWA) portion of the Resource 3  
Conservation and Recovery Act (RCRA) Part B permit (permit number: SCO 170 022 560) 4  
(South Carolina Department of Health and Environmental Control [SCDHEC], May 4, 1990). 5  
These conditions are consistent with the RCRA Corrective Action Program, whose objectives are 6  
to evaluate the nature and extent of any hazardous waste or constituent releases, and to identify, 7  
develop, and implement appropriate corrective measures to protect human health and the 8  
environment. The scope of the RCRA Facility Investigation (RFI) includes the entire naval base, 9  
which has been divided into Zones A through L to accelerate the RFI process. This Zone L RFI 10  
Report, prepared by EnSafe, is submitted to satisfy condition IV.C.6 of the HSWA portion of the 11  
Part B permit (SCDHEC, May 4, 1990). 12

### 1.1 Charleston Naval Complex Description and Background 13

Section 1.1 of the *Draft Zone A RCRA Facility Investigation Report* (EnSafe/Allen & Hoshall 14  
[E/A&H] 1996a) details the description and background of CNC. Several facilities within CNC 15  
are currently being leased to private industrial clients. 16

### 1.2 Base Closure Process for Environmental Cleanup 17

Section 1.2 of the *Draft Zone A RFI Report* details the base closure process for environmental 18  
cleanup. Where appropriate in this document, Areas of Concern (AOCs) and Solid Waste 19  
Management Units (SWMUs) are collectively referred to as *sites*. The sites in Zone L extend 20  
beyond multiple zones and due to this uniqueness, data sets from Zone L have been compared to 21  
other zones' data sets in order to define nature and extent of contamination along site boundaries. 22

### 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, as shown in Figure 1.1. The Restoration Advisory Board (RAB) and the Building Economic Solutions Together (BEST) committees ranked the investigation and cleanup priority of the zones. In 1994, BEST was replaced by the CNC Redevelopment Authority (RDA), which has authority to establish leases for the transferred property. Zone L is unique in that it has no geographic boundary within the contiguous property of CNC and is comprised of the sanitary sewer system excluding domestic sources, the storm sewer system, and the railroad system. At least part of one or more components of Zone L are within the boundaries of the remaining 10 investigative zones within the contiguous CNC property.

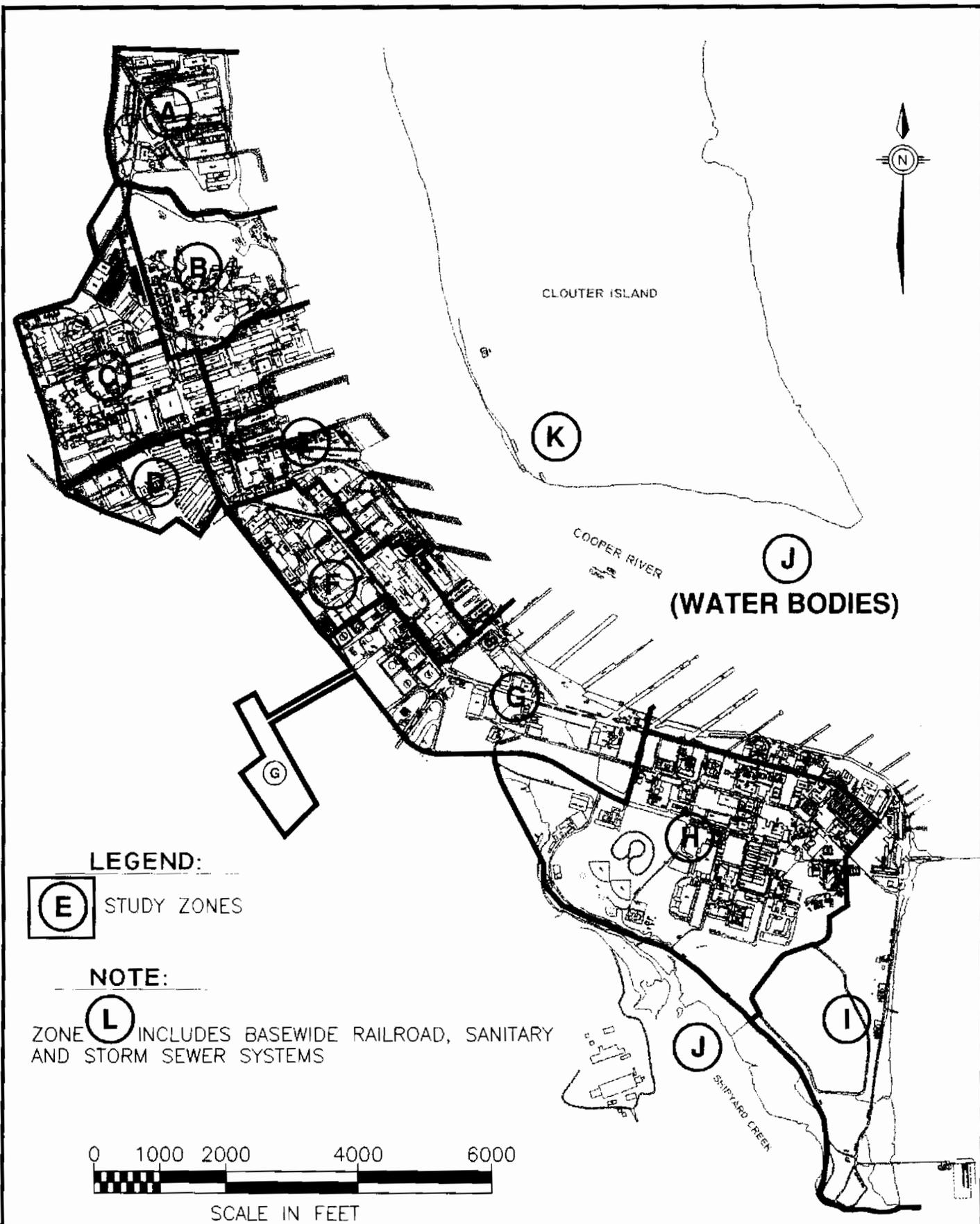
### 1.4 Current Investigation

#### Objective

The objectives of the RFI are to characterize the nature and extent of contaminants associated with releases from SWMUs and AOCs, evaluate contaminant migration pathways, and 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 evaluated by conducting a baseline risk assessment (BRA) to assess the risks posed to human health and the environment by individual and/or groups of sites within a zone.

#### Field Investigation Scope

Three sites were identified in Zone L through the RCRA Facility Assessment (RFA) process. Each site in Zone L is discussed in detail in the *Final RCRA Facility Assessment for Naval Base Charleston* (E/A&H, June 6, 1995), and the *Final Zone L RFI Work Plan* (E/A&H 1996b). Investigative approaches for each site were developed and proposed based on the best available

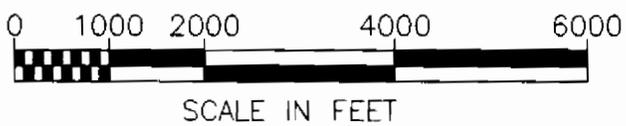


**LEGEND:**

**(E)** STUDY ZONES

**NOTE:**

ZONE **(L)** INCLUDES BASEWIDE RAILROAD, SANITARY AND STORM SEWER SYSTEMS



ZONE L  
RCRA FACILITY  
INVESTIGATION REPORT  
NAVAL BASE CHARLESTON  
CHARLESTON, SC

FIGURE 1.1  
INVESTIGATIVE ZONE BOUNDARIES

information at that time, and were subject to modification based on additional site information 1  
availability and/or site conditions. The RCRA investigatory designations used are defined below: 2

- *No Further Investigation (NFI)* — This designation was applied to AOCs or SWMUs with 3  
sufficient data to thoroughly assess the potential hazards associated with the site and 4  
determine that it does not pose a threat to human health or the environment. 5
- *Confirmatory Sampling Investigation (CSI)* — This designation was applied to AOCs or 6  
SWMUs for which insufficient data was available to thoroughly assess the potential site 7  
hazards. Generally, a limited amount of "confirmatory" samples was needed to determine 8  
whether a hazard exists. The result of the CSI determines whether no further investigation 9  
is appropriate or a full-scale RFI is warranted. 10
- *RFI* — This designation was applied to AOCs or SWMUs if visual evidence, historical 11  
information such as spill reports, or analytical data indicated that a release of hazardous 12  
substances to the environment has occurred. A complete characterization of the site is 13  
needed to determine the nature and extent of contamination, identify migration pathways, 14  
identify actual and potential receptors, and to evaluate the ecological and human health 15  
risks posed by the site. 16

The approved final RFI work plan outlined an investigative strategy for each of the three Zone L 17  
sites discussed herein. Table 1.1 summarizes each Zone L AOC and SWMU requiring 18  
investigation. Figure 1.2 identifies each site's location. 19

**Table 1.1**  
**Zone L**  
**AOC and SWMU Summary**

AOCs and SWMUs	Site Description	Investigative Approach	Previous Investigations	Investigation Grouping
SWMU 37	Sanitary sewer system (Including oil/water separators, septic tanks, latrines cross connects)	RFI	None	Investigated independently
AOC 699	Storm sewer system	RFI	None	Investigated independently
AOC 504	Railroad system	RFI	None	Investigated independently

## 1.5 Previous Investigations 1

In addition to data generated during this investigation, pertinent data from previous investigations at CNC sites have been incorporated, along with other historical information. 2  
3

## 1.6 RFI Report Organization 4

To facilitate review, the RFI report has been formatted to discuss zone-wide information, overall technical approach, and evaluation methodologies first. Following this are the AOC and SWMU specific evaluations and conclusions. These general sections are sequenced according to the natural progression of an RFI investigation. The zone-wide sections are: 5  
6  
7  
8

- 1.0 Introduction 9
- 2.0 Physical Setting 10
- 3.0 Field Investigation 11
- 4.0 Data Validation 12
- 5.0 Data Evaluation and Background Comparison 13
- 6.0 Fate and Transport 14
- 7.0 Human Health Risk Assessment 15

- 8.0 Ecological Risk Assessment 1
- 9.0 Corrective Measures 2

The site-specific sections are: 3

- 10.0 Site-Specific Evaluations 4
- 11.0 Conclusions and Preliminary Recommendations 5

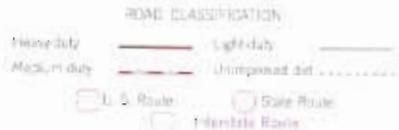
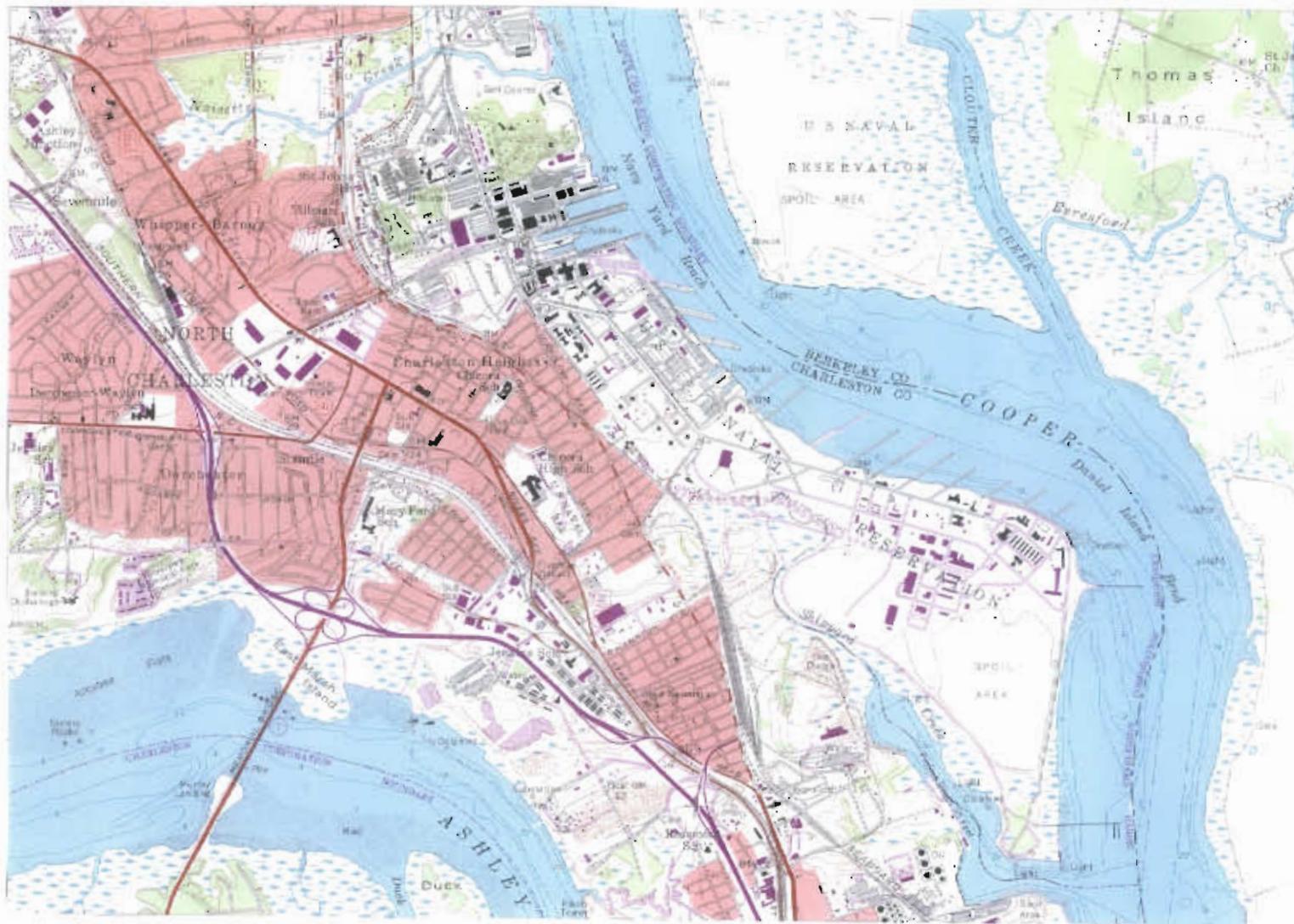
followed by: 6

- 12.0 References 7
- 13.0 Signatory Requirement 8

Section 10 of the RFI follows the same zone-wide outline as Sections 1 through 9, but on a site-specific (per AOC and SWMU) basis. The section is subdivided by specific AOCs or SWMUs, or site groupings, and includes the actual data summaries, risk calculations, and corrective measures evaluations specific to each area. In this manner, the entire investigation sequence, including conclusions, is contained within a site-specific section for easy reference. 9  
10  
11  
12  
13

Section 11 summarizes the conclusions and risk-management considerations from each Section 10 site-specific summary. This organization makes it easy to determine which sites have been recommended for the CMS and which are recommended for no further action. Section 12 is a compilation of references. 14  
15  
16  
17

<b>2.0</b>	<b>CHARLESTON NAVAL COMPLEX PHYSICAL SETTING</b>	1
<b>2.1</b>	<b>Regional Settings</b>	2
	Physical settings for CNC are presented in the following sections.	3
<b>2.1.1</b>	<b>Regional Physiographic and Geologic Setting</b>	4
	The CNC area regional physiography and geology are described in Section 2.1.1 of the <i>Zone A RFI Report</i> (EnSafe, 1998). Local topography is presented in Figure 2-1.	5 6
<b>2.1.2</b>	<b>Regional Hydrology and Hydrogeology</b>	7
	The regional hydrology and hydrogeology for the CNC area is described in Section 2.2.1 of the <i>Zone A RFI Report</i> (EnSafe 1998). Major surface water features may be seen on Figure 2-1.	8 9
<b>2.1.3</b>	<b>Regional Climate</b>	10
	Regional climate is discussed in Section 2.3 of the <i>Zone A RFI Report</i> (EnSafe,1998).	11
<b>2.2</b>	<b>Zone L Geologic Investigation</b>	12
	Geological and stratigraphic information for Zone L has been obtained from soil and monitoring well borings completed during RFI activities for Zones A, B, C, D, E, F, G, H, and I. Lithologic samples acquired using hollow-stem auger, wet rotary, and rotasonic drilling methods were classified and logged by an E/A&H geologist as described in the <i>Final Comprehensive Sampling and Analysis Plan RCRA Facility Investigation</i> (E/A&H, July 1996).	13 14 15 16 17
<b>2.2.1</b>	<b>Monitoring Wells</b>	18
	RFI activities in Zone L included the installation of 12 shallow monitoring wells at one or more locations in Zones A, C, E, G, H, and I (Figure 2-2) using hollow-stem auger drilling methods.	19 20



**ZONE L**  
RCRA FACILITY  
INVESTIGATION REPORT  
NAVAL BASE CHARLESTON  
CHARLESTON, SC

**FIGURE 2.1**  
TOPOGRAPHY OF  
NAVAL BASE CHARLESTON  
AND  
SURROUNDING AREAS

Date: 12/14/98 DWG. Name: 2912C145

Monitoring wells were installed at existing or former oil/water separator and septic tank sites associated with SWMU 37. Table 2.1 lists the Zone L monitoring wells and summarizes well construction data. Zone L monitoring well lithology and construction logs are presented in Appendix B.

### 2.2.2 Geotechnical

No Shelby tube samples or geotechnical analyses were performed as part of Zone L RFI activities. Shelby tube samples collected as part of CNC RFI drilling programs in other zones were collected and analyzed for porosity, bulk density, grain size distribution, specific gravity, percent moisture, and vertical permeability. Thin-wall 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 on areal distribution, lithology type, and sample uniformity in order to develop a range of coverage for characterizing the predominant lithologies encountered at CNC. Geotechnical data for CNC are presented in the respective Zones.

**Table 2.1**  
**Zone L Monitoring Well Construction Data**

Well ID	Date Installed	TOC elev. (ft msl)	Ground elev. (ft msl)	Drilled Data (ft bgs)			DTW* (ft)	GW elev.* (ft)
				TOS	BOS	BOW		
NBCL037A01	5/20/97	12.69	10.3	5.0	14.7	15.0	11.47	1.22
NBCL037A02	5/21/97	6.39	6.5	2.0	11.7	12.0	2.24	4.15
NBCL037C01	5/22/97	9.42	7.1	2.0	11.7	12.0	5.11	4.31
NBCL037C02	5/22/97	11.19	8.5	3.0	12.7	13.0	5.80	5.39
NBCL037E01	5/22/97	9.11	9.0	2.5	12.2	12.5	3.88	5.23
NBCL037E02	5/22/97	9.20	9.1	3.0	12.7	13.0	3.92	5.28
NBCL037G01	5/20/97	13.25	10.2	4.0	13.7	14.0	7.80	5.45
NBCL037G02	5/20/97	10.87	11.1	5.0	14.7	15.0	8.00	2.87
NBCL037H01	5/21/97	8.97	9.1	3.0	12.7	13.0	4.26	4.71
NBCL037H02	5/20/97	10.95	8.8	4.0	13.7	14.0	5.61	5.34
NBCL037H03	5/21/97	8.55	6.4	3.0	12.7	13.0	4.80	3.75

**Table 2.1**  
**Zone L Monitoring Well Construction Data**

Well ID	Date Installed	TOC elev. (ft msl)	Ground elev. (ft msl)	Drilled Data (ft bgs)			DTW* (ft)	GW elev.* (ft)
				TOS	BOS	BOW		
NBCL037I01	5/21/97	6.61	6.6	2.0	11.7	12.0	4.05	2.56

**Notes:**

- TOC = Top of well casing 2
- msl = Mean sea level 3
- bgs = below ground surface 4
- TOS = Top of screened interval 5
- BOS = Bottom of screened interval 6
- BOW = Bottom of well (end cap) 7
- DTW = Depth to water from TOC (ft) 8
- GW = Groundwater 9
- \* = Depth to groundwater varies over time; data from May 27-30, 1997, are presented here. 10

**2.2.3 CNC Geology**

The shallow wells installed during the Zone L RFI encountered only Quaternary age sediments or construction fill materials. However, subsurface investigations for other CNC RFI activities have identified Quaternary and Tertiary age sediments across the site. The lowermost stratigraphic unit encountered during CNC RFI activities is the Ashley Formation member of the Mid-Tertiary age Cooper Group. Overlying the Ashley are younger Upper Tertiary and Quaternary age stratigraphic units.

Complexity of the geologic system varies across CNC. Quaternary stratigraphy for the southern third of CNC consists primarily of an upper sand and a lower sand unit separated by soft marsh clay of variable thickness. Locally the lower sand unit may be absent such that soft marsh clay directly overlies Tertiary age sediments. The northern two-thirds of CNC become much more geologically complex and is comprised of several Quaternary and Tertiary age lithologic units; soft marsh clay no longer dominates the stratigraphic section. Coarse clastics, inorganic clays, and indurated older organic clays begin to dominate the Quaternary section north of a line between the

Cooper River and the upper limits of Shipyard Creek. Above this line soft marsh clay and peats occur sporadically, and are typically associated with former and current fluvial settings.

Stratigraphic units encountered during RFI activities across CNC are presented in the following sections in ascending order. Complete discussion of geologic information for each Zone L subzone is presented in the respective Zone RFI reports.

### **2.2.3.1 Tertiary Age Sediments**

#### **Ashley Formation**

The oldest lithology encountered during CNC RFI investigations has been the Ashley Formation, the youngest member of the Eocene-Oligocene age Cooper Group. The Ashley Formation (Ta) was deposited in an open-marine shelf environment during a rise in sea level in the late Oligocene (Weems and Lemon, 1993).

The Ashley Formation was encountered throughout CNC at depths ranging from approximately 16 ft below ground surface (ft bgs) at location GDE28D in Zone E, to 85 ft bgs at location GDI05D in Zone I. However, 14 deep well borings advanced in the northernmost portion of Zone E and the deep well boring at GDB04D in the southern portion of Zone B were terminated before encountering the Ashley Formation. Consequently, the nature of the contact at depth between the Ashley and overlying sediments along the boundary between Zones B and E is not known.

#### **Upper Tertiary (Undifferentiated)**

Four Tertiary age units are placed stratigraphically above the Ashley Formation. They are (in ascending order) the Chandler Bridge, Edisto, Marks Head, and Goose Creek Limestone formations (Weems and Lemon, 1993). Upper Tertiary marine regression-transgression sequences produced considerable erosion of each unit prior to deposition of the next. This has resulted in typically unconformable contacts where many of the intervening stratigraphic units are no longer

present. Elements of three Upper Tertiary age units were encountered during other RFI activities. These units have been identified only by microscopic examination of a few select samples recovered from Zone E deep well borings. Consequently, they have not been individually identified on maps or cross-sections prepared for RFI reports, and have been grouped as undifferentiated Upper Tertiary (Tu). The three Tu units have been tentatively identified as the Chandler Bridge Formation, Marks Head Formation, and Goose Creek Limestone (Katuna, June 1997). It is not known if sediments of the Edisto Formation have been encountered at CNC, therefore they are not discussed here.

#### **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, backbarrier lagoons, tidal inlets, and shallow-marine shelf systems. Due to crustal uplift in the Charleston region during the Quaternary, many barrier to backbarrier 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 (Weems and Lemon, 1993). 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 (Weems and Lemon, 1993). Although Weems and Lemon have identified and correlated several formations of Quaternary-age sediments, it can be difficult to determine discrete formational units within the Quaternary system. Field identification is especially difficult since characteristics may only be evident at the microscopic level.

Throughout CNC, Quaternary age sediments extend from the top of Tertiary-age sediments to just below ground surface. These sediments range from  $\geq 105$  feet thick at Zone B location GDB04D

to 15 feet thick at Zone E location GDE28D, including anthropogenic deposits. Pleistocene age Wando Formation sediments (deposited 65,000 to 130,000 years ago) constitute the bulk of the Quaternary section throughout CNC, and are occasionally overlain by Holocene age sand and clay deposits as well as construction fill.

In general, the Wando Formation depositional period encompasses three distinct high sea-level stands in the late Pleistocene (Weems and Lemon, 1993). As a result, Wando composition consists of repeating sequences of backbarrier clayey sand and clay deposits, barrier island sand deposits, and near shore shelf-sand deposits.

In Holocene time, rivers and streams have down cut the Wando sediment sequences, leaving scours that have filled with clay and silty sand deposits typical of low-energy environments. These younger deposits may resemble Wando deposits and further complicate the interpretation of local geology. Consequently, a series of Quaternary age litho-stratigraphic units has been established for purposes of discussion.

#### **Quaternary Clay 'older'**

The Quaternary Clay "older" (Qco) unit generally consists of dark gray to black, very stiff, dense, dewatered marsh clay. Sand intervals within this unit tend to be very thin and discontinuous. Interbedded sand in the upper portion of the section decreased rapidly with depth to trace occurrences. This unit correlates with the dewatered marsh clay (Qdm) unit presented in the *Zone A RFI Report*. Qco is typically found in the northern two-thirds of CNC.

#### **Quaternary Sand 'older'**

The older Quaternary sand (Qso) unit is typically a gray to dark gray, fine to medium-grained sand often containing shell fragments and occasional thin, dark gray, clay laminae. Members of the Qso unit occur as relatively thin, discontinuous sand units which may intersect and coalesce within

Qco, and as a more substantive unit in contact with overlying younger sediments. For the purposes of this discussion, the Qso unit will be considered contemporaneous with the lower sand unit (Qsl) as used in the *Zone I RFI Report*. This correlates with the Qsl illustrated on the *Zone I RFI Report* geologic cross-sections, and applies to Zones H and I.

### **Quaternary Clay and Sand 'older'**

The older Quaternary Clay and Sand (Qcso) unit consists of interbedded older dark gray clay and sand. It may either be part of the interbedded clay and sand associated with upper Qco sediments in the northern two-thirds of CNC, where it may be part of an overall coarsening upwards cycle, or as a series of alternating dark gray clay and gray sand beds associated with Qso deposition.

### **Quaternary Clay**

The Quaternary clay (Qc) unit consists of inorganic clays and silts. Coloration may range from a medium gray to orange, occasionally blue-green. Sand content will vary, but the predominant grain size is clay. It is typically soft to firm, moist to wet, and plastic. Qc is found throughout CNC , but to an increasing degree in the northern two-thirds of CNC .

### **Quaternary Sand**

The Quaternary sand (Qs) unit is typically a very fine to fine-grained, silty, quartzose, sand which may contain some clay. Coloration varies from light gray to orange with occasional faint laminations. Qs is pervasive across CNC but becomes increasingly more significant in the northern one-half of CNC. For the purposes of this discussion, the Qs unit will be considered to be contemporaneous with the upper sand (Qsu) unit as applied to the *Zone I RFI Report*. This unit correlates with the Qsu illustrated in *Zone I RFI Report* cross-sections and applies to Zones H and I. Portions of Qsu in Zones H and I may also include some fill material.

**Quaternary Clay and Sand**

1

Interbedded sand and inorganic clays constitute the Quaternary clay and sand (Qcs) unit.

2

**Quaternary Marsh Clay**

3

Quaternary marsh clay (Qm) is dark gray to black, soft, sticky, and occasionally thinly laminated with sand and shelly lenses. Marsh clay is prevalent in the southern third of CNC .

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**Quaternary Peat**

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The Quaternary peat (Qp) unit is typically composed of brown vegetation, mainly marsh grasses. It is often associated with marsh clay sediments and may have minor interbedded sand. This unit occurs sporadically throughout CNC, and is typically of limited areal extent.

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**Quaternary Marsh Clay and Peat**

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The Quaternary marsh clay and peat (Qmp) unit consists of interbedded marsh clay and peat/organic detritus. Marsh clay may dominate the unit.

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**Quaternary Marsh Sand and Peat**

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The Quaternary marsh sand and peat (Qsp) unit consists of interbedded marsh clay, peat, and sand.

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**2.2.3.3 Soil**

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Due to extensive surface soil disturbance at CNC during its operational history, approximately the upper 5 feet of the subsurface are typically a mixture of artificial fill and native sediments. However, the extent of fill placement varies within CNC . Areas where extensive excavations have been performed or where native soils were unsuitable for foundation support may have undergone more extensive fill placement. Fill materials have been categorized into the following four units for this report.

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**Run of Crusher**

Run of crusher consists of 0.5-inch to 0.75-inch gravel with a clayey silt and sand matrix. It is typically used as a subgrade for pavement and construction. Here it also includes any sandy gravel used as fill in the near surface.

**Fill Clay**

Fill clay (Fc) consists of compacted clay backfill, and may contain sand and other coarse fractions. Clay used as fill material may consist of organic or inorganic clayey sediment. The degree of compaction may vary as a function of intended use, such as general fill or as structural fill for high load-bearing capacity. Fc occurs predominantly along the quay wall south of Dry Dock 5, and in the quay wall area north of the Dry Dock 1 and 2 turning basin.

**Fill Sand**

The predominant fill material in Zone E is orange sand which is typically very fine to fine-grained quartz. Fill sand (Fs) ranges from 2 to 8 feet thick and typically occurs from < 1 to 3 ft bgs.

**Fill Undifferentiated**

The undifferentiated fill (Fu) unit consists of various materials including clay, gravel, concrete, bricks, and sand.

**2.2.4 SWMU 37 Monitoring Well Geology**

Geologic information in the immediate area around each of the SWMU 37 groundwater monitoring wells is presented in this section. Estimates regarding subsurface geology at these locations are based on the specific Zone RFI geologic reports. These reports should be reviewed for complete discussion of geologic settings for each subzone.

**Subzone A**

Two shallow wells were installed in Subzone A. Well 037A01 is located in the southwest corner of Subzone A, just north of Noisette Creek. Lithologies described for this well consist of 12 feet of Qs overlying Qc. Depth to the Ashley Formation beneath 037A01 is approximately 35 feet. The Ashley Formation near 037A01 is overlain (in ascending order) by an estimated 25 feet of Qs, and 7 feet of Qc. Estimated lithologic thicknesses are based on cross-section data presented in Section 2.0 of the *Zone A RFI Report* (EnSafe, 1998).

Well 037A02 is located near well pair GDA003/03D in the southeast corner of Subzone A, just west of the Cooper River. Lithologic descriptions for well 037A02 describe primarily 9 feet of Qs overlying Qc. Depth to the Ashley beneath 037A02 is approximately 35 feet, and overlying the Ashley beneath 037A02 is an estimated 32 feet of clayey material consisting of Qdm, Qm, and Qc (in ascending order).

**Subzone C**

Two shallow wells were installed in Subzone C, 037C01 and 037C02, adjacent to the southeast edge of SWMU 44 in the northernmost portion of Subzone C. Lithologic descriptions for these wells indicate approximately 5 to 6 feet of sand and clayey fill material overlying Qm. Depth to the Ashley in this area is approximately 47 feet, and overlain primarily by Qs with minor occurrences of lenticular Qc and Qm units. Projected subsurface lithologies are based on geologic data presented in Section 2.0 of the *Zone C RFI Report* (EnSafe, 1998).

**Subzone E**

Two shallow wells were installed in Subzone E. Well 037E01 is located midway along the southeast side of Building 236, which is south of Dry Dock #5. Lithologic descriptions for this well indicate 9 feet of clayey sand fill overlying Qm. Depth to the Ashley Formation at well

037E01 is estimated at 29 ft bgs. Overlying the Ashley are approximately 15 feet of Tu, 9 feet of Qc, and 5 feet of Fs and ROC (in ascending order).

Monitoring well 037E02 is located in AOC 542, in the northwestern quarter of Subzone E. Lithologic descriptions for this well indicate 7 feet of sandy fill material overlying Qc w/some interbedded Qs. Depth to the Ashley Formation is estimated at 65 ft bgs, overlain by approximately 14 feet of Qco, 2 feet of Qcso, 9 feet of Qso, 27 feet of Qs, and 8 feet of Fs and ROC (in ascending order). All values are estimated from geologic data presented in Section 2.0 of the *Zone E RFI Report* (EnSafe,1997).

### **Subzone G**

Two shallow wells were installed in Subzone G, 037G01 and 037G02, west of fuel storage tank 3900-E western corner of Subzone G. Lithologic descriptions for these wells indicate 10 to 12 feet of Qs and Qc overlying Qm. The closest stratigraphic control is at deep well GDG02D. The Ashley Formation is approximately 25 to 30 ft bgs in this area, and overlain (in ascending order) by 5 feet of Tu, 11 feet of Qc, 5 feet of Qm, and 4 feet of Qc. Estimated thicknesses are based on data in Section 2.0 of the *Zone G RFI Report* (EnSafe, 1998).

### **Subzone H**

Three shallow wells were installed in Subzone H. Well 037H01 is just north of Building 1303, which is just south of Hobson Avenue in the northern portion of Subzone H. Lithologic descriptions for this well indicate Qsu with minor Qc in the upper 13 feet with depth to the Ashley estimated at 64 ft bgs. The subsurface lithologic control closest to 037H01 is at deep well GDI16D in Subzone I. The lithologic section in the area of 037H01 is projected to be very similar to that of GDI16D, based on subsurface elevation contours of the upper surface of the Ashley Formation. The Ashley is overlain by approximately 14 feet of Qsl, 40 feet of Qm, and 10 feet of Qsu.

Well 037H02 is just south of the former base commissary (Building 655) in south-central Subzone H. Lithologic descriptions for this well indicate approximately 10 feet of Qsu overlying Qm. Depth to the Ashley at 037H02 is approximately 62 ft bgs. Lithologic data from deep well borings GDI01D and GDI02D indicate that approximately (in ascending order)  $\leq$  12 feet of Qsl, 40 feet of Qm, and 10 feet of Qsu overlie the Ashley Formation.

Well 037H03 is located south of Building 1984 in SWMU 14. Lithologic descriptions for this well indicate 10 feet of clayey sand overlying Qm. Depth to the Ashley at this location is approximately 36 ft bgs. Lithologic data from deep well borings 01403D and 01404D indicate approximate thicknesses (in ascending order) of  $\leq$  4 feet of Qsl, 25 feet of Qm, and 7 feet of Qsu. All estimates are based on geologic data in the *Zone H RFI Report* (EnSafe, 1998).

### **Subzone I**

Shallow well 037I01, the only SWMU 37 well installed in Subzone I, is located just west of Building NS16 and just south of the Cooper River. Lithologic descriptions for this well indicate 4 feet of sandy fill overlying interbedded Qsu and Qm. Depth to the Ashley Formation at this location is approximately 67 ft bgs, and is overlain (in ascending order) by approximately 14 feet of Qsl, 40 feet of Qm, and 13 feet of Qsu. Thickness estimates are based on the geologic boring log for deep well GDI16D and geologic data from the *Zone H and Zone I RFI Reports* (EnSafe, 1998).

### **2.2.5 Geology in Zone L Organic Compound Exceedance Areas**

Compounds of concern were detected during Zone L DPT and soil boring investigations in Subzones E and F. Areas in which detections of organic compounds exceeded RBCs, SSLs, or MCLs for either shallow soil or groundwater in these two Subzones are described in the following sections, and depicted on Figure 2-2.

**2.2.5.1 Subzone E DPT/Soil Boring Organic Compound Exceedance Areas**

Detections of organic compounds exceeding RBCs, SSLs, or MCLs associated with the Zone L RFI Subzone E DPT and soil boring activities occurred primarily north of Dry Dock 1 in the northern quarter of Zone E. Data in Section 2.0 of the *Zone E RFI Report* indicate that the near surface (0 ft MSL) areal geology in this portion of Zone E consists primarily of Qs material with minor occurrences of Qc. Various types of construction fill overlie Qs and Qc. North of well GDE26D the basal confining unit for the area north of Dry Dock 1 transitions from the Ashley Formation to Qco. Depth to the basal confining unit ranges from approximately 35 ft bgs at GDE26D to 55 ft bgs at 52601D.

Other detections of organic compounds occur in isolated areas of limited extent. Two of these areas are near the former Power House (Building 32), and another is just north of Building 177. The near surface (0 ft MSL) geology in this area of Zone E consists predominantly of Qs and overlying fill materials. Near surface geology in a detection area just north of Building 80 is dominated by Qc and overlying fill materials. Topography of the Ashley Formation in this area of CNC is fairly flat, with depths ranging from approximately 26 ft bgs at GDE15D to 29 ft bgs at 57401D.

Organic compound were also detected in portions of Zones E and F near well GDE004. Near surface (0 ft MSL) geology in this portion of CNC is dominated by Qm with minor occurrences of Qs, and Qc. Fill material typically overlies the native sediments. Topography of the Ashley Formation in this area is very flat, with depths ranging from approximately 33 ft bgs at GDE04D to 35 ft bgs at 61302D.

**2.2.5.2 Subzone F DPT/Soil Boring Organic Compound Exceedance Areas**

Zone L RFI DPT and soil boring activities detected organic compounds at several location throughout Subzone F. Organic compounds exceeded risk, soil screening, or MCL limits in four

areas across this subzone. Geologic data in Section 2.0 of the *Zone F RFI Report (1998)* indicate that near surface geology in Zone F consists primarily of Qc and Qm with some interbedded sand, which are in turn typically overlain by fill materials. The basal confining unit for Subzone F, the Ashley Formation, occurs at depths ranging from 22 ft bgs at location GDF01D in the northern portion of Subzone F, to 39 ft bgs at GDE08D on the east-central boundary between Subzones E and F. Subzone F shows little development of Qs.

### **2.3 Zone L Hydrogeology**

No specific hydrogeological investigation was performed for the Zone L RFI. Zone-specific hydrogeological assessments have been performed for Zones A, B, C, D, E, F, G, H, and I at CNC. Discussions of aquifer characteristics may be found in the zone specific RFI reports.

Aquifer characterization at CNC was facilitated by water level measurements, slug tests, specific capacity tests, geotechnical data analyses, a grain size-hydraulic conductivity evaluation, pumping tests, and tidal influence studies.

#### **2.3.1 Surficial Aquifer**

The surficial aquifer extends from the water table to the top of the confining unit. The Tertiary-age Ashley Formation is the regional confining unit and was encountered throughout CNC, except along the boundary between Zones B and E. Instead, Qco was found at typical Ta elevations. In this portion of CNC extensive erosion into Ta has been filled with younger Qco. The relative thickness of the Qco and lack of sand development within this unit indicates that the Qco behaves as the local confining unit within this area of the site, or where it directly overlies the Ashley. Erosion of the upper Ashley contact has resulted in an undulating surface in the top of the basal confining unit for the surficial aquifer. The highest and lowest Ta unit elevations were encountered at -6.1 and  $\leq -75.8$  ft msl at GDE28D and 02301D, respectively. Elevation of the Ta contact is generally between -10 and -30 ft msl across much of CNC.

### 2.3.2 Groundwater Flow Direction 1

Groundwater flow directions for each zone at CNC are found in the respective RFI reports. 2  
 SWMU 37 well locations have been plotted on the appropriate shallow groundwater elevation 3  
 contour maps originally presented in the respective RFI reports, and are presented in Appendix 4  
 B of this Report. 5

The Cooper River, Shipyard Creek, and Noisette Creek shorelines were treated as specified head 6  
 boundaries when generating shallow well groundwater elevation contours since they are obvious 7  
 groundwater discharge areas. Therefore, the equipotential lines parallel the shoreline. Although 8  
 dry docks and quay walls were built to limit surface water-groundwater interaction, they were 9  
 treated as native river boundaries for simplicity. 10

### 2.3.3 Horizontal Hydraulic Gradient 11

The horizontal hydraulic gradient ( $i$ ) is a measure of the difference in hydraulic head ( $\Delta h$ ) (change 12  
 in groundwater elevation) between two points divided by the distance ( $\Delta x$ ) between these points. 13  
 It is a unitless value that quantitatively describes the slope of the water table. Table 2.2 presents 14  
 the calculated horizontal gradients for groundwater flow in areas associated with SWMU 37 15  
 monitoring wells. 16

**Table 2.2**  
**Horizontal Hydraulic Gradients Near SWMU 37 Shallow Wells**

SWMU 37 Well	$\Delta h$ (ft)	$\Delta x$ (ft)	$i$	19
037A01	3	400	0.008	20
037A02	4	110	0.036	21
037C01	3	500	0.006	22
037C02	3	500	0.006	23
037E01	6	410	0.014	24
037E02	0.6	600	0.001	25

**Table 2.2**  
**Horizontal Hydraulic Gradients Near SWMU 37 Shallow Wells**

SWMU 37 Well	$\Delta h$ (ft)	$\Delta x$ (ft)	i	
037G01	5	360	0.014	1
037G02	5	360	0.014	2
037H01	2	530	0.004	3
037H02	3	420	0.007	4
037H03	2	560	0.004	5
037I01	2	360	0.006	6

Notes: 7  
 $\Delta h$  = Hydraulic head (change in groundwater elevation) 8  
 $\Delta x$  = Horizontal distance between head measurements 9  
 i = Horizontal hydraulic gradient 10

### 2.3.4 Vertical Hydraulic Gradient 11

No shallow/deep well pairs were installed during the Zone L RFI. However, vertical hydraulic 12  
 gradients were calculated using groundwater level data collected from shallow/deep well pairs in 13  
 the zone specific RFIs. Vertical hydraulic gradients were calculated by dividing the difference 14  
 between groundwater elevations in shallow and deep well pairs by the vertical distance between 15  
 the bottom of each respective well screen. Positive values indicate downward vertical gradients 16  
 whereas negative values indicate an upward vertical gradient. 17

### 2.3.5 Subzone Groundwater Flow 18

Groundwater flow directions and gradients relative to the SWMU 37 monitoring well locations, 19  
 as well as SWMU 37 and AOC 699 DPT organic compound detections, are presented here by 20  
 subzone. Flow directions and gradients are based on data in the individual zone RFI reports. 21  
 SWMU 37 wells and areas of Zone L detection exceedances are marked on the shallow 22  
 groundwater elevation contour maps (Appendix B). 23

**Subzone A**

Shallow groundwater near well 037A01 flows south toward Noisette Creek. The direction of shallow groundwater flow at 037A02 is east toward the Cooper River. Deep groundwater flow direction beneath both wells is easterly toward the Cooper River. Vertical gradients in Zone A are typically downward, based on the *Zone A RFI Report*.

**Subzone C**

Shallow groundwater for both wells flows north toward Noisette Creek. There was insufficient information to develop deep well groundwater elevation contours in the *Zone C RFI Report*. However, given the proximity to well 037A01, the direction of deep groundwater flow beneath these wells should also be toward the Cooper River. A downward vertical gradient in this area is indicated by the vertical gradient for the nearest deep/shallow well pairs (GDA002/02D and GDB001/01D).

**Subzone E**

The direction of shallow groundwater flow across Zone E is generally toward the Cooper River, but is locally variable. Shallow groundwater flow at well 037E01 is north towards Dry Dock #5, and southwest from well 037E02 toward a groundwater depression correlating with sewers constructed along Avenue D. Invert depths were measured in several sewer manholes in the northern half of Zone E. A comparison between invert depths and depth to groundwater in these areas indicates that many of the sewer lines were constructed below the water table. These sewer lines and associated construction fill materials may locally alter and redirect shallow groundwater movement in this area. Deep groundwater flows east toward the Cooper River. Vertical hydraulic gradients are downward at well 037E0, as they are across most of Subzone E. However, the vertical gradient is slightly negative around well 037E02, indicating an upward vertical gradient.

**Subzone F**

No shallow wells were installed in Subzone F as part of SWMU 37. However, organic compounds were detected above RBCs, SSLs, or MCLs during Zone L Subzone F RFI sampling near AOC 607, as discussed in Section 10. Groundwater flow at AOC 607 is generally northwest to southeast, based on Zone F RFI groundwater elevation data from shallow wells. However, there is a slight groundwater depression at well 607006. Sewer invert depths were measured in 20 of the sewer manholes at AOC 607. A comparison of invert depths and depth to groundwater at AOC 607 indicates that many of the sewer lines were constructed below the water table. These sewer lines and associated construction fill materials may locally alter and redirect shallow groundwater movement in this area. Zone F RFI shallow well groundwater elevation contours are presented in Appendix B. Deep well groundwater typically flows east towards the Cooper River. However, there is a slight groundwater high associated with deep well 60706D. Vertical gradients at AOC 607 calculated during the Zone F RFI were typically positive, which indicates a downward gradient direction. However, the vertical gradient calculated for the 607006/06I/06D well cluster indicates an upward vertical gradient at that location.

**Subzone G**

Shallow and deep groundwater flow are east towards the Cooper River. The direction of deep groundwater flow is also East towards the Cooper River. Vertical gradient information for Subzone G indicates that directions vary within the zone, but the vertical gradient is downward near the two SWMU 37 wells.

**Subzone H**

Shallow groundwater flow in Subzone H is toward the surface water bodies surrounding the peninsular portion of CNC. Shallow groundwater flow direction at the Subzone H SWMU 037 wells are: 037H01 - northeast toward the Cooper River, 037H02 - southwest toward Shipyard Creek, and 037H03 - east toward the Cooper River. Groundwater elevation contours presented

in the *Zone H RFI Report* depict a groundwater high in the northwest portion of the zone. Consequently, deep groundwater flow directions relative to the SWMU 37 wells are similar to those of shallow groundwater flow. Vertical groundwater gradients near wells 037H01 and 037H03 are positive, indicating a downward vertical gradient. The vertical groundwater gradient near well 037H02 is negative, indicating an upward vertical gradient.

### **Subzone I**

Subzone I constitutes the waterfront surrounding Subzone H. Therefore, shallow groundwater in Subzone I flows toward the surface water bodies surrounding the peninsular portion of CNC. The direction of deep and shallow groundwater flow at well 037I01 is north toward the Cooper River. Vertical groundwater gradients in this area are positive, indicating a downward vertical gradient.

### **2.3.6 Horizontal Hydraulic Conductivity**

Several methods were used to calculate horizontal hydraulic conductivity ( $K_h$ ) for various sites and lithologies at CNC. Horizontal hydraulic conductivity data are presented for each zone in the individual RFI reports. No  $K_h$  tests were performed as part of the Zone L RFI. However, the most current and comprehensive  $K_h$  evaluation was performed as part of the Zone E RFI. Horizontal hydraulic conductivity results from the various testing methods used in the Zone E RFI were combined to produce a representative effective conductivity value ( $K_{eff}$ ) for the predominant lithologic units at CNC. Table 2.3 presents the  $K_{eff}$  values for each lithology in addition to porosity and vertical hydraulic conductivity ( $K_v$ ) averages (see Section 2.0 of the *Zone E RFI Report* [EnSafe,1997]).

**Table 2.3**  
**Geometric Means of Hydraulic Parameters for Zone E Lithology Types**  
**Based on All Estimation Methods**

General description	Lithologic unit	$K_{eff}$ (ft/d)	$K_v$ (ft/d)	Porosity
Fill	Fs	120	ND	0.40 <sup>b</sup>
	Fc	0.84 <sup>a</sup>	0.0018	0.37
	Fu	4.3	0.0081	0.62
Quaternary Clays	Qm, Qmp, Qp	0.42	0.0033	0.56
	Qc	0.84 <sup>a</sup>	0.0018	0.37
	Qco	0.84 <sup>a</sup>	0.0061	0.54
Quaternary Sands	Qs, Qsp	11	1.324	0.40
	Qso <sup>b</sup>	3.8	1.324 <sup>b</sup>	0.40 <sup>b</sup>
	Qcso	1.3	0.0757	0.52
Tertiary sand, silts, clays	Tu	0.07	0.1389	0.42
Tertiary Ashley Formation	Ta	ND	0.0481	0.47

**Notes:**

All hydraulic conductivity values are geometric means.

a = No Qco or Fc  $K_{eff}$  data; Qc used as best estimate.

b = No Qso or Fs geotechnical data; Qs data used as best estimate.

ND = No data applicable.

ft/d = feet per day

Several lithologic units for which no specific data were collected were assigned values from the most similar lithologic unit, e.g., Qc values are used for the Qco unit in the table.

### 2.3.7 Horizontal Groundwater Velocity

Groundwater velocities were calculated for the predominant shallow groundwater flow direction at each SWMU 37 monitoring well. Velocities were calculated using the following formula:

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

where V is the horizontal groundwater velocity,  $K_h$  is the hydraulic conductivity along the flowpath in feet/day,  $i$  is the horizontal hydraulic gradient, and  $n_e$  is the effective porosity.

For calculation purposes, it was assumed that groundwater flows directly downgradient from the well and that there were no preferential hydraulic pathways altering groundwater flow along the flowpaths. Groundwater flow velocities have been calculated for the predominant transmissive unit observed in association with the well. Velocity was calculated using physical and hydraulic parameters established during the Zone E RFI, presented in Table 2.4.

**Table 2.4**  
**Groundwater Velocities (ft/d) Based On Subzone RFI Contour Data**

Well Name	$K_h$	Horizontal Gradient	Porosity	Velocity	Lithology
037A01	11	0.008	0.40	0.220	Qs
037A02	11	0.036	0.40	0.990	Qs
037C01	0.42	0.006	0.56	0.005	Qm
037C02	0.42	0.006	0.56	0.005	Qm
037E01	0.84	0.008	0.37	0.018	Qc
037E02	11	0.001	0.40	0.028	Qs
037G01	11	0.014	0.40	0.385	Qs
037G02	0.84	0.014	0.37	0.032	Qc
037H01	11	0.004	0.40	0.110	Qs
037H02	11	0.007	0.40	0.193	Qs
037H03	11	0.004	0.40	0.110	Qs

**Table 2.4**  
**Groundwater Velocities (ft/d) Based On Subzone RFI Contour Data**

Well Name	$K_h$	Horizontal Gradient	Porosity	Velocity	Lithology
037I01	11	0.006	0.40	0.026	Qs

*Notes:*

- $K_h$  = Horizontal conductivity in ft/d
- $i$  = Horizontal hydraulic gradient
- $n_c$  = Effective porosity
- $v$  = Velocity in ft/d
- ft/d = feet per day

### 2.3.8 Tidal Influence 1

Since the eastern boundary of CNC is adjacent to the Cooper River, it is important to understand 2  
 how tides in the river might influence groundwater flow. Much of CNC is separated from the 3  
 Cooper River by a quay wall, a 45 to 55 foot deep structure composed of sheet pilings reportedly 4  
 driven to the top of the Ashley Formation. However, large portions of eastern CNC have a typical 5  
 river shoreline without a quay wall, although riprap and fill material with associated debris 6  
 constitute much of the shoreline material. Quay wall structures are associated with pier and ship 7  
 handling areas of CNC. Zone B, and much of Zones A and I have no quay wall structure. 8

Tidal influence studies were undertaken in many of the zone RFIs. Tidal influence was most 9  
 intensively studied for the Zone E RFI. These findings are presented in Section 2.0 of the *Zone E* 10  
*RFI Report*. Major findings from the Zone E tidal influence study were as follows: 11

- Tidal influence was generally limited to 300 feet from the waterfront. The magnitude of 12  
 tidal response was primarily a function of the permeability of the geologic units. 13

- Underprediction of observed tidal amplitudes at GDE023 and GDE24D could not be accounted for entirely by changing the input parameters of aquifer transmissivity and storage. Anthropogenic influences probably dictate the tidal responses at these locations. 1  
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- Close agreement between observed time lags at each well location indicates that tidal response within the aquifer is effectively constant despite hydrogeologic heterogeneity and varying distances from the tidal source. 4  
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In general, the man-made quay wall appears to have a dampening effect on tidal influence on the groundwater system. However, other anthropogenic influences such as storm sewers, which drain the shallow subsurface to the Cooper River through the quay wall, act as local conduits. As such, the sewer system extends the tidal influence inland and reduces the tidal lag time response in the aquifer. 7  
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Greater sensitivity to tidal changes was seen at locations dominated by Qs and Qso deposits due to the greater relative permeability of these units compared with Quaternary clays and silts, and the Tu unit. Primarily, the most sensitive aspect of tidal oscillations was the magnitude of tidal amplitudes. Lag times, when not affected by anthropogenic sources, were relatively consistent despite lithology. 12  
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### **2.3.9 Lithologic Unit Summary** 17

The following is a summary of the predominant lithologic units as they pertain to CNC groundwater movement. The individual zone RFI reports discuss specifics with respect to hydraulic and geotechnical properties. 18  
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**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 overlying the Ashley. Lithologic cross-sections presented by Weems and Lemon (1993) show the Ashley Formation to have a laterally consistent overall thickness. Samples collected from the Ashley at CNC have high clay and silt content, with varying sand content depending greatly on depth within the formation.

**2.3.9.2 Upper Tertiary Undifferentiated (Tu)**

The Tu unit has an average vertical permeability approximately three times greater than that of the Ashley Formation based on CNC geotechnical testing data.

Horizontal permeability ( $K_h$ ) values for Tu sediments vary over several orders of magnitude, reflecting variability in lithologic texture. Wells completed in Tu sediments are typically low in groundwater yield.

**2.3.9.3 Quaternary Age Sediments**

The various Quaternary age lithologies encountered at CNC reflect widely diverse depositional systems. Despite such variability, the Quaternary age sediments are hydraulically connected and behave as one surficial aquifer which may have locally unconfined, semiconfined, confined, and perched zones. Consequently, these sediments exhibit localized influences on the hydrogeologic system throughout CNC. In terms of effective horizontal hydraulic conductivity, values from the geometric means based on Zone E test data ranged from  $Q_m$  (0.42 ft/d), to  $Q_c$  (0.84 ft/d), to  $Q_{so}$  (1.3 ft/d), to  $Q_s$  (11 ft/d). Quaternary aquifer sediments are typically responsive to tidal influences when in proximity to the Cooper River, or where storm sewers or similar features may extend the tidal influence further inland.

**2.3.9.4 Fill Materials**

Fill materials consisting of ROC, clay, sand, dredged effluent material, and undifferentiated mixtures of the three are present to various depths throughout Zone L. They are typically shallow and may not exist below the water table, although perched conditions may develop when fill is placed on top of less permeable materials. Perched conditions may manifest as small, anomalous "groundwater" highs. Permeable backfill in trenches may also act as a conduit for groundwater movement.

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### 3.0 FIELD INVESTIGATION

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

#### 3.1 Investigation Objectives

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

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

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

##### 3.2.1 Sample Identification

All environmental samples collected during this investigation were identified using a 10-character alphanumeric system describing samples by site, sample matrix, location, and other pertinent information. This system is detailed in Section 11.4 of the CSAP. The first three characters

identify the site where the sample was collected. The fourth and fifth characters represent the quality control or matrix code. Characters six through eight designate sampling location: boring or well number, sampling station, existing well identification, and others. The final two characters represent sample-specific identification such as depth to the nearest foot, depth interval, sampling event for water samples, and others. Appendix C is the complete data report for all samples collected in Zone L.

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

- Soil Borings Samples — SB
- Groundwater Samples — GW
- Sediment Samples — MO
- Soil Direct Push Technology (DPT) Samples — SP
- Groundwater Direct Push Technology Samples — GP

### 3.2.2 Soil Sampling

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

#### 3.2.2.1 Soil Boring Sample Locations

The soil boring samples were collected based on the boring locations for SWMU 37 (oil/water separators and septic tanks) and AOC 504 (railroad system) as proposed in the *Final Zone L RFI Work Plan*. Some original sample locations were modified due to inaccessibility, subsurface obstructions, or utility locations. Soil boring samples collected for the Zone L investigation were identified according to the following convention. All identification numbers for soil borings collected during the Zone L investigation consisted of 14 characters. The first four characters are

a prefix and are not to be included in the sample identification scheme. The first three characters (NBC for borings) identify them as CNC borings. The fourth character identifies the investigatory zone in which the borings were collected (Zone L in this case). Characters 5, 6, and 7 identify the site at which the borings were collected. The eight and ninth characters are for the soil boring identification scheme (SB). The tenth, eleventh, and twelfth characters identify the individual boring number. The thirteenth character identifies the zone in which the boring was collected and the fourteenth character identifies the depth of the boring (1 for 0 to 1foot, 2 for 3 to 5feet). A complete example of typical soil boring identifications follows:

- NBCL037SB001A1 is boring number 001 at SWMU 37 in Zone A, the upper-interval, at CNC.

Soil boring locations will be identified for Zone L and previous zone investigations on AUTOCAD and GIS figures as shown below:

- 037SB001 is soil boring number 001 at SWMU 37.

### **3.2.2.2 Soil Boring Sample Collection**

Stainless-steel hand augers, spoons, and mixing bowls were used to collect soil samples for laboratory analysis. In addition, to gain access to soil beneath the concrete and asphalt in Zone L, a concrete and asphalt coring machine was used. Composite soil samples were collected from the upper, 0- to 1-foot below ground surface (bgs) interval and the lower, 3- to 5-foot bgs interval. The 0- to 1-foot bgs interval is referred to in this report as the "1" or upper-interval sample. The 3- to 5-foot bgs interval is referred to as the "2" or lower-interval sample. At locations overlain by concrete or asphalt, the upper-interval sample was collected from the base of the pavement, taking precaution not to include any asphaltic material. A clean, decontaminated hand auger was

used to collect the sample from the lower-interval. A relatively high water table prohibited sampling in some of the lower-intervals because saturated samples were not submitted for analysis.

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

Section 3.2.2.3 of the Zone A RFI report details the procedures to prepare, package, and ship soil samples collected during the Zone L RFI investigation. The samples were shipped priority overnight via FedEx to Southwest Laboratory of Oklahoma in Tulsa.

### 3.2.2.4 Soil Boring Sample Analysis

A total of 182 soil boring samples (90 for SWMU 37 and 92 for AOC 504) were analyzed per USEPA Method SW-846 at DQO Level III unless otherwise noted, as follows:

- Volatile organic compounds (VOCs) USEPA Method 8260
- Semivolatile organic compounds (SVOCs) USEPA Method 8270
- Pesticides/polychlorinated biphenyls (PCBs) USEPA Method 8080
- Cyanide USEPA Method 9010
- Metals Title 40 Code of Federal Regulations (CFR) Part 264 Appendix IX
- Herbicides (AOC 504 only) USEPA Method 8151

### 3.2.2.5 Soil DPT Soil Locations

Collection of the soil DPT samples was based on the DPT locations for SWMU 37 (sanitary sewer system), AOC 699 (storm sewer system) and AOC 504 (railroad system) as proposed in the *Final Zone L RFI Work Plan*. Some of the original sample locations were modified due to inaccessibility, subsurface obstructions, or utility locations. Soil DPT samples collected for the Zone L investigation were identified according to the following convention. All identification numbers for soil DPT samples collected during the Zone L investigation consisted of

10 characters. Characters 1, 2, and 3 identify the site at which the borings were collected. The fourth and fifth characters are for the soil DPT identification scheme (SP). The sixth, seventh, and eighth characters identify the individual DPT number. The ninth character identifies the zone in which the boring was collected and the tenth character identifies that one sample was collected at that location. A complete example of typical soil DPT identifications follows.

- 037SP001A1 is soil DPT number 001 at SWMU 37 in Zone A.

Soil DPT locations will be identified on AUTOCAD and GIS figures as shown below:

- 037SP001 is soil DPT number 001 at SWMU 37.

In certain situations, samples have a character such as A in the eighth character instead of a number, because a sample had been earlier identified with the same numbering scheme.

### **3.2.2.6 Soil DPT Sample Collection**

Soil was collected using a DPT rig, as described in Sections 4.3.3 and 6.1.3 of the approved final CSAP.

### **3.2.2.7 Soil DPT Sample Preparation, Packaging, and Shipment**

Guidelines in Section 11 of the approved final CSAP were followed for preparing, packaging, and shipping soil DPT samples collected during the Zone L RFI investigation. The samples were shipped priority overnight via FedEx to Southwest Laboratory of Oklahoma in Tulsa.

**3.2.2.8 Soil DPT Sample Analysis**

A total of 367 soil DPT samples (216 for SWMU 37, 40 for AOC 504 and 111 for SWMU 699) were analyzed per USEPA Method SW-846 at data quality objective (DQO) Level II unless otherwise noted, as follows:

- VOCs USEPA Method 8260
- Cyanide USEPA Method 9010
- Metals Title 40 CFR Part 264 Appendix IX

**3.2.3 Monitoring Well Installation and Development**

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

Monitoring wells installed for the Zone L RFI investigation were identified according to the following convention. All identification numbers for monitoring wells installed during the Zone E investigation consist of 14 characters. The first four characters are a prefix and are not to be included in the sample identification scheme. The first three characters (NBC for all wells) identify them as CNC wells. The fourth character identifies the investigatory zone in which the monitoring wells were installed (L in this case). Characters 5, 6, and 7 identify the site (SWMU 37) at which the monitoring wells were installed. The eighth and ninth characters are for the monitoring well identification scheme (GW). The tenth, eleventh, and twelfth characters identify the individual well number. The thirteenth character identifies the zone in which the well

was installed and the fourteenth character identifies the quarterly sampling event. A complete example of typical monitoring well identifications follows:

- NBCL037GW001A1 is well number 001 at SWMU 37 in Zone A, the first quarter, at CNC .

Identification of Zone L monitoring well locations on AUTOCAD and GIS figures will be as such:

- 037A01 is well number 001 at SWMU 37 in Zone A for AUTOCAD figures.
- 037GW001 is well number 001 for GIS figures.

Monitoring wells from previous Zone investigations will be identified as show below:

- 039001 is well number 001 at SWMU 39 for AUTOCAD figures.
- 039GW001 is well number 001 at SWMU 39 for GIS figures.

### 3.2.3.1 Shallow Monitoring Well Installation

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

Shallow well borings were continuously sampled beginning at least 3 feet bgs using 2-foot long split-spoon samples. These soil samples were visually classified and screened for organic vapors

and radiologic emissions by the onsite geologist. These samples were not retained for chemical analysis.

Shallow monitoring wells are constructed using 2-inch inside diameter (ID) flush threaded PVC screen and riser. A 10-foot section of 0.010-inch machine slot screen used in each expansion cap completed the well. The screen and riser were set inside the hollow-stem auger. Filter pack sand was poured into the annular space between the hollow-stem auger and PVC to at least 1-foot above the top of the screen. The augers were carefully removed during filter pack placement to ensure uniform placement of the filter pack. Bentonite pellets were placed to ground surface, then hydrated with potable water. After allowing sufficient time for the bentonite pellets to hydrate, protective surface completions were constructed. Flush-mount (manhole type), or above-grade type protective well completions were installed depending on the well location. Flush-mount well completions were installed in vehicle traffic areas such as parking lots. Above-grade steel protective well completions were installed at all other areas. A monitoring well identification tag listing the well number, date installed, drilling subcontractor, and depth to groundwater was attached to each well.

For flush mounts, a 2-foot by 2-foot section of material, typically concrete or asphalt, was removed from around the borehole to approximately 4 inches deep. An 8-inch ID by 8-inch deep flush-mount cover with a bolt-down access cover was then placed over the capped well. Concrete was added to fill the 2-foot by 2-foot excavated area and shaped to provide a gently sloping surface away from the cover. Locking expansion caps and keyed-alike locks were placed on each monitoring well with a flush-mount cover.

Above-grade well completions were installed using a 3.5-foot long by 4-inch square steel protective surface casing placed over the PVC riser pipe. Care was taken not to compromise the integrity of the bentonite seal overlying the filter pack material. The protective casings were

hinged approximately 6 inches from the top to allow access to the top of the PVC well riser pipe. 1  
The hinged covers for each above-grade protective casing were designed to allow for security 2  
locking. A 3-foot by 3-foot concrete pad approximately 6 inches thick was then constructed 3  
around each protective casing. Weep holes were drilled through the well protector at a height that 4  
would not allow water to rise above the top of the well. A bumper post with a diameter of at least 5  
3 inches was set just outside each accessible corner of the pad. Each well was fitted with an 6  
expanding well cap and each hinged cover was secured with a keyed-alike lock. 7

### 3.2.3.2 Surface Casing Construction 9

Section 3.2.3.4 of the Zone A RFI report details the surface casing construction process. 10

### 3.2.3.3 Monitoring Well Development 12

Section 3.2.3.5 of the Zone A RFI report details Zone L monitoring well development. 13

### 3.2.4 Monitoring Well Groundwater Sampling 15

Section 6 of the CSAP details the groundwater sampling process. The following subsections 16  
summarize the site-specific methods applied in Zone L. 17

#### 3.2.4.1 Monitoring Well Groundwater Sampling Locations 19

Groundwater samples were collected from monitoring wells based on approved locations identified 20  
in the *Final Zone L RFI Work Plan*. Some proposed locations were adjusted due to inaccessibility 21  
or obstructing utilities. 22

#### 3.2.4.2 Monitoring Well Groundwater Sample Collection 24

Monitoring well groundwater was sampled according to Section 3.2.4.2 of the Zone A RFI report. 25

### 3.2.4.3 Monitoring Well Groundwater Sample Preparation, Packaging, and Shipment

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

### 3.2.4.4 Monitoring Well Groundwater Sample Analysis

A total of twelve shallow monitoring wells were installed at various sites throughout the base for Zone L. Groundwater samples were analyzed per USEPA Method SW-846 at DQO Level III as follows:

- VOCs USEPA Method 8260
- SVOCs USEPA Method 8270
- Pesticides/PCBs USEPA Method 8080
- Cyanide USEPA Method 9010
- Metals Title 40 CFR Part 264 Appendix IX

### 3.2.5 Water DPT Locations

Collection of the water DPT samples was based on the DPT locations for SWMU 37 and AOC 699 as proposed in the *Final Zone L RFI Work Plan*. Some of the original sample locations were modified due to inaccessibility, subsurface obstructions, or utility locations. Water DPT samples collected for the Zone L investigation were identified according to the following convention. All identification numbers for soil DPT samples collected during the Zone L investigation consisted of 10 characters. Characters 1, 2, and 3 identify the site at which the water DPT samples were collected. The fourth and fifth characters are for the water DPT identification scheme (GP). The sixth, seventh, and eighth characters identify the individual DPT number. The ninth character identifies the zone in which the DPT sample was collected and tenth character indicates that one

sample was one taken at that location. A complete example of typical water DPT identifications follows:

- 037GP001A1 is water DPT number 001 at SWMU 37 in Zone A.

Water DPT locations will be identified on AUTOCAD and GIS figures as shown below:

- 037GP001 is water DPT number 001 at SWMU 37.

In certain situations, samples, have a letter such as "A" in the eighth character instead of a number, because a sample had been earlier identified with the same numbering scheme.

#### **3.2.5.1 Water DPT Sample Collection**

Water was collected using a DPT rig, as described in Sections 4.3.3 and 6.1.3 of the approved final CSAP.

#### **3.2.5.2 Water DPT Sample Preparation, Packaging, and Shipment**

Guidelines in Section 11 of the approved final CSAP were followed for preparing, packaging, and shipping water DPT samples collected during the Zone L RFI investigation. The samples were shipped priority overnight via FedEx to Southwest Laboratory of Oklahoma in Tulsa.

#### **3.2.5.3 Water DPT Sample Analysis**

A total of 472 water DPT samples (328 for SWMU 37 and 144 for SWMU 699) were analyzed per USEPA Method SW-846 at DQO) Level II unless otherwise noted:

- VOCs USEPA Method 8260
- Cyanide USEPA Method 9010
- Metals Title 40 CFR Part 264 Appendix IX

### 3.2.6 Sediment Sampling

Section 7 of the CSAP details sediment sampling methods. The following subsections summarize those methods as applied in the Zone L RFI.

#### 3.2.6.1 Sediment Sample Locations

Sediment samples were collected from the locations proposed in the *Final Zone E RFI Work Plan*. All sediment sample locations were accessible. Sediment samples collected for the Zone L investigation were identified according to the following convention. All identification numbers for sediment samples collected during the Zone L investigation consisted of 10 characters. Characters 1, 2, and 3 identify the site at which the sediment samples were collected. The fourth character identifies the sediment identification scheme (M). The fifth, sixth, seventh, and eighth characters identify the individual sediment number. The ninth character identifies, the zone in which zone the sediment sample was collected and the tenth character indicates that one or more samples was collected at that location. A complete example of typical sediment sample identifications follows.

- 699M0001E1 is sediment number 0001 at AOC 699 in Zone E.

Sediment locations will be identified on AUTOCAD and GIS figures as follows:

- 699M0001 is sediment number 001 at AOC 699.

#### 3.2.6.2 Sediment Sample Collection

Sediment samples were collected using a Young grab sampler. This weighted dredge sampler was lowered to the surface, where the jaws were opened to "grab" a sample, which was then winched to the surface. The sampler was then retrieved and the jaws opened to collect the sediment

sample. VOC samples were collected immediately from the sampler. The rest of the sample was homogenized in the bowl and placed into appropriate sample containers.

### **3.2.6.3 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 L RFI. The following summarizes those activities.

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

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

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

**3.2.6.4 Sediment Sample Analysis**

Six sediment samples were analyzed using the following USEPA Method SW-846 parameters:

- VOCs                                   USEPA Method 8240
- Cyanide                               USEPA Method 9010
- Metals                                 Title 40 CFR Part 264 Appendix IX

**3.2.7 Vertical and Horizontal Surveying**

Section 3.2.8 of the Zone A RFI report details procedures for vertical and horizontal surveying in Zone L.

**3.2.8 Decontamination Procedures**

Section 3.2.10 of the Zone A RFI report details the decontamination procedures used during the Zone L RFI.

## 4.0 DATA VALIDATION

### 4.1 Introduction

DQOs are qualitative and quantitative statements specifying the quality of data required to support decisions during environmental response actions. The level of certainty regarding data precision varies with the intended end use. According to USEPA guidance, *Data Quality Objectives for Remedial Response Activities, Development Process*, EPA/540/G-87/003 (USEPA, March 1987), the levels of analytical data are as follows:

- Level I — Field screening or analysis using portable instruments. Results are often neither compound-specific nor quantitative, but are available in real-time. This is the least costly analytical option.
- 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 within several hours.
- 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.
- Level IV — All analyses are performed in an offsite analytical laboratory following rigorous QA/QC protocols and documentation meeting or exceeding CLP requirements.

- 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 modification may be required for specific constituents or detection limits. CLP special analytical services (SAS) are Level V.

For the Zone L RFI at CNC, analytical Level II and Level III data were deemed appropriate for the intended data uses: site characterization, data gap explanations, and corrective measure determinations/design.

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 data evaluation of environmental media sample analyses for the Zone L 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 data usability 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 identification
- Analyte quantification
- QC blanks (trip, method, equipment, field, rinsate)
- Matrix spike recoveries
- Performance evaluation (PE) samples (when specified)
- Analytical method precision
- Total measurement error determination

RFI environmental samples were collected at Zone L from May 1997 to February 1998. All Level II samples were analyzed by Target Environmental Services, Inc., and the Level III samples were analyzed by 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**  
**Charleston Naval Complex Analytical Program**

Analytical Methods	Data Quality Level	Method Reference
Volatile Organic Compounds (VOCs)	II/III	SW-846 8260
Semivolatile Organic Compounds (SVOCs)	III	SW-846 8270
Pesticides/Polychlorinated biphenyls (PCBs)	III	SW-846 8080
Chlorinated Herbicides	III	SW-846 8150
Cyanide	II/III	USEPA 9012
TAL Metals	II/III	SW-846 6010/7060/7421/7470/7740/7841

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.

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

<b>4.2.1 Organic Evaluation Criteria</b>	1
Section 4.2.1 of the Zone A RFI Report discusses the organic evaluation criteria as they apply to the Zone L RFI. Appendix D includes the complete analytical dataset for Zone L.	2 3
<b>4.2.1.1 Holding Times</b>	4
Section 4.2.1.1 of the Zone A RFI Report discusses organic sample holding times as they apply to the Zone L RFI.	5 6
<b>4.2.1.2 GC/MS Instrument Performance Checks</b>	7
Section 4.2.1.2 of the Zone A RFI Report discusses performance standards for VOC and SVOC analyses as they apply to the Zone L RFI.	8 9
<b>4.2.1.3 Surrogate Spike Recoveries</b>	10
Section 4.2.1.3 of the Zone A RFI Report discusses organic surrogate compounds as they apply to the Zone L RFI.	11 12
<b>4.2.1.4 Instrument Calibration</b>	13
Section 4.2.1.4 of the Zone A RFI Report discusses instrument calibration as they apply to organic data evaluation for the Zone L RFI.	14 15
<b>4.2.1.5 Matrix Spike/Matrix Spike Duplicate</b>	16
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 L RFI.	17 18
<b>4.2.1.6 Laboratory Control Samples and Laboratory Duplicates</b>	19
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 L RFI.	20 21

**4.2.1.7 Blank Analysis**

Section 4.2.1.7 of the Zone A RFI Report discusses blank analyses as they apply to organic data evaluation for the Zone L RFI.

**4.2.1.8 Field-Derived Blanks**

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 L RFI.

**4.2.1.9 Internal Standard Performance**

Section 4.2.1.9 of the Zone A RFI Report discusses internal standard performances as they apply to organic data evaluation for the Zone L RFI.

**4.2.1.10 Diluted Samples**

A special evaluation was performed for diluted samples to determine if method detection limits were sufficiently low to be compared with reference concentrations (e.g., Maximum Contaminant Levels [MCLs], Risk-Based Concentrations [RBCs], etc.). Table 4.2 lists the diluted samples for Zone L.

**Table 4.2  
 Diluted Soil Sample Summary**

<b>Method</b>	<b>Sample ID</b>	<b>Parameter</b>	<b>Result</b>	<b>Units</b>	<b>VQUAL</b>
SW846-PEST	504SB002E2	4,4'-DDD	97.00	µg/kg	D
SW846-PEST	504SB001F1	4,4'-DDD	58.00	µg/kg	D
SW846-PEST	037SB005G1	4,4'-DDD	41.00	µg/kg	D
SW846-PEST	037SB013H2	4,4'-DDD	230.00	µg/kg	D
SW846-PEST	037SB002C1	4,4'-DDE	110.00	µg/kg	D
SW846-PEST	504SB002E2	4,4'-DDE	110.00	µg/kg	D
SW846-PEST	504SB009F1	4,4'-DDE	27.00	µg/kg	D
SW846-PEST	037SB005G1	4,4'-DDE	140.00	µg/kg	D
SW846-PEST	037SB006G1	4,4'-DDE	390.00	µg/kg	D

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

Method	Sample ID	Parameter	Result	Units	VQUAL
SW846-PEST	037SB013G1	4,4'-DDE	71.00	µg/kg	DJ
SW846-PEST	037SB014G1	4,4'-DDE	95.00	µg/kg	DJ
SW846-PEST	037SB013H2	4,4'-DDE	81.00	µg/kg	D
SW846-PEST	504SB006B1	4,4'-DDT	410.00	µg/kg	DJ
SW846-PEST	504SB008B1	4,4'-DDT	63.00	µg/kg	D
SW846-PEST	037SB001C1	4,4'-DDT	140.00	µg/kg	D
SW846-PEST	037SB002C1	4,4'-DDT	74.00	µg/kg	D
SW846-PEST	037SB005G1	4,4'-DDT	190.00	µg/kg	D
SW846-PEST	037SB006G1	4,4'-DDT	210.00	µg/kg	D
SW846-PEST	037SB009H1	4,4'-DDT	68.00	µg/kg	DJ
SW846-PEST	037SB011H2	4,4'-DDT	120.00	µg/kg	DJ
SW846-PEST	037SB012H1	4,4'-DDT	87.00	µg/kg	DJ
SW846-PEST	037SB014H2	4,4'-DDT	1500.00	µg/kg	DJ
SW846-PEST	037CB014H2	4,4'-DDT	2400.00	µg/kg	DJ
SW846-PEST	037SB005E1	Dieldrin	14.00	µg/kg	DJ
SW846-PEST	037SB009H1	Endosulfan II	5.00	µg/kg	DJ
SW846-PEST	037SB011H2	Endosulfan II	9.20	µg/kg	DJ
SW846-PEST	037SB012H1	Endosulfan II	9.40	µg/kg	DJ
SW846-PEST	504SB006B1	Endrin	170.00	µg/kg	DJ
SW846-PEST	037SB010E2	Endrin	290.00	µg/kg	DJ
SW846-PEST	037SB011E1	Endrin	190.00	µg/kg	D
SW846-PEST	037CB011E1	Endrin	150.00	µg/kg	DJ
SW846-PEST	037SB002H1	Endrin	170.00	µg/kg	DJ
SW846-PEST	504SB006B1	Endrin aldehyde	94.00	µg/kg	DJ
SW846-PEST	037SB009H1	Endrin aldehyde	59.00	µg/kg	DJ
SW846-PEST	037SB011H2	Endrin aldehyde	120.00	µg/kg	D
SW846-PEST	037SB012H1	Endrin aldehyde	73.00	µg/kg	D
SW846-PEST	037SB013H1	Endrin aldehyde	750.00	µg/kg	DJ
SW846-PEST	037SB013H2	Endrin aldehyde	44.00	µg/kg	D
SW846-PEST	037SB014H2	Endrin aldehyde	1300.00	µg/kg	DJ
SW846-PEST	037CB014H2	Endrin aldehyde	2800.00	µg/kg	DJ
SW846-PEST	037SB011E1	Heptachlor	83.00	µg/kg	D

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

Method	Sample ID	Parameter	Result	Units	VQUAL
SW846-PEST	037CB011E1	Heptachlor	57.00	µg/kg	DJ
SW846-PEST	037SB002H1	Heptachlor	270.00	µg/kg	D
SW846-PEST	037SB002H2	Heptachlor	57.00	µg/kg	D
SW846-PEST	037SB005E1	Heptachlor epoxide	22.00	µg/kg	D
SW846-PEST	037SB011E1	Heptachlor epoxide	37.00	µg/kg	DJ
SW846-PEST	037CB011E1	Heptachlor epoxide	57.00	µg/kg	DJ
SW846-PEST	037SB002H1	Heptachlor epoxide	58.00	µg/kg	DJ
SW846-PEST	037CB014H2	Heptachlor epoxide	90.00	µg/kg	DJ
SW846-PEST	037SB008I2	Heptachlor epoxide	58.00	µg/kg	D
SW846-PEST	504SB006B1	alpha-Chlordane	89.00	µg/kg	DJ
SW846-PEST	037SB005E1	alpha-Chlordane	70.00	µg/kg	D
SW846-PEST	037SB010E1	alpha-Chlordane	180.00	µg/kg	D
SW846-PEST	037SB010E2	alpha-Chlordane	1400.00	µg/kg	D
SW846-PEST	037SB011E1	alpha-Chlordane	850.00	µg/kg	D
SW846-PEST	037CB011E1	alpha-Chlordane	930.00	µg/kg	D
SW846-PEST	037SB012E1	alpha-Chlordane	74.00	µg/kg	D
SW846-PEST	504SB002E2	alpha-Chlordane	18.00	µg/kg	D
SW846-PEST	037SB002H1	alpha-Chlordane	360.00	µg/kg	D
SW846-PEST	037SB002H2	alpha-Chlordane	66.00	µg/kg	D
SW846-PEST	037SB008I2	alpha-Chlordane	38.00	µg/kg	D
SW846-PEST	037SB005E1	gamma-Chlordane	100.00	µg/kg	D
SW846-PEST	037SB010E1	gamma-Chlordane	230.00	µg/kg	D
SW846-PEST	037SB010E2	gamma-Chlordane	1800.00	µg/kg	D
SW846-PEST	037SB011E1	gamma-Chlordane	1100.00	µg/kg	D
SW846-PEST	037CB011E1	gamma-Chlordane	1200.00	µg/kg	D
SW846-PEST	037SB012E1	gamma-Chlordane	180.00	µg/kg	D
SW846-PEST	504SB002E2	gamma-Chlordane	150.00	µg/kg	D
SW846-PEST	037SB002H1	gamma-Chlordane	970.00	µg/kg	D
SW846-PEST	037SB002H2	gamma-Chlordane	180.00	µg/kg	D
SW846-PEST	037SB012H1	gamma-Chlordane	59.00	µg/kg	D
SW846-PEST	037SB013H2	gamma-Chlordane	9.80	µg/kg	DJ
SW846-PEST	037CB020H1	gamma-Chlordane	29.00	µg/kg	DJ

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

Method	Sample ID	Parameter	Result	Units	VQUAL
SW846-PEST	037SB008I2	gamma-Chlordane	130.00	µg/kg	D
SW846-PEST	037SB009H1	Aroclor-1260	1400.00	µg/kg	D
SW846-PEST	037SB011H2	Aroclor-1260	2800.00	µg/kg	D
SW846-PEST	037SB012H1	Aroclor-1260	1700.00	µg/kg	D
SW846-PEST	037SB012H2	Aroclor-1260	750.00	µg/kg	D
SW846-PEST	037SB013H1	Aroclor-1260	18000.00	µg/kg	DJ
SW846-PEST	037SB014H2	Aroclor-1260	30000.00	µg/kg	DJ
SW846-PEST	037CB014H2	Aroclor-1260	64000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Anthracene	16000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Benzo(a)anthracene	43000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Benzo(a)pyrene	32000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Benzo(k)fluoranthene	35000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Chrysene	48000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Fluoranthene	74000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Phenanthrene	50000.00	µg/kg	DJ
SW846-SVOA	037SB004G1	Pyrene	170000.00	µg/kg	DJ

**Notes:**

- VQUAL = Validation Qualifier
- D = Diluted result
- DJ = Estimated diluted result

**4.2.2 Inorganic Evaluation Criteria**

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

**4.2.2.1 Holding Times**

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

<b>4.2.2.2 Instrument Calibration</b>	1
Section 4.2.2.2 of the Zone A RFI Report discusses instrument calibrations as they apply to inorganic data evaluation for the Zone L RFI.	2 3
<b>4.2.2.3 Blank Analysis</b>	4
Section 4.2.2.3 of the Zone A RFI Report discusses inorganic blank analyses as they apply to inorganic data evaluation for the Zone L RFI.	5 6
<b>4.2.2.4 Inductively Coupled Argon Plasma Interference Check Samples</b>	7
Section 4.2.2.4 of the Zone A RFI Report discusses inductively coupled argon plasma (ICAP) interference check samples as they apply to inorganic data evaluation for the Zone L RFI.	8 9
<b>4.2.2.5 Laboratory Control Samples</b>	10
Section 4.2.2.5 of the Zone A RFI Report discusses laboratory control samples as they apply to inorganic data evaluation for the Zone L RFI.	11 12
<b>4.2.2.6 Spike Sample Analysis</b>	13
Section 4.2.2.6 of the Zone A RFI Report discusses spike sample analyses as they apply to inorganic data evaluation for the Zone L RFI.	14 15
<b>4.2.2.7 Laboratory Duplicates</b>	16
Section 4.2.2.7 of the Zone A RFI Report discusses laboratory duplicates as they apply to inorganic data evaluation for the Zone L RFI.	17 18
<b>4.2.2.8 ICAP Serial Dilutions</b>	19
Section 4.2.2.8 of the Zone A RFI Report discusses ICAP serial dilutions as they apply to inorganic data evaluation for the Zone L RFI.	20 21

**4.2.2.9 Atomic Absorption (AA) Duplicate Injections and Postdigestion Spike Recoveries** 1

Section 4.2.2.9 of the Zone A RFI Report discusses AA duplicate injections and postdigestion spike 2  
recoveries as they apply to inorganic data evaluation for the Zone L RFI. 3

**4.3 Zone L Data Validation Reports** 4

A complete copy of the Zone L Data Validation Reports along with a table of validation qualifiers 5  
are included in Appendix E. These reports are the outcome of the evaluations described above and 6  
are specific to the analytical data collected during the Zone L RFI. During data validation review 7  
of Zone L soil and groundwater analytical sample results, the following deficiencies and/or 8  
problems were noted in the volatile, semivolatile, and metals methods per site. 9

For Direct Push Technology (DPT) samples in subzone B, SWMU 037, the volatile method 10  
detected acetone and carbon disulfide in the equipment blanks. For DPT samples in subzone E, 11  
site 037, the volatile method detected acetone, chloroform, bromodichloromethane, and 12  
dibromochloromethane in the trip and equipment blanks. In subzone F, chloroform, 13  
bromodichloromethane, and dibromochloromethane were detected in the trip blanks for the volatile 14  
method. For subzone G, chloroform, bromodichloromethane, dibromochloromethane, and 15  
bromoform were detected in the trip blanks. For subzone H, carbon disulfide, chloroform, and 16  
bromodichloromethane were detected in the trip blanks. The metals method for the DPT samples 17  
in subzone H detected calcium, copper, iron, lead, magnesium, manganese, sodium, and zinc 18  
detected in the equipment blank. 19

For soil boring samples in AOC 504, subzone A, the volatile method detected methylene chloride 20  
and acetone in the trip and method blanks and chloroform in the distilled water and equipment 21  
blanks. The semivolatile method detected bis(2-Ethylhexyl)phthalate in the distilled water, 22  
equipment, and method blanks, and benzoic acid was detected in the distilled and equipment 23  
blanks. The pesticide method detected methoxychlor in the method blank. The metals method 24

detected aluminum, arsenic, barium, calcium, copper, iron, lead, magnesium, manganese, 1  
mercury, sodium, vanadium, and zinc in the distilled and equipment blanks. The method blanks 2  
had detections of aluminum, calcium, chromium, cobalt, copper, cyanide, potassium, selenium, 3  
sodium, and tin. 4

For soil boring samples in AOC 504, subzone B, the volatile method detected methylene chloride 5  
detected in the trip and method blanks. Acetone and chloroform were detected in the method 6  
blanks. The semivolatile method detected butylbenzylphthalate and bis(2-Ethylhexyl)phthalate 7  
in the method blanks. 8

For soil boring samples in AOC 504, subzone C, the volatile method detected methylene chloride, 9  
acetone, chloroform, and trichloroethene in the method blanks. Acetone and methylene were 10  
detected in the trip blank, and chloroform in the distilled water, equipment, and trip blanks. The 11  
semivolatile method showed detections of phenol in the distilled water and equipment blanks, 12  
2,4,6-trichlorophenol in the distilled water blank, and bis(2-Ethylhexyl)phthalate and 4-chloro- 13  
3-methylphenol in the method blank. The pesticide method detected methoxychlor in the method 14  
blank. The metals method detected aluminum, chromium, nickel, and zinc in the equipment 15  
blank; antimony, cobalt, and magnesium in the distilled water blank; and iron, manganese, and 16  
sodium in the distilled and equipment blanks. Aluminum, antimony, beryllium, cadmium, 17  
calcium, cobalt, cyanide, lead, nickel, sodium, tin, and zinc were detected in the method blanks. 18

For soil samples in SWMU 037, subzone E, the volatile method showed detections of methylene 19  
chloride in the distilled water, equipment, trip, and method blanks; acetone in the trip, distilled, 20  
and method blanks; chloroform in the distilled water, equipment, and method blanks; and 21  
bromodichloromethane in the equipment and distilled water blanks. The semivolatile method 22  
detected di-n-butylphthalate in the equipment blank, and bis(2-Ethylhexyl)phthalate in the distilled 23  
water, equipment, and method blanks. Butylbenzylphthalate was detected in the method blank. 24

The metals method detected aluminum, antimony, arsenic, beryllium, chromium, copper, iron, magnesium, manganese, nickel, potassium, silver, and thallium in the distilled water and equipment blanks. The method blank showed detections of aluminum, antimony, beryllium, cadmium, calcium, cobalt, lead, silver, sodium, and tin; cyanide was detected in the method blanks.

For soil boring samples in AOC 504, subzone E, the volatile method detected methylene chloride, acetone, and chloroform in the trip blanks, and chloroform and bromodichloromethane in the distilled water and equipment blanks. The semivolatile method detected di-n-butylphthalate in the equipment blank, and bis(2-Ethylhexyl)phthalate in the distilled water and equipment blanks. The metals method had detections of antimony, arsenic, beryllium, chromium, copper, manganese, nickel, sodium, and thallium in the equipment and distilled water blanks.

For soil boring samples in AOC 504, subzone F, the volatile method detected acetone, methylene chloride, and chloroform in the trip and method blanks. The metals method showed detections of aluminum, iron, manganese, and tin in the method blanks.

For SWMU 037, subzone G, acetone, methylene chloride and chloroform were detected in the trip and method blanks. The pesticide method detected methoxychlor in the method blank. The metals method showed aluminum, cobalt, copper, cyanide, lead, nickel, silver, selenium, and tin.

For SWMU 037, subzone H, acetone and methylene chloride were detected in the trip blanks, and bromodichloromethane in the distilled water blank. The method blanks showed detections of methylene chloride and acetone. The pesticide method detected methoxychlor in the method blank. The metals method showed detections of antimony, beryllium, copper, lead, potassium, and sodium in the distilled water and equipment blanks. Aluminum, beryllium, calcium, cyanide, lead, selenium, silver, sodium, and tin were detected in the method blanks.

For SWMU 037, subzone I, acetone and methylene chloride were detected in the volatile method and trip blanks. The metals method showed detections of aluminum, cobalt, cyanide, selenium, silver, and tin in the method blanks.

For groundwater samples in subzone A, methylene chloride was detected in the trip and method blanks, and chloroform in the method blank. The semivolatile method detected bis(2-Ethylhexyl)phthalate in the method blank. The metals method detected aluminum, barium, cobalt, cyanide, and sodium in the method blanks.

For groundwater samples in subzone C, the semivolatile method detected phenol and bis(2-Ethylhexyl)phthalate in the method blanks. The metals method detected aluminum, antimony, beryllium, cobalt, and sodium in the method blanks.

For groundwater samples in subzone E, the volatile method detected chloroform and bromodichloromethane in the distilled water, equipment, and trip blanks, and dibromochloromethane in the trip blank. The semivolatile method detected bis(2-Ethylhexyl)phthalate in the distilled water, equipment, and method blanks. The metals method detected barium, beryllium, calcium, cyanide, and manganese in the equipment and distilled water blanks. The method blanks showed detections of barium, cobalt, cyanide, and sodium.

For groundwater samples in subzone F, the volatile method detected chloroform in the distilled water and equipment blanks, and bromodichloromethane was detected in the distilled water blank. The semivolatile method detected bis(2-Ethylhexyl)phthalate in the distilled water, equipment, and method blanks. The distilled water blank for metals showed detections of aluminum, beryllium, calcium, cobalt, mercury, potassium, and sodium. The equipment blank showed detections of

aluminum, arsenic, beryllium, cobalt, lead, mercury, sodium; the method blank showed arsenic and lead. Cyanide was detected in the distilled water and equipment blanks.

For groundwater samples in subzone G, the semivolatile method detected phenol and bis(2-Ethylhexyl)phthalate in the method blanks. The metals method detected barium, cyanide, and mercury in the method blanks.

For groundwater samples in subzone H, the semivolatile method showed detections of di-n-butylphthalate and bis(2-Ethylhexyl)phthalate in the method blanks. The metals method detected aluminum, antimony, barium, cobalt, and cyanide in the method blanks.

For groundwater samples in subzone I, methylene chloride was detected in the volatile method blank, and barium, cyanide, and mercury were detected in the metals method blanks.

Review of the analytical data showed no elevated detection limits.

Southwest Laboratory of Oklahoma's Method Detection Limit Study

**Tetra-Octa Dioxin/Furans-High Res Mass Spec**

Test Code	MS790	
Method	SW846/8290, High Resolution Method	
Matrix	Water-Soil	
Extract Volume	1000 mL - 10g	
Initial Calibration	1.0/2.5/5 - 200/500/1000 ng/mL	
Continuing Calibration	10/25/50 ng/mL	

Compound	MDL's	Water	Soil	
	CAS Number	pg/L	ng/Kg	
2378-TCDD	1746-01-6	6.79	0.17	1
12378-PeCDD	40321-76-4	6.64	0.74	2
123478-HxCDD	39227-28-6	17.63	0.82	3
123678-HxCDD	57653-85-7	13.56	0.89	4
123789-HxCDD	19408-74-3	15.35	0.96	5
1234678-HpCDD	35822-39-4	14.44	0.41	6
OCDD	3268-87-9	21.46	0.59	7
2378-TCDF	51207-31-9	2.96	0.39	8
12378-PeCDF	57117-41-6	5.58	0.27	9
23478-PeCDF	57117-31-4	13.26	0.60	10
123478-HxCDF	70648-26-9	7.96	0.54	11
123678-HxCDF	57117-44-9	8.68	0.57	12
123789-HxCDF	72918-21-9	17.87	0.69	13
234678-HxCDF	60851-34-5	16.00	0.88	14
1234678-HpCDF	67562-39-4	10.99	0.26	15
1234789-HpCDF	55673-89-7	17.98	0.53	16
OCDF	39001-02-0	10.63	0.32	17

**Volatiles**

Test Code	MS300			20
Method	SW846 8240, 3rd Edition, November 1986/September 1994			21
Matrix	Soil-Water			22
Sample Volume	5 g - 5 mL			23
Initial Calibration	5-20-50-100-200 ppb , %RSD < 30% for CCC compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100			24
Continuing Calibration	50 ppb, %D < 20% for CCC Compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100			25

Compound	MDL's	Water	Soil	
	CAS Number    μg/L	μg/kg	μg/kg	
Chloromethane	74-87-3	0.96	1.6	29
Vinyl Chloride	75-01-4	1.4	1.8	30
Bromomethane	74-83-9	1.8	2.0	31
Chloroethane	75-00-3	1.4	2.1	32
1,1-Dichloroethene	75-35-4	1.4	1.8	33
Acetone	67-64-1	1.6	2.6	34

Compound	MDL's CAS Number	Water µg/L	Soil µg/kg	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Carbon Disulfide	75-15-0	1.5	2.0	3
Methylene Chloride	75-09-2	3.0	1.8	4
1,2-Dichloroethene (total)	540-59-0	0.97	2.1	5
trans-1,2-Dichloroethene	156-60-5	0.97	2.1	6
1,1-Dichloroethane	75-34-3	0.97	2.0	7
Vinyl Acetate	108-05-4	0.92	1.6	8
cis-1,2-Dichloroethene	156-59-2	0.93	1.9	9
2-Butanone	78-93-3	0.88	1.6	10
Chloroform	67-66-3	0.85	1.9	11
1,1,1-Trichloroethane	71-55-6	1.3	1.8	12
Carbon Tetrachloride	56-23-5	1.2	1.9	13
Benzene	71-43-2	15	1.7	14
1,2-Dichloroethane	107-06-2	0.44	2.0	15
Trichloroethene	79-01-6	1.0	1.9	16
1,2-Dichloropropane	78-87-5	0.76	1.9	17
Bromodichloromethane	75-27-4	0.68	1.9	18
2-Chloroethyl Vinyl Ether	110-75-8	0.54	4.4	19
cis-1,3-Dichloropropene	10061-01-5	0.58	2.0	20
4-Methyl-2-Pentanone	108-10-1	1.8	1.9	21
Toluene	108-88-3	1.0	1.7	22
trans-1,3-Dichloropropene	10061-02-6	0.60	1.8	23
1,1,2-Trichloroethane	79-00-5	0.45	1.9	24
Tetrachloroethene	127-18-4	1.2	2.2	25
2-Hexanone	591-78-6	0.62	2.4	26
Dibromochloromethane	124-48-1	0.78	1.6	27
Chlorobenzene	108-90-7	0.83	1.9	28
Ethylbenzene	100-41-4	1.2	1.9	29
m,p-Xylene	13-302-07	2.2	3.9	30
Xylene (Total)	1330-20-7	2.2	3.9	31
o-Xylene	95-47-6	0.93	1.9	32
Styrene	100-42-5	0.8	2.1	33
Bromoform	75-25-2	1.0	1.7	34
1,1,2,2-Tetrachloroethane	79-34-5	1.3	1.7	35

	<b>Semivolatile</b>				1
Test Code	MS500				2
Method	SW846 8270, 3rd Edition, November 1986, PQL Table II, Revision 0, September 1986				3 4
Matrix	Water-Soil				5
Extract Volume	1000 mL - 30g				6
Initial Calibration	20-50-100-120-160 ng, %RSD for CCC compounds = 30%, SPCC = RF > 0.05				7 8
Continuing Calibration	50 ng, %D = 25% for CCC Compounds, SPCC = RF > 0.05				9
		<b>MDL's</b>	<b>Water</b>	<b>Soil</b>	10
<b>Compound</b>	<b>Case Number</b>		<b>µg/L</b>	<b>µg/kg</b>	11
Phenol	108-95-2		3.3	100	12
bis(2-Chloroethyl)ether	111-44-4		3.4	100	13
2-Chlorophenol	95-57-8		3.3	97	14
1,3-Dichlorobenzene	541-73-1		2.6	100	15
1,4-Dichlorobenzene	106-46-7		2.8	120	16
Benzyl alcohol	100-51-6		3.6	82	17
1,2-Dichlorobenzene	95-50-1		3.0	100	18
2-Methylphenol	95-48-7		2.9	130	19
bis(2-Chloroisopropyl)ether	108-60-1		3.5	89	20
4-Methylphenol	106-44-5		3.4	94	21
N-Nitroso-di-n-propylamine	621-64-7		2.8	87	22
Hexachloroethane	67-72-1		2.3	94	23
Isophorone	78-59-1		3.0	100	24
Nitrobenzene	98-95-3		3.5	100	25
2-Nitrophenol	88-75-5		3.4	99	26
2,4-Dimethylphenol	105-67-9		3.9	160	27
bis(2-Chloroethoxy)methane	111-91-1		3.3	99	28
2,4-Dichlorophenol	120-83-2		2.6	110	29
Benzoic acid	65-85-0		9.2	150	30
1,2,4-Trichlorobenzene	120-82-1		2.9	94	31
Naphthalene	91-20-3		2.6	110	32
4-Chloroaniline	106-47-8		3.3	210	33
Hexachlorobutadiene	87-68-3		3.0	90	34
4-Chloro-3-methylphenol	59-50-7		2.6	90	35
2-Methylnaphthalene	91-57-6		2.4	85	36
Hexachlorocyclopentadiene	77-47-4		NA	75	37
2,4,6-Trichlorophenol	88-06-2		2.6	110	38
2,4,5-Trichlorophenol	95-95-4		2.7	110	39

Compound	MDL's Case Number	Water µg/L	Soil µg/kg	
2-Chloronaphthalene	91-58-7	2.1	110	1
2-Nitroaniline	88-74-4	2.8	110	2
Dimethylphthalate	131-11-3	0.8	120	3
Acenaphthylene	208-96-8	2.4	120	4
2,6-Dinitrotoluene	606-20-2	4.0	110	5
3-Nitroaniline	99-09-2	3.6	150	6
Acenaphthene	83-32-9	2.2	100	7
2,4-Dinitrophenol	51-28-5	2.9	100	8
4-Nitrophenol	100-02-7	2.6	93	9
Dibenzofuran	132-64-9	1.9	110	10
2,4-Dinitrotoluene	121-14-2	3.9	100	11
Diethylphthalate	84-66-2	1.2	120	12
Fluorene	86-73-7	1.8	100	13
4-Chlorophenyl-phenylther	7005-72-3	2.2	120	14
4-Nitroaniline	100-01-6	2.8	150	15
4,6-Dinitro-2-methylphenol	534-52-1	2.4	100	16
N-nitrosodiphenylamine	86-30-6	2.4	110	17
4-Bromophenyl-phenylether	101-55-3	2.3	86	18
Hexachlorobenzene	118-74-1	2.6	84	19
Pentachlorophenol	87-86-5	2.3	76	20
Phenanthrene	85-01-8	2.6	110	21
Anthracene	120-12-7	2.6	100	22
Di-n-butylphthalate	84-74-2	2.0	110	23
Fluoranthene	206-44-0	1.9	100	24
Pyrene	129-00-0	1.2	120	25
Buytylbenzylphthalate	85-68-7	1.1	120	26
Benzo(a)anthracene	56-55-3	1.0	100	27
3,3'-Dichlorobenzidine	91-94-1	2.4	120	28
Chrysene	218-1-9	0.9	100	29
bis(2-Ethylhexyl)phthalate	117-81-7	3.5	140	30
Di-n-octylphthalate	117-84-0	2.0	110	31
Benzo(b)fluoranthene	205-99-2	1.8	120	32
Benzo(k)fluoranthene	207-08-9	2.1	100	33
Benzo(a)pyrene	50-32-8	1.6	83	34
Indeno(1,2,3-cd)pyrene	193-39-5	1.6	110	35
Dibenz(a,h)anthracene	53-70-3	1.6	120	36
Benzo(g,h,i)perylene	191-24-2	1.6	130	37
				38
				39

	<b>Pesticide/PCB</b>	1
Test Code	GC800	2
Method	SW846 8080A, 3rd Edition, November 1986	3
Matrix	Water-Soil	4
Extract Volume	1000 mL - 30g	5
Initial Calibration	5 point calibration, %RSD=20%	6
Continuing Calibration	Single point calibration, %D = 15%	7

	<b>MDL's</b>	<b>Water</b>	<b>Soil</b>	8
<b>Compound</b>	<b>CAS Number</b>	<b>µg/L</b>	<b>µg/kg</b>	9
alpha-BHC	319-84-6	0.002	0.130	10
beta-BHC	319-85-7	0.001	0.120	11
delta-BHC	319-86-8	0.006	0.086	12
gamma-BHC(Lindane)	58-89-9	0.002	0.068	13
Heptachlor	76-44-8	0.019	0.095	14
Aldrin	309-00-2	0.001	0.062	15
Heptachlor epoxide	1024-57-3	0.004	0.051	16
Endosulfan I	959-98-8	0.003	0.098	17
Dieldrin	60-57-1	0.004	0.170	18
4,4'-DDE	72-55-9	0.006	0.150	19
Endrin	72-20-8	0.008	0.120	20
Endosulfan II	33213-65-9	0.006	0.110	21
4'4'-DDD	72-54-8	0.004	0.100	22
Endosulfan sulfate	1031-07-8	0.002	0.250	23
4'4'-DDT	50-29-3	0.009	0.250	24
Methoxychlor	72-43-5	0.021	0.390	25
Endrin ketone	53494-70-5	0.004	0.110	26
Endrin aldehyde	7421-36-3	0.008	0.220	27
alpha-Chlordane	5193-71-9	0.002	0.250	28
gamma-Chlordane	5103-74-2	0.002	0.130	29
Toxaphene	8001-35-2	0.016	2.000	30
Aroclor-1016	12674-11-2	0.210	2.600	31
Aroclor-1221	11104-28-2	0.062	2.300	32
Aroclor-1232	11141-16-5	0.280	1.800	33
Aroclor-1242	53469-21-9	0.024	1.600	34
Aroclor-1248	12672-29-6	0.096	2.200	35
Aroclor-1254	11097-69-1	0.140	3.200	36
Aroclor-1260	11096-82-5	0.170	2.700	37

	<b>Pesticides, Organophosphorous</b>	1
Test Code	GC880	2
Method	SW846-8140, EPA methodology	3
Matrix	Water-Soil	4
Extract Volume	1000 mL - 30g	5
Initial Calibration	5 point calibration, %RSD = 20%	6
Continuing Calibration	Single point calibration, %D = 15%	7

	<b>MDL's</b>	<b>Water</b>	<b>Soil</b>	8
<b>Compound</b>	<b>CAS Number</b>	<b>µg/L</b>	<b>µg/kg</b>	9
Dichlorvos	62-73-7	0.29	17.0	10
Mevinphos	7786-34-7	0.47	30.0	11
Demeton S	8065-48-3	0.27	19.0	12
Ethoprop	13194-48-4	0.23	17.0	13
Naled	300-76-5	0.50	60.0	14
Phorate	298-02-2	0.18	11.0	15
Diazinon	333-41-5	0.33	19.0	16
Disulfoton	298-04-4	0.22	12.0	17
Parathion-methyl	298-00-0	0.04	3.5	18
Ronnel	299-84-3	0.41	22.0	19
Fenthion	55-38-9	0.20	6.9	20
Chlorpyrifos	2921-88-2	0.20	9.9	21
Trichloroanate	327-98-0	0.20	9.5	22
Stirophos	22248-79-9	0.57	79.0	23
Tokuthion	34643-46-4	0.34	16.0	24
Merphos	150-50-5	0.29	15.0	25
Fensulfothion	115-90-2	0.60	78.0	26
Bolstar	35400-43-2	0.20	9.2	27
Azinphos-methyl	86-50-0	0.26	85.0	28
Coumaphos	56-72-4	0.41	100.0	29

	<b>Acid Herbicides</b>	30
Test Code	GC570	31
Method	SW846-8150, EPA methodology	32
Matrix	Water-Soil	33
Extract Volume	1000 mL - 30g	34
Initial Calibration	5 point calibration, %RSD = 20%	35
Continuing Calibration	Single point calibration, %D = 15%	36

<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil µg/kg</b>	
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

**Metals Reporting Limits  
by Low Level ICP**

Method	SW846 Third Edition, November 1986, Method 6010A	13
Matrix	Water-Soil	14
Extract Volume	100mL - 1g	15
Initial Calibration	0-500 µg/L - varies	16
Continuing Calibration	½ high std	17

<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil mg/kg</b>	
Aluminum	7429-90-5	8.0	1.30	20
Antimony	7440-36-0	1.6	0.27	21
Arsenic	7440-38-2	2.1	0.31	22
Barium	7440-39-3	0.3	0.06	23
Beryllium	7440-41-7	0.2	0.03	24
Boron	7440-42-8	11.0	2.60	25
Cadmium	7440-43-9	0.3	0.05	26
Calcium	7440-70-2	43.0	1.90	27
Chromium	7440-47-3	1.0	0.07	28
Cobalt	7440-48-4	0.8	0.06	29
Copper	7440-50-8	1.4	0.26	30
Iron	7439-89-6	20.0	1.60	31
Lead	7439-92-1	0.9	0.18	32
Magnesium	7439-95-4	43.0	4.70	33
Manganese	7439-96-5	0.3	0.04	34

<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil mg/kg</b>	
Molybdenum	7439-98-7	0.9	0.18	1
Nickel	7440-02-0	0.7	0.12	2
Potassium	7440-09-7	55.0	7.00	3
Selenium	7782-49-2	3.4	0.24	4
Scandium	440-20-2	0.1	0.02	5
Strontium	7440-24-6	0.2	0.07	6
Silicon	7440-21-3	35.0	15.00	7
Silver	7440-22-4	1.0	0.17	8
Sodium	7440-23-5	19.0	4.90	9
Thallium	7440-28-0	5.0	0.46	10
Tin	7440-31-5	14.0	0.45	11
Titanium	7440-32-6	0.7	0.05	12
Vanadium	7440-62-2	1.1	0.13	13
Zinc	7440-66-6	5.8	1.10	14

**Metals Reporting Limits  
by ICP**

Method	SW846 Third Edition, November 1986, Method 6010			17
Matrix	Water-Soil			18
Extract Volume	100mL - 1g			19
Initial Calibration	0-1000 µg/L - varies			20
Continuing Calibration	½ high std			21

<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	24
Antimony	7440-36-0	12	1.7	25
Arsenic	7440-38-2	32	3.1	26
Barium	7440-39-3	1.0	0.19	27
Beryllium	7440-41-7	1.0	0.10	28
Boron	7440-42-8	17	2.5	29
Cadmium	7440-43-9	1.3	0.11	30
Calcium	7440-70-2	39	23.0	31
Chromium	7440-47-3	1.9	0.38	32
Cobalt	7440-48-4	2.8	0.46	33
Copper	7440-50-8	8.3	0.73	34
Iron	7439-89-6	18	1.7	35

<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil mg/kg</b>	
Lead	7439-92-1	12	1.5	1
Magnesium	7439-95-4	25	6.1	2
Manganese	7439-96-5	1.2	0.10	3
Molybdenum	7439-98-7	5.7	25	4
Nickel	7440-02-0	6.5	0.59	5
Potassium	7440-09-7	560	57.0	6
Selenium	7782-49-2	28	3.1	7
Silicon	7440-21-3	70	23.0	8
Silver	7440-22-4	1.4	0.25	9
Sodium	7440-23-5	27	50.0	10
Thallium	7440-28-0	48	4.6	11
Tin	7440-31-5	17	2.1	12
Titanium	7440-32-6	1.0	0.14	13
Vanadium	7440-62-2	2.2	0.27	14
Zinc	7440-66-6	11	1.1	15

	<b>Mercury</b>			18
	<b>by Cold Vapors</b>			19
Test Code	MT310			20
Method	SW846 Third Edition, November 1986			21
Matrix	Water-Soil			22
Extract Volume	100mL - 0.6g			23
Initial Calibration	0 - 10.0 µg/L			24
Continuing Calibration	½ high std			25

<b>Compound</b>	<b>MDL's CAS Number</b>	<b>Water µg/L</b>	<b>Soil mg/kg</b>	
Mercury	7439-97-6	0.12	0.030	26

	<b>Miscellaneous Inorganic Analyses</b>			29
Test Code	Methods various			30
Method				31
Matrix	Water-Soil			32
Extract Volume				33
Initial Calibration				34
Continuing Calibration				35

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<b>Compound</b>	<b>MDL's Method</b>	<b>Water mg/L</b>	<b>Soil mg/Kg</b>	
Chloride (IC)	EPA300.0	0.07	0.7	1
Cyanide (Total)	SW846-9010	2.0	0.5	2
Hexavalent Chromium	SW846-7196	0.005	0.20	3
Sulfate (IC)	EPA300.0	0.1	0.9	4
Total Dissolved Solids	EPA160.1	4	—	5
				6
				7

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

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

Types of compounds detected at Zone L include VOCs, SVOCs, pesticides, PCBs, and inorganics. Concentrations of detected compounds were compared to corresponding listed values in the USEPA Region III *Risk-Based Concentration Table* (April 1998), to evaluate the significance of detected compounds, to determine where any additional sampling should be conducted to define the extent of contamination, and to develop investigative endpoints. Detected soil Zone L inorganic chemical concentrations were also compared to the corresponding background reference concentrations from previous zone investigations. The comparisons pertain only to the protection of human health and do not address protection of ecological receptors. Risk to the ecosystem from site contaminants is assessed in Section 8.

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

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

Organic compound concentrations in Zone L soil and groundwater samples were compared to risk-based concentrations (RBCs). Each compound's frequency of detection mean value, and range of detected concentrations were also compiled (see Section 10).

For screening purposes carcinogenic polynuclear aromatic hydrocarbons (cPAHs) were converted 1  
to benzo(a)pyrene equivalents (BEQs) in accordance with recent EPA guidance. Section 5.1 of 2  
the Zone A RFI Report details the guidance and procedures followed during the Zone L RFI. 3

## **5.2 Inorganic Analytical Results Evaluation**

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Sample analytical results for inorganics are often difficult to evaluate because inorganics occur 5  
naturally and are ubiquitous in soil, and frequently present in groundwater as well. Compounding 6  
this difficulty is the fact that much of the soil at CNC is dredge-fill material that has been placed 7  
onsite. The following is a step-by-step description of procedures used to determine background 8  
for inorganics in soil and groundwater at CNC and the statistical approach for comparing 9  
background data to site data. 10

Many chemicals, particularly carcinogenic metals such as arsenic and beryllium, are typically 11  
detected at concentrations much higher than their corresponding risk-based screening levels. It 12  
is usually necessary to supplement site-specific sampling efforts with an attempt to determine the 13  
non-site-related concentrations of these chemicals. The problem is how to determine these 14  
reference (or background) concentrations, and how much higher than background a parameter 15  
must be at a site before it is of concern. USEPA Region IV guidance on this subject recommends 16  
using twice the mean concentration of the background samples as an upper bound limit, and 17  
considers any site-related sample concentration higher to be contaminated. Although this method 18  
is appropriate with small datasets, it would be less appropriate to use with the large background 19  
datasets developed for soil and groundwater at CNC. The larger datasets allowed the use of more 20  
sophisticated statistical tests. EnSafe used a dual testing procedure to compare AOC/SWMU 21  
inorganic constituent concentrations to those of the background datasets. Parametric or 22  
nonparametric upper tolerance limits (UTLs) were calculated and used as reference concentrations 23  
in combination with Wilcoxon rank sum tests to make the comparisons. Background values for 24

surface soil, subsurface soil, shallow groundwater, and deep groundwater were calculated in accordance with established procedures for CNC.

### **5.2.1 Background Datasets**

Section 5.2.1 of the Zones A through I RFI Report details the procedures followed in developing the respective inorganic background data sets.

### **5.2.2 Nondetect Data**

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

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

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

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

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

**5.2.5 Tolerance Interval or Reference Concentration Test**

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Section 5.2.5 of the Zone A RFI Report details procedures for determining the tolerance interval or reference concentration test.

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**5.2.6 Wilcoxon Rank Sum Test**

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Section 5.2.6 of the Zone A RFI Report details procedures for the Wilcoxon rank sum test when comparing data.

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**5.2.7 Summary of Statistical Techniques Used**

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Section 5.2.7 of the Zone A RFI Report summarizes techniques that allow statistical inference.

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

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Section 5.2.8 of the Zone A RFI Report describes the scenario for comparison of Wilcoxon test results to USEPA RBCs.

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**5.2.9 Conclusion**

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

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### 5.2.10 Background Values

Tables 5.1 through 5.4 summarize the characteristics of background datasets in each CNC zone for surface soil, subsurface soil, shallow groundwater, and deep groundwater. In all of the background calculations, nondetect (ND) values were treated as discussed in Section 5.2.2.

**Table 5.1**  
 Comparison of Background Reference Values for Surface Soil at CNC

Inorganic Chemical	Zone A UTL mg/kg (n=13)	Zone B UTL mg/kg (n=15)	Zone C UTL mg/kg (n=45)	Zone D UTL mg/kg (n=6)	Zone E UTL mg/kg (n=25)	Zone F UTL mg/kg (n=6)	Zone G UTL mg/kg (n=9)	Zone H UTL mg/kg (n=104)	Zone I UTL mg/kg (n=15)
Aluminum	12800 P	15500 P	9990 P	8700 M	26600 P	18500 M	18700 M	29000 P	27400 N
Antimony	ND	X	0.55 N	0.92 M	1.77 N	0.79 M	2.89 M	X	ND
Arsenic	9.44 P	17.1 P	14.2 P	5.55 M	23.9 N	19.9 M	17.2 M	15.6 P	21.6 P
Barium	53.0 P	98.7 P	77.2 P	30.1 M	130 P	61.5 M	109 M	40.3 P	54.2 P
Beryllium	X	1.23 P	X	0.19 M	1.7 P	1.05 M	1.20 M	1.37 P	0.95 N
Cadmium	X	ND	0.65 N	0.07 M	1.5 N	0.26 M	1.07 M	1.05 N	0.61 N
Chromium	50.4 P	75.7 P	26.4 P	12.4 M	94.6 P	34.8 M	42.8 M	59.1 P	34.5 P
Cobalt	4.4 N	21.9 P	3.22 P	9.46 M	19.0 P	15.1 M	6.60 M	5.86 P	5.8 N
Copper	165 P	225 P	34.7 P	40.6 M	66.0 P	48.2 M	260 M	27.6 P	240 P
Cyanide	ND	ND	ND	0.18 M	0.5 N	0.29 M	0.38 M	ND	ND
Lead	140 P	114 P	330 P	18.8 M	265 N	180 M	181 M	118 P	203 N
Manganese	98.1 P	464 P	92.5 P	28.6 M	302 N	307 M	325 M	583 P	419 N
Mercury	0.3 N	1.55 N	0.24 N	0.05 M	2.60 P	0.62 M	1.03 M	0.485 P	0.47 N
Nickel	13.55 P	43.6 P	12.3 P	4.68 M	77.1 P	12.6 M	20.6 M	33.4 P	23.9 P
Selenium	1.2 N	2.8 N	1.44 P	0.91 M	1.7 N	1.15 M	1.22 M	2.0 N	1.49 P
Silver	ND	1.7 N	X	0.43 M	X	1.85 M	ND	X	X
Thallium	ND	ND	ND	ND	2.8 N	ND	0.85 M	1.1 N	ND
Tin	ND	14.8 N	2.95 P	ND	59.4 P	9.38 M	9.67 M	X	7.5 N
Vanadium	29.24 P	52.6 P	23.4 P	9.73 M	94.3 P	48.9 M	60.9 M	73.0 P	113 P
Zinc	207.6 P	366 P	159 P	25.1 M	827 P	198 M	519 M	214 P	206 P

**Notes:**

- P = Parametric UTL
- N = Nonparametric UTL
- X = No UTL calculated (ND > 90%)
- M = Twice the mean
- ND = Not detected

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**Table 5.2**  
**Comparison of Background Reference Values for Subsurface Soil at CNC**

Inorganic Chemical	Zone A UTL mg/kg (n=12)	Zone B UTL mg/kg (n=14)	Zone C UTL mg/kg (n=30)	Zone D UTL mg/kg (n=6)	Zone E UTL mg/kg (n=24)	Zone F UTL mg/kg (n=6)	Zone G UTL mg/kg (n=7)	Zone H UTL mg/kg (n=63)	Zone I UTL mg/kg (n=6)
Aluminum	28240 P	17700 P	23700 P	10300 M	41100 P	17100 M	23600 M	46200 P	18900 M
Antimony	ND	X	.92 N	ND	1.6 N	ND	ND	X	ND
Arsenic	9.84 P	10.8 N	14.1 N	4.08 M	19.9 P	18.2 M	15.5 M	22.5 P	6.45 M
Barium	40.01 P	65.0 N	68.5 P	29.7 M	64.1 P	51.8 M	644.5 M	43.8 P	36.0 M
Beryllium	ND	1.61 P	0.98 N	0.75 M	2.71 P	1.20 M	1.63 M	1.62 P	0.67 M
Cadmium	ND	ND	0.28 N	0.38 M	0.96 N	0.09 M	0.48 M	1.1 N	0.54 M
Chromium	63.4P	48.1 N	12.5 P	22.3 M	75.2 N	32.2 M	43.4 M	84.2 P	51.3 M
Cobalt	1.7N	10.6 N	7.1 N	2.89 M	14.9 N	6.85 M	8.14 M	14.9 P	3.48 M
Copper	33.69 P	47.0 P	42.2 P	ND	152 P	30.4 M	32.6 M	31.6 P	11.5 M
Cyanide	ND	ND	ND	0.16 M	X	0.24 M	0.22 M	ND	ND
Lead	22.01P	145 P	73.2 P	7.87 M	173 N	51.7 M	66.3 M	68.7 P	12.3 M
Manganese	85.54P	288 N	106 P	29.9 M	881 P	469 M	291 M	1410 P	118 M
Mercury	ND	2.0 N	0.30 N	0.05 M	1.59 P	0.23 M	0.31 M	0.74 P	ND
Nickel	35.0 N	29.9 N	16.7 P	6.76 M	57.0 P	8.85 M	18.3 M	29.9 P	15.7 M
Selenium	1.74P	3.8 N	2.90 N	1.46 M	2.4 N	1.24 M	1.26 M	2.7 N	1.77 M
Silver	X	1.8 N	ND	0.36 M	ND	ND	ND	X	ND
Thallium	ND	ND	X	0.57 M	ND	1.24 M	0.95 M	1.3 N	ND
Tin	X	1.3 N	2.37 P	ND	9.23 P	ND	2.96 M	ND	ND
Vanadium	77.32P	102 N	56.9 N	15.1 M	155 P	49.4 M	72.5 M	132 P	38.1 M
Zinc	164.6P	238 N	243 P	30.1 M	886 P	84.2 M	145 M	130 P	36.2 M

**Notes:**

- P = Parametric UTL
- N = Nonparametric UTL
- X = No UTL calculated (ND > 90%)
- M = Twice the mean
- ND = Not detected

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**Table 5.3**  
 Comparison of Background Reference Values for Shallow Groundwater at CNC

Inorganic Chemical	Zone A UTL µg/L (n=12)	*Zone B UTL µg/L (n=4)	Zone C UTL µg/L (n=8)	Zone D UTL µg/L (n=1)	Zone E UTL µg/L (n=100)	Zone F UTL µg/L (n=2)	Zone G UTL µg/L (n=4)	Zone H UTL µg/L (n=44)	Zone I UTL µg/L (n=76)
Aluminum	3210 M		410 M	1410 D	2810 P	224 M	692 M	X	1440 N
Antimony	ND		ND	ND	X	ND	4.85 M	ND	X
Arsenic	7.4 N		6.07 M	5.4 D	18.7 N	16.7 M	17.8 M	21.5 P	23.0 N
Barium	104 M		1637 M	17.6 D	211 P	94.3 M	31 M	323 P	110 P
Beryllium	ND		0.33 M	0.8 D	0.43 N	0.66 M	ND	ND	1.1 N
Cadmium	ND		ND	ND	X	0.82 M	0.53 M	ND	X
Chromium	8.7 M		1.99 M	3.8 D	12.3 N	2.05 M	3.88 M	ND	14.3 N
Cobalt	ND		1.33 M	ND	2.5 N	10.9 M	1.45 M	X	2.2 N
Copper	15.7 M		1.9 M	ND	2.7 N	ND	8.33 M	ND	4.4 N
Cyanide	ND		ND	ND	7.9 N	3.30 M	3.8 M	X	25.2 N
Lead	4.7 M		3.27 M	3.8 D	4.8 N	ND	4.6 M	4.7 P	4.4 N
Manganese	577 N		608 M	30.6 D	2560 N	2010 M	2906 M	2440 P	5430 P
Mercury	ND		ND	ND	X	ND	ND	ND	X
Nickel	ND		3.59 M	3.4 D	15.2 N	5.55 M	4.08 M	X	13.3 P
Selenium	ND		ND	ND	X	ND	4.3 M	3.2 P	ND
Silver	ND		1.26 M	ND	X	ND	1.65 M	ND	X
Thallium	ND		ND	ND	5.4 N	5.58 M	ND	5.3 N	6.6 N
Tin	NA		ND	ND	X	ND	ND	ND	X
Vanadium	5.4 M		1.96 M	ND	11.4 P	1.58 M	15.4 M	X	14.0 P
Zinc	83.2 M		13.2 M	ND	27.3 N	ND	15.6 M	ND	24.4 N

**Notes:**

- P = Parametric UTL
- N = Nonparametric UTL
- X = No UTL calculated (ND > 90%)
- M = Twice the mean
- ND = Not detected
- D = Twice the detected value
- \* = No site-specific groundwater samples were collected

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**Table 5.4**  
**Comparison of Background Reference Values for Deep Groundwater at CNC**

Inorganic Chemical	Zone A UTL µg/L (n=12)	*Zone B UTL µg/L (n=4)	Zone C UTL µg/L (n=8)	Zone D UTL µg/L (n=1)	Zone E UTL µg/L (n=100)	Zone F UTL µg/L (n=2)	Zone G UTL µg/L (n=4)	Zone H UTL µg/L (n=44)	Zone I UTL µg/L (n=76)
Aluminum	245 M		22.2 M	ND	319 N	77.7 M	23.5 M	723 MN	180 N
Antimony	ND		ND	ND	X	ND	3.9 M	ND	X
Arsenic	11.1 N		ND	8.4 D	16.4 N	16.2 M	5.4 M	8.2 N	14.2 N
Barium	179 N		52.2 M	31.8 D	218 P	200 M	316 M	237 P	347 P
Beryllium	ND		0.32 M	ND	1.2 N	0.46 M	ND	ND	1.2 N
Cadmium	ND		ND	ND	X	0.77 M	ND	X	X
Chromium	7.3 N		ND	ND	15.5 N	1.31 M	2.37 M	X	6.7 N
Cobalt	12.1 M		ND	ND	12.9 N	67.0 M	10.6 M	3.2 MN	2.3 N
Copper	5.8 M		ND	ND	X	ND	ND	ND	X
Cyanide	0.05 M		ND	ND	37.3 N	4.30 M	ND	ND	27.2 N
Lead	ND		ND	ND	X	ND	ND	4.3 MN	X
Manganese	2690 N		147 M	320 D	869 P	1256 M	537 M	998 P	261 N
Mercury	ND		ND	ND	0.2 N	ND	ND	X	X
Nickel	21.1M		ND	ND	42.2 N	61.1 M	21.7 M	X	6.8 N
Selenium	ND		ND	ND	X	ND	2.9 M	2.1 MN	ND
Silver	ND		ND	ND	X	2.70 M	ND	ND	ND
Thallium	2.0 N		ND	ND	6.5 N	8.18 M	ND	X	7.1 N
Tin	X		ND	ND	X	ND	ND	ND	347 N
Vanadium	10.9 M		0.54 M	ND	5.3 N	1.13 M	16.2 M	9.3 MN	15.7 N
Zinc	66.2 M		ND	ND	11.8 N	ND	ND	X	22.1 N

**Notes:**

- P = Parametric UTL
- N = Nonparametric UTL
- X = No UTL calculated (ND > 90%)
- M = Twice the mean
- ND = Not detected
- D = Twice the detected value
- \* = No site-specific groundwater samples were collected
- MN = Modified nonparametric UTL

## 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 such as climate, hydrology, topography, and geology determine weathering and erosional transport processes. Microscopic characteristics of site soil, sediment, and water, as well as the chemical and physical properties of the constituents, govern the processes of infiltration, advection, diffusion, dispersion, erosion, and volatilization that move constituents within or between media. A discussion of fate and transport will help to identify potential receptors that may be impacted by constituent movement in the environment.

After evaluating Zone L for the above characteristics, three potential routes of constituent migration have been evaluated:

- Constituents leaching from soil to groundwater
- Constituents migrating from groundwater into surface water bodies
- VOCs released from surface soil into air

### **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 increase 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. Compounds 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 below 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**

Chemical Property	Critical Value	High (>)	Low (<)
Vapor pressure	10 <sup>-3</sup> mm Hg	volatile	nonvolatile
Density <sup>a</sup>	1 g/cm <sup>3</sup>	sinks/falls	floats/rises
Solubility <sup>a</sup>	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 <sup>a</sup> (K <sub>oc</sub> )	10 to 10000 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 with respect to the properties listed above.	exhibits predictable behavior with respect 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

Since Zone L overlaps most of the other investigative Zones that comprise the CNC, the physical properties needed to compute soil screening levels for protection of groundwater are provided in the Table 6.2 specific to each investigative Zone's RFI Report. Section 10 discusses SWMU- or AOC-specific fate and transport, migration pathways, and potential receptors.

Compounds with similar chemical and physical properties display similar fate and transport behavior, making it possible to group contaminants into the following categories based on those properties: VOCs, SVOCs, pesticides/PCBs, chlorinated herbicides, and inorganics.

### **VOCs**

The chemical and physical properties with the greatest influence on the fate and transport of VOCs are solubility, Henry's law constant, and vapor pressure. Typical fate and transport characteristics are:

- VOCs can leach from soils into groundwater.
- VOCs tend to be highly mobile in both soil and groundwater.
- VOCs tend to volatilize from both soil and groundwater.
- VOCs tend to dissipate relatively quickly.

The VOCs have low molecular weights, moderate Henry's law constants, varying organic carbon/water partitioning coefficients, and high solubilities and vapor pressures. Densities may be less than or greater than that of water. Overall, VOCs are expected to be highly mobile in the environment and therefore quick to migrate from soil and groundwater.

## SVOCs

The chemical and physical properties with the greatest influence on the fate and transport of SVOCs are solubility, vapor pressure, and organic carbon/water partitioning coefficient. Typical fate and transport characteristics are:

- SVOCs tend to sorb to soil particles.
- SVOCs tend to be immobile in the environment.
- SVOC movement often occurs by colloidal suspension.
- SVOCs exhibit greater mobility when coupled with "carrier" compounds.

SVOCs have high molecular weights; wide-ranging vapor pressures, solubilities, and Henry's law constants; moderate to high densities; and generally high organic carbon/water partitioning coefficients. Overall, SVOCs are expected to be relatively immobile in soils and diffuse only slightly to groundwater. The most notable exceptions to anticipated SVOC immobility in the environment are the phenols and substituted phenols, which exhibit higher solubilities.

## Pesticides/PCBs

The chemical and physical properties with the greatest influence on the fate and transport of pesticides/PCBs are solubility, Henry's law constant, and organic carbon/water partitioning coefficient. Typical fate and transport characteristics are:

- Pesticides/PCBs tend to sorb to soil particles.
- Pesticides/PCBs tend to be hydrophobic (avoid water).
- Pesticides/PCBs tend to be immobile in the environment.
- Pesticides/PCBs tend to degrade relatively slowly.

Pesticides/PCBs have moderate molecular weights, generally high densities and organic carbon/water partitioning coefficients; and generally low solubilities, vapor pressures, and Henry's law constants. Overall, pesticides/PCBs are anticipated to be immobile and persistent in the environment, not readily diffusing into groundwater.

### **Chlorinated Herbicides**

Solubility has the greatest influence on the fate and transport of chlorinated herbicides. Typical fate and transport characteristics are:

- Chlorinated herbicides can leach from soil particles to groundwater.
- Chlorinated herbicides tend to be mobile in both soil and groundwater.
- Chlorinated herbicides tend to degrade relatively slowly.

Chlorinated herbicides have low Henry's law constants and vapor pressures, and moderate molecular weights, organic carbon/water partitioning coefficients, and solubilities. Overall, chlorinated herbicides are expected to be moderately mobile in groundwater with some retention in soil.

### **Inorganics**

Solubility has the greatest influence on the fate and transport of inorganics. Typical fate and transport characteristics are:

- Inorganics tend to sorb to soil particles, particularly clays.
- Inorganics are not degradable.
- Inorganics tend to have moderate to low mobility; however, in environments where pH is less than 5 (i.e., acidic conditions), inorganics can become mobile.

Properties of the surrounding environmental media tend to dictate the fate and transport mechanisms of inorganic elements. Generally, inorganics are anticipated to be immobile and to remain adsorbed to soil particles, not readily diffusing into groundwater.

### 6.1.2 Media Properties Affecting Fate and Transport

The properties of environmental media used to evaluate fate and transport are total organic carbon (TOC), normalized partitioning coefficient, cation exchange capacity (CEC), redox conditions, pH, soil type, and retardation rate. The following briefly discusses these properties.

#### Total Organic Carbon

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

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

$K_d$  is used to predict the capacity for a constituent to partition between soil and water; it is a function of both the constituent and the soil. To estimate  $K_d$ , the constituent's organic carbon/water partitioning coefficient ( $K_{oc}$ ) is adjusted by the soil's TOC:  $K_d = K_{oc} f_{oc}$ . Soil/constituent combinations with higher  $K_d$ s have a higher potential for sorption.

#### Cation Exchange Capacity

CEC reflects the soil's capacity to adsorb ions, neutralizing ionic deficiencies on the surfaces of its particles. Generally, trivalent ions are preferentially adsorbed to soil over divalent ions, and divalent ions are preferentially adsorbed over monovalent ions. Soils with high CEC values have the potential to adsorb inorganic ions and organic compounds with dipole moments. CEC varies

directly with clay content, depending on the type of clay. The amount of cation exchange also depends on soil pH.

### Redox Conditions

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

### pH

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

### Soil Type

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

### Retardation Factor (R)

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

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

Where:

R = Retardation factor

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

$\rho_b$  = Soil dry bulk density (kg/L)

n = Soil total porosity

The soil and aquifer parameters used to evaluate fate and transport for Zone L can be found in the Table 6.3 specific to the overlapping subzone. The approximate time of travel for advective groundwater flow from various Zone L sites to downgradient water bodies (Cooper River or Noisette Creek), depending on direction of flow, local groundwater gradient, and local hydraulic conductivity can be found in the Table 6.4 specific to the overlapping subzone.

## 6.2 Fate and Transport Approach for Zone L

As presented earlier in this section, three potential routes of constituent migration have been evaluated for Zone L. Each subzone has been evaluated for site conditions that promote these migration pathways.

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 potential transfer mechanism 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 L fate and transport were evaluated using constituent-specific chemical and physical properties, assumed soil and aquifer properties, USEPA risk-based screening concentrations, and grid-based background reference concentrations.

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, no screening or formal assessment was performed for that pathway. Fate and transport were not evaluated for essential nutrients (calcium, iron, magnesium, potassium, and sodium), nor for chlorides or sulfates, which are abundant in shallow coastal/estuarine environments. Section 10 contains discussions of 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 for impacting the surficial aquifer. Due to the nature and age of most SWMU/AOC operations, it might be assumed that any compounds with the potential to migrate from soil into the surficial aquifer would have done so already. This assumption would be appropriate in areas of the CNC that have a thin, moderately permeable soil layer above the water table and less appropriate in areas where these conditions do not exist. However, all soil constituents were evaluated for their potential threat to groundwater regardless of whether the constituent was detected in groundwater. The screening process may be summarized as follows:

*Quantitative* – Maximum soil constituent concentrations for each SWMU/AOC (or group thereof) were compared to leachability-based generic soil-to-groundwater screening levels (SSLs) 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 or 20 depending on the particular overlapping subzone.

Inorganic soil background reference values for each investigative Zone at the CNC were determined after consultation with the project team technical subcommittee. The background reference values for Zone L were applied according to the specific overlapping subzone. 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, irrespective of their sources as naturally occurring or anthropogenic soil constituents.

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, April 1998, assuming a target hazard quotient (THQ) of 1.0.
- Groundwater background reference values for inorganics (using the values for the appropriate subzone).

Quantitative screening defines the list of chemicals to be considered for detailed fate and transport assessment. It reveals constituents in soil having 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. It was assumed that if soil concentrations do not exceed conservative leachability-based screening levels, there is no significant threat to groundwater via leachate migration. Likewise, if current groundwater concentrations do not exceed risk-based tap water screening values or background, it was concluded that current soil/groundwater equilibria 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 or 20 (depending on the particular overlapping subzone), rather than site-specific SSLs. The conservative nature of the DAFs chosen for each CNC investigative zone is further justified in the RFI Report specific to that Zone. As a screening tool, generic SSLs are used to compile a conservative, inclusive list of potential fate and transport concerns; detailed fate and transport assessments then evaluate the identified concerns to facilitate risk management decisions.

*Detailed Assessment* — Upon completion of the quantitative screening process, site constituent concentrations exceeding the screening values were examined to delineate the magnitude, number, and areal extent of soil impacts potentially affecting groundwater. Maximum constituent concentrations in surface soil were compared to those in subsurface samples to estimate the extent of downward migration. The number and spatial distribution of exceedances were noted. Relative concentrations in soil and groundwater were compared.

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

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

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 the Cooper River or Noisette Creek. Surface water was not sampled as part of the Zone L 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 and/or surface water were compared to appropriate screening values. Relative to human health evaluation, maximum groundwater results for each SWMU/AOC (or group thereof) were compared to the greater of:

- Tap water risk-based screening levels as presented in USEPA Region III RBC tables, April 1998, assuming a target hazard quotient (THQ) of 1.0
- Groundwater background reference values for inorganics (using values from the appropriate overlapping subzone)

To evaluate potential impact on ecological receptors, maximum groundwater analytical results for each SWMU/AOC were also compared to USEPA saltwater surface water chronic screening values (also known as ambient water quality criteria, or AWQC) for hazardous waste sites, from *Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment*, November 1995.

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 current 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 AWQC, it is assumed that those chemicals present no risk to ecological receptors resulting from groundwater discharge to surface water. This screening assessment

purposely does not consider effects of dilution and attenuation on transport between the affected well(s) and the surface water discharge point, or 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.

*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. The number and spatial distribution of exceedances were noted.

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 possessing the greatest potential to volatilize and become airborne 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 VOCs detected in surface soil 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).

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 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 above soil-to-air screening levels may have the potential for localized ambient air impacts but not be of a magnitude to pose a long-term or widespread threat through inhalation pathways. The detailed assessment identified these cases and determined which areas of soil contamination may require supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

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

The fate and transport screening procedure was designed as a conservative method to identify and evaluate soil and groundwater constituents with the potential to impact groundwater and surface water quality in the Cooper River or Noisette Creek. The screening tables identify the constituents, while the detailed assessments evaluate their significance. The procedure depends heavily on EPA's soil screening methodology, and makes many simplifying assumptions that come directly from the 1996 *Soil Screening Guidance*. This section compares some of the assumptions of the screening procedure with actual conditions encountered at SWMUs and AOCs in Zone L in an attempt to demonstrate the conservative nature of the method. The screening assumptions are shown in italics, followed by commentary.

1. *The contaminant source is infinite (i.e., steady-state concentrations are maintained during the future exposure period).* At the many sites, 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. 1 2 3 4
  
2. *Each soil contaminant is uniformly distributed from the surface to the top of the aquifer, at a concentration equal to the maximum value reported from any of the samples.* Site conditions vary greatly, as seen in sample analytical results. Most often, screening exceedances are reported from a relatively small percentage of samples, as presented in the detailed assessments. 5 6 7 8
  
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 lagoons and other low-energy environments, many CNC soils and lithologic units exhibit clay content varying from moderate to very high. 9 10 11 12 13
  
4. *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 or 20:1 by groundwater, or (b) 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 L 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. 14 15 16 17 18 19 20 21 22

5. *An appropriate human health screen for Zone L groundwater is EPA's Region III tap water RBCs using a total hazard quotient of 1.0.* Although no water-supply wells are completed in the surficial aquifer at the CNC or nearby, and high percentages of CNC groundwater samples that were analyzed for chloride, iron, manganese, sulfate, or TDS reported concentrations exceeding USEPA's Secondary MCLs, groundwater was evaluated as if it were potential drinking water. Since the focus of the fate and transport analysis was on individual chemical concentrations and behavior rather than risk, a THQ of 1.0 was considered appropriate. The many built-in conservatisms discussed above should more than make up for any possible compounding effects of multiple contaminants in environmental media.

6. *An appropriate ecological screen for surface water in the Cooper River or Noisette Creek 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).* Shipyard Creek and the portion of the Cooper River opposite CNC are both 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.

## 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 it on a site-specific basis. 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  
2  
3
- Supplemental Guidance to RAGS: Region IV Bulletin, *Provisional Guidance of Quantitative Risk Assessment of PAHs*, (USEPA Region IV, 1993), (PAH Guidance). 4  
5
- *Exposure Factors Handbook*, (USEPA, 1989d). 6
- USEPA Region III *Risk-Based Concentration Table, October 1997*, (USEPA Region III, October 1997), (RBC Screening Tables). 7  
8
- *Technical Memorandum Guidance on Estimating Exposure to VOCs During Showering*, (USEPA, 1991c). 9  
10

These references are identified fully in Section 12, References. 11

## 7.2 Objectives 12

Chemical contamination at the site must be characterized adequately before a risk assessment can 13  
be used to determine whether detected concentrations have the potential for toxic effects or 14  
increased cancer incidences and before it can become a basis for making remedial decisions. To 15  
characterize the study area, the amount, type, and location of contaminant sources are studied. 16  
Variables include the pathways of exposure (media type and migration routes); the type, 17  
sensitivities, exposure duration, and dynamics of the exposed populations (receptors); and the 18  
toxicological properties of identified contaminants. 19

The objectives of the HHRA are to:

- Characterize the source media and determine the chemicals of potential concern (COPCs) for affected environmental media;
- Identify potential receptors and quantify potential exposures for those receptors under current and future conditions for all affected environmental media;
- Qualitatively and quantitatively evaluate the adverse effects associated with the site-specific COPCs in each medium;
- Characterize the potential baseline carcinogenic risk and noncarcinogenic hazards associated with exposure to impacted environmental media at Zone L under current and future conditions;
- Evaluate the uncertainties related to exposure predictions, toxicological data, and resultant carcinogenic risk and noncarcinogenic hazard predictions; and
- Establish RGOs for chemicals of concern (COCs) in each environmental medium based on risk/hazard to facilitate risk management decision-making.

### ***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. 1  
2
  
- *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. 3  
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- *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. 6  
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8
  
- *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. 9  
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11
  
- *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. 12  
13  
14
  
- *Uncertainty:* Discussion and evaluation of the areas of recognized uncertainty in human health risk assessments in addition to medium- and exposure pathway-specific influences. 15  
16
  
- *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. 17  
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19

- *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.

This general process was followed for HHRAs prepared for Zone L sites.

### 7.3 Human Health Risk Assessment Methods

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 L.

#### 7.3.1 Data Sources

As part of each investigation, soil, groundwater, sediment, and/or other environmental media samples (as applicable) were collected and analyzed to delineate the sources, nature, magnitude, and extent of any contamination associated with current or past site operations. The data analyzed for each SWMU or AOC were from the RFI and associated sampling activities.

#### 7.3.2 Data Validation

Data validation is an independent, systematic process of evaluating data after they are collected and comparing them to established criteria to confirm that they are of the technical quality necessary to support the RFI decisions. Parameters specific to the data are reviewed to determine whether they meet the stipulated DQOs. The data quality objectives address five principal parameters: precision, accuracy, completeness, comparability, and representativeness. To verify that these objectives are met, field measurements, sampling and handling procedures, laboratory analysis and reporting, and nonconformances and discrepancies in the data are examined to determine compliance with appropriate and applicable standards.

Level III data collected for the Zone L RFI were validated in accordance with the USEPA CLP Functional Guidelines as discussed in Section 4 of this report. Complete data validation reports for the Zone L dataset are included in Appendix D.

### 7.3.3 Management of Site-Related Data

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

- Analytical methods not specific for a particular chemical, such as TOC or total organic halogen.
- Field screening instruments, including total organic vapor monitoring units and organic vapor analyzers.
- The inorganic data from groundwater samples collected during the DPT investigation.

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

In addition, the HHRAs addressed limitations of analytical results by including estimated concentrations for nondetected parameters. A nondetect indicates that the analyte was not detected above the quantitation limit of the sample (*U*-qualified results), which is determined by the analytical method, the instrument used, and possible matrix interferences. However, an analyte could be nondetected and still be present at any concentration between zero and the quantitation

limit. For this reason, one-half the  $U$  value could serve as an unbiased estimate of the nondetect. 1  
Because the estimated values of  $J$ -qualified hits were frequently much lower than the sample 2  
quantitation limits of  $U$ -qualified nondetects for organic compounds, one-half of each  $U$  value was 3  
compared to one-half of the lowest hit (normally  $J$ -qualified) at the same site. The lesser of these 4  
two values was used as the best estimate of the concentration that was potentially present below 5  
the sample quantitation limit, and was inserted into the adjusted data set used to calculate exposure 6  
point concentration (see Section 7.3.6 for discussion of the exposure point concentration). 7

For inorganic chemicals, the decision rule was less complex: one-half of each  $U$  value represented 8  
the concentration of the corresponding sample when compiling the adjusted dataset. If two 9  
nondetects were reported for any one location (a result of QA/QC samples), one-half the lesser 10  
of the  $U$  values was compared to the lowest hit at the site (for organics, as above) or applied 11  
directly (for inorganics) to estimate a concentration value to be used in the Zone L RFI risk 12  
calculations. If a parameter was not detected at a SWMU/AOC, neither data management method 13  
was applied, and the parameter was not considered in screening or formal assessment. 14

Once the dataset was complete (i.e., after elimination of faulty data, consolidation of duplicate data 15  
values, and quantification of censored values), statistical methods were used to evaluate the RFI 16  
analytical results and to identify COPCs at potential receptor locations. The statistical methods 17  
used in data evaluation are discussed below. The rationale used to develop this methodology and 18  
the statistical techniques to implement it are based on the following sources: 19

- RAGS Part A 20
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987) 21
- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (USEPA, 1992c) 22

Microsoft FoxPro, Corel Quattro Pro, and SPlus for Windows<sup>1</sup> were used to manage data and calculate statistics. For each set of data describing the concentration of chemicals in a contaminated area, the following information was tabulated: frequency of detection, range of detected values, average of detected concentrations, and the calculated 95% upper confidence limit (UCL) for the mean of log transformed values of the concentration (UCLs were calculated for COPCs only).

#### **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 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 of the RFI. To reduce the list and focus the risk assessment on COPCs, site-related data were compared to risk-based screening concentrations and background concentrations.

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

## 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 *Determination of COCs by Risk-Based Screening, USEPA Region III*, October 22, 1997. According to this guidance, USEPA used a target HQ of 1 and a risk goal of  $10^{-6}$  to calculate screening concentrations for noncarcinogens and carcinogens, respectively. 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  $\mu\text{g/L}$ .

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 quantification and risk/hazard projections for cPAHs in soil and groundwater were performed 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. Surrogate compounds were selected based on structural, chemical, or toxicological similarities.

Groundwater RBC screening relevance is discussed in Sections 7.3.6 and 7.3.8. Because groundwater beneath most of Zone L areas contain chlorides and/or TDS above 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 groundwater, an additional risk-based screening was conducted as part of the fate and transport assessment. Fate and transport methods are explained in Section 6; site-specific discussions are in Section 10.

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

Soil and groundwater background concentrations specific to each subzone were used for screening purposes in Zone L. The statistical methods and rationale used to determine background concentrations and compare site data to background detailed in Section 5 of the report associated with specific subzone. After risk- and hazard-based screening values were compared, CPSS were retained for further consideration as COPCs in the HHRA if their maximum detected concentrations exceeded corresponding background concentrations. These comparisons help account for chemicals common in nature, such as aluminum, manganese, and arsenic. By virtue of this process, risk and/or hazard associated with naturally occurring chemicals is not addressed where their concentrations are not above corresponding background values.

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

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

were eliminated from the human health risk assessment: calcium, iron, magnesium, potassium, and sodium.

### **Summary of COPCs**

Screening evaluations results are presented on a medium-specific basis in Section 10, the Nature of Contamination discussion. In summary, the risk information usually obtained from the Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST) is necessary to calculate risk and hazard estimates and risk-based screening values. This information is based on toxicological and epidemiological data which are critiqued and approved by the scientific and regulatory community (i.e., listed in IRIS and/or HEAST). Risk 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, the data were screened using risk-based and background values. A COPC was identified only if it was reported at a maximum concentration above both its RBC and its background reference concentration.

#### **7.3.5 Calculation of Risk and Hazard**

As previously discussed, CPSSs that exceed their respective screening values are considered COPCs. The subsequent identification of COCs is a two-phase process. First, exposure pathways exceeding the screening criteria established by USEPA and SCDHEC are identified. Identifying COCs from the refined list of COPCs involves calculating chemical-specific cancer risks and HQs for COPCs, estimating exposure-pathway risk/hazard, evaluating frequency and consistency of detection and relative chemical toxicity, then comparing these values to background concentrations. In the next step, COPCs which individually exceed  $10^{-6}$  ILCR or an HQ greater than 0.1 in a pathway of concern are retained as COCs. Section 7.3.7 discusses cancer risk thresholds and noncancer toxicity.

### 7.3.6 Exposure Assessment

This step is designed to determine the magnitude of contact a potential receptor may have with site-related COPCs. Exposure assessment involves four stages:

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

#### Exposure Setting and Land Use

During this part of the HHRA process, the basic layout of the site as well as the suspected source(s) of contamination are described. In addition, the site’s projected future use is discussed, if known. Present Zone L land uses include railroad lines, sanitary sewer, and storm sewer.

#### Potentially Exposed Populations

In each site-specific HHRA, this section describes who may be exposed to contaminants in environmental media. For the Zone L HHRAs, the potentially exposed populations addressed were current and future site workers, as well as hypothetical future site residents. Because current site workers would be expected to have limited contact with contaminated media, worker-related exposure was addressed exclusively for maximally exposed future site workers. The future site worker scenario assumes that groundwater exposures will include both ingestion and inhalation via showering. While providing a reasonably conservative assessment of future site worker risk/hazard, this approach also renders a highly conservative approximation of risk/hazard for

current site workers. It also accounts for the fact that the specific nature of future industrial uses cannot be definitively stated.

### **Exposure Pathways**

This section of each HHRA summarizes how potential receptors (site workers, residents, etc.) may be exposed to contaminated media. In general, soil matrix-related pathways include incidental ingestion and dermal contact. For groundwater, ingestion and inhalation of volatilized contaminants were the primary pathways of exposure evaluated.

### **Exposure Point Concentrations**

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

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

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

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

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

where:

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

USEPA Region IV guidance prefers an alternative to the 95% UCL for exposures involving groundwater. EPCs for groundwater were calculated as the arithmetic mean concentration of a COPC in the most concentrated area of the plume. As the definition of a plume for any given COPC becomes more uncertain, a UCL may be calculated for comparison to the arithmetic mean of the COPC in the most concentrated area of the plume. For some COPCs at certain sites it was more appropriate to use the UCL or the maximum detected concentration as the groundwater EPC.

The calculated values for the 95% UCL (or arithmetic mean in the most concentrated area of the plume) are presented in tables that statistically summarize COPCs identified in each environmental medium. For soil, included for each COPC are the number of samples analyzed, mean and standard deviation of the natural log-transformed data (including the nondetect values), the H-statistic, and the maximum of detected concentrations. For groundwater, included for each COPC are the number of detects, the number of samples analyzed, and any statistical parameters used to determine the EPC.

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

As previously discussed in the data management subsection (Section 7.3.3) of this report, analytical results are presented as "nondetects" when chemical concentrations in samples do not exceed the detection or quantitation limits for the analytical procedures as applied to each sample.

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

### **Quantification of Exposure**

This section describes the models, equations, and input parameter values used to quantify doses or intakes of the COPCs for the surface soil and groundwater exposure pathways. The models are designed to estimate route- and medium-specific factors, which are multiplied by the EPC to

estimate chronic daily doses. The intake model variables generally reflect 50th or 95th percentile values which, ensure that the estimated intakes represent the reasonable maximum exposure (RME) when they are applied to the EPC. Formulae were derived from RAGS, Part A unless otherwise indicated. Table 7.1 lists input parameters used to compute chronic daily intake (CDI) for potential receptors exposed to surface soil and/or groundwater contaminants. Because Zone L is part of BRAC III, future site use cannot be assumed with any certainty. Therefore, the conservative assumptions were used to account for any reasonable future use. Zone L media analytical results and exposure methods have been designed so that exposure estimates can be refined as base reuse plans materialize. Age-adjusted ingestion factors were derived for the potential future residential receptors (resident adult and child combined) for carcinogenic endpoints. These factors consider the difference in daily ingestion rates for soil and drinking water, body weights, and exposure durations for children (ages 1 to 6) and adults (ages 7 to 31). The exposure frequency is assumed to be identical for the adult and child exposure groups.

**Table 7.1  
 Parameters Used to Estimate CDI at RME**

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

**Table 7.1**  
**Parameters Used to Estimate CDI at RME**

Pathway Parameters	Resident Adult	Resident Child	Adult Worker	Units
Conversion Factor	1E-6	1E-6	1E-6	kg/mg
Body Weight	70 <sup>a</sup>	15 <sup>a</sup>	70 <sup>a</sup>	kg
Averaging Time, Noncancer	8,760 <sup>e</sup>	2,190 <sup>e</sup>	9125 <sup>e</sup>	days
Averaging Time, Cancer	25,550 <sup>f</sup>	25,550 <sup>f</sup>	25,550 <sup>f</sup>	days

**Notes:**

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

**Surface Soil Pathway Exposure** 1

**Ingestion of COPCs in Surface Soil** 2

The following equation is used to estimate the ingestion of COPCs in soil: 3

$$CDI_s = (C_s)(IR)(EF)(ED)(F)(FI)/(BW)(AT) \quad 5$$

**where:** 6

- CDI<sub>s</sub> = ingested dose (mg/kg-day) 7
- C<sub>s</sub> = concentration of contaminant in soil (mg/kg) 8
- IR = ingestion rate (mg/day) 9
- EF = exposure frequency (days/year) 10
- ED = exposure duration (years) 11
- F = conversion factor (10<sup>-6</sup> kg/mg) 12
- FI = fraction ingested from contaminated source (unitless) 13
- BW = body weight (kg) 14
- AT = averaging time (days) 15

## Dermal Contact with COPCs in Surface Soil

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

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

where:

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

## Groundwater Pathway Exposure

### Ingestion and Inhalation of COPCs in Groundwater

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

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

where:

$CDI_w$	=	ingested/inhaled dose (mg/kg-day)
$C_w$	=	concentration of contaminant in water (mg/L)
IR	=	ingestion rate (L/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

Figures 7.1 and 7.2 provide the formulae for calculating the CDI for soil and groundwater, respectively.

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

### **7.3.7 Toxicity Assessment**

#### **Carcinogenicity and Noncancer Effects**

The USEPA has established a classification system for rating the potential carcinogenicity of environmental contaminants based on the weight of scientific evidence. The cancer classes are described below. Cancer weight-of-evidence class "A" (human carcinogens) means that human toxicological data have shown a proven correlation between exposure and the onset of cancer (in varying forms). The "B1" classification indicates some human exposure studies have implicated the compound as a probable carcinogen. Weight-of-evidence class "B2" indicates a possible human carcinogen, a description based on positive laboratory animal data (for carcinogenicity) in the absence of human data. Weight-of-evidence class "C" identifies possible human carcinogens, and class "D" indicates a compound not classifiable for its carcinogenic potential. The USEPA has established SFs for carcinogenic compounds. The SF is defined as a "plausible upper-bound estimate of the probability of a response (cancer) per unit intake of a chemical over a lifetime" (RAGS, Part A).

Figure 7.1

Formulae for Calculating CDI for Soil

SOIL INGESTION PATHWAY

Residential Scenario:

*Noncarcinogens-Residential Scenario:*

$$CDI_{NC-C} = \frac{C_S * IR_{soil/child} * EF_{res} * F * FI * ED_{child}}{AT_{NC-C} * BW_{child}}$$

$$CDI_{NC-C} = \frac{C_S * IR_{soil/child} * EF_{res} * F * FI * ED_{child}}{AT_{NC-C} * BW_{child}}$$

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

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

SOIL DERMAL CONTACT PATHWAY

Residential Scenario:

*Noncarcinogens-Child-Residential Scenario:*

$$CDI_{NC-A} = \frac{C_S * CA_{soil/adult} * EF_{res} * F * FC * AF * ABS * ED_{adult}}{AT_{NC-A} * BW_{adult}}$$

$$CDI_{NC-A} = \frac{C_S * CA_{soil/adult} * EF_{res} * F * FC * AF * ABS * ED_{adult}}{AT_{NC-A} * BW_{adult}}$$

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

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

**Figure 7.1 (Continued)**  
**Formulae for Calculating CDI for Surface Soil**

<b>Variable</b>	<b>Description</b>
$BW_{child}$	average child body weight (ages 1-6) (kg)
$BW_{adult}$	average adult body weight (kg)
ABS	absorbance factor (unitless value specific to organic versus inorganic compounds)
AF	adherence factor (1 mg/cm <sup>2</sup> )
$ED_{child}$	child exposure duration during; ages 1-6 (yr)
$ED_{adult}$	adult exposure duration during; ages 7-31 (yr)
$ED_{adult-w}$	adult worker exposure duration (yr)
$EF_{res}$	residential exposure frequency (days/year)
$EF_w$	worker exposure frequency (days/year)
$IR_{soil/child}$	child soil intake rate (mg/day)
$IR_{soil/adult}$	adult soil intake rate (mg/day)
FC	fraction contacted from contaminated source (unitless)
$CA_{soil/child}$	child soil dermal contact area (cm <sup>2</sup> )
$CA_{soil/adult}$	adult soil dermal contact area (cm <sup>2</sup> )
$AT_C$	averaging time (carcinogen)
$AT_{NC-A}$	averaging time (noncarcinogen adult)
$AT_{NC-C}$	averaging time (noncarcinogen child)
$C_s$	chemical concentration in surface soil (mg/kg)
FI	fraction ingested from contaminated source (unitless)
F	conversion factor (10 <sup>-6</sup> kg/mg)

**Notes:**

CDI indicates Chronic Daily Intake

The worker scenario risk and hazard were calculated by substituting worker-specific assumptions into the adult portions of the formulae and then deleting the child portions of the formulae.

Figure 7.2

Formulae for Calculating CDI for Groundwater

GROUNDWATER INGESTION PATHWAY

Residential Scenario:

*Noncarcinogens-Child-Residential Scenario:*

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

*Noncarcinogens-Adult-Residential Scenario:*

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

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

$$CDI_C = \frac{C_W}{AT_C} \left[ \frac{IR_{water/child} * EF_{res} * F * FI * ED_{child}}{BW_{child}} + \frac{IR_{water/adult} * EF_{res} * F * FI * ED_{adult}}{BW_{adult}} \right]$$

**Figure 7.2 (Continued)**

**Formulae for Calculating CDI for Groundwater**

**PATHWAY: GROUNDWATER INHALATION WHILE SHOWERING**

**Residential Scenario:**

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

$$CDI_{\text{ingestion}} = CDI_{\text{inhalation}}$$

<b>Variable</b>	<b>Description</b>
$BW_{\text{child}}$	average child body weight (ages 1-6) (kg)
$BW_{\text{adult}}$	average adult body weight (kg)
$ED_{\text{child}}$	child exposure duration during ages 1-6 (yr)
$ED_{\text{adult}}$	adult exposure duration during ages 7-31 (yr)
$ED_{\text{adult-w}}$	adult worker exposure duration (yr)
$EF_{\text{res}}$	residential exposure frequency (days/year)
$EF_{\text{w}}$	worker exposure frequency (days/year)
$IR_{\text{water/child}}$	child water intake rate (mg/day)
$IR_{\text{water/adult}}$	adult water intake rate (mg/day)
FI	fraction ingested from contaminated source (unitless)
$AT_{\text{C}}$	averaging time (carcinogen)
$AT_{\text{NC-A}}$	averaging time (noncarcinogen adult)
$AT_{\text{NC-C}}$	averaging time (noncarcinogen child)
$C_{\text{w}}$	chemical concentration in groundwater (mg/L)

**Notes:**

CDI indicates Chronic Daily Intake

The worker scenario risk and hazard were calculated by substituting worker-specific assumptions into the adult portions of the formulae and then deleting the child portions of the formulae.

In addition to potential carcinogenic effects, most substances also can produce other toxic responses at doses greater than experimentally derived threshold concentrations. The USEPA has derived RfD values for these substances. A chronic RfD is defined as *an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure concentration for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime*. These toxicological values are used in risk formulae to assess the upper-bound level of cancer risk and noncancer hazard associated with exposure to a given contaminant concentration.

For carcinogens, the potential risk posed by a chemical is computed by multiplying the CDI (as mg/kg-day) by the SF (in reciprocal mg/kg-day). The HQ (for noncarcinogens) is computed by dividing the CDI by the RfD. The USEPA has set standard limits (or points of departure) for carcinogens and noncarcinogens to evaluate whether significant risk is posed by a chemical (or combination of chemicals). For carcinogens, the point of departure is  $10^{-6}$ , with a generally accepted range of  $10^{-6}$  to  $10^{-4}$ . These risk values correlate with a 1-in-1,000,000 and a 1-in-10,000 excess incidence of cancer resulting from exposure to xenobiotics (all pathways).

For noncarcinogens, other toxic effects are generally considered possible if the HQ (or sum of HQs for a pathway, HI) exceeds unity (a value of 1). Although both cancer risk and noncancer hazard are generally additive (within each group) only if the target organ is common to multiple chemicals, a most conservative estimate of each may be obtained by summing the individual risks or hazards, regardless of target organ. The following HHRA have taken the universal summation approach for each class of toxicant. Additional details regarding the risk formulae applied to site data are provided in the Risk Characterization section of this document.

Critical studies used in establishing toxicity classifications by USEPA are shown in the IRIS database (primary source) and/or HEAST, Fiscal Year 1995 (secondary source). If toxicological

information is unavailable in IRIS or HEAST, values were obtained from reports issued by the Environmental Criteria and Assessment Office (ECAO)/National Center for Environmental Assessment (NCEA). Where applicable, these values were also included in the database for these HHRAs. The HHRA for each site with identified COPCs includes a table summarizing toxicological data in the form of RfDs and SFs obtained for the relevant COPCs, as well as uncertainty/modifying factors, target organs, and cancer classes (where available).

### **Toxicity Profiles for COPCs**

In accordance with RAGS, the HHRAs include brief toxicological profiles for all COPCs. Most information for the profiles was gleaned from IRIS and HEAST, and the toxicological database information table. Any additional references are noted specifically in the profiles. The profiles summarize adverse effects of COPCs and the amounts associated with such effects.

### **7.3.8 Risk Characterization**

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

Generally, the risk characterization follows the methodology prescribed by RAGS Part A, as modified by more recent information and supplemental guidance cited earlier. The USEPA methods are appropriately designed to be health-protective, and tend to overestimate, rather than

underestimate, risk. The risk results, therefore, are generally overly conservative, because risk characterization involves multiplying the conservative assumptions built into the exposure and toxicity assessments.

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

### **Risk Characterization Methodology**

Potential risks to humans following exposure to COPCs are estimated using methods established by USEPA, when available. These health-protective methods are likely to overestimate risk. Risks from hazardous chemicals are calculated for either carcinogenic or noncarcinogenic effects. Some carcinogenic chemicals may also pose a noncarcinogenic hazard. The potential human health effects associated with chemicals that produce systemic toxic and carcinogenic influences are characterized for both types of health effects. As mentioned in Section 7.3.6, inhalation exposure-related risk and hazard were computed using appropriate route-specific (inhalation) SFs and RfDs (where available).

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

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

Appendix A of RAGS, Part A, states that in the absence of specific data, an assumption of 5% oral absorption efficiency would be relatively conservative. Supplemental Guidance to RAGS: Region IV Bulletin indicates that in the absence of specific data, USEPA Region IV suggests an oral to dermal absorption factor of 80% for VOCs, 50% for SVOCs and 20% for inorganics. These percentages (or associated fractions) were used in the HHRA and are reflected in the applicable risk/hazard results.

### *Carcinogenic Effects of Chemicals*

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

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

where:

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

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

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

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

$$\text{Risk}_p = \text{ILCR}(\text{chem}_1) + \text{ILCR}(\text{chem}_2) + \dots + \text{ILCR}(\text{chem}_n)$$

where:

$\text{Risk}_p$  = total pathway risk of cancer incidence  
 $\text{ILCR}(\text{chem}_i)$  = incremental lifetime excess cancer risk for a specific chemical

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

### *Noncarcinogenic Effects of Chemicals*

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

$$\text{HQ} = \text{CDI}/\text{RfD}$$

where:

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

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

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

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

where:

HI = Hazard Index (unitless)

HQ = Hazard Quotient (unitless)

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

### Surface Soil Pathways

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

### Groundwater Pathways

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

### Other Applicable Pathways

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

## **COCs Identified**

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

Under the traditional risk-based COC trigger provisions, no carcinogenic COCs would be identified for a particular receptor group/pathway combination if the overall cumulative site risk is less than  $10^{-4}$ . However, as described in Section 7.3.7 of this report, the cumulative risk threshold used to identify COCs in the following HHRAs is two orders of magnitude more conservative,  $10^{-6}$ .

## **Risk/Hazard Maps**

In addition to the standard tabular presentation of risk/hazard, point maps summarizing risk and hazard were plotted where appropriate for applicable environmental media. As an extension of conventional risk/hazard interpretations, excess cancer risk and/or hazard were calculated for each sample location by summing the contributions of each COC detected in the corresponding sample. Each mapped sample location was then color-coded to signify a cumulative range of risk or hazard.

Arc<sup>2</sup>, a standard graphical data presentation and geographic information system package, was used to plot the risk/hazard projections on SWMU/AOC base maps. Section 7.3.9 discusses the uncertainties involved in the mapping process. The point maps illustrate risks or hazards associated with COPCs in the subject medium. The risk or hazard for individual locations was based exclusively on chemicals detected. Tables summarize the data used to generate graphical presentations. Summarizing the data on maps allows the reviewer to determine the nature of the contaminants identified and helps in screening remedial alternatives during the CMS.

### **7.3.9 Risk Uncertainty**

This section of the HHRAs 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

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<sup>2</sup> Reference to specific software products are not to be construed as an endorsement by the U. S. Navy or E/A&H.

based on the upper limit estimates of exposure to each chemical, the margin of safety of the cumulative incremental risk is the sum of all the individual safety margins applied throughout the process. Use of these safety margins during all exposure and risk/hazard computations provides an extremely conservative means of predicting potential human health effects. The margins of safety or "conservatisms" inherent in each step of the human health risk assessment are addressed in the Risk Uncertainty discussions. It is not possible to eliminate all uncertainties or potential variability in the risk assessment process; however, recognizing the influences of these factors is fundamental to understanding and subsequently using risk assessment results.

The risk uncertainty section of each HHRA presents the uncertainty and/or variability of site-specific and medium/pathway-specific factors introduced as part of the risk assessment process, in addition to other factors influencing the uncertainty of the calculated incremental excess cancer risks and hazard quotients/indices. Calculated risk/hazard levels reflect the underlying variability of the analytical results that they are based on; they also embody uncertainty about potentially unsampled maxima and minima in the analytes. The exposure pathways considered for selection in the exposure assessment 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 exposure 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 over 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 L investigation are presented in Section 10 of this RFI, which includes results from AOC and SWMU sites. The purpose of the data evaluation is to verify that the QC requirements of the dataset have been met and to characterize questionable data. The analytical methods and DQO laboratory deliverables are summarized in Section 4, Data Validation.

Most analytical results for environmental samples have inherent uncertainty. This uncertainty 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 under 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 pathways of concern and COPCs which 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 risk-based concentrations 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. 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. Additionally, Zone L soil data are compared to cross-media transport soil screening values in the fate and transport discussion of this report to identify other potential indirect exposure pathways.

#### ***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 L RFI after comparing the data to risk-based screening values. The outcome was used to determine whether concentrations differed significantly between onsite and background locations, as detailed in Section 7.3.4.

#### ***Elimination of Essential Nutrients***

In accordance with RAGS, the following nutrients were eliminated from Zone L HHRAs: calcium, sodium, potassium, magnesium, and iron. 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.

## **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 L sites is not likely, based on current site uses, the nature of surrounding buildings, and potential reuse plans. If these areas were developed as residential sites, most of the present infrastructure 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. 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 L location as a source of potable or process water. A basewide system provides drinking and process water to buildings throughout Zone L. This system is to remain in operation under the current base reuse plan. As a result, shallow groundwater would not be expected to be used under future site use scenarios. Therefore, the scenario established to project risk/hazard associated with shallow groundwater exposure is highly conservative, and associated pathways are not expected to be completed in the future.

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

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

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

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

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

The UCL calculation method includes the H-statistic which is based on the number of samples analyzed for each COPC and the standard deviation of the results. To obtain this number, a table must be referenced, and the value must be interpolated (an estimation) from the table. The equation for the H-statistic has not been provided in the supplemental guidance, nor does the document referred to in the guidance provide the equation. Although the statistic appears to be nonlinear, local linearity was assumed to facilitate interpolation of the statistic for each COPC addressed in the HHRAs.

Linear interpolation provides a good estimate of H; however, both the UCL formula and H are natural log values. The effect of multiplying natural log numbers is not equivalent to multiplying untransformed values. When data are log transformed, adding two numbers is the equivalent of multiplying the two numbers if they were not transformed. The effect of multiplying a number while in log form is exponential; and here, H is applied as a multiplier. In summary, using this method to calculate the UCL has the effect of overestimating, and often provides concentrations greater than the maximum detected onsite. For all datasets having fewer than 10 total samples for a specific medium, the maximum concentrations detected were used as EPCs. The limited number of soil and groundwater samples used to assess site conditions often resulted in considerable variability between data 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. In accordance with RAGS, the lesser of either the maximum concentration or the UCL is used as the EPC. As reviewed above, summation of risk based on maximum concentrations leads to overestimation of exposure, especially in the case of low detection frequency or spatially segregated COPCs. This concept is further discussed below.

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

Because of the influence of standard deviation on EPC, low frequency of detection can cause COPCs to be addressed inappropriately in the risk assessment. More specifically, COPCs detected only once or twice in all samples analyzed (having concentrations exceeding the RBCs and reference concentrations) would be expected to have relatively higher standard deviations as concentration variability or range widens. 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 EPC is assumed to be widely distributed spatially. It is not feasible for a receptor to be simultaneously exposed to maximum concentrations of different contaminants at several locations. The use of the maximum concentrations (or the UCL) is questionable for these contaminants and the calculated risk and hazard could be skewed upward due to the low frequency of detection.

In some instances, it is possible to define hot spots within the investigation area. A hot spot is an isolated area of concentrated contamination within a larger area which is not impacted, or much less so. Exposure quantification in the presence of a hot spot may be achieved by calculating an FI/FC from 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 L HHRA's.

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

In addition to the typical uncertainties inherent in toxicity values, parameters that do not have corresponding RBCs due to the lack of approved toxicological values were not included in the CDI calculation data. This does not indicate that chemicals lacking approved toxicological values pose no risk/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 (or isolated areas of gross contamination) 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.

#### **7.3.10 Risk Summary**

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

#### **7.3.11 Remedial Goal Options**

RGOs are chemical concentrations computed to equate with specific risk and/or hazard goals that may be established for a particular site. As previously discussed, COCs are identified as any COPC that significantly contributes to a pathway of concern. A pathway having an ILCR greater than  $10^{-6}$  or an HI greater than 1 is defined as a pathway of concern, and an individual chemical which contributes either  $10^{-6}$  ILCR or 0.1 HQ is considered to significantly contribute to the pathway ILCR or HI. Based on this method, COCs were identified which required calculating RGOs; they are listed in the risk characterization section of the HHRA for each site. RGOs were calculated for all COCs contributing to a pathway risk of  $10^{-6}$  or greater. Inclusion in the RGO table does not necessarily indicate that remedial action will be required to address a specific chemical. Instead, RGOs are provided to facilitate risk management decisions.

In accordance with USEPA Supplemental RGO Guidance, RGOs were calculated at  $10^{-4}$ ,  $10^{-5}$ , and  $10^{-6}$  risk levels for carcinogenic COCs and HQ goals of 3, 1, and 0.1 for noncarcinogenic COCs.

RGOs for carcinogens were based on the lifetime weighted average for the site resident and the 1  
adult site worker. Calculations of hazard-based RGOs based on either the hypothetical child 2  
resident or the adult site worker was noted in the corresponding tables. 3

**8.0 PRELIMINARY ECOLOGICAL RISK EVALUATION**

A screening ecological risk evaluation was conducted for Zone L areas of the Cooper River near storm water sewer outfalls determined to have cross-connects from sources other than storm water runoff. By comparing the maximum concentrations of contaminants detected in sediment samples to appropriate values promulgated by USEPA Region IV, an analysis was conducted to guide future studies regarding risk to ecological receptors in the Cooper River. A complete screening ecological risk assessment cannot be completed at this time due to unresolved background issues concerning other possible contributors to Cooper River sediment contamination and naturally occurring metals. These components are required to properly identify potential sources and address possible downstream migration of contaminants. The Zone J RCRA Facility Investigation report, coupled with studies conducted by the Naval Research Laboratory (NRL), will better define contaminant sources found during investigations of Cooper River sediments.

Through dye tracing, it was determined that five storm water outfalls discharging into the Cooper River have cross-connects to various buildings' floor drains, sump drains, sinks, and cooling systems (summarized in Table 8.1). This section will focus on the sediment samples collected closest to these outfalls. Surface water samples, though collected during the Zones E and J investigations and referenced in Figures 8.1 through 8.5, will not be included in this section due to the river's high flow rate. More specifically, long-term predictions regarding adverse effects to ecological receptors cannot be determined from "snapshot" samples of surface water.

**Table 8.1  
 Dye Test Cross-Connect Locations**

<b>Building Number</b>	<b>Building Name</b>	<b>Outfall of Cross-Connect</b>	<b>Location of Cross-Connect(s)</b>
1119	Former Location of Galvanizing Shop, 1941	27	Two restroom facilities.
3	Inside Machine Shop, 1906	23	Two floor drains in southwest corner of shop room.

**Table 8.1  
 Dye Test Cross-Connect Locations**

<b>Building Number</b>	<b>Building Name</b>	<b>Outfall of Cross-Connect</b>	<b>Location of Cross-Connect(s)</b>
68	Former Battery Acid Facility, 1942	41	All floor drains (28 total).
69	Storehouse, Former Galvanizing Shop, 1980	38	Two floor drains and an eyewash station in and near the mechanical room.
13	QA Office and Laboratory, 1906	30	All laboratory sinks on the first and second floors including the annex (20 total), and two floor drains in the annex.
177	Electric and Electronics Shop, 1955	30	Two floor drains and two sump drains in the west annex.
9	Temporary Service Shop, 1906	30	Large restroom facility in north wing, all cooling systems' drains (10 total), and one sump drain in the south wing foundry. Two shop sinks in the north wing and mid-section.

**8.1 Zone Rationale**

Basewide, eight Ecological Study Areas (ESAs) were designated to assist in appropriately qualifying geographic boundaries with contiguous habitats or similar ecosystem distributions (Figure 8.6). Within these ESAs, Areas of Ecological Concern (AECs) were further specified to focus the investigation relative to potential SWMU/AOC contribution and consequent receptor exposure. This survey methodology, which is used for the Zone L RFI report, is also described in the Zone L RFI Work Plan (EnSafe, November 27, 1996).

Zone configurations were based on SWMU or AOC locations, and therefore do not necessarily parallel ESA boundaries. Zone L encompasses the railways and sanitary and storm sewer systems which are located basewide throughout the ESAs. The outfalls addressed are all located within ESA VI.



**LEGEND**

- SEDIMENT/SURFACE WATER SAMPLE LOCATION
- SEDIMENT SAMPLE LOCATION



ZONE L - RCRA  
FACILITY INVESTIGATION  
NAVAL BASE CHARLESTON  
CHARLESTON, SC

FIGURE 8.1  
SUBZONE E  
SEDIMENT AND SURFACE WATER  
SAMPLE LOCATIONS



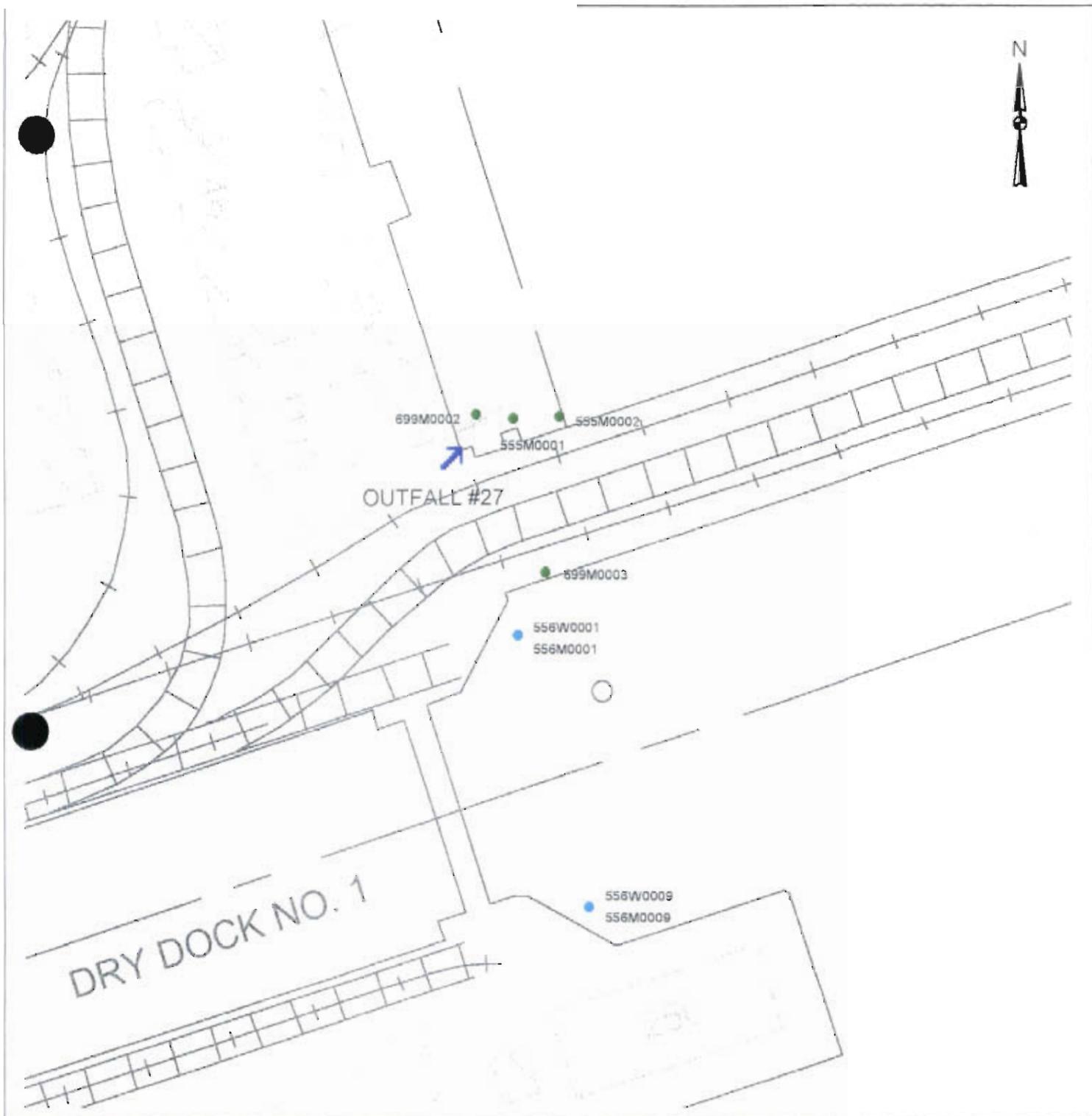
**LEGEND**

-  STORMWATER OUTFALL
-  SEDIMENT SAMPLE LOCATION



ZONE L - RCRA  
 FACILITY INVESTIGATION  
 NAVAL BASE CHARLESTON  
 CHARLESTON, SC

FIGURE 8.2  
 SUBZONE E - OUTFALL #23  
 SEDIMENT SAMPLE LOCATIONS



**LEGEND**

-  STORMWATER OUTFALL
-  SEDIMENT/SURFACE WATER SAMPLE LOCATION
-   SEDIMENT SAMPLE LOCATION

75 0 75 150 Feet




ZONE L - RCRA  
 FACILITY INVESTIGATION  
 NAVAL BASE CHARLESTON  
 CHARLESTON, SC

FIGURE 8.3  
 SUBZONE E - OUTFALL #27  
 SEDIMENT AND SURFACE WATER  
 SAMPLE LOCATIONS



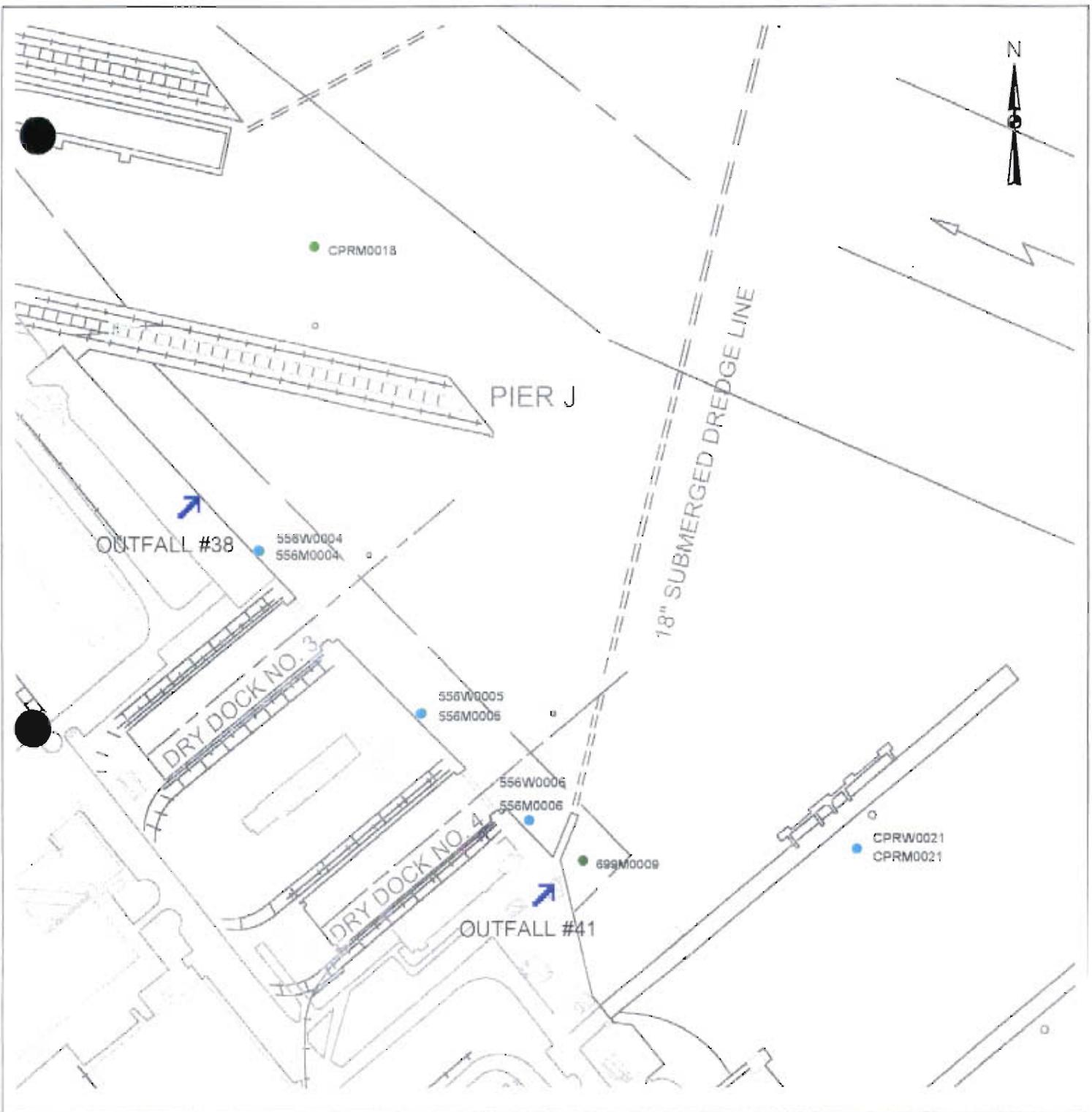
**LEGEND**

-  STORMWATER OUTFALL
-  SEDIMENT/SURFACE WATER SAMPLE LOCATION
-  SEDIMENT SAMPLE LOCATION



ZONE L - RCRA  
 FACILITY INVESTIGATION  
 NAVAL BASE CHARLESTON  
 CHARLESTON, SC

FIGURE 8.4  
 SUBZONE E - OUTFALL #30  
 SEDIMENT AND SURFACE WATER  
 SAMPLE LOCATIONS



**LEGEND**

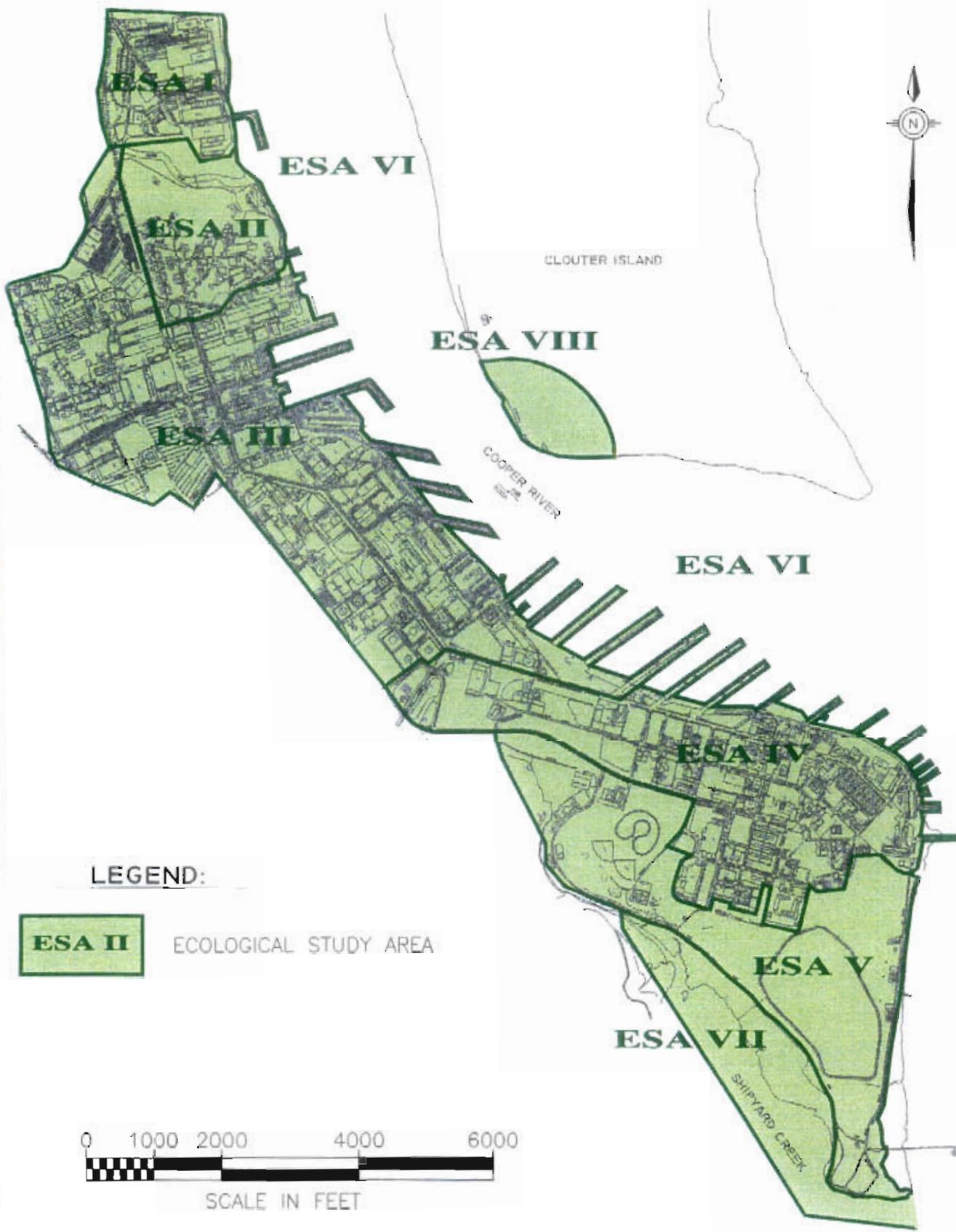
-  STORMWATER OUTFALL
-  SEDIMENT/SURFACE WATER SAMPLE LOCATION
-  SEDIMENT SAMPLE LOCATION

200 0 200 400 Feet



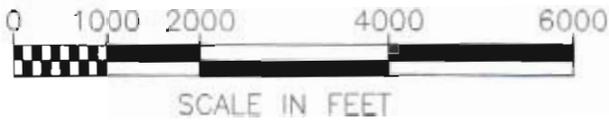

ZONE L - RCRA  
 FACILITY INVESTIGATION  
 NAVAL BASE CHARLESTON  
 CHARLESTON, SC

FIGURE 8.5  
 SUBZONE E - OUTFALLS #38 AND #41  
 SEDIMENT AND SURFACE WATER  
 SAMPLE LOCATIONS



**LEGEND:**

**ESA II**      ECOLOGICAL STUDY AREA



ZONE I  
RCRA FACILITY  
INVESTIGATION REPORT  
NAVAL BASE CHARLESTON  
CHARLESTON, SC

FIGURE 8.6  
ECOLOGICAL  
STUDY AREAS  
LOCATION MAP

Date: 08/20/98      DWG Name: 2912C003

Figure 8.1 shows all sediment and surface water sample locations in the Cooper River. Figures 8.2 through 8.5 show the location of each outfall and nearby sediment and surface water sample locations. Due to their proximity to one another and the bi-directional flow of the river, Outfall Numbers 38 and 41 have been considered together. Since cross-connects may have received various types of pollutants, all analytes will be included in this assessment to determine the need for further studies.

## 8.2 Threatened and Endangered Species

Several threatened, endangered, and species of concern could occur at CNC . Table 8.2 shows all species currently listed on state and federal registers that have been historically or recently identified at CNC .

**Table 8.2**  
**Federal and State - Listed Threatened, Endangered and Candidate Species**  
**that Occur or Potentially Occur at CNC**

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

**Table 8.2**  
**Federal and State - Listed Threatened, Endangered and Candidate Species**  
**that Occur or Potentially Occur at CNC**

Species		Residence Status	Status	
Common Name	Scientific Name		USF&WS	SCWMRD
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
<b>Fish</b>				
Shortnose Sturgeon	<i>Acipenser brevirostrum</i>	LM	E	E
<b>Plants</b>				
Canby's Dropwort	<i>Oxypolis canbyi</i>	UR	E	E
Pondberry	<i>Lindera melissifolia</i>	UR	E	E
Incised Groovebur	<i>Agrimonia incisa</i>	UR	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>Psilotum nudum</i>	UR	-	SL
Climbing Fern	<i>Lygodium palmatum</i>	UR	-	SL

**Table 8.2**  
**Federal and State - Listed Threatened, Endangered and Candidate Species**  
**that Occur or Potentially Occur at CNC**

Species		Residence Status	Status	
Common Name	Scientific Name		USF&WS	SCWMRD
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 portulacasfrum</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.
- CR = Confirmed resident.
- LR = Likely resident.
- PR = Possible resident.
- UR = Unlikely resident.
- LM = Likely migrant or occasional visitor.
- PM = Possibly migrant or occasional visitor.
- UM = Unlikely migrant or occasional visitor.
- SC = Of concern, state.
- SR = Status review.
- E = Endangered.
- T = Threatened.
- SL = State listed.
- RC = Of concern, regional.
- NC = Of concern, national.
- C-2 = Candidate species for federal listing, Category 2.
- T/SA = Threatened due to similarity of appearance.
- USF&WS = U.S. Fish and Wildlife Service.
- SCWMRD = South Carolina Wildlife and Marine Resources Department.

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

### 8.3 Conceptual Model

Figure 8.7 presents a conceptual model of the potential contaminant pathway from possible sources (outfalls) to ecological receptors in the Cooper River. The conceptual model selected for ecological risk associated with Zone L storm water outfalls consists of benthic species exposure to sediment contamination. The pollutants detected in sediments will be compared to Sediment Screening Values (SSVs) from *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997).

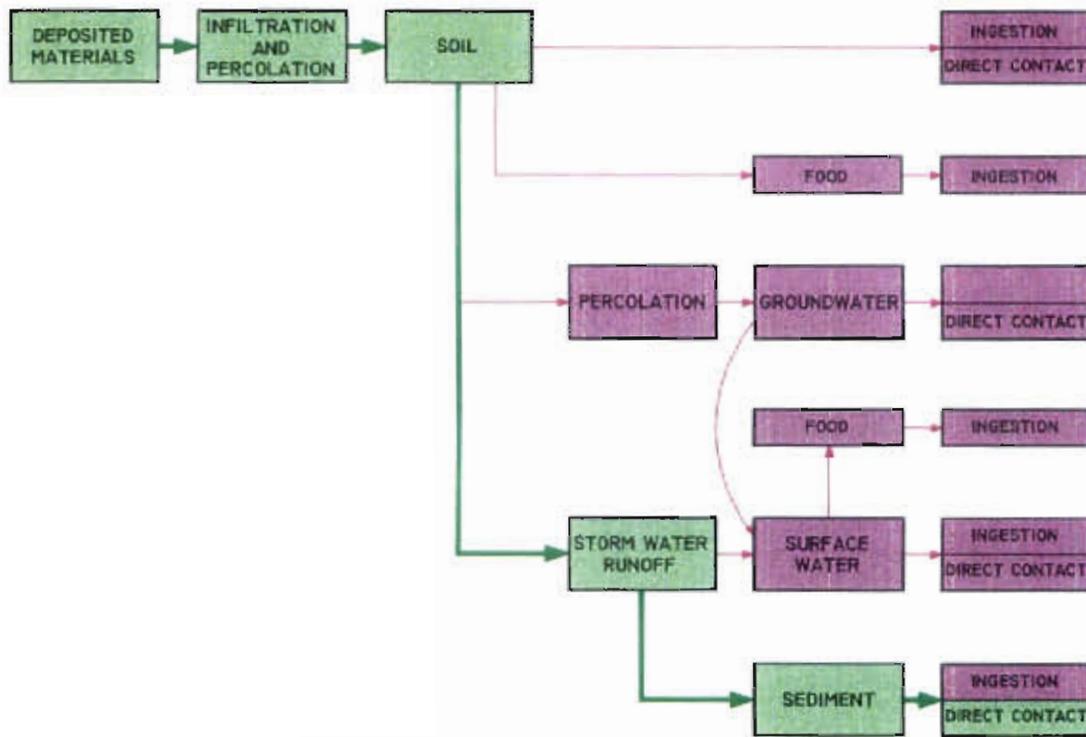
### 8.4 Selection of Ecological Chemicals of Potential Concern

Contaminants of Concern have been identified from past RFI investigations at CNC. From these, it was necessary to identify contaminants posing a potential hazard to wildlife, designated as Ecological Chemicals of Potential Concern (ECPCs). For sediments, these are defined if the maximum concentration either:

- exceeds the USEPA Region IV SSV, or
- exceeds the most conservative effects level found in literature, or
- if neither of these benchmarks is available.

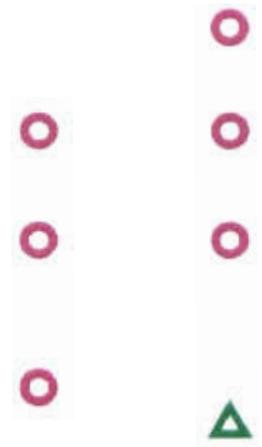
Sample locations from the Zone L RFI, as well as Zones E and J, were used in this evaluation. Table 8.3 provides a summary of the parameters collected for each of the sediment sample locations identified in Figures 8.2 through 8.5.

PRIMARY SOURCE	PRIMARY RELEASE MECHANISM	SECONDARY SOURCE	SECONDARY RELEASE MECHANISM	PATHWAY	EXPOSURE ROUTE
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RECEPTOR			
TERRESTRIAL WILDLIFE	AQUATIC *	TERRESTRIAL PLANTS	TERRESTRIAL INVERTEBRATES

\* INCLUDES INVERTEBRATES, PLANTS, ALGAE, AMPHIBIANS, AND FISH



**LEGEND**

- SOIL → SELECTED SOURCE/RELEASE MECHANISM AND SELECTED PATHWAY
- SURFACE WATER → POSSIBLE SOURCE/RELEASE MECHANISM AND POSSIBLE PATHWAY
- SELECTED RECEPTOR
- POSSIBLE RECEPTOR – NOT ASSESSED DUE TO INSUFFICIENT INFORMATION



ZONE L  
RCRA FACILITY  
INVESTIGATION REPORT  
NAVAL BASE CHARLESTON  
CHARLESTON, SC

FIGURE 8.7  
CONTAMINANT PATHWAY MODEL  
FOR  
ECOLOGICAL RECEPTORS



**Table 8.3**  
**Parameters Collected at Sample Locations**

Sample ID	VOC	SVOC	Pest/PCB	Metals	Cyanide	Organotins	Herbicides	OP Pest	Hexavalent Chromium	Dioxins
<b>Outfall No. 23</b>										
054M000101		X		X		X				
054M000201		X		X		X				
054N000201		X		X		X	X	X	X	X
054M000301		X				X				
054M000401		X				X				
699M0001E1	X			X	X					
<b>Outfall No. 27</b>										
555M000101			X <sup>1</sup>	X						
555M000201			X <sup>1</sup>	X						
556M000101	X	X	X	X	X					
556M000901	X	X		X						
699M0002E1	X			X	X					
699M0003E1	X			X	X					
<b>Outfall No. 30</b>										
081M000101	X	X	X	X	X	X				
081M000201	X	X	X	X	X	X				
556M000701	X	X	X	X	X					

Table 8.3  
 Parameters Collected at Sample Locations

Sample ID	VOC	SVOC	Pest/PCB	Metals	Cyanide	Organotins	Herbicides	OP Pest	Hexavalent Chromium	Dioxins
556M000801	X	X	X	X	X					
<b>556N000801</b>	X	X	X	X	X		X	X	X	X
699M0004E1	X			X	X					
<b>Outfall Nos. 38 and 41</b>										
CPRM001801	X	X	X	X	X	X				
CPRM002101	X	X	X	X	X	X				
556M000401	X	X	X	X	X	X				
556M000501	X	X	X	X	X					
556M000601	X	X	X	X	X	X				
699M000901	X			X	X					

*Notes:*  
 OP Pest = Organophosphorous pesticide.  
 Pest/PCB = Pesticide/Polychlorinated Biphenyl  
 SVOC = Semivolatile Organic Compounds  
 VOC = Volatile Organic Compounds

Sample IDs containing an "M" are sediment samples, those with an "N" are duplicate sediment samples.  
 Sample IDs shown in **bold** indicate duplicate samples analyzed for Appendix IX parameters, including an expanded list of VOCs and SVOCs, if these parameters were collected.

<sup>1</sup> Sample was only analyzed for PCBs from the SW846 Method 8080 Pest/PCB list.

Calcium, iron, magnesium, potassium, and sodium were not included in this assessment, as they are naturally occurring nutrients. Also, the results from both primary and duplicate samples were used. For compounds detected in both the primary and duplicate sample, concentrations for both detections were averaged and listed as one concentration. For compounds that were detected in only one, the primary or the duplicate sample, the detected value was used. Tables 8.4a through 8.4d present comparisons of concentrations in outfall samples to the SSVs.

**Table 8.4a**  
**Outfall Number 23**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
<b>Metals and Cyanide (mg/kg)</b>					
Aluminum	5/5	2,140 - 23,000	NA	NC	Yes
Antimony	5/5	0.65 - 23.2	1.9	1.9	No
Arsenic	5/5	3.7 - 21.5	7.24	3.0	Yes
Barium	5/5	19.5 - 56.8	NA	NC	Yes
Beryllium	5/5	0.26 - 2.5	NA	NC	Yes
Cadmium	5/5	0.17 - 0.45	1	0.45	No
Chromium	5/5	28.4 - 45.0	52.3	0.86	No
Cobalt	5/5	2.9 - 18.3	NA	NC	Yes
Copper	5/5	36.5 - 427	18.7	22.8	Yes
Lead	5/5	57.5 - 482	30.2	16.0	Yes
Manganese	5/5	47.1 - 299	NA	NC	Yes
Mercury	5/5	0.06 - 0.64	0.13	4.9	Yes
Nickel	5/5	14.4 - 42.4	15.9	2.67	Yes
Selenium	4/5	0.8 - 1.9	NA	NC	Yes
Silver	2/5	0.71 - 0.75	2	0.38	No
Thallium	1/5	1.1	NA	NC	Yes
Vanadium	5/5	5.4 - 68.6	NA	NC	Yes
Zinc	5/5	118 - 1,390	124	11.2	Yes
Tin	3/5	4.8 - 55.7	NA	NC	Yes

**Table 8.4a**  
**Outfall Number 23**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
Cyanide	0/1	N/A	NA	N/A	No
<b>Semivolatile Organic Compounds (µg/kg)</b>					
2-Methylnaphthalene	1/4	220	330	0.67	No
Acenaphthene	1/4	640	330	1.9	Yes
Anthracene	1/4	1,400	330	4.2	Yes
Benzo(a)anthracene	3/4	210 - 2,600	330	7.9	Yes
Benzo(a)pyrene	3/4	210 - 2,200	330	6.67	Yes
Benzo(b)fluoranthene	2/4	170 - 230	NA	NC	Yes
Benzo(g,h,i)perylene	3/4	120 - 1,200	NA	NC	Yes
Benzo(k)fluoranthene	3/4	210 - 3,600	NA	NC	Yes
Chrysene	3/4	160 - 2,900	330	8.8	Yes
Dibenz(a,h)anthracene	2/4	90 - 720	330	2.2	Yes
Dibenzofuran	1/4	590	NA	NC	Yes
Fluoranthene	3/4	260 - 6,700	330	20	Yes
Fluorene	1/4	760	330	2.3	Yes
Indeno(1,2,3-cd)pyrene	3/4	110 - 1,100	NA	NC	Yes
Naphthalene	1/4	590	330	1.8	Yes
Phenanthrene	2/4	260 - 6,900	330	21	Yes
Pyrene	4/4	130 - 5,600	330	17	Yes
<b>Dioxins (ng/kg)</b>					
123678-HxCDD	1/1	1.685	NA	NC	Yes
123789-HxCDD	1/1	2.538	NA	NC	Yes
1234678-HpCDD	1/1	37.785	NA	NC	Yes
OCDD	1/1	723.954	NA	NC	Yes
123678-HxCDF	1/1	1.156	NA	NC	Yes
123789-HxCDF	1/1	0.939	NA	NC	Yes
1234678-HpCDF	1/1	3.233	NA	NC	Yes
OCDF	1/1	6.228	NA	NC	Yes

**Table 8.4a**  
**Outfall Number 23**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
Total Tetra-Dioxins	1/1	5.185	NA	NC	Yes
Total Penta-Dioxins	1/1	8.159	NA	NC	Yes
Total Hexa-Dioxins	1/1	95.971	NA	NC	Yes
Total Hepta-Dioxins	1/1	156.054	NA	NC	Yes
Total Hexa-Furans	1/1	2.095	NA	NC	Yes

**Notes:**

- a = Effects levels represent USEPA Region IV (1997) Sediment Screening Values (SSVs)
- HQ = Hazard Quotient calculated using maximum concentration divided by EL.
- ECPC = Ecological Chemical of Potential Concern
- NA = Value is not available
- N/A = Value is not applicable
- NC = Value could not be calculated

**Table 8.4b**  
**Outfall Number 27**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
<b>Metals and Cyanide (mg/kg)</b>					
Aluminum	6/6	2,450 - 21,500	NA	NC	Yes
Antimony	3/6	0.86 - 4.4	12	0.37	No
Arsenic	6/6	5.30 - 21.2	13.0	1.63	Yes
Barium	6/6	17.5 - 90.8	NA	NC	Yes
Beryllium	6/6	0.19 - 1.2	NA	NC	Yes
Cadmium	4/6	0.21 - 3.6	1	3.6	Yes
Chromium	6/6	39.3 - 230	52.3	4.40	Yes
Cobalt	6/6	3.6 - 9.4	NA	NC	Yes
Copper	6/6	24.6 - 220	18.7	12	Yes
Lead	6/6	26.3 - 515	30.2	17.1	Yes
Manganese	6/6	104 - 824	NA	NC	Yes
Mercury	4/6	0.11 - 0.30	0.13	2.3	Yes
Nickel	6/6	11.4 - 102	15.9	6.42	Yes

**Table 8.4b**  
**Outfall Number 27**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
Selenium	2/6	0.63 - 1.20	NA	NC	Yes
Silver	2/6	0.67 - 0.68	2	0.34	No
Thallium	1/6	1.8	NA	NC	Yes
Vanadium	6/6	12.1 - 56.0	NA	NC	Yes
Zinc	6/6	79.6 - 1,250	124	10.1	Yes
Tin	3/6	13.6 - 546	NA	NC	Yes
Cyanide	0/4	N/A	NA	N/A	No
<b>Volatile Organic Compounds (µg/kg)</b>					
2-Butanone (MEK)	2/4	32 - 42	NC	NA	Yes
Carbon Disulfide	1/4	6.0	NC	NA	Yes
<b>Semivolatile Organic Compounds (µg/kg)</b>					
Chrysene	1/2	350	330	1.1	Yes
Fluoranthene	1/2	810	330	2.5	Yes
Pyrene	2/2	470 - 690	330	2.1	Yes

**Notes:**

- a = Effects levels represent USEPA Region IV (1997) Sediment Screening Values (SSVs)
- HQ = Hazard Quotient calculated using maximum concentration divided by EL.
- ECPC = Ecological Chemical of Potential Concern
- NA = Value is not available
- N/A = Value is not applicable
- NC = Value could not be calculated

**Table 8.4c**  
**Outfall Number 30**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
<b>Metals and Cyanide (mg/kg)</b>					
Aluminum	5/5	4,380 - 13,300	NA	NC	Yes
Antimony	1/5	7.0	12	0.58	No
Arsenic	5/5	9.1 - 18.7	13.0	1.4	Yes
Barium	5/5	15.0 - 29.6	NA	NC	Yes

Table 8.4c  
 Outfall Number 30  
 Constituents in Sediment

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
Beryllium	5/5	0.48 - 1.1	NA	NC	Yes
Cadmium	1/5	0.48	1	0.48	No
Chromium	5/5	20.9 - 151	52.3	2.89	Yes
Cobalt	5/5	3.4 - 8.0	NA	NC	Yes
Copper	5/5	25.6 - 164	18.7	8.77	Yes
Lead	5/5	13.4 - 996	30.2	33.0	Yes
Manganese	5/5	85.4 - 569	NA	NC	Yes
Mercury	3/5	0.090 - 0.12	0.13	0.92	No
Nickel	5/5	7.30 - 25.2	15.9	1.59	Yes
Selenium	1/5	0.54	NA	NC	Yes
Silver	1/5	0.37	2	0.19	No
Vanadium	5/5	21.3 - 50.7	NA	NC	Yes
Zinc	5/5	55.4 - 341	124	2.75	Yes
Tin	1/5	12.0	NA	NC	Yes
Cyanide	0/5	N/A	NA	N/A	No
<b>Volatile Organic Compounds (µg/kg)</b>					
2-Butanone (MEK)	4/5	21 - 33	NA	NC	Yes
Acetone	2/5	350 - 570	NA	NC	Yes
Carbon Disulfide	4/5	10. - 21	NA	NC	Yes
<b>Semivolatile Organic Compounds (µg/kg)</b>					
Acenaphthene	2/4	690 - 1,100	330	3.3	Yes
Anthracene	2/4	1,200	330	3.6	Yes
Benzo(a)anthracene	4/4	370 - 1,800	330	5.5	Yes
Benzo(a)pyrene	4/4	300 - 1,500	330	4.6	Yes
Benzo(b)fluoranthene	3/4	300 - 1,100	NA	NC	Yes
Benzo(g,h,i)perylene	2/4	450 - 710	NA	NC	Yes
Benzo(k)fluoranthene	4/4	320 - 2,200	NA	NC	Yes
Carbazole	1/1	220	NA	NC	Yes

**Table 8.4c**  
**Outfall Number 30**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
Chrysene	4/4	430 - 1,900	330	5.8	Yes
Di- <i>n</i> -octyl phthalate	1/4	290	NA	NC	Yes
Dibenz(a,h)anthracene	2/4	250 - 360	330	1.1	Yes
Dibenzofuran	1/4	390	NA	NC	Yes
Fluoranthene	4/4	780 - 4,600	330	14	Yes
Fluorene	2/4	520 - 730	330	2.2	Yes
Indeno(1,2,3-cd)pyrene	2/4	430 - 690	NA	NC	Yes
Naphthalene	1/4	250	330	0.76	No
Phenanthrene	2/4	1,800 - 2,400	330	7.3	Yes
Pyrene	4/4	840 - 4,400	330	13	Yes
<b>Pesticides/PCBs (<math>\mu\text{g}/\text{kg}</math>)</b>					
Endrin Ketone	1/4	11	NA	NC	Yes
<b>Dioxins/Furans (ng/kg)</b>					
123478-HxCDD	1/1	2.76	NA	NC	Yes
123789-HxCDD	1/1	3.06	NA	NC	Yes
1234678-HpCDD	1/1	70.7	NA	NC	Yes
OCDD	1/1	970.	NA	NC	Yes
1234678-HpCDF	1/1	7.86	NA	NC	Yes
OCDF	1/1	22.4	NA	NC	Yes
Total Hexa-Dioxins	1/1	68.9	NA	NC	Yes
Total Hepta-Dioxins	1/1	377	NA	NC	Yes
Total Hexa-Furans	1/1	3.07	NA	NC	Yes
Total Hepta-Furans	1/1	7.86	NA	NC	Yes

**Notes:**

- a = Effects levels represent USEPA Region IV (1997) Sediment Screening Values (SSVs)
- HQ = Hazard Quotient calculated using maximum concentration divided by EL.
- ECPC = Ecological Chemical of Potential Concern
- NA = Value is not available
- N/A = Value is not applicable
- NC = Value could not be calculated

**Table 8.4d**  
**Outfall Numbers 38 and 41**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level*	HQ	ECPC
<b>Metals and Cyanide (mg/kg)</b>					
Aluminum	6/6	2,770 - 30,100	NA	NC	Yes
Antimony	2/6	0.75 - 1.7	12	0.14	No
Arsenic	6/6	1.86 - 21.6	13.0	1.66	Yes
Barium	6/6	14.1 - 35.6	NA	NC	Yes
Beryllium	6/6	0.49 - 1.3	NA	NC	Yes
Cadmium	4/6	0.29 - 0.79	1	0.79	No
Chromium	6/6	23.6 - 55.4	52.3	1.1	Yes
Cobalt	6/6	4.1 - 7.9	NA	NC	Yes
Copper	6/6	21.0 - 1,930	18.7	103	Yes
Lead	6/6	24.4 - 220.	30.2	7.28	Yes
Manganese	6/6	162 - 721	NA	NC	Yes
Mercury	3/6	0.05 - 0.31	0.13	2	Yes
Nickel	6/6	7.80 - 32.6	15.9	2.05	Yes
Selenium	2/6	0.60 - 10.5	NA	NC	Yes
Thallium	1/6	2.9	NA	NC	Yes
Vanadium	6/6	6.3 - 73	NA	NC	Yes
Zinc	6/6	70.6 - 774	124	6.24	Yes
Tin	1/6	35.0	NA	NC	Yes
Cyanide	0/6	N/A	NA	N/A	No
<b>Volatile Organic Compounds (µg/kg)</b>					
2-Butanone (MEK)	4/6	4.0 - 82	NA	NC	Yes
Acetone	5/6	300 - 4,100	NA	NC	Yes
Carbon Disulfide	2/6	9.0 - 12.0	NA	NC	Yes
<b>Semivolatile Organic Compounds (µg/kg)</b>					
Acenaphthene	3/5	260 - 730	330	2.2	Yes
Acenaphthylene	1/5	350	330	1.1	Yes
Anthracene	4/5	880 - 2,500	330	7.6	Yes

**Table 8.4d**  
**Outfall Numbers 38 and 41**  
**Constituents in Sediment**

Constituent	Frequency of Detection	Range of Concentrations Detected	Effects Level <sup>a</sup>	HQ	ECPC
Benzo(a)anthracene	4/5	840 - 6,400	330	19	Yes
Benzo(a)pyrene	4/5	420 - 5,500	330	17	Yes
Benzo(b)fluoranthene	3/5	450 - 4,300	NA	NC	Yes
Benzo(g,h,i)perylene	3/5	1,100 - 3,300	NA	NC	Yes
Benzo(k)fluoranthene	4/5	530 - 11,000	NA	NC	Yes
Chrysene	4/5	800 - 10,000	330	30	Yes
Dibenz(a,h)anthracene	3/5	540 - 1,500	330	4.6	Yes
Dibenzofuran	2/5	150 - 390	NA	NC	Yes
Fluoranthene	4/5	2,600 - 18,000	330	55	Yes
Fluorene	2/5	320 - 680	330	2.1	Yes
Indeno(1,2,3-cd)pyrene	3/5	1,100 - 3,000	NA	NC	Yes
Phenanthrene	4/5	760 - 5,700	330	17	Yes
Pyrene	4/5	1,900 - 10,000	330	30.	Yes
<b>SW846 Pesticides/PCBs (µg/kg)</b>					
4,4'-DDE	1/5	7.6	3.3	2.3	Yes
Endrin Ketone	2/5	7.8 - 14	NA	NC	Yes
Methoxychlor	1/5	45	NA	NC	Yes

**Notes:**

- a = Effects levels represent USEPA Region IV (1997) Sediment Screening Values (SSVs)
- HQ = Hazard Quotient calculated using maximum concentration divided by EL.
- ECPC = Ecological Chemical of Potential Concern
- NA = Value is not available
- N/A = Value is not applicable
- NC = Value could not be calculated

## 8.5 Contaminant Fate and Transport

The complex history and hydrodynamics of the Cooper River, including its diversion and  
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 rediversion projects, its high volume of flow, tidal influence, varying salinity regimes, high  
 concentration of industry (historical and current), far-field forcing, dredging, and other factors all

affect contaminant fate and transport. The study *A Physical and Ecological Characterization of the Charleston Harbor Estuarine System* (VanDolah, et al., 1990) provides information on the general conditions of the Cooper River, but is not source-specific. A preliminary investigation by NRL (*Technical Memo, NAVBASE Charleston - Zone J RCRA Facility Investigation*, July 15, 1998); pointed out the limits of these and the Zone J data as collected. Limitations include the spatial rather than both the spatial and temporal nature of these data, the comparisons of the "detections" to USEPA Region IV's SSVs without knowledge of historical sediment quality, research suggesting that the area of the Cooper River in front of CNC is a sediment depositional area and thus not a major source of downriver impacts, and the lack of research into other potentially responsible parties (PRPs). At present, not enough data exist on the physical dynamics of the river or past conditions to address the fate and transport of contaminants. Nor can it be determined if the Navy is responsible for the contamination detected, and if so, to what degree.

## **8.6 Exposure Pathways and Assessment**

Contact/interface is the exposure pathway used to evaluate the aquatic receptors with water and sediment. An assessment endpoint has been selected to evaluate the need for further research into aquatic community health, with a preliminary measurement endpoint that predicts chronic effects to aquatic community species.

## **8.7 Ecological Effects Assessment**

In addition to determining the exposure potentials associated with each outfall, the effects of certain ECPCs on selected receptors was examined. Based on the known characteristics of these potential contaminants or "stressors," their associated effects can be better predicted.

***Stressor Characteristics***

**Inorganics**

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

Arsenic occurs naturally and is constantly changing as it cycles through the environment. Many inorganic arsenicals are known teratogens and are more toxic than organic arsenicals (Eisler, 1988). Adverse effects to aquatic organisms have been reported at concentrations of 19 to 48 ppb in water.

Cadmium is a relatively rare heavy metal. It is a known teratogen and carcinogen and probably a mutagen, and has been implicated as the cause of severe deleterious effects on fish and other wildlife.

Hexavalent chromium ( $\text{Cr}^{6+}$ ) produces more adverse effects to biota than does the trivalent phase. However, separate analyses for hexavalent chromium were not performed on any samples that exceeded the SSVs for total chromium. Of the samples that were analyzed for hexavalent chromium, no detections were found.

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

In sediments, lead is primarily found in association with iron and manganese hydroxides, and may also form associations with clay and organic matter. Under oxidizing conditions, lead tends to remain tightly bound to sediments, but is released into the water column under reducing conditions. Lead may accumulate to relatively high concentrations in aquatic biota.

Mercury is a known mutagen, teratogen, and carcinogen. It adversely affects reproduction, growth, development, motor coordination, and metabolism, and is slow to deplete. Organomercury compounds produce more adverse effects than inorganic mercury compounds. Inorganic mercury can be modified to organic mercury compounds through biological transformation.

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

No information was available on the toxicological effects of other inorganic ECPCs in sediment.

### **Organics**

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

Most environmental concerns have focused on PAHs that range in molecular weight from 128.16 (naphthalene) to 300.36 (coronene). Generally, lower molecular weight PAH compounds, containing two or three aromatic rings, exhibit significant acute toxicity but are not carcinogenic. High molecular weight PAH compounds, those with four to seven rings, are significantly less toxic, but are demonstrably carcinogenic, mutagenic, or teratogenic to aquatic species. PAHs

show little tendency to biomagnify in food chains because most are rapidly metabolized (Eisler, 1987a).

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

Trace amounts of dioxins are present in some commercial herbicides and chlorophenols (Eisler, 1986). The most toxic and extensively studied dioxin is 2,3,7,8-TCDD. Laboratory studies with birds, mammals, aquatic organisms, and other species have demonstrated that exposure to 2,3,7,8-TCDD can result in acute and delayed mortality as well as mutagenic and reproductive effects. In soil, microbial decomposition of TCDD is slow (Ramel, 1978) and uptake by vegetation is considered negligible (Blair, 1973). While 2,3,7,8-TCDD has not been detected in the two samples analyzed for dioxins, the congeners listed in Tables 8.4a and 8.4c may exhibit similar effects, but to a lesser degree than 2,3,7,8-TCDD

## 8.8 Ecological Risk Evaluation

### *Assessment of Potential Receptors*

Potential adverse ecological effects to aquatic species from identified ECPCs have been predicted based on SSVs using a preliminary screening approach. Maximum sediment concentrations for ECPCs have been divided by the SSV to produce an HQ. HQs with a result higher than one are considered to demonstrate a potential risk. Values higher than 10 are considered to be of moderate potential risk and above 100, extreme risk.

**8.8.1 Outfall-Specific Risk Characterization**

***Outfall Number 23***

According to Table 8.4a, the following analytes' maximum concentrations exhibited values greater than the SSVs producing HQs greater than one:

Analyte	HQ
Antimony	1.9
Arsenic	3.0
Copper	22.8
Lead	16.0
Mercury	4.9
Nickel	1.62
Zinc	11.2
Acenaphthene	1.9
Anthracene	4.2
Benzo(a)anthracene	7.9
Benzo(a)pyrene	6.67
Chrysene	8.8
Dibenz(a,h)anthracene	2.2
Fluoranthene	20.
Fluorene	2.3
Naphthalene	1.8
Phenanthrene	21
Pyrene	17

In addition, hazard quotients could not be calculated for aluminum, barium, beryllium, cobalt, manganese, selenium, thallium, vanadium, tin, benzo(b)fluoranthene, benzo(g,h,i)perylene,

benzo(k)fluoranthene, dibenzofuran, indeno(1,2,3-cd)pyrene, and various dioxins and chlorinated dibenzofurans. Therefore, these have also been considered as ECPCs based on the criteria used to define these. However, the degree to which these compounds affect the overall health of the aquatic community cannot be determined.

Three metals (copper, lead, and zinc) and three PAHs produced HQs greater than 10, the level used to indicate potentially moderate risk. This, in addition to the HQs greater than one, indicate that the potential exists for adverse effects to the benthic aquatic community in the vicinity of Outfall Number 23.

Of the 11 PAHs detected in Outfall 23 sediments with HQs greater than one, five are considered Low Molecular Weight (LMW) - exhibiting significant acute toxicity but not shown to be carcinogenic. The other six PAHs are considered High Molecular Weight (HMW) and exhibit significantly less acute toxicity, but are demonstrably carcinogenic, mutagenic, and teratogenic to aquatic species. The possible adverse effects of the other compounds are summarized in Section 8.7.

### ***Outfall Number 27***

Table 8.4b indicates the following analytes with HQs greater than one:

Analyte	HQ
Arsenic	1.63
Cadmium	3.6
Chromium	4.40
Copper	12
Lead	17.1
Mercury	2.3

Nickel	6.42	1
Zinc	10.1	2
Chrysene	1.1	3
Fluoranthene	2.5	4
Pyrene	2.1	5

HQs could not be determined for aluminum, barium, beryllium, cobalt, manganese, selenium, thallium, vanadium, tin, 2-butanone, and carbon disulfide. Only two of the five samples collected to assess the environmental conditions at Outfall 27 were analyzed for SVOCs. However, these samples confirmed the presence of the PAHs found throughout this assessment, although they seem to be present to a lesser degree. Three metals; copper, lead, and zinc, produced HQs greater than 10, indicating that they pose the potential for moderate risk.

The three PAHs detected at Outfall 27 with HQs greater than one are all HMW and have exhibited carcinogenic, mutagenic, and teratogenic effects on aquatic species. The possible adverse effects for the inorganics are summarized in Section 8.7

**Outfall Number 30**

The following analytes exhibited HQs greater than one:

Analyte	HQ	
Arsenic	1.4	17
Chromium	2.89	18
Copper	8.77	19
Lead	33.0	20
Nickel	1.59	21
Zinc	2.75	22

Acenaphthene	3.3	1
Anthracene	3.6	2
Benzo(a)anthracene	5.5	3
Benzo(a)pyrene	4.6	4
Chrysene	5.8	5
Dibenz(a,h)anthracene	1.1	6
Fluoranthene	14	7
Fluorene	2.2	8
Phenanthrene	7.3	9
Pyrene	13	10

Other analytes detected that do not have SSVs include aluminum, barium, beryllium, cobalt, manganese, selenium, vanadium, 2-butanone, acetone, carbon disulfide, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, carbazole, di-*n*-octyl phthalate, chlorinated dibenzofuran, indeno(1,2,3-cd)pyrene, endrin ketone, and various dioxin and chlorinated dibenzofuran congeners.

Three of the analytes listed above, lead, fluoranthene, and pyrene, exhibited HQs in the moderate risk category (10 or greater).

Of the 11 PAHs detected at Outfall 30 with HQs greater than one, five are LMW and six are HMW, indicating the potential for both acute and chronic effects. The possible effects of the inorganic compounds are summarized in Section 8.7.

**Outfall Numbers 38 and 41**

The following analytes exhibited HQs greater than one:

Analyte	HQ	
Arsenic	1.66	
Chromium	1.1	
Copper	103	
Lead	7.28	
Mercury	2	
Nickel	2.05	
Zinc	6.24	
Acenaphthene	2.2	
Acenaphthylene	1.1	
Anthracene	7.6	
Benzo(a)anthracene	19	
Benzo(a)pyrene	17	
Chrysene	30	
Dibenz(a,h)anthracene	4.6	
Fluoranthene	55	
Fluorene	2.1	
Phenanthrene	17	
Pyrene	30.	
4,4'-DDE	2.3	

Analytes detected for which no SSVs are available include aluminum, barium, beryllium, cobalt, manganese, selenium, thallium, vanadium, tin, 2-butanone, acetone, carbon disulfide, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenzofuran,

indeno(1,2,3-cd)pyrene, endrin ketone, and methoxychlor. HQs in excess of 10 include benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene, indicating a potential for moderate risk to aquatic receptors. The HQ for copper (103) is indicative of extreme risk.

Five LMW and six HMW PAHs with HQs greater than one were detected at this outfall. Of the six PAHs that exceeded an HQ of 10, four were HMW, which have been shown to produce chronic effects but exhibit significantly less acute toxicity than LMW PAHs. The HQ value of 103 for copper indicates extreme risk. As stated in Section 8.7, copper is readily accumulated by aquatic organisms and is associated with both acute and chronic toxicity.

### **Discussion of Findings**

While each outfall location has been assessed separately, general trends appear in the data. These include high concentration/SSV ratios for inorganics including arsenic (maximum concentration exceeded SSV at all four sites examined), copper (maximum concentration exceeded SSV at all four sites examined, including one order of magnitude at Outfalls 23 and 27 and two orders of magnitude at Outfalls 38 and 41), chromium (exceeded SSV at three of four sites), lead (exceeded SSV at all four sites, including an HQ of 17.1 at Outfall 27 and 33.0 at Outfall 30), mercury (exceeded SSV at three of four sites), nickel (exceeded SSV at all four sites), and zinc (exceeded SSV at all four sites including an HQ of 10.1 at Outfall 27). PAHs were also prevalent at all four of the sites examined, particularly at Outfalls 38 and 41 where six of the 11 PAHs detected produced HQs in excess of 10. These findings indicate that risk potential exists at the outfalls determined to have cross-connects. These data do not, however, suggest that the Navy is solely responsible for the contaminants found. Rather, they may indicate that high levels of certain contaminants are prevalent throughout the Cooper River's near-shore zone. More studies of the dynamics of the river and other PRPs are needed to determine the contamination source.

The NRL report cited several lines of evidence indicating that the PAH contamination may originate upriver. Evidence includes:

- the presence of a bacterially inhibitory plume upriver;
- historical information on pulp mill plume contaminant releases that are largely consistent with CNC sediment contamination;
- presence of a salt wedge in the water column ( $\Delta 5\text{‰}$ ) that would inhibit resuspended CNC sediments from transport into the upper water column seston;
- lack of connection between the amount of contaminants coming from the base storm water outfalls and the amount depositing in river sediments;
- the presence of upriver PAH "hot spots" and rapid LMW PAH mineralization rates;
- high LMW to HMW PAH ratios in upriver stations, suggesting current PAH sources;
- findings of general contamination around the CNC sediments are consistent with a depositional area impacted by contaminated upriver seston settling out of the water column;
- depositional rates (measured with sediment traps) between CNC and the pulp mill suggest high deposition of PAH-contaminated materials at CNC, similar to that found near the pulp mill;
- the ratios of PAH compounds in CNC nepheloid layers and sediments are similar to those found at the pulp mill outfall upriver of CNC.

## 8.9 Uncertainty

General uncertainties associated with the ecological risk evaluation (ERA) for Zone L include:

- degradation of chemicals has not been considered in the ECPC selection process
- specific effects on area biota are unknown
- SSVs for some ECPCs were unavailable
- synergistic or antagonistic effects are unknown

- for some ECPCs, only assumptions can be made based on similar compounds or classes of elements 1  
2
- maximum exposure scenarios and concentrations may tend to overestimate risk potentials 3
- SSVs are obtained from laboratory studies and may not reflect field-based exposure scenarios 4  
5
- due to the highly mobile substrate, sediment data reproducibility cannot be ascertained. 6

#### **8.10 Risk Summary**

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The potential for risk to benthic species exists at all four outfalls examined, but the source of the contaminants has yet to be determined. Preliminary studies indicate an upstream source for the PAHs detected (NRL, 1998). Some metals also pose a potential risk. Without knowledge of background conditions, however, it cannot be determined if these metals are due to anthropogenic sources or are representative of background conditions. Further studies are needed in order to resolve these issues in this turbulent and complex ecosystem. 8  
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## 9.0 CORRECTIVE MEASURES

According to Permit Condition IV. E. Corrective Action Plan, SCDHEC will review the final RFI report and notify CNC, of the need for further investigations, corrective actions, a corrective action study, or plans to meet the requirements of R.61-79.264.101, Corrective Action for SWMUs. This section has been prepared based on SCDHEC's comment that "the RFI report should discuss whether the extent of contamination has been defined, and proposed recommended actions for the SWMUs and AOCs, such as collection of additional samples, proceed into a Corrective Measures Study, or No Further Investigation, whichever is appropriate." The CNC project team established action levels for assessing whether to conduct a CMS at 1E-06 residential risk and/or groundwater exceeding MCLs. The following discussions address the overall approach for looking at CMS, list potential remedies, and outline the steps involved in conducting a CMS. Site-specific conclusions about which sites will require corrective measures are discussed in Section 10, Site-Specific Evaluations.

### 9.1 Introduction

Any CMS at CNC will be conducted according to standard methods presented in the guidance document, *RCRA Corrective Action Plan* (USEPA, 1994) and per project team consensus. Standard methodology has been presented in the *Comprehensive CMS Work and Project Management Plans*, and will also be detailed each zone-specific CMS Work Plan. The plans will facilitate collecting necessary data, evaluating potential alternatives, and developing a final remedial alternative by establishing set procedures for evaluation and assessment.

To establish this procedure, zone-specific CMS Work Plans will outline basic elements of the CMS report. The overall structure of the work plan will be explained to illustrate the decision-making process. The subsequent CMS Report that is generated as part of the CMS process is briefly described below:

<b>CMS Report Outline</b>	1
A. Introduction/Purpose	2
B. Description of Current Conditions	3
C. Corrective Action Objectives	4
D. Identification, Screening, and Development of Corrective Measures Alternatives	5
E. Evaluation of a Final Corrective Measure	6
F. Recommendation by a Permittee/Respondent for a Final Corrective Measure	7
G. Public Involvement Plan	8
H. Treatability Study Results	9

Each required element will be discussed in detail in the Comprehensive and/or zone-specific CMS Work Plans. The discussion will achieve the following:

- Identify minimum requirements for CMS reports in each area. 12
- Define the base pool of technologies to be evaluated for each medium. 13
- Describe the remedial technology identification and screening processes. 14
- Describe the remedial alternative evaluation process. 15

Issues to be discussed under each element of the CMS report are identified below: 16

- An activity-specific description of the overall purpose of the CMS for CNC. 17

*SWMUs and AOCs at CNC will be discussed in the CMS Work Plan on a zone-wide basis. Activities, contaminants, and issues specific to each zone will be discussed. The CMS Work Plan will identify: specific sites to be addressed in the CMS, any focused approach (such as naming a primary technology in lieu of the full screening), subsequent remedial goals, and CMS data needs.* 18  
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- A description of the corrective action objectives for CNC, including how target media cleanup standards, points of compliance, or risk assessments will be established and performed for each site, zone, and activity.

*Cleanup standards will be developed for each site, zone, or activity using multiple exposure scenarios (residential, commercial, or industrial) for that area. BRAs, conducted in conjunction with the RFI for each zone, will be used to identify areas with unacceptable risk/hazard as per the multiple exposure scenarios. During the CMS, areas with unacceptable risk and/or hazard will be evaluated according to media, primary contaminants contributing to risk, and the potential for groundwater contamination. Primary cleanup standards for groundwater will be MCLs, or RBCs for those constituents where MCLs do not apply.*

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

*Tables similar to those the NAVBASE RFI Work Plans will be used in the CMS Report to present the pool of technologies initially evaluated in the CMS. These tables represent a range of technologies with different applications; each technology must be screened and evaluated before it is eliminated 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 Report 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.*

*Once technologies have been screened, they will be assembled into corrective action alternatives, which will be evaluated according to criteria discussed below.* 1  
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- A description of the general approach to investigating and evaluating potential corrective action measures. 3  
4

Corrective measures alternatives will be evaluated using four primary and five secondary criteria, listed below: 5  
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***Primary*** 7

1. Protection of human health and the environment. 8
2. Attainment of media cleanup standards set by the implementing agency. 9
3. Control the source of releases so as to reduce or eliminate, to the extent practical, further releases that may pose a threat to human health and the environment. 10  
11
4. Compliance with any applicable standards for management of wastes. 12

***Secondary*** 13

1. Long-term reliability and effectiveness 14
2. Reduction in the toxicity, mobility, or volume of waste. 15
3. Short-term effectiveness 16
4. Implementability 17
5. Cost 18

Potential remedial alternatives will be described and evaluated according to these criteria, which are used to gauge their relative effectiveness and implementability.

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

*Treatability studies will be implemented for sites that require complex technical remedial solutions. For example, air stripping technologies usually do not require treatability studies to determine optimal operation processes for treating groundwater. However, ultraviolet (UV)/oxidation, an innovative technology, may require extensive treatability testing to determine oxidant dosages and retention times.*

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

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

*Statement of basis/response to comments will be handled through SCDHEC and Southern Division, Naval Facilities Engineering Command (SOUTHDIV). The Comprehensive Long-Term Environmental Action Navy (CLEAN) contractor, EnSafe, will assist the SCDHEC and the Navy in preparing statement of basis/response to comments. Permit modifications will be managed through the Caretaker Site Office (CSO) as the permit holder. SOUTHDIV will assist the CSO in managing the permit modification process. According to the RCRA permit issued May 4, 1990 (Appendix C), Facility Submission*

*Summary, a permit modification is required to prepare and conduct a Corrective Action Study/Plan.* 1  
2

- A description of the overall project management approach, including levels of authority (i.e., organizational charts), lines of communication, project schedules, budgets, and personnel. 3  
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*Overall project management is the responsibility of SOUTHDIV for the CSO. Lines of authority, communication, and project schedules have been developed and agreed upon and are provided in the Comprehensive Project Management Plan, August 30, 1994, and amendments. In general, SOUTHDIV is responsible for ensuring that permit conditions are satisfied, with the ultimate responsibility held by the CSO. The budget for conducting a CMS is defined by SOUTHDIV with funds provided by the U.S. Congress. EnSafe will assign qualified personnel on an as-needed basis for project-specific CMS items. EnSafe will manage the CMS effort through its Charleston, South Carolina, office.* 6  
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- A description of the qualifications of personnel directing or performing the work. 14

*EnSafe will use qualified registered South Carolina engineers and geologists where required.* 15  
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## **9.2 Remedy Selection Approach** 17

As agreed in the *Final Comprehensive Project Management Plan*, remedies will be selected in accordance with statutory and RCRA CMS criteria. 18  
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- Particular attention will be given to the following items when evaluating alternatives: 1
- Background concentrations, particularly of inorganic compounds 2
  - Land use/risk assessment 3
  - Base-wide groundwater impacts 4
  - Presumptive remedies 5

### 9.3 Proposed Remedy 6

Before selecting and implementing a corrective measure for releases, environmental and 7  
cost-effectiveness goals must be established. Typically, the environmental goal is to reduce 8  
exposure via direct contact with air, groundwater, and surface water pathways to an acceptable 9  
level. The cost-effectiveness goal usually entails using the least costly alternative that is both 10  
technically feasible and reliable to achieve the environmental goals. 11

### 9.4 Development of Target Media Cleanup Goals 12

Cleanup goals will be developed for each site at CNC where risk or hazard exceeds acceptable 13  
levels, or MCLs are exceeded as specified in the Part B permit. The *RCRA Corrective Action Plan* 14  
(USEPA, 1994) outlines issues to be considered in developing cleanup goals for groundwater, soil, 15  
surface water, sediment, and air. These recommendations are outlined below. Zone L sites 16  
requiring further evaluation will undergo a CMS under the subzone in which the site is located. 17  
During the CMS, alternatives will be developed according to future land use for residential and/or 18  
worker scenarios. Two sets of alternatives may be presented for each site; they may differ due 19  
to the media cleanup standards for residential versus site worker scenarios. 20

**9.4.1 Groundwater Cleanup Goals**

The CMS will provide information to support development of cleanup goals for all Appendix IX constituents found in groundwater during the facility investigation. The following information may be required:

- For any constituents for which an MCL has been promulgated under the Safe Drinking Water Act.
- Background concentration of the constituent in groundwater.
- An alternate standard (e.g., an alternative concentration limit for a regulated unit), to be approved by the implementing agency.

Additional factors to be considered while developing cleanup goals include classification and primary use of the contaminated groundwater unit, proposed future uses for groundwater, proximity to surface water, etc.

**9.4.2 Soil Cleanup Goals**

The CMS will provide information to support the development of soil cleanup goals. The following information may be required:

- The volume, physical, and chemical characteristics of wastes in the unit.
- The effectiveness and reliability of containing, confining, and collecting systems and structures in preventing contaminant migration.

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• The hydrologic characteristics of the unit and the surrounding area, including surrounding topography.	1 2
• Regional precipitation patterns.	3
• The existing quality of surface soil, including other sources of contamination and their cumulative impact on surface soil.	4 5
• The potential for contaminant migration and impact to underlying groundwater.	6
• Land use patterns in the region.	7
• The potential for health risks caused by human exposure to waste constituents.	8
• The potential for damage to wildlife, food chains, vegetation, and physical structures caused by exposure to waste constituents.	9 10
Additional information which may be considered includes background soil concentrations and regulatory guidance.	11 12
<b>9.4.3 Surface Water and Sediment Cleanup Goals</b>	13
The CMS will provide information to support the development of surface water and sediment cleanup goals. The following information may be required:	14 15
• The volume and physical and chemical characteristics of wastes in the unit.	16

- The effectiveness and reliability of containing, confining, and collecting systems and structures in preventing contaminant migration. 1  
2
  
- The hydrologic characteristics of the unit and the surrounding area, including surrounding topography. 3  
4
  
- Regional precipitation patterns. 5
  
- The quantity, quality, and direction of groundwater flow. 6
  
- Proximity of the unit to surface water. 7
  
- Current and potential uses of nearby surface water and any established water quality standards. 8  
9
  
- The existing quality of surface water, including other sources of contamination and their cumulative impacts. 10  
11
  
- The potential for damage to wildlife, food chains, vegetation, and physical structures caused by exposure to waste constituents. 12  
13
  
- Land use patterns in the region. 14
  
- The potential for health risks caused by human exposure to waste constituents. 15

Additional data which may be considered include the presence of endangered, threatened, or ecologically sensitive species, National Oceanic and Atmospheric Association sediment values, etc.

#### **9.4.4 Air Cleanup Goals**

The CMS will provide information to support the development of air cleanup goals. The following information may be required:

- The volume and physical and chemical characteristics of waste in the unit, including the potential for emission and dispersal of gases, aerosols, and particulates.
- The effectiveness and reliability of systems and structures to reduce or prevent emissions of hazardous constituents to the air.
- The operating characteristics of the unit.
- The atmospheric, meteorological, and topographic characteristics of the unit and the surrounding areas.
- The existing quality of the air, including other sources of contamination and their cumulative impact on that medium.
- The potential for health risks caused by human exposure to waste constituents.
- The potential for damage to wildlife, vegetation, and physical structures caused by exposure to waste constituents.

Other factors which may be considered include National Ambient Air Quality Standards, state and local air quality regulations, etc.

## **9.5 Identification, Screening, and Development of Corrective Measures Technologies**

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

### **9.5.1 Identification of Corrective Measures Technologies**

Each site will be assessed using the cleanup standard methodology described in Section 9.2. An initial list of impacted media and contaminants of concern has been compiled in the RFI. The site-specific evaluations in Section 10 will identify soil, groundwater and sediment as the contaminated media. Major contaminants at each site have been grouped into one or more of the following categories:

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

Potential remedial technologies are described in Section 9.5.2. Table 9.1 lists non-treatment options for soil, groundwater/leachate, sediment, surface water, and air. These options include

removal containment, and disposal. Table 9.2 lists treatment options for each type of compound and medium. These tables supply general waste management options for various situations.

It should be noted that some sites may contain a combination of contaminants (i.e., inorganics, pesticides, and PCBs). As a result, multiple technology types may be required to remove these contaminants. However, some sites will only contain one type of contaminant.

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

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

### **9.5.2 Description of Pre-screened Technologies**

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

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

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

**Notes:**

POTW = Publicly Owned Treatment Works  
 NPDES = National Pollutant Discharge Elimination System  
 N/A = Not Applicable

Table 9.2  
 Treatment Technology Options

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

**Table 9.2  
 Treatment Technology Options**

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

***In-Situ Soil Treatment*** 1

**Bioremediation** 2

This technology uses microorganisms to biologically oxidize contaminants into harmless chemicals such as carbon dioxide and water. The organisms can be naturally occurring or they can be added to the soil. In many circumstances, nutrients can be supplemented to enhance this process. Nitrate and phosphate are often the limited nutrients at a site. However, an insufficient number of electron acceptors 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 of the compounds. Nonchlorinated VOCs and SVOCs are typically good candidates for this technology. 3  
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**Solidification/Stabilization** 11

This technology consists of mixing reagents with soil to prevent contaminants from leaching to the groundwater below. This technology immobilizes contaminants, preventing migration, but does not remove the contaminants. 12  
13  
14

***Ex-Situ Soil Treatment*** 15

All ex-situ soil treatments require excavation to another location, or at least bringing the material to the surface. Heavy equipment is typically used to move the soil. If contaminated soil is limited in volume and considered nonhazardous, it may be feasible to dispose of it in a landfill. If sites have a limited area of contaminated soil, it may be feasible to remove the soil with heavy equipment and treat it ex-situ, or if nonhazardous, it could be disposed in the SWMU 9 landfill. 16  
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**Soil Washing**

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

**Thermal Desorption**

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

**Thermal Destruction/Incineration**

This technology is used in conjunction with ex-situ soil technologies. The contaminant is typically removed from the soil matrix and transferred to an air stream, which is treated with the thermal destruction on a catalyst or burned in an incinerator, or a combination of the two. High temperatures (1800°F to 2000°F) are required to destroy organics such as PCBs, dioxins, furans, and pesticides.

**Solidification/Stabilization**

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

***In-Situ Groundwater Treatment***

**Bioremediation**

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

**Intrinsic Remediation**

This technology, also called natural attenuation, simply allows naturally occurring bioremediation, oxidation, hydrolysis, dispersion, and advection to occur unassisted. No nutrients or electron acceptors are added to the site and the site may be monitored to observe contaminant reduction. Many case studies have successfully demonstrated this technology on TPH and chlorinated solvent-impacted sites.

***Ex-Situ Groundwater Treatment***

Any ex-situ treatment of groundwater requires a system of extraction wells and pumps to deliver the groundwater to the treatment location.

**Chemical Precipitation**

Because the solubility of many metals is a function of pH, chemical agents can be added to water to change its pH and render the metals insoluble. In other cases, a chemical can be added to

chelate the metal and precipitate it out of the solution. Either way, the contaminants can then be removed by filtering.

### **Air Stripping**

Groundwater can be extracted from the subsurface and pumped to a nearby publicly owned treatment works (POTW). While the contaminated groundwater is in the aeration basin of the water treatment plant, the volatile compounds (compounds with a high Henry's Law Constant) will mass transfer from the water to the air. Steam can also be used to heat the groundwater, causing organics to volatilize. These air vapors can be treated with an appropriate technology or can be permitted as an air emission source.

### **Chemical Oxidation/UV-Ozone**

Ozone, one of the strongest chemical oxidizers can be generated with UV light sources. Almost any organic compound can be oxidized. When water passes through a flowstream surrounded by UV lights, oxygen in the water is converted to ozone and the organics are oxidized into harmless by-products. Compounds that typically are recalcitrant to biological oxidation, such as chlorinated organics, can easily be oxidized with ozone. Good light transmission is essential; which renders turbid water an inappropriate candidate for UV ozonation.

### **Activated Sludge**

Activated sludge treatment of wastes occurs in a wastewater treatment plant. The activated sludge process uses microorganisms to convert organic wastes to inorganic wastes and/or bacterial cell mass, carbon dioxide, and water.

### 9.5.3 Screening Criteria

When more than one technology applies to a specific site, it is necessary to evaluate their limitations to show why certain CMS technologies may prove infeasible to implement based on waste- and site-specific conditions. Therefore, for each technology, the following criteria will be discussed:

- Site characteristics
- Waste characteristics
- Technology limitations

#### Site Characteristics

Site characteristics define the site and any constraints that may impact selecting and implementing remedial technologies. Characteristics to be considered primarily include the current and future use of the site or SWMU. Other characteristics include the contaminated media, areal distribution of contamination, and depth to/of contamination. Current migration pathways and the potential for intrinsic remediation will also be considered. Each site may have one or two technology lists which will be evaluated for residential and BRAC-specified future uses.

#### Waste Characteristics

Waste characteristics define the nature of contamination. The primary waste characteristic to be considered is the general type of contamination – volatiles, semivolatiles, pesticides/herbicides, PCBs, dioxins, and inorganic compounds. Also critical is the presence of halogenated compounds, such as chlorinated benzenes or trichloroethylene.

Where multiple types of contamination are present (such as PCBs and dioxins, or pesticides and volatiles), certain technologies may be eliminated from consideration due to their inability to effectively treat the wastes. For example, soil vapor extraction (SVE) typically is not used on pesticide sites, although it is very effective for most volatile compounds. If both contaminants must be treated concurrently, SVE would be eliminated from further evaluation. Where appropriate, contaminant concentrations will be considered to screen remedial technologies.

### **Technology Limitations**

Technology limitations are used to assess the implementation feasibility of a particular technology. These limitations may include technical restrictions on application, including the presence of a shallow water table, depth to bedrock, etc. Additional limitations include minimum or maximum process volumes, such as technologies that are cost-effective only when contaminated soil volume exceeds 1,000 cubic yards. Other possible limitations include effectiveness in meeting treatment goals and remedial time frame. Technologies meeting this screening criterion may differ from residential to BRAC-specified use scenarios due to the differences in cleanup goals.

### **9.6 Identification of Corrective Measures Alternatives**

Once specific remedial technologies are identified for the site, they will be assembled into specific alternatives that may meet the corrective action objectives for all media. Each alternative may consist of an individual technology or a combination of technologies (e.g., treatment train). Depending on site-specific situations, different alternatives may be considered for separate areas of the facility.

Less complex sites may be relatively straight forward and may only require evaluating one or two alternatives. Because the CNC CMS will evaluate both residential and BRAC-specified future uses, two sets of alternatives may be developed for each site.

## 9.7 Evaluation of Corrective Measures Alternatives

Each proposed alternative (including single alternatives) will be evaluated according to five standards reflecting the major technical components of remedies, including cleanup of releases, source control, and management of wastes generated by remedial activities. The specific standards are provided below. The first four factors are considered primary evaluation criteria, whereas the last five factors are considered secondary evaluation criteria.

- Protection of human health and the environment.
- Attainment of media cleanup standards set by the implementing agency.
- Control the source of releases so as to reduce or eliminate, to the extent practical, further releases that may threaten human health and/or the environment.
- Compliance with any applicable standards for managing wastes.
- Consider other factors.

These standards are detailed in the following sections.

### 9.7.1 Protection of Human Health and the Environment

Corrective action remedies must be protective of human health and the environment. The degree of protection afforded by each alternative will be discussed in this section. Remedies may include measures that are necessary for protectiveness, but are not directly related to media cleanup, source control, or waste management. For example, access controls and deed restrictions may

prevent contact with contaminated media while intrinsic remediation or attenuation processes are monitored or augmented. This section will discuss any short-term remedies that may be implemented to meet this standard.

### **9.7.2 Attainment of Media Cleanup Standards Set by the Implementing Agency**

Each alternative will be evaluated as to whether the potential remedy will achieve the remedial objective(s). This evaluation will estimate the time frame needed for each alternative to attain these standards. The selected remedy will be required to attain media cleanup standards set by the implementing agency, which may be derived from current state, federal, or other regulations or standards. The media cleanup standard will often play a large part in determining the extent of and technical approaches to the remedy. In some cases, the practical capabilities of remedial technologies (or other technical aspects of the remedy) may influence, to some degree, the cleanup standards that are established.

### **9.7.3 Control the Sources of Releases**

As part of the CMS report, source control measures will be evaluated to determine if they are necessary to control or eliminate further releases that may threaten human health or the environment. If a source control measure is proposed, it will include a discussion on how well the method is expected to work, given site conditions and the known reliability of the selected technology.

Source control measures will be considered when it is necessary to stop further environmental degradation by controlling or eliminating further releases that may threaten human health or the environment. In some cases, without source control measures, clean up efforts may be ineffective or will at best become a perpetual remedial effort. In these cases, an effective source control program may be essential to ensure the long-term effectiveness and protectiveness of the corrective

action program. Source control measures may include all protective remedies to control the source. Such remedies may include partial waste removal, capping, slurry walls, in-situ treatment and/or stabilization, and consolidation.

#### **9.7.4 Compliance with Any Applicable Standards for Management of Wastes**

Each alternative will discuss how the specific waste management activities will comply with all applicable state or federal regulations, such as closure requirements, land disposal restrictions, etc.

#### **9.7.5 Other Factors**

Five general factors will be considered in selecting/approving a remedy that meets the four primary standards listed above. These factors combine technical measures and management controls to address the environmental problems at the site. The five general decision factors include:

- Long-term reliability and effectiveness
- Reduction of toxicity, mobility, or volume of wastes
- Short-term effectiveness
- Implementability
- Cost

#### **Long-Term Reliability and Effectiveness**

The CMS will evaluate whether the technology or a combination of technologies has been used effectively under similar site conditions, whether failure of any one technology in the alternative would have an immediate impact on receptors, and whether the alternative would have the flexibility to deal with uncontrollable site changes.

This criterion will assess the proposed useful life of the overall alternative and its component technologies. Useful life is defined as the length of time the level of effectiveness can be maintained. Typically, most corrective measure technologies deteriorate over time. Deterioration can often be slowed through proper system operation and maintenance, but the technology may eventually require replacement to maintain effectiveness. The CMS will consider these issues.

### **Reduction of the Toxicity, Mobility, or Volume of Wastes**

Estimates of how much the corrective measures alternatives will reduce the waste toxicity, mobility, or volume may help in assessing this criterion. In general, preferred remedies employ treatment capable of eliminating (or substantially reducing) the potential for contaminated media to cause future environmental releases or other risks to human health and the environment.

In some situations, reducing toxicity, mobility, or volume may not be practical or even desirable. For example, large municipal-type landfills or unexploded munitions may be extremely dangerous to handle and the short-term risks of treatment outweigh the potential long-term benefits.

### **Short-Term Effectiveness**

The short-term effectiveness of each alternative will be assessed, including: the potential for fire, explosion, and exposure to hazardous substances; as well as threats associated with treatment, excavation, transportation, and redispal or containment of waste material. This criterion is important in densely populated areas and where waste characteristics are such that risks to workers or the environment are high, and special protective measures are needed.

## **Implementability**

Each alternative will be evaluated to assess any potential impacts on the time required to implement a given remedy. Information to consider for implementability includes:

- The administrative activities needed to implement the corrective measure alternative (e.g., permits, rights-of-way, offsite approvals, etc.) and the length of time these activities will take.
- The constructability, time necessary for implementation and beneficial results.
- The availability of adequate offsite treatment, storage capacity, disposal and technical services, and materials.
- The availability of prospective technologies for each corrective measure alternative.

## **Cost**

The CMS will consider the relative cost for each remedy. This criterion is especially useful when several technologies offer the same degree of protection to human health and the environment but vary dramatically in cost. Cost estimates will include: engineering, site preparation, construction, materials, labor, sampling/analysis, waste management/disposal, permitting, health and safety measures, training, operations and maintenance, etc.

### **9.8 Ranking the Corrective Measures Alternatives**

Once corrective measures have been discussed for each site using applicable scenarios (residential and/or BRAC-specified future use), alternatives for each will be ranked in order of desirability.

The ranking system will apply a weighting factor selected by the project team to determine the importance of each corrective measure criterion. The weighting factors will be developed by the project team during the CMS. Table 9.3 shows the ranking system format. 1  
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Table 9.3 presents a hypothetical site where soil is contaminated with relatively high (10 to 1,000 ppm) PAH concentrations. Three alternatives were developed: excavation and disposal in a permitted landfill, excavation and thermal treatment, and capping in-situ. This example shows format and nature of comparisons that will be made in the CMS. 4  
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6  
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Once the weighting factors are selected, the rankings are set by multiplying the criteria values by the weighting factor. The weighted criteria values are then summed. Alternatives are ranked in order, with the highest total being the most preferable choice and the lowest being the least preferable. 8  
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**Table 9.3**  
**Comparison and Ranking of Alternatives**

Objective & Criteria	Weighting* Factor	Alternative 1			Alternative 2			Alternative 3		
		Description	Meets Criteria	Weighted Criteria Value	Description	Meets Criteria	Weighted Criteria Value	Description	Meets Criteria	Weighted Criteria Value
Protection of human health and the environment		Protective of human health and community	3		Protective of human health and community	3		Protective of human health and community	3	
Attainment of media cleanup standards		Excavates soil above cleanup goals	3		Excavates soil above cleanup goals	3		Does not meet media clean up standards	1	
Control the sources of releases		Eliminates source material above cleanup goals	3		Eliminates source material above cleanup goals	3		Controls sources of releases through containment, reduction in leachate	3	
Compliance with any applicable standards for management of wastes		Must comply with LDRs, USDOT regulations	3		Must comply with LDRs, air emissions regulations	3		Must comply with RCRA cap requirements, monitoring	3	
<b>Other Factors</b>										
Long-term reliability and effectiveness		Effective over the long term	3		Effective over the long term	3		Effective with regular maintenance activities.	3	
Reduction in toxicity, mobility, and volume		Does not reduce toxicity, mobility, or volume	1		Reduces toxicity, mobility, and volume through treatment	4		Does not reduce toxicity, mobility, or volume	1	
Short-term effectiveness		Minimal exposure to site workers during excavation	3		Minimal exposure to site workers during excavation and treatment	3		Minimal exposure to site workers during excavation	4	

**Table 9.3**  
**Comparison and Ranking of Alternatives**

Objective & Criteria	Weighting* Factor	Alternative 1			Alternative 2			Alternative 3		
		Description	Meets Criteria	Weighted Criteria Value	Description	Meets Criteria	Weighted Criteria Value	Description	Meets Criteria	Weighted Criteria Value
Implementability		Easily implemented, common approach to contaminated soil	4		Requires mobile treatment unit mobilization; may be time inefficient	2		Easily implemented, common approach to contaminated soil	3	
<b>Other Factors</b>										
Cost		Present worth cost = \$193,000	3		Present worth cost = \$354,000	1		Present worth cost = \$8,000	4	
<b>Totals</b>										

**Notes:**

Criteria ranking values:  
 4 = Criteria exceeded  
 3 = Criteria met  
 2 = Criteria may be met  
 1 = Criteria not met

\*Weighting factors will be determined by project team  
 LDRs = Land Disposal Restrictions  
 USDOT = U.S. Department of Transportation