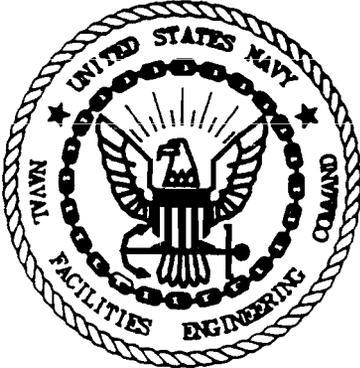


N61165.AR.003203
CNC CHARLESTON
5090.3a

RESOURCE CONSERVATION AND RECOVERY ACT FACILITY INVESTIGATION REPORT
VOLUME I OF V SECTIONS 1 TO 9 CNC CHARLESTON SC
12/31/1997
NAVFAC SOUTHERN

**ZONE F
RCRA FACILITY
INVESTIGATION REPORT
NAVBASE CHARLESTON**

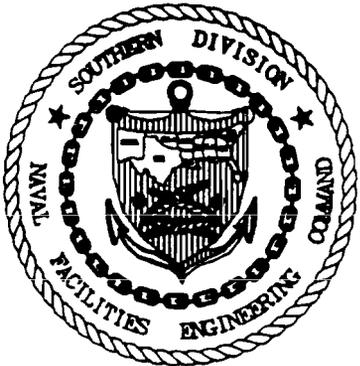


**VOLUME I of V
SECTIONS 1 to 9**

**CONTRACT N62467-89-D-0318
CTO-029**

Prepared for:

**Comprehensive Long-Term Environmental Action Navy
(CLEAN)
Charleston Naval Shipyard
Charleston, South Carolina**



Prepared by:

**EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901)372-7962**

**December 31, 1997
Revision: 0**



DEPARTMENT OF THE NAVY
SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
P.O. BOX 190010
2155 EAGLE DRIVE
NORTH CHARLESTON, S.C. 29419-9010

5090/11
Code 18710
2 Apr 99

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

Subj: SUBMITTAL OF ADDENDA TO THE ZONE F AND G RCRA FACILITY
INVESTIGATION REPORTS

Dear Mr. Litton:

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

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

Sincerely,

A handwritten signature in black ink that reads "David P. Dodds".

DAVID P. DODDS
Remedial Project Manager
Environmental Department

Encl:

(1) Draft Zone F and G RFI Report Addenda, EnSafe, dated 31 March 1999

Copy to:

SCDHEC (Paul Bergstrand, Johnny Tapia), USEPA (Dann Spariosu)
CSO Naval Base Charleston (Billy Drawdy), SOUTHNAVFACENGCOM (Tony Hunt)
SPORTENVDETCASN (Bobby Dearhart)



DEPARTMENT OF THE NAVY

SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
P.O. BOX 190010
2155 EAGLE DRIVE
NORTH CHARLESTON, S.C. 29419-9010

5090/11
Code 1877
9 January 1998

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

Subj: ZONE F RCRA FACILITY INVESTIGATION REPORT

Dear Mr. Litton:

The purpose of this letter is to submit the Zone F Draft Final RCRA Facility Investigation for Naval Base Charleston. The Report is submitted to fulfill the requirements of condition IV.B.2 of the RCRA Part B permit issued to the Navy by the South Carolina Department of Health and Environmental Control and U.S. Environmental Protection Agency.

We request that the Department and the EPA review the report and provide comment or approval as appropriate. If you should have any questions, please contact Billy Drawdy or Matthew A. Hunt at (803) 743-9985 (Ext.29) and (803) 820-5525 respectively.

Sincerely,

A handwritten signature in black ink, appearing to read "P.M. Rose", written over a circular stamp or mark.

P.M. ROSE
LCDR, CEC, U.S. Navy
Caretaker Site Officer
By direction

Encl: (1) Zone F Draft RFI Report dated 31 December 1997

Copy to:

SCDHEC (Paul Bergstrand, Johnny Tapia), USEPA (Dann Spariosu)
SOUTHDIV (Matthew Hunt), CSO Naval Base Charleston (Billy Drawdy, Daryle Fontenot)
SPORTENVDETCASN (Dearhart)

Blind copy to:

1877

18 Circ

187 Circ

Daily-J:\1877\zonef.ltr

**ZONE F
RCRA FACILITY
INVESTIGATION REPORT
NAVBASE CHARLESTON**

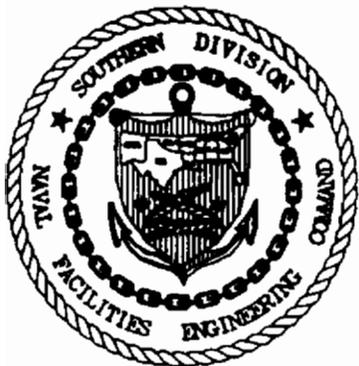


**VOLUME I of V
SECTIONS 1 to 9**

**CONTRACT N62467-89-D-0318
CTO-029**

Prepared for:

**Comprehensive Long-Term Environmental Action Navy
(CLEAN)
Charleston Naval Shipyard
Charleston, South Carolina**



Prepared by:

**EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901)372-7962**

**December 31, 1997
Revision: 0**

Table of Contents

ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR NAVBASE ZONE F	a.1
1.0 INTRODUCTION	1.1
1.1 NAVBASE Description and Background	1.1
1.2 Base Closure Process for Environmental Cleanup	1.1
1.3 Investigative Zone Delineation	1.2
1.4 Current Investigation	1.2
1.5 Previous Investigations	1.4
1.6 RFI Report Organization	1.7
2.0 PHYSICAL SETTING	2.1
2.1 Regional Setting	2.1
2.1.1 Regional Physiographic and Geologic Description	2.1
2.1.2 Regional Hydrologic and Hydrogeologic Background	2.1
2.1.3 Regional Climate	2.1
2.2 Zone F Geologic Investigation	2.1
2.2.1 Monitoring Wells	2.1
2.2.2 Geotechnical Analyses	2.7
2.2.3 Zone F Geology	2.7
2.3 Zone F Hydrogeology	2.17
2.3.1 Surficial Aquifer	2.17
2.3.2 Groundwater Flow Direction	2.18
2.3.3 Horizontal Hydraulic Gradient	2.21
2.3.4 Horizontal Groundwater Conductivity	2.21
2.3.5 Horizontal Groundwater Velocity	2.27
2.3.6 Tidal Influence	2.29
2.3.7 Vertical Hydraulic Gradient	2.33
2.3.8 Lithologic Unit Summary	2.33
3.0 FIELD INVESTIGATION	3.1
3.1 Investigation Objectives	3.1
3.2 Sampling Procedures, Protocols, and Analyses	3.1
3.2.1 Sample Identification	3.3
3.2.2 Soil Sampling	3.3
3.2.3 Monitoring Well Installation and Development	3.6
3.2.4 Groundwater Sampling	3.11
3.2.5 Sediment Sampling	3.12
3.2.6 DPT Screening Surveys	3.13
3.2.7 Vertical and Horizontal Surveying	3.14
3.2.8 Aquifer Characterization	3.14
3.2.9 Decontamination Procedures	3.14

4.0	DATA VALIDATION	4.1
4.1	Introduction	4.1
4.2	Validation Summary	4.1
	4.2.1 Organic Evaluation Criteria	4.2
	4.2.2 Inorganic Evaluation Criteria	4.7
4.3	Zone F Data Validation Reports	4.8
	4.3.1 Soil Blanks	4.8
	4.3.2 Groundwater Blanks	4.14
4.4	Method Detection Limits	4.18
5.0	DATA EVALUATION AND BACKGROUND COMPARISON	5.1
5.1	Organic Compound Analytical Results Evaluation	5.1
5.2	Inorganic Analytical Results Evaluation	5.2
	5.2.1 Grid-Based Background Dataset	5.3
	5.2.2 Nondetect Data	5.3
	5.2.3 Developing Datasets for Sites	5.4
	5.2.4 Comparing Site Values to Background	5.4
	5.2.5 Reference Concentration Test	5.4
	5.2.6 Wilcoxon Rank Sum Test	5.4
	5.2.7 Summary of Techniques Used	5.5
	5.2.8 Combined Results of the Reference Concentration and Wilcoxon Rank Sum Tests	5.6
	5.2.9 Conclusion	5.6
	5.2.10 Background Reference Values	5.7
6.0	FATE AND TRANSPORT	6.1
6.1	Properties Affecting Fate and Transport	6.3
	6.1.1 Contaminant Properties Affecting Fate and Transport	6.3
	6.1.2 Media Properties Affecting Fate and Transport	6.3
6.2	Fate and Transport Approach for Zone F	6.9
	6.2.1 Soil to Groundwater Cross-Media Transport	6.10
	6.2.2 Groundwater-to-Surface Water Cross-Media Transport	6.17
	6.2.3 Surface Soil-to-Sediment Cross-Media Transport	6.19
	6.2.4 Soil-to-Air Cross-Media Transport	6.20
6.3	Fate and Transport Screening Assumptions Versus Site Conditions	6.21
7.0	HUMAN HEALTH RISK ASSESSMENT	7.1
7.1	Introduction	7.1
7.2	Objectives	7.1
7.3	Human Health Risk Assessment Methods	7.3
	7.3.1 Data Sources	7.3
	7.3.2 Data Validation	7.4
	7.3.3 Management of Site-Related Data	7.4
	7.3.4 Selection of Chemicals of Potential Concern	7.6

7.3.5	Calculation of Risk and Hazard	7.10
7.3.6	Exposure Assessment	7.11
7.3.7	Toxicity Assessment	7.11
7.3.8	Risk Characterization	7.11
7.3.9	Risk Uncertainty	7.11
7.3.10	Risk Summary	7.20
7.3.11	RGOs	7.20
8.0	ECOLOGICAL RISK ASSESSMENT	8.1
9.0	CORRECTIVE MEASURES	9.1
9.1	Introduction	9.1
9.2	Remedy Selection Approach	9.6
9.3	Proposed Remedy	9.7
9.4	Development of Target Media Cleanup Goals	9.7
9.5	Identification, Screening, and Development of Corrective Measures Technologies	9.7
9.5.1	Identification of Corrective Measure Technologies	9.7
9.5.2	Description of Prescreened Technologies	9.10
9.5.3	Screening Criteria	9.14
9.6	Identification of Corrective Measures Alternatives	9.15
9.7	Evaluation of Corrective Measures Alternatives	9.16
9.8	Ranking the Corrective Measures Alternatives	9.16
10.0	SITE-SPECIFIC EVALUATIONS	10.1
10.1	SWMU 4, Pesticide Storage Building; AOC 619, Former Oil Storage Yard	10.1.1
10.1.1	Site Geology and Hydrogeology	10.1.1
10.1.2	Field Investigation Approach	10.1.7
10.1.3	Soil Sampling and Analysis	10.1.7
10.1.4	Sediment Sampling and Analysis	10.1.60
10.1.5	Groundwater Sampling and Analysis	10.1.65
10.1.6	Fate and Transport Assessment for SWMU 4 and AOC 619	10.1.72
10.1.7	Human Health Risk Assessment for SWMU 4 and AOC 619	10.1.82
10.1.8	Corrective Measures Considerations	10.1.116
10.2	SWMU 36, Building 68 Battery Shop; AOC 620, Battery Shop, Building 68	10.2.1
10.2.1	Site Geology and Hydrogeology	10.2.1
10.2.2	Field Investigation Approach	10.2.5
10.2.3	Soil Sampling and Analysis	10.2.5
10.2.4	Groundwater Sampling and Analysis	10.2.36
10.2.5	Fate and Transport Assessment for Combined SWMU 36 and AOC 620	10.2.52

	10.2.6 Human Health Risk Assessment for SWMU 36 and AOC 620	10.2.62
	10.2.7 Corrective Measures Considerations	10.2.108
10.3	SWMU 109, Abrasive Blast Media Storage Area	10.3.1
	10.3.1 Site Geology and Hydrogeology	10.3.1
	10.3.2 Field Investigation Approach	10.3.4
	10.3.3 Soil Sampling and Analyses	10.3.4
	10.3.4 Sediment Sampling and Analyses	10.3.21
	10.3.5 Groundwater Sampling and Analysis	10.3.31
	10.3.6 Fate and Transport Assessment for SWMU 109	10.3.35
	10.3.7 Human Health Risk Assessment	10.3.38
	10.3.8 Corrective Measures Considerations	10.3.72
10.4	AOC 607, Dry Cleaning Building 1189	10.4.1
	10.4.1 Site Geology and Hydrogeology	10.4.1
	10.4.2 Field Investigation Approach	10.4.16
	10.4.3 DPT Screening Survey	10.4.16
	10.4.4 Soil Sampling and Analyses	10.4.17
	10.4.5 Sediment Sampling and Analysis	10.4.34
	10.4.6 Groundwater Sampling and Analysis	10.4.46
	10.4.7 Fate and Transport Assessment for AOC 607	10.4.93
	10.4.8 Human Health Risk Assessment	10.4.104
	10.4.9 Corrective Measures Considerations	10.4.152
10.5	AOC 609, Station, Building 1346	10.5.1
	10.5.1 Site Geology and Hydrogeology	10.5.2
	10.5.2 Field Investigation Approach	10.5.6
	10.5.3 Soil Sampling and Analyses	10.5.6
	10.5.4 Groundwater Sampling and Analysis	10.5.22
	10.5.5 Fate and Transport Assessment for AOC 609	10.5.55
	10.5.6 Human Health Risk Assessment	10.5.61
	10.5.7 Corrective Measures Considerations	10.5.105
10.6	AOC 611, Grease Rack and Hobby Shop, Former Building 1264	10.6.1
	10.6.1 Site Geology	10.6.1
	10.6.2 Field Investigation Approach	10.6.1
	10.6.3 Soil Sampling and Analyses	10.6.3
	10.6.4 Fate and Transport Assessment for AOC 611	10.6.34
	10.6.5 Human Health Risk Assessment for AOC 611	10.6.39
	10.6.6 Corrective Measures Considerations	10.6.72
10.7	AOC 613, Old Locomotive Repair Shop, Former Building 1169; AOC 615, Old Chain Locker, Building 1391 and SWMU 175, Crane Painting Area, Near Building 1277	10.7.1
	10.7.1 Site Geology and Hydrogeology	10.7.2
	10.7.2 Field Investigation Approach	10.7.7
	10.7.3 DPT Screening Survey	10.7.11
	10.7.4 Sediment Sampling and Analysis	10.7.85

	10.7.5 Groundwater Sampling and Analysis	10.7.99
	10.7.6 Fate and Transport Assessment	10.7.144
	10.7.7 Human Health Risk Assessment	10.7.151
	10.7.8 Corrective Measures Considerations	10.7.229
10.8	AOC 616, Paint Shop, Former Building 1201	10.8.1
	10.8.1 Site Geology	10.8.1
	10.8.2 Field Investigation Approach	10.8.1
	10.8.3 Soil Sampling and Analyses	10.8.1
	10.8.4 Fate and Transport Assessment for AOC 616	10.8.16
	10.8.5 Human Health Risk Assessment	10.8.19
	10.8.6 Corrective Measures Considerations	10.8.33
10.9	AOC 617, Galvanizing Plant, Former Building 1176	10.9.1
	10.9.1 Site Geology and Hydrogeology	10.9.1
	10.9.2 Field Investigation Approach	10.9.1
	10.9.3 Soil Sampling and Analyses	10.9.5
	10.9.4 Groundwater Sampling and Analysis	10.9.28
	10.9.5 Fate and Transport Assessment for AOC 617	10.9.35
	10.9.6 Human Health Risk Assessment for AOC 617	10.9.49
	10.9.7 Corrective Measures Considerations	10.9.85
10.10	AOC 709, Former Fuel Distribution System Area 16	10.10.1
	10.10.1 Site Geology and Hydrogeology	10.10.1
	10.10.2 Field Investigation Approach	10.10.1
	10.10.3 Soil Sampling and Analysis	10.10.5
	10.10.4 Groundwater Sampling and Analysis	10.10.15
	10.10.5 Fate and Transport Assessment for AOC 709	10.10.27
	10.10.6 Human Health Risk Assessment	10.10.33
	10.10.7 Corrective Measures Considerations	10.10.54
11.0	CONCLUSIONS AND PRELIMINARY RECOMMENDATIONS	11.1
11.1	SWMU 4, Pesticide Storage Building; AOC 619, Former Oil Storage Yard	11.3
11.2	SWMU 36, Building 68 Battery Shop; AOC 620, Battery Shop, Building 68	11.4
11.3	SWMU 109, Abrasive Blast Media Storage Area	11.4
11.4	AOC 607, Dry Cleaning Building 1189	11.5
11.5	AOC 609, Service Station, Building 1346	11.6
11.6	AOC 611, Grease Rack and Hobby Shop, Former Building 1264	11.7
11.7	AOC 613, Old Locomotive Repair Shop, Former Building 1169; AOC 615, Old Chain Locker, Building 1391 and SWMU 175, Crane Painting Area, Near Building 1277	11.8
11.8	AOC 616, Paint Shop, Former Building 1201	11.9
11.9	AOC 617, Galvanizing Plant, Former Building 1176	11.10
11.9	AOC 617, Galvanizing Plant, Former Building 1176	11.10

12.0	REFERENCES	12.1
13.0	SIGNATORY REQUIREMENT	13.1

List of Figures

Figure 1-1	Investigative Zone Boundaries	1.3
Figure 1-2	Zone F AOC and SWMU Location Map	1.5
Figure 2-1	Zone F Monitoring Well Location Map	2.2
Figure 2-2	Lithologic Cross Sections A-A', C-C', D-D', E-E'	2.8
Figure 2-3	Lithologic Cross Section B-B'	2.9
Figure 2-4	Topography of the Top of the Ashley Formation	2.10
Figure 2-5	Zone F Shallow Groundwater Low Tide Potentiometric Map	2.19
Figure 2-6	Zone F Shallow Groundwater High Tide Potentiometric Map	2.20
Figure 2-7	Zone F Deep Groundwater Low Tide Potentiometric Map	2.22
Figure 2-8	Zone F Deep Groundwater High Tide Potentiometric Map	2.23
Figure 2-9	Surficial Aquifer Aerial Distribution of Hydraulic Conductivity	2.28
Figure 2-10	Zone F Shallow Groundwater Tidal Variation	2.30
Figure 2-11	Zone F Deep Groundwater Tidal Variation	2.31
Figure 2-12	Zone F Vertical Hydraulic Gradients	2.34
Figure 3-1	Zone F Grid-Based Soil Sample Location Map	3.5
Figure 3-2	Zone F Grid-Based Groundwater Sample Location Map	3.8
Figure 10.1-1	Sampling Locations, SWMU 4 and AOC 619	10.1.2
Figure 10.1-2	SWMU 4, AOC 619 and 620 Lithologic Cross Section A-A'	10.1.3
Figure 10.1-3	SWMU 4, AOC 619 and 620 Lithologic Cross Section B-B'	10.1.4
Figure 10.1-4	Shallow Groundwater Low Tide Potentiometric Map, SWMU 4 and AOC 619.	10.1.5
Figure 10.1-5	Shallow Groundwater High Tide Potentiometric Map, SWMU 4 and AOC 619.	10.1.6
Figure 10.1-6	Benzene in Subsurface Soil AOC 619 and SWMU 4	10.1.53
Figure 10.1-7	Trichloroethene in Subsurface Soil AOC 619 and SWMU 4	10.1.54
Figure 10.1-8	Methylene Chloride in Subsurface Soil AOC 619 and SWMU 4	10.1.55
Figure 10.1-9	BEQs in Surface Soil AOC 619 and SWMU 4	10.1.56
Figure 10.1-10	Chromium in Subsurface Soil AOC 619 and SWMU 4	10.1.57
Figure 10.1-11	Manganese in Surface Soil AOC 619 and SWMU 4	10.1.58
Figure 10.1-12	Thallium in Subsurface Soil AOC 619 and SWMU 4	10.1.59
Figure 10.1-13	Chloromethane in Shallow Groundwater High-Tide Potentiometric Map AOC 619 and SWMU 4	10.1.73
Figure 10.1-14	Thallium in Shallow Groundwater AOC 619 and SWMU 4	10.1.74
Figure 10.1-15	Point Risk Estimates for Surface Soil Residential Scenario AOC 619 and SWMU 4	10.1.112
Figure 10.1-16	Point Risk Estimates for Groundwater Residential Scenario AOC 619 and SWMU 4	10.1.113
Figure 10.1-17	Point Hazard Estimates for Groundwater Residential Scenario AOC 619 and SWMU 4	10.1.117

Figure 10.2-1	Sampling Locations, SWMU 36 and AOC 620	10.2.2
Figure 10.2-2	Shallow Groundwater Low-Tide Potentiometric Map, SWMU 36 and AOC 620	10.2.3
Figure 10.2-3	Shallow Groundwater High-Tide Potentiometric Map, SWMU 36 and AOC 620	10.2.4
Figure 10.2-4	BEQs in Surface Soil, SWMU 36 and AOC 620	10.2.8
Figure 10.2-5	4-Methylphenol in Subsurface Soil, SWMU 36 and AOC 620	10.2.9
Figure 10.2-6	Arclor-1254 in Surface Soil, SWMU 36 and AOC 620	10.2.37
Figure 10.2-7	Aroclor-1260 in Surface Soil, SWMU 36 and AOC 620	10.2.38
Figure 10.2-8	Aluminum in Surface Soil, SWMU 36 and AOC 620	10.2.39
Figure 10.2-9	Arsenic in Surface Soil, SWMU 36 and AOC 620	10.2.40
Figure 10.2-10	Chromium in Surface Soil, SWMU 36 and AOC 620	10.2.41
Figure 10.2-11	Chromium in Subsurface Soil, SWMU 36 and AOC 620	10.2.42
Figure 10.2-12	Lead in Surface Soil, SWMU 36 and AOC 620	10.2.43
Figure 10.2-13	Barium in Shallow Groundwater, SWMU 36 and AOC 620	10.2.53
Figure 10.2-14	Lead in Shallow Groundwater, SWMU 36 and AOC 620	10.2.54
Figure 10.2-15	Thallium in Shallow Groundwater, SWMU 36 and AOC 620	10.2.55
Figure 10.2-16	Probability Distribution of Blood Lead Levels Child 0-7 Years. Residential Scenario, SWMU 36 and AOC 620	10.2.89
Figure 10.2-17	Probability Distribution of Blood Lead Levels. Child 5-6 Years Commercial/Industrial Scenario. SWMU 36 and AOC 620.	10.2.91
Figure 10.2-18	Point Risk Estimates for Surface Soil Residential Scenario, SWMU 36 and AOC 620	10.2.102
Figure 10.2-19	Point Hazard Estimates for Surface Soil Residential Scenario, SWMU 36 and AOC 620.	10.2.103
Figure 10.2-20	Point Risk Estimates for Surface Soil Industrial Scenario, SWMU 36 and AOC 620.	10.2.104
Figure 10.2-21	Point Hazard Estimates for Groundwater Residential Scenario, SWMU 36 and AOC 620	10.2.109
Figure 10.3-1	Sampling Locations, SWMU 109	10.3.2
Figure 10.3-2	Shallow Groundwater Potentiometric Map, SWMU 109	10.3.3
Figure 10.3-3	BEQs in Surface Soil, SWMU 109	10.3.7
Figure 10.3-4	Arsenic in Surface Soil	10.3.22
Figure 10.3-5	Beryllium in Surface Soil, SWMU 109	10.3.23
Figure 10.3-6	Chromium in Surface Soil, SWMU 109	10.3.24
Figure 10.3-7	Manganese in Surface Soil, SWMU 109	10.3.25
Figure 10.3-8	Vanadium in Surface Soil, SWMU 109	10.3.26
Figure 10.3-9	Point Risk Estimates for Surface Soil Residential Scenario	10.3.62
Figure 10.3-10	Point Hazard Estimates for Surface Soil Residential Scenario	10.3.63
Figure 10.3-11	Point Risk Estimates for Surface Soil Industrial Scenario	10.3.68
Figure 10.4-1	DPT Screening Locations-AOC 607	10.4.2
Figure 10.4-2	Sampling Locations-AOC 607	10.4.3
Figure 10.4-3	Cross Section A-A', AOC 607	10.4.4
Figure 10.4-4	Cross Section B-B', AOC 607	10.4.5
Figure 10.4-5	Shallow Groundwater Potentiometric Low Tide Map, AOC 607	10.4.6

Figure 10.4-6	Shallow Groundwater High tide Potentiometric Map, AOC 607	10.4.7
Figure 10.4-7	Intermediate Groundwater Low-Tide Potentiometric Map, AOC 607	10.4.9
Figure 10.4-8	Deep Groundwater Low Tide Potentiometric Map, AOC 607	10.4.10
Figure 10.4-9	Deep Groundwater High Tide Potentiometric Map, AOC 607	10.4.11
Figure 10.4-10	Shallow/Intermediate Vertical Hydraulic Gradient, AOC 607	10.4.12
Figure 10.4-11	Intermediate/Deep Vertical Hydraulic Gradient, AOC 607	10.4.13
Figure 10.4-12	Shallow Groundwater Tidal Variation, AOC 607	10.4.14
Figure 10.4-13	Deep Groundwater Tidal Variation, AOC 607	10.4.15
Figure 10.4-14	Tetrachloroethene in Subsurface Soil, AOC 607	10.4.35
Figure 10.4-15	Aluminum in Surface Soil, AOC 607	10.4.36
Figure 10.4-16	1,1-Dichloroethene in Shallow Groundwater, AOC 607	10.4.72
Figure 10.4-17	1,2-Dichloroethene In Shallow Groundwater, AOC 607	10.4.73
Figure 10.4-18	Tetrachloroethene in Shallow Groundwater, AOC 607	10.4.74
Figure 10.4-19	Trichloroethene in Shallow Groundwater, AOC 607	10.4.75
Figure 10.4-20	Vinyl Chloride in Shallow Groundwater, AOC 607	10.4.76
Figure 10.4-21	Pentachlorophenol in Shallow Groundwater, AOC 607	10.4.77
Figure 10.4-22	1,1-Dichloroethene in Intermediate Groundwater, AOC 607	10.4.78
Figure 10.4-23	1,2-Dichloroethene in Intermediate Groundwater, AOC 607	10.4.79
Figure 10.4-24	Tetrachloroethene in Intermediate Groundwater, AOC 607	10.4.80
Figure 10.4-25	Trichloroethene in Intermediate Groundwater, AOC 607	10.4.81
Figure 10.4-26	Chloromethane in Deep Groundwater, AOC 607	10.4.83
Figure 10.4-27	Tetrachloroethene in Deep Groundwater, AOC 607	10.4.84
Figure 10.4-28	Trichloroethene in Deep Groundwater, AOC 607	10.4.85
Figure 10.4-29	Aluminum in Shallow Groundwater, AOC 607	10.4.86
Figure 10.4-30	Arsenic in Shallow Groundwater, AOC 607	10.4.87
Figure 10.4-31	Chromium in Shallow Groundwater, AOC 607	10.4.88
Figure 10.4-32	Vanadium in Shallow Groundwater, AOC 607	10.4.89
Figure 10.4-33	Antimony in Shallow Groundwater, AOC 607	10.4.90
Figure 10.4-34	Lead in Shallow Groundwater, AOC 607	10.4.91
Figure 10.4-35	Arsenic in Intermediate Groundwater, AOC 607	10.4.92
Figure 10.4-36	Aluminum in Deep Groundwater, AOC 607	10.4.94
Figure 10.4-37	Arsenic in Deep Groundwater, AOC 607	10.4.95
Figure 10.4-38	Chromium in Deep Groundwater, AOC 607	10.4.96
Figure 10.4-39	Lead in Deep Groundwater, AOC 607	10.4.97
Figure 10.4-40	Probability Distribution of Blood Lead Levels for Child 0-7 Years Residential Scenario - AOC 607.	10.4.136
Figure 10.4-41	Point Risk Estimates for Groundwater Residential Scenario, AOC 607	10.4.144
Figure 10.4-42	Point Hazard Estimates for Groundwater Residential Scenario, AOC 607	10.4.145
Figure 10.5-1	Sampling Locations, AOC 609	10.5.3
Figure 10.5-2	Shallow Groundwater Low-Tide Potentiometric Map, AOC 609 . . .	10.5.4
Figure 10.5-3	Shallow Groundwater High-Tide Potentiometric Map, AOC 609 . . .	10.5.5
Figure 10.5-4	BEQs in Surface Soil, AOC 609	10.5.23
Figure 10.5-5	Antimony in Surface Soil, AOC 609	10.5.24

Figure 10.5-6	Arsenic in Surface Soil, AOC 609	10.5.25
Figure 10.5-7	Beryllium in Surface Soil, AOC 609	10.5.26
Figure 10.5-8	Manganese in Surface Soil, AOC 609	10.5.27
Figure 10.5-9	Benzene in Shallow Groundwater, AOC 609	10.5.42
Figure 10.5-10	Chlorobenzene in Shallow Groundwater, AOC 609	10.5.43
Figure 10.5-11	Ethylbenzene in Shallow Groundwater, AOC 609	10.5.44
Figure 10.5-12	Toluene in Shallow Groundwater, AOC 609	10.5.45
Figure 10.5-13	Xylene in Shallow Groundwater, AOC 609	10.5.46
Figure 10.5-14	2,4-Dimethylphenol in Shallow Groundwater, AOC 609	10.5.47
Figure 10.5-15	2-Methylphenol in Shallow Groundwater, AOC 609	10.5.48
Figure 10.5-16	4-Methylphenol in Shallow Groundwater, AOC 609	10.5.49
Figure 10.5-17	Naphthalene in Shallow Groundwater, AOC 609	10.5.50
Figure 10.5-18	Aluminum in Shallow Groundwater, AOC 609	10.5.51
Figure 10.5-19	Arsenic in Shallow Groundwater, AOC 609	10.5.52
Figure 10.5-20	Arsenic in Deep Groundwater, AOC 609	10.5.53
Figure 10.5-21	Manganese in Deep Groundwater, AOC 609	10.5.54
Figure 10.5-22	Point Risk Estimates for Surface Soil Residential Scenario	10.5.95
Figure 10.5-23	Point Hazard Estimates for Surface Soil Residential Scenario	10.5.99
Figure 10.5-24	Point Risk Estimates for Surface Soil Industrial Scenario	10.5.100
Figure 10.5-25	Point Risk Estimates for Groundwater Residential Scenario	10.5.101
Figure 10.5-26	Point Hazard Estimates for Groundwater Residential Scenario	10.5.102
Figure 10.6-1	Sampling Locations, AOC 611	10.6.2
Figure 10.6-2	BEQs in Surface Soil, AOC 611	10.6.4
Figure 10.6-3	Aroclor-1260 in Surface Soil, AOC 611	10.6.25
Figure 10.6-4	Arsenic in Surface Soil, AOC 611	10.6.26
Figure 10.6-5	Arsenic in Subsurface Soil, AOC 611	10.6.27
Figure 10.6-6	Cadmium in Surface Soil, AOC 611	10.6.28
Figure 10.6-7	Chromium in Surface Soil, AOC 611	10.6.29
Figure 10.6-8	Copper in Surface Soil, AOC 611	10.6.30
Figure 10.6-9	Lead in Surface Soil, AOC 611	10.6.31
Figure 10.6-10	Mercury in Surface Soil, AOC 611	10.6.32
Figure 10.6-11	Mercury in Subsurface Soil, AOC 611	10.6.33
Figure 10.6-12	Point Risk Estimates for Surface Soil Residential Scenario, AOC 611	10.6.64
Figure 10.6-13	Point Hazard Estimates for Surface Soil Residential Scenario	10.6.69
Figure 10.6-14	Point Risk Estimates for Surface Soil Industrial Scenario	10.6.70
Figure 10.7-1	DPT Screening Locations — AOC 613/615 and SWMU 175	10.7.3
Figure 10.7-2	Sediment and Groundwater Sampling Locations — AOC 613/615 and SWMU 175	10.7.4
Figure 10.7-3	SWMU 175, AOCs 613 and 615, Lithologic Cross Section A-A'	10.7.5
Figure 10.7-4	SWMU 175, AOCs 613 and 615, Lithologic Cross Section B-B'	10.7.6
Figure 10.7-5	Shallow Groundwater Low-Tide Potentiometric Map, AOC 613, AOC 615, SWMU 175	10.7.8
Figure 10.7-6	Deep Groundwater Low-Tide Potentiometric Map AOC 613, AOC 615, and SWMU 175	10.7.9

Figure 10.7-7	Deep Ground	10.7.10
Figure 10.7-8	BEQs in Surface Soils, AOC 613 & 615 and SWMU 175	10.7.83
Figure 10.7-9	Benzo(a)anthracene in Subsurface Soil, AOC 613 & 165 and SWMU 175	10.7.84
Figure 10.7-10	Aluminum in Surface Soil	10.7.86
Figure 10.7-11	Arsenic in Surface Soil	10.7.87
Figure 10.7-12	Beryllium in Surface Soil	10.7.88
Figure 10.7-13	Chromium in Surface Soil	10.7.89
Figure 10.7-14	Manganese in Surface Soil	10.7.90
Figure 10.7-15	Thallium in Surface Soil	10.7.91
Figure 10.7-16	Vanadium in Surface Soil	10.7.92
Figure 10.7-16a	Benzene in Shallow Groundwater	10.7.122
Figure 10.7-17	Chloromethane in Shallow Groundwater	10.7.123
Figure 10.7-18	1,2-Dichloroethene in Shallow Groundwater	10.7.124
Figure 10.7-19	Tetrachloroethene in Shallow Groundwater	10.7.125
Figure 10.7-20	Toluene in Shallow Groundwater	10.7.126
Figure 10.7-21	Trichloroethene in Shallow Groundwater	10.7.127
Figure 10.7-22	2-Methynaphthalene in Shallow Groundwater	10.7.128
Figure 10.7-23	Acenaphthene in Shallow Groundwater	10.7.129
Figure 10.7-24	Bis (2-ethylhexyl)phthalate in Shallow Groundwater	10.7.130
Figure 10.7-25	Fluorene in Shallow Groundwater	10.7.131
Figure 10.7-26	Phenanthrene in Shallow Groundwater	10.7.132
Figure 10.7-27	Pyrene in Shallow Groundwater	10.7.133
Figure 10.7-28	Aluminum in Shallow Groundwater	10.7.134
Figure 10.7-29	Arsenic in Shallow Groundwater	10.7.135
Figure 10.7-30	Beryllium in Shallow Groundwater	10.7.136
Figure 10.7-31	Cadmium in Shallow Groundwater	10.7.137
Figure 10.7-32	Chromium in Shallow Groundwater	10.7.138
Figure 10.7-33	Lead in Shallow Groundwater	10.7.139
Figure 10.7-34	Manganese in Shallow Groundwater	10.7.140
Figure 10.7-35	Thallium in Shallow Groundwater	10.7.141
Figure 10.7-36	Vanadium in Shallow Groundwater	10.7.142
Figure 10.7-37	Zinc in Shallow Groundwater	10.7.143
Figure 10.7-38	Probability Distribution of Blood Lead Levels	10.7.187
Figure 10.7-39	Point Risk Estimates for Surface Soil Residential Scenario	10.7.195
Figure 10.7-40	Point Hazard Estimates for Surface Soil Residential Scenario	10.7.196
Figure 10.7-41	Point Risk Estimates for Surface Soil Industrial Scenario	10.7.210
Figure 10.7-42	Point Risk Estimates for Groundwater Residential Scenario	10.7.211
Figure 10.7-43	Point Hazard Estimates for Groundwater Residential Scenario	10.7.212
Figure 10.8-1	Sampling Locations, AOC 616	10.8.2
Figure 10.8-2	Antimony in Surface Soil, AOC 616	10.8.17
Figure 10.9-1	Sampling Locations, AOC 617	10.9.2
Figure 10.9-2	Shallow Groundwater Low-Tide Potentiometric Map, AOC 617	10.9.3
Figure 10.9-3	Shallow Groundwater High-Tide Potentiometric Map, AOC 617	10.9.4
Figure 10.9-4	BEQs in Surface Soil, AOC 617	10.9.24

Figure 10.9-5	Benzo(a)anthracene in Subsurface Soil, AOC 617	10.9.25
Figure 10.9-6	Aroclor-1260 in Subsurface Soil, AOC 617	10.9.26
Figure 10.9-7	Antimony in Subsurface Soil, AOC 617	10.9.27
Figure 10.9-8	Aluminum in Shallow Groundwater, AOC 617	10.9.36
Figure 10.9-9	Arsenic in Shallow Groundwater, AOC 617	10.9.37
Figure 10.9-10	Cadmium in Shallow Groundwater, AOC 617	10.9.38
Figure 10.9-11	Cobalt in Shallow Groundwater, AOC 617	10.9.39
Figure 10.9-12	Manganese in Shallow Groundwater, AOC 617	10.9.40
Figure 10.9-13	Nickel in Shallow Groundwater, AOC 617	10.9.41
Figure 10.9-14	Thallium in Shallow Groundwater, AOC 617	10.9.42
Figure 10.9-15	Zinc in Shallow Groundwater, AOC 617	10.9.43
Figure 10.9-16	Point Risk Estimates for AOC 617	10.9.79
Figure 10.9-17	Point Risk Estimates for Groundwater Residential Scenario, AOC 617	10.9.82
Figure 10.9-18	Point Hazard Estimates for Groundwater Residential Scenario, AOC 617	10.9.83
Figure 10.10-1	Soil and Groundwater Sampling Locations, AOC 709	10.10.2
Figure 10.10-2	Shallow Groundwater Low-Tide Potentiometric Map, AOC 709	10.10.3
Figure 10.10-3	Shallow Groundwater High-Tide Potentiometric Map, AOC 709	10.10.4
Figure 10.10-5	Point Risk Estimates for Groundwater Residential Scenario AOC 709	10.10.52
Figure 10.10-6	Point Hazard Estimates for Groundwater Residential Scenario AOC 709	10.10.55

List of Tables

Table 1.1	Zone F AOC and SWMU Summary	1.6
Table 2.1	Zone F Monitoring Well Construction Data	2.3
Table 2.2	Zone F Geotechnical Sample Data	2.11
Table 2.3	Zone F Horizontal Hydraulic Gradients	2.24
Table 2.4	Zone F Horizontal Hydraulic Conductivities	2.24
Table 2.5	Zone F Groundwater Velocity Results	2.29
Table 2.6	Zone F Vertical Hydraulic Gradients	2.35
Table 4.1	Zone F DPT Diluted Samples	4.4
Table 4.2	Zone F Soil Diluted Samples	4.4
Table 4.3	Zone F Water Diluted Samples	4.6
Table 4.4	Zone F Southwest Laboratory of Oklahoma's Method Detection Limit Study for Dioxins	4.19
Table 4.5	Zone F Southwest Laboratory of Oklahoma's Method Detection Limit Study for VOCs	4.20
Table 4.6	Zone F Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs	4.22

Table 4.7	Zone F Southwest Laboratory of Oklahoma’s Method Detection Limit Study for Pesticides/PCB	4.25
Table 4.8	Zone F Southwest Laboratory of Oklahoma’s Method Detection Limit Study for Pesticides, Organophosphorus	4.27
Table 4.9	Zone F Southwest Laboratory of Oklahoma’s Method Detection Limit Study for Herbicides	4.28
Table 4.10	Zone F Southwest Laboratory of Oklahoma’s Method Detection Limit Study for Metals by Low-Level ICP Method	4.29
Table 4.11	Zone F Southwest Laboratory of Oklahoma’s Method Detection Limit Study for Metals by ICP Method	4.30
Table 4.12	Zone F Southwest Laboratory of Oklahoma’s Method Detection Limit Study for Mercury by Cold Vapors	4.32
Table 4.13	Zone F Southwest Laboratory of Oklahoma’s Method Detection Limit Study for Miscellaneous Inorganics	4.32
Table 5.1	Zone F Background Reference Values	5.7
Table 6.1	Zone F Constituent Characteristics Based On Chemical and Physical Properties	6.4
Table 6.2	Zone F Soil Parameters Used to Evaluate Fate and Transport	6.7
Table 6.3	Zone F Travel Time Analysis	6.9
Table 6.4	Calculation of Soil-to-Groundwater Soil Screening Levels	6.13
Table 9.1	Zone F Removal/Containment/Disposal Options	9.9
Table 9.2	Zone F Treatment Technology Options	9.9
Table 10.1.1	Zone F SWMU 4 and AOC 619 Soil Samples	10.1.8
Table 10.1.2	Zone F SWMU 4 and AOC 619 Organic Compound Analytical Results for Soil	10.1.10
Table 10.1.3	Zone F SWMU 4 and AOC 619 Inorganic Analytical Results for Soil	10.1.15
Table 10.1.4	Zone F SWMU 4 and AOC 619 Analytes Detected in Surface and Subsurface Soil	10.1.18
Table 10.1.5	Zone F SWMU 4 and AOC 619 Organic Compound Analytical Results for Sediment	10.1.61
Table 10.1.6	Zone F SWMU 4 and AOC 619 Inorganics Analytical Results for Sediment	10.1.62
Table 10.1.7	Zone F Analytes Detected in SWMU 4 and AOC 619 Sediment Samples	10.1.63
Table 10.1.8	SWMU 4 and AOC 619 Groundwater Samples and Analyses	10.1.65
Table 10.1.9	Zone F SWMU 4 and AOC 619 Organic Compound Analytical Results for Groundwater	10.1.66
Table 10.1.10	Zone F SWMU 4 and AOC 619 Inorganics Analytical Results for Groundwater	10.1.67
Table 10.1.11	Zone F SWMU 4 and AOC 619 Analytes Detected in Groundwater	10.1.68
Table 10.1.12	Chemicals Detected in Surface Soil, Subsurface Soil, and Shallow Groundwater Comparisons to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations	10.1.76
Table 10.1.13	Soil to Air Volatilization Screening Analysis	10.1.81

Table 10.1.14	Chemical Present in Site Samples SWMU 4 and AOC 619 - Surface Soil	10.1.83
Table 10.1.15	Chemicals Present in Site Samples SWMU 4 and AOC 619 - Groundwater	10.1.85
Table 10.1.16	Exposure Pathways Summary — Combined SWMU 4	10.1.86
Table 10.1.17	Summary of Statistical Analysis Surface Soil COPCs; SWMU 4 and AOC 619	10.1.89
Table 10.1.18	Chronic Daily Intakes Incidental Ingestion of Surface Soil, SWMU 4 and AOC 619	10.1.90
Table 10.1.19	Chronic Daily Intakes Dermal Contact with Surface Soil, SWMU 4 and AOC 619	10.1.91
Table 10.1.20	Chronic Daily Intakes Ingestion of COPCs in Groundwater, SWMU 4 and AOC 619	10.1.92
Table 10.1.21	Toxicological Reference Information for Chemicals of Potential Concern SWMU 4 and AOC 619	10.1.93
Table 10.1.22	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, SEMU 4 and AOC 619	10.1.98
Table 10.1.23	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact With Surface Soil, SWMU 4 and AOC 619	10.1.99
Table 10.1.24	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, SWMU 4 and AOC 619	10.1.101
Table 10.1.25	Hazard Quotients and Incremental Lifetime Cancer Risks Inhalation of Groundwater Contaminants Through Domestic Use, SWMU 4 and AOC 619	10.1.102
Table 10.1.26	Summary of Risk and Hazard-based COCs SWMU 4 and AOC 619 ..	10.1.104
Table 10.1.27	Summary of Risk and Hazard SWMU 4 and AOC 619	10.1.111
Table 10.1.28	Point Estimates of Risk and Hazard - Surface Soil Pathways Residential Scenario SWMU 4 and AOC 619	10.1.114
Table 10.1.29	Point Estimates of Risk and Hazard - Groundwater Pathways Residential Scenario	10.1.118
Table 10.1.30	Remedial Goal Options for Soil SWMU 4 and AOC 619	10.1.119
Table 10.1.31	Residential-Based Remedial Goal Options Groundwater SWMU 4 and AOC 619	10.1.120
Table 10.1.32	Potential Corrective Measures for SWMU 4 and AOC 619	10.1.121
Table 10.2.1	Zone F SWMU 36 and AOC 620 Soil Samples and Analyses	10.2.6
Table 10.2.2	Zone F SWMU 36 and AOC 620 Organic Compound Analytical Results for Soil	10.2.10
Table 10.2.3	Zone F SWMU 36 and AOC 620 Inorganic Analytical Results for Soil	10.2.15
Table 10.2.4	Zone F SWMU 36 and AOC 620 Analytes Detected in Surface and Subsurface Soil	10.2.18
Table 10.2.5	SWMU 36 and AOC 620 Groundwater Samples	10.2.44
Table 10.2.6	Zone F SWMU 36 and AOC 620 Organic Analytical Results for Groundwater	10.2.45
Table 10.2.7	Zone F SWMU 36 and AOC 620 Inorganic Analytical Results for Groundwater	10.2.46

Table 10.2.8	Zone F SWMU 36 and AOC 620 Analytes Detected in Shallow Groundwater	10.2.48
Table 10.2.9	Chemicals Detected in Surface Soil, Subsurface Soil, and Shallow Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Chronic Screening Levels, and Background Concentrations, SWMU 36 and AOC 620	10.2.56
Table 10.2.10	Soil-to-Air Volatilization Screening Analysis, SWMU 36 and AOC 620	10.2.61
Table 10.2.11	Chemicals Present in Site Samples, SWMU 36 and AOC 620	10.2.63
Table 10.2.12	Chemicals Present in Site Samples — Groundwater, SWMU 36 and AOC 620	10.2.66
Table 10.2.13	Exposure Pathways Summary — Combined SWMU 36	10.2.67
Table 10.2.14	Summary of Statistical Analysis Surface Soil COPC, SWMU 36 and AOC 620	10.2.70
Table 10.2.15	Chronic Daily Intakes Incidental Ingestion of Surface Soil, SWMU 36 and AOC 620	10.2.71
Table 10.2.16	Chronic Daily Intakes Dermal Contact with Surface Soil, SWMU 36 and AOC 620	10.2.72
Table 10.2.17	Chronic Daily Intakes Ingestion of COPCs in Groundwater, SWMU 36 and AOC 620	10.2.73
Table 10.2.18	Toxicological Reference Information for Chemicals of Potential Concern, SWMU 36 and AOC 620	10.2.75
Table 10.2.19	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, SWMU 36 and AOC 620	10.2.82
Table 10.2.20	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, SWMU 36 and AOC 620	10.2.83
Table 10.2.21	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, SWMU 36 and AOC 620	10.2.85
Table 10.2.22	Lead Model Results — Residential Scenario, SWMU 36 and AOC 620	10.2.87
Table 10.2.23	Lead Model Results — Commercial/Industrial Scenario, SWMU 36 and AOC 620	10.2.92
Table 10.2.24	Summary of Risk and Hazard-based COCs, SWMU 36 and AOC 620	10.2.94
Table 10.2.25	Summary of Risk and Hazard, SWMU 36 and AOC 620	10.2.100
Table 10.2.26	Point Estimates of Risk and Hazard — Soil Pathways Residential Scenario, SWMU 36 and AOC 620	10.2.105
Table 10.2.27	Point Estimates of Risk and Hazard — Soil Pathways Industrial Scenario, SWMU 36 and AOC 620	10.2.107
Table 10.2.28	Point Estimates of Risk and Hazard — Groundwater Pathways Residential Scenario, SWMU 36 and AOC 620	10.2.110
Table 10.2.29	Remedial Goal Options for Soil, SWMU 36 and AOC 620	10.2.111
Table 10.2.30	Residential-Based Remedial Goal Options Groundwater, SWMU 36 and AOC 620	10.2.112

Table 10.2.31	Potential Corrective Measures for SWMU 36 and AOC 620	10.2.113
Table 10.3.1	SWMU 109 Soil Samples and Analyses	10.3.5
Table 10.3.2	SWMU 109 Organic Compound Analytical Results for Soil	10.3.8
Table 10.3.3	SWMU 109 Inorganic Analytical Results for Soil	10.3.11
Table 10.3.4	SWMU 109 Analytes Detected in Surface and Subsurface Soil	10.3.14
Table 10.3.5	SWMU 109 Sediment Samples	10.3.27
Table 10.3.6	SWMU 109 Organic Compound Analytical Results for Sediment	10.3.27
Table 10.3.7	SWMU 109 Inorganic Analytical Results for Sediment	10.3.28
Table 10.3.8	SWMU 109 Analytes Detected in Sediment Samples	10.3.29
Table 10.3.9	SWMU 109 Groundwater Samples	10.3.32
Table 10.3.10	SWMU 109 Inorganic Analytical Results for Groundwater	10.3.33
Table 10.3.11	SWMU 109 Analytes Detected in Shallow Groundwater	10.3.34
Table 10.3.12	Chemicals Detected in Surface Soil, Subsurface Soil, and Shallow Groundwater Comparison to SSLs, Tap Water RBCs, Saltwater Surface Water Chronic Screening Levels, and Background Concentrations, SWMU 109	10.3.36
Table 10.3.13	Chemicals Present in Site Samples SWMU 109 — Surface Soil	10.3.40
Table 10.3.14	Chemicals Present in Site Samples SWMU 109 — Shallow Groundwater	10.3.41
Table 10.3.15	Exposure Pathways Summary — SWMU 109	10.3.43
Table 10.3.16	Chronic Daily Intakes Incidental Ingestion of Surface Soil, SWMU 109	10.3.45
Table 10.3.17	Chronic Daily Intakes Dermal Contact with Surface Soil, SWMU 109	10.3.46
Table 10.3.18	Toxicological Reference Information for Chemicals of Potential Concern, SWMU 109	10.3.47
Table 10.3.19	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, SWMU 109	10.3.54
Table 10.3.20	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, SWMU 109	10.3.55
Table 10.3.21	Summary of Risk and Hazard-based COCs, SWMU 109	10.3.57
Table 10.3.22	Summary of Risk and Hazard, SWMU 109	10.3.64
Table 10.3.23	Point Estimates of Risk and Hazard — Surface Soil Pathways Residential Scenario, SWMU 109	10.3.65
Table 10.3.24	Point Estimates of Risk and Hazard — Surface Soil Pathways Industrial Scenario, SWMU 109	10.3.69
Table 10.3.25	Remedial Goal Options for Soil, SWMU 109	10.3.71
Table 10.3.26	Potential Corrective Measures for SWMU 109	10.3.73
Table 10.4.1	AOC 607 Soil Samples and Analyses	10.4.18
Table 10.4.2	Zone F AOC 607 Organic Compound Analytical Results for Soil	10.4.19
Table 10.4.3	Zone F AOC 607 Inorganic Analytical Results for Soil	10.4.21
Table 10.4.4	AOC 607 Analytes Detected in Surface and Subsurface Soil	10.4.24
Table 10.4.5	AOC 607 Sediment Samples and Analyses	10.4.37
Table 10.4.6	AOC 607 Organic Compound Analytical Results for Sediment	10.4.38
Table 10.4.7	AOC 607 Inorganics Analytical Results for Sediment	10.4.40

Table 10.4.8	AOC 607 Analytes Detected in Sediment Samples	10.4.41
Table 10.4.9	AOC 607 Groundwater Samples and Analyses	10.4.46
Table 10.4.10	Zone F AOC 607 Organic Analytical Results for Shallow Groundwater	10.4.49
Table 10.4.11	Zone F AOC 607 Inorganic Analytical Results for Shallow Groundwater	10.4.50
Table 10.4.12	Zone F AOC 607 Organic Analytical Results for Intermediate Groundwater	10.4.52
Table 10.4.13	Zone F AOC 607 Inorganic Analytical Results for Intermediate Groundwater	10.4.53
Table 10.4.14	Zone F AOC 607 Organic Analytical Results for Deep Groundwater	10.4.55
Table 10.4.15	Zone F AOC 607 Inorganic Analytical Results for Deep Groundwater	10.4.56
Table 10.4.16	Zone F AOC 607 Analytes Detected in Groundwater	10.4.58
Table 10.4.17	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater Comparisons to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 607	10.4.98
Table 10.4.18	Soil to Air Volatilization Screening Analysis, AOC 607	10.4.102
Table 10.4.19	Summary of Chemical Present in Site Samples AOC 607, Surface Soil	10.4.106
Table 10.4.20	Summary of Chemicals Present in Site Samples AOC 607 - Combined Shallow, Intermediate, and Deep Groundwater	10.4.107
Table 10.4.21	Exposure Pathways Summary — AOC 607	10.4.110
Table 10.4.22	Statistical Analysis of COPCs in Surface Soil, AOC 607	10.4.112
Table 10.4.23	Determination of Groundwater EPCs, AOC 607	10.4.114
Table 10.4.24	Chronic Daily Intakes Incidental Ingestion os Surface Soil, AOC 607	10.4.115
Table 10.4.25	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 607	10.4.116
Table 10.4.26	Chronic Daily Intakes Inhalation of Volatile Organic Compounds Eminating from Soil, AOC 607	10.4.117
Table 10.4.27	Chronic Daily Intakes Ingestion of COPCs in Groundwater, AOC 607	10.4.119
Table 10.4.28	Toxicological Reference Information for Chemicals of Potential Concern, AOC 607	10.4.120
Table 10.4.29	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 607	10.4.127
Table 10.4.30	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 607	10.4.128
Table 10.4.31	Hazard Quotients and Incremental Lifetime Cancer Risks Inhalation of Volatile Organic Chemicals Eminating from Soil, AOC 607	10.4.129

Table 10.4.32	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, AOC 607	10.4.131
Table 10.4.33	Hazard Quotients and Incremental Lifetime Cancer Risks Inhalation of Contaminants in Groundwater Resulting from Domestic Use, AOC 607	10.4.132
Table 10.4.34	Lead Model Results - Future Residential Scenario, AOC 607	10.4.135
Table 10.4.35	Summary of Risk and Hazard-based COCs, AOC 607	10.4.138
Table 10.4.36	Point Estimates of Risk and Hazard - Groundwater Pathways Residential Scenario, AOC 607	10.4.146
Table 10.4.37	Remedial Goal Options Groundwater AOC 607	10.4.153
Table 10.4.38	Potential Corrective Measures for AOC 607	10.4.155
Table 10.5.1	AOC 609 Soil Samples	10.5.7
Table 10.5.2	AOC 609 Organic Compound Analytical Results for Soil	10.5.8
Table 10.5.3	AOC 609 Inorganic Analytical Results for Soil	10.5.11
Table 10.5.4	AOC 609 Analytes Detected in Surface and Subsurface Soil	10.5.14
Table 10.5.5	AOC 609 Groundwater Samples	10.5.28
Table 10.5.6	AOC 609 Organic Analytical Results for Groundwater	10.5.30
Table 10.5.7	AOC 609 Inorganic Analytical Results for Groundwater	10.5.32
Table 10.5.8	AOC 609 Analytes Detected in Groundwater	10.5.35
Table 10.5.9	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 609	10.5.56
Table 10.5.10	Soil-to-Air Volatilization Screening Analysis, AOC 609	10.5.60
Table 10.5.11	Chemicals Present in Site Samples, AOC 609 — Surface Soil	10.5.63
Table 10.5.12	Chemicals Present in Site Samples, AOC 609 — Groundwater	10.5.65
Table 10.5.13	Exposure Pathways Summary — AOC 609	10.5.66
Table 10.5.14	Chronic Daily Intakes incidental Ingestion of Surface Soil, AOC 609	10.5.69
Table 10.5.15	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 609	10.5.70
Table 10.5.16	Chronic Daily Intakes Ingestion of COPCs in Groundwater, AOC 609	10.5.71
Table 10.5.17	Toxicological Reference Information for Chemicals of Potential Concern, AOC 609	10.5.72
Table 10.5.18	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 609	10.5.81
Table 10.5.19	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 609	10.5.82
Table 10.5.20	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, AOC 609	10.5.85
Table 10.5.21	Hazard Quotients and Incremental Lifetime Cancer Risks Inhalation of Contaminants in Groundwater Resulting from Domestic Use, AOC 609	10.5.86
Table 10.5.22	Summary of Risk and Hazard-based COCs, AOC 609	10.5.89

Table 10.5.23	Summary of Risk and Hazard, AOC 609	10.5.96
Table 10.5.24	Point Estimates of Risk and Hazard — Soil Pathways Residential Scenario, AOC 609	10.5.97
Table 10.5.25	Point Estimates of Risk and Hazard — Surface Soil Pathways Industrial Scenario, AOC 609	10.5.103
Table 10.5.26	Point Estimates of Risk and Hazard — Groundwater Pathways Residential Scenario, AOC 609	10.5.104
Table 10.5.27	RGOs Surface Soil, AOC 609	10.5.106
Table 10.5.28	RGOs Groundwater, AOC 609	10.5.107
Table 10.5.29	Potential Corrective Measures for AOC 609	10.5.108
Table 10.6.1	AOC 611 Soil Samples and Analyses	10.6.5
Table 10.6.2	AOC 611 Organic Compound Analytical Results for Soil	10.6.6
Table 10.6.3	AOC 611 Inorganic Analytical Results for Soil	10.6.10
Table 10.6.4	AOC 611 Analytes Detected in Surface and Subsurface Soil	10.6.13
Table 10.6.5	Chemicals Detected in Surface and Subsurface Soil Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 611	10.6.35
Table 10.6.6	Soil-to-Air Volatilization Screening Analysis, AOC 611	10.6.38
Table 10.6.7	Chemicals Present in Site Samples, AOC 611 — Surface Soil	10.6.41
Table 10.6.8	Exposure Pathways Summary — AOC 611	10.6.43
Table 10.6.9	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 611	10.6.46
Table 10.6.10	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 611	10.6.47
Table 10.6.11	Toxicological Reference Information for Chemicals of Potential Concern, AOC 611	10.6.48
Table 10.6.12	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 611	10.6.55
Table 10.6.13	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact With Surface Soil, AOC 611	10.6.56
Table 10.6.14	Summary of Risk and Hazard-based COCs, AOC 611	10.6.59
Table 10.6.15	Summary of Risk and Hazard, AOC 611	10.6.65
Table 10.6.16	Point Estimates of Risk and Hazard — Soil Pathways Residential Scenario, AOC 611	10.6.66
Table 10.6.17	Point Estimates of Risk and Hazard — Soil Pathways Industrial Scenario, AOC 611	10.6.71
Table 10.6.18	Remedial Goal Options for Soil, AOC 611	10.6.73
Table 10.6.19	Potential Corrective Measures for AOC 611	10.6.74
Table 10.7.1	AOCs 613/615 and SWMU 175 Screening Samples	10.7.12
Table 10.7.2	Zone F AOC 613/615 and SWMU 175 Organic Compound Analytical Results for Soil	10.7.17
Table 10.7.3	Zone F AOC 613/615 and SWMU 175 Inorganic Analytical Results for Soil	10.7.22
Table 10.7.4	Zone F AOC 613/615 and SWMU 175 Analytes Detected in Surface and Subsurface Soil	10.7.25

Table 10.7.4a	Zone F AOCs 613/615 and SWMU 175 Sediment Samples and Analyses	10.7.93
Table 10.7.5	Zone F AOC 613/615 and SWMU 175 Organic Compound Analytical Results for Sediment	10.7.93
Table 10.7.6	Zone F AOC 613/615 and SWMU 175 Inorganic Analytical Results for Sediment	10.7.95
Table 10.7.7	Zone F AOC 613/615 and SWMU 175 Analytes Detected in Sediment Samples	10.7.96
Table 10.7.8	Zone F AOCs 613/615 and SWMU 175 Groundwater Samples and Analyses	10.7.100
Table 10.7.9	Zone F AOC 613/615 and SWMU 175 Organic Analytical Results for Shallow and Deep Groundwater	10.7.101
Table 10.7.10	Zone F AOC 613/615 and SWMU 175 Inorganic Analytical Results for Shallow and Deep Groundwater	10.7.104
Table 10.7.11	Zone F AOC 613/615 and SWMU 175 Analytes Detected in Groundwater	10.7.107
Table 10.7.12	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Chronic Screening Levels, and Background Concentrations	10.7.145
Table 10.7.13	Soil to Air Volatilization Screening Analysis	10.7.150
Table 10.7.14	Chemicals Present in Site Samples Surface Soil	10.7.153
Table 10.7.15	Chemicals Present in Site Samples - Shallow and Deep Groundwater	10.7.155
Table 10.7.16	Exposure Pathways Summary — Combined AOC 613	10.7.157
Table 10.7.17	Summary of Statistical Analysis Surface Soil COPCs	10.7.159
Table 10.7.18	Determination of Groundwater EPCs	10.7.161
Table 10.7.19	Chronic Daily Intakes Incidental Ingestion of Surface Soil	10.7.163
Table 10.7.20	Chronic Daily Intakes Dermal Contact with Surface Soil	10.7.164
Table 10.7.21	Chronic Daily Intakes Ingestion of COPCs in Groundwater	10.7.165
Table 10.7.22	Toxicological Reference Information for Chemicals of Potential Concern	10.7.166
Table 10.7.23	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion	10.7.178
Table 10.7.24	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact With Surface Soil	10.7.179
Table 10.7.25	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion	10.7.181
Table 10.7.26	Hazard Quotients and Incremental Lifetime Cancer Risks Inhalation of Contaminants in groundwater Resulting from Domestic Use	10.7.182
Table 10.7.27	Lead Model Results	10.7.186
Table 10.7.28	Summary of Risk and Hazard-Based COCs	10.7.189
Table 10.7.29	Summary of Risk and Hazard	10.7.197
Table 10.7.30	Point Estimates of Risk and Hazard - Surface Soil Pathways	10.7.198

Table 10.7.31	Point Estimates of Risk and Hazard - Surface Soil Pathways Industrial Scenario	10.7.213
Table 10.7.32	Point Estimates of risk and Hazard - Groundwater Pathways Residential Scenario	10.7.219
Table 10.7.33	Remedial Goal Options for Soil	10.7.227
Table 10.7.34	Residential-Based Remedial Goal Options Groundwater	10.7.228
Table 10.7.35	Potential Corrective Measures for AOC 613	10.7.230
Table 10.8.1	AOC 616 Soil Samples	10.8.3
Table 10.8.2	AOC 616 Organic Compound Analytical Results for Soil	10.8.4
Table 10.8.3	AOC 616 Inorganic Analytical Results for Soil	10.8.7
Table 10.8.4	AOC 616 Analytes Detected in Surface and Subsurface Soil	10.8.10
Table 10.8.5	Chemicals Detected in Surface Soil and Subsurface Soil Comparison to SSLs, and Background Concentrations, AOC 616	10.8.18
Table 10.8.6	Soil-to-Air Volatilization Analysis, AOC 616	10.8.20
Table 10.8.7	Chemicals Present in Site Samples, AOC 616 — Surface Soil	10.8.21
Table 10.8.8	Exposure Pathways Summary — AOC 616	10.8.23
Table 10.8.9	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 616	10.8.25
Table 10.8.10	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 616	10.8.26
Table 10.8.11	Toxicological Reference Information for Chemicals of Potential Concern, AOC 616	10.8.27
Table 10.8.12	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 616	10.8.29
Table 10.8.13	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 616	10.8.30
Table 10.8.14	Summary of Risk and Hazard, AOC 616	10.8.34
Table 10.9.1	AOC 617 Soil Samples and Analyses	10.9.6
Table 10.9.2	AOC 617 Organic Compound Analytical Results for Soil	10.9.7
Table 10.9.3	AOC 617 Inorganic Analytical Results for Soil	10.9.11
Table 10.9.4	AOC 617 Analytes Detected in Surface and Subsurface Soil	10.9.14
Table 10.9.5	AOC 617 Groundwater Samples	10.9.28
Table 10.9.6	AOC 617 Organic Analytical Results for Groundwater	10.9.29
Table 10.9.7	AOC 617 Inorganic Analytical Results for Groundwater	10.9.30
Table 10.9.8	AOC 617 Analytes Detected in Shallow Groundwater	10.9.32
Table 10.9.9	Chemicals Detected in Surface Soil, Subsurface Soil, and Shallow Groundwater; Comparison to SSLs, Tap Water RBCs, Saltwater Surface Water Chronic Screening Levels, and Background Concentrations, AOC 617	10.9.44
Table 10.9.10	Chemicals Present in Site Samples AOC 617 — Surface Soils	10.9.50
Table 10.9.11	Chemicals Present in Site Samples AOC 617 — Shallow Groundwater	10.9.51
Table 10.9.12	Exposure Pathways Summary — AOC 617	10.9.53
Table 10.9.13	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 617	10.9.56

Table 10.9.14	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 617	10.9.57
Table 10.9.15	Chronic Daily Intakes Ingestion of COPCs in Shallow Groundwater, AOC 617	10.9.58
Table 10.9.16	Toxicological Reference Information for Chemicals of Potential Concern, AOC 617	10.9.59
Table 10.9.17	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 617	10.9.66
Table 10.9.18	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 617	10.9.67
Table 10.9.19	Hazard Quotients and Incremental Lifetime Cancer Risks Shallow Groundwater Ingestion, AOC 617	10.9.69
Table 10.9.20	Summary of Risk and Hazard-based COCs, AOC 617	10.9.71
Table 10.9.21	Summary of Risk and Hazard, AOC 617	10.9.80
Table 10.9.22	Point of Estimates of Risk and Hazard – Surface Soil Pathways Residential Scenario, AOC 617	10.9.81
Table 10.9.23	Point Estimates of Risk and Hazard – Groundwater Pathways Residential Scenario, AOC 617	10.9.84
Table 10.9.24	Remedial Goal Options for Surface Soil, AOC 617	10.9.86
Table 10.9.25	Residential-Based Remedial Goal Options Shallow Groundwater, AOC 617	10.9.87
Table 10.9.26	Potential Corrective Measures for AOC 617	10.9.89
Table 10.10.1	Zone F AOC 709 Soil Samples and Analysis	10.10.6
Table 10.10.2	Zone F AOC 709 Organic Compound Analytical Results for Subsurface Soil	10.10.7
Table 10.10.3	Zone F AOC 709 Inorganic Compound Analytical Results for Subsurface Soil	10.10.9
Table 10.10.4	Zone F AOC 709 Analytes Detected in Subsurface Soil	10.10.11
Table 10.10.5	Zone F AOC 709 Groundwater Sampling Summary	10.10.17
Table 10.10.6	Zone F AOC 709 Organic Compound Analytical Results for Groundwater	10.10.18
Table 10.10.7	Zone F AOC 709 Inorganic Analytical Results for Groundwater	10.10.19
Table 10.10.8	Zone F AOC 709 Analytes Detected in Groundwater	10.10.22
Table 10.10.9	Chemicals Detected in Subsurface Soil and Shallow Groundwater, Comparison to SSLs, Tap Water RBCs, Saltwater Surface Water Chronic Screening Levels and Background Concentrations.	10.10.30
Table 10.10.10	Chemicals Present in Site Samples AOC 709 - Shallow Groundwater	10.10.34
Table 10.10.11	Exposure Pathways Summary – AOC 709	10.10.36
Table 10.10.12	Summary of Statistical Analysis Shallow Groundwater COPCs; AOC 709	10.10.38
Table 10.10.13	Chronic Daily Intakes Ingestion of COPCs in Shallow Groundwater, AOC 709	10.10.40
Table 10.10.14	Toxicological Reference Information for Chemicals of Potential Concern AOC 709	10.10.41

Table 10.10.15	Hazard Quotients and Incremental Lifetime Cancer Risks Shallow Groundwater Ingestion, AOC 709	10.10.44
Table 10.10.16	Summary of Risk and Hazard-based COCs, AOC 709	10.10.46
Table 10.10.17	Summary of Risk and Hazard AOC 709	10.10.51
Table 10.10.18	Point Estimates of Risk and Hazard - Groundwater Pathways Residential Scenario	10.10.53
Table 10.10.19	Point Estimates of Risk and Hazard - Groundwater Pathways Industrial Scenario	10.10.57
Table 10.10.20	Residential-Based Remedial Goal Options Groundwater AOC 709	10.10.59
Table 10.10.21	Potential Corrective Measures for AOC 709	10.10.60
Table 11.1	Zone F Site Conclusions and Preliminary Recommendations	11.2
Table 11.2	SWMU 4 and AOC 619 Conclusion Summary	11.3
Table 11.3	SWMU 36 and AOC 620 Conclusion Summary	11.4
Table 11.4	SWMU 109 Conclusion Summary	11.5
Table 11.5	AOC 607 Conclusion Summary	11.6
Table 11.6	AOC 609 Conclusion Summary	11.7
Table 11.7	AOC 611 Conclusion Summary	11.7
Table 11.8	AOCs 613/615 and SWMU 175 Conclusion Summary	11.9
Table 11.9	AOC 611 Conclusion Summary	11.10
Table 11.10	AOC 617 Conclusion Summary	11.10
Table 11.11	AOC 709 Conclusion Summary	11.11

List of Appendices

Appendix A	Monitoring Well Construction Diagrams
Appendix B	Shelby Tube Sample Data Summary
Appendix C	AQTESOLV Results
Appendix D	Analytical Data Summary
Appendix E	Data Validation Reports

ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR NAVBASE ZONE F

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

AA	Atomic Absorption
AL	Action Level
AOC	Area of Concern
AQTESOLV	Aquifer Test Solver
b	Aquifer Thickness
BEQ	Benzo(a)pyrene Equivalent
BEST	Building Economic Solutions Together
bgs	Below ground surface
BOS	Bottom of screen
BOW	Bottom of well
BRA	Baseline Risk Assessment
BRAC	Base Realignment and Closure Act of 1988 and Defense Base Closure and Realignment Act of 1990, collectively
CAMU	Corrective Action Management Unit
CCC	Calibration Check Compounds
CDD	Chlorinated dibenzo-p-dioxin
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
cm/sec	centimeters per second
CMS	Corrective Measures Study
CNS	Central Nervous System
CNSY	Charleston Naval Shipyard
COC	Chemical of Concern
cPAH	Carcinogenic Polynuclear Aromatic Hydrocarbon
COPC	Chemical of Potential Concern
CPSS	Chemical Present in Site Samples
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
CSAP	Comprehensive Sampling and Analysis Plan
CSI	Confirmatory Sampling Investigation
CT	Central Tendency
D	Density/Diluted sample
DAF	Dilution Attenuation Factor
DJ	Diluted sample, results estimated
DPT	Direct Push Technology
DQO	Data Quality Objective

E/A&H	EnSafe/Allen & Hoshall
EPC	Exposure Point Concentration
ESDSOPQAM	Environmental Services Division Standard Operating Procedures and Quality Assurance Manual
FC	Fraction Contacted
FI	Fraction Ingested
f_{oc}	Fraction organic carbon content
ft bgs	feet below ground surface
ft/day	feet per day
ft/ft	feet per foot (gradient)
ft msl	feet above mean sea level
GC/MS	Gas Chromatography/Mass Spectroscopy
GEL	General Engineering Laboratories, Inc.
g/cc	grams per cubic centimeter
g/mole	grams per mole
HHRA	Human Health Risk Assessment
HI	Hazard Index
HL	Henry's Law Constant
HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments
HTTD	High-Temperature Thermal Desorption
i	Horizontal Hydraulic Gradient
ICAP	Inductively Coupled Argon Plasma
ICM	Interim Corrective Measure
ILCR	Incremental Lifetime Excess Cancer Risk
IRIS	Integrated Risk Information System
K	Hydraulic Conductivity
K_d	Normalized Partitioning Coefficient
Kg/L	Kilograms per liter
$K_{g_{oc}/L_{water}}$	Kilograms of organic carbon per liter of water
K_h	Geometric mean of hydraulic conductivity
K_v	Vertical permeability
K_{oc}	Organic Carbon/Water Partitioning Coefficient
LCS	Laboratory Control Sample
LNAPL	Light non-aqueous phased liquid
LTDD	Low-Temperature Thermal Desorption

MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MW	Molecular Weight
meq/100g	Milliequivalent per one hundred grams
mg/kg	Milligrams per kilogram
N	Soil porosity
NA	Not analyzed/not applicable
n_e	Effective porosity
ng/kg	Nanograms per kilogram
ng/ml	Nanograms per milliliter
NAVBASE	Naval Base Charleston
ND	Nondetects
NDA	No data available
NFA	No Further Action
NFI	No Further Investigation
NM	Not measured
NOAEL	No-observed-adverse-effects level
NPDES	National Pollutant Discharge Elimination System
OP	Organophosphorous
PAH	Polynuclear Aromatic Hydrocarbins
PCB	Polychlorinated biphenyl
pg/L	Picograms per liter
POTW	Publicly Owned Treatment Works
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
Qc	Quaternary Clay
Qm	Quaternary Marsh Clay
Qs	Quaternary Sand
Qundif	Quaternary Undifferentiated Unit
R	Retardation Factor
RAB	Restoration Advisory Board
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RDA	Charleston Naval Complex Redevelopment Authority/Recommended Daily Allowance
RFA	RCRA Facility Assessment
RfD	Reference Dose

RfD _o	Reference Dose-oral
RFI	RCRA Facility Investigation
RGO	Remedial Goal Option
RME	Reasonable Maximum Exposure
RRF	Relative Response Factor
S	Aquifer Storativity
SCDHEC	South Carolina Department of Health and Environmental Control
SF	Slope Factor
SMCL	Secondary Maximum Contaminant Level
SOUTHDIV	Southern Division Naval Facilities Engineering Command
SPCC	Spill Prevention, Control and Countermeasures
SPORTENV- DETCHASN	Supervisor of Shipbuilding, Conversion and Repair, USN, Portsmouth Detachment Environmental, Charleston, SC
SQL	Sample Quantitation Limit
SSL	Soil Screening Level
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
T	Aquifer Transmissivity
T _{1/2}	Half Life
Ta	Ashley Formation
TCDD	Tetrachlorodibenzo-p-dioxin
TDS	Total Dissolved Solids
TEF	Toxic Equivalency Factor
TEQ	TCDD Equivalency Quotient
THQ	Target Hazard Quotient
TOC	Top of Casing/Total Organic Carbon
TOS	Top of screen
TPH	Total Petroleum Hydrocarbons
TTAL	Treatment Technique Actin Level
Tu	Tertiary Undifferentiated Unit
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
UTL	Upper Tolerance Limit
UV	Ultraviolet
V	Horizontal Groundwater Velocity
VOC	Volatile Organic Compound
VP	Vapor Pressure

Δx	Distance Between Points
Δh	Hydraulic Head
ρ_b	Dry soil bulk density
$\mu\text{g}/\text{kg}$	Microgram per kilogram
$\mu\text{g}/\text{L}$	Microgram per liter
%D	Percent Difference
%RSD	Percent Relative Standard Deviation

FILING INSTRUCTIONS

The following is a list of the pages in the *Draft Zone F RCRA Facility Investigation Report*, dated December 31, 1997 that have been revised. The obsolete pages presently in your binders are listed in the column headed "Remove." New and replacement pages are listed in the column headed "Replace."

If you have any questions, please call 843-884-0029.

List of Changes/Revisions	<u>Remove</u> <u>Pages</u>	<u>Replace</u> <u>Pages</u>
Table of Contents - updated.	i - xiv	i - xvi
Volume III of V – Sections 10.5 to 13		
AOC 709 Section 10.10	-	10.10.1 to 10.10.60
Section 11.0	Remove all pages except for the figures	11.1 to 11.11
Volume IV of V – Appendix A to D		
Appendix A	-	Add to the back
Appendix D	-	Add to the back
Volume V of V – Appendix E		
Appendix E	-	Add to the back

1.0 INTRODUCTION

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

1.1 NAVBASE Description and Background

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

1.2 Base Closure Process for Environmental Cleanup

Section 1.2 of the *Draft Zone A RFI Report* details the base closure process for environmental cleanup. Where appropriate in this document, Areas of Concern (AOCs) and Solid Waste Management Units (SWMUs) are collectively referred to as *sites*. Due to their proximity and similarity in materials, many sites in Zone F have been grouped for investigative purposes and share data from sample points in order to define nature and extent of contamination along site boundaries.

1.3 Investigative Zone Delineation

Due to the size of the base and the level of detail required for investigations, NAVBASE 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 Charleston Naval Complex Redevelopment Authority (RDA), which has authority to establish leases for the transferred property. Zone F is bordered by the controlled industrial area (Zone E) to the north and east; Avenue "D" South and the base boundary to the west; and Hobson Avenue, Wood Street, and Thirteenth Street (Zone G) to the south.

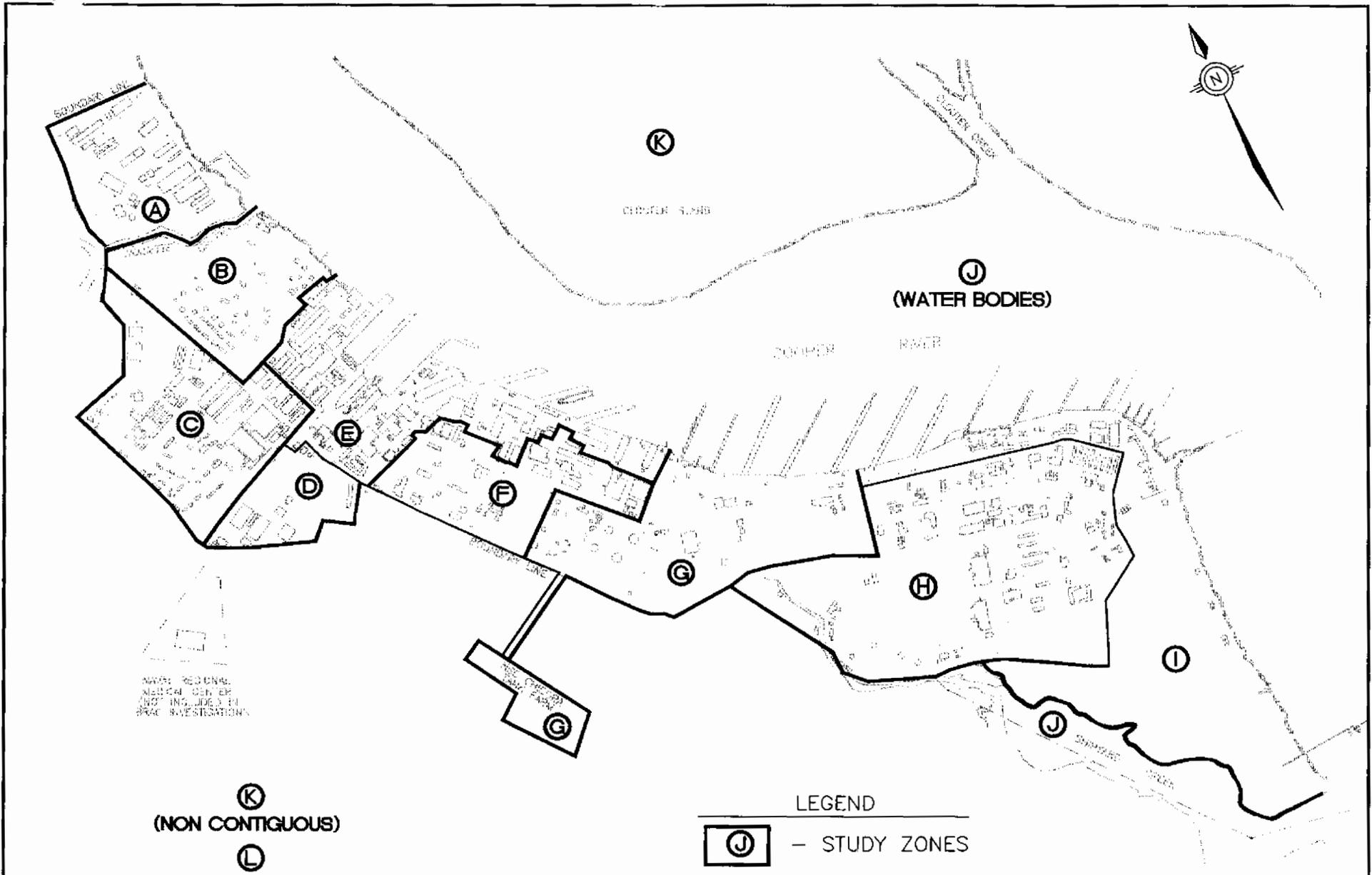
1.4 Current Investigation

Objective

The objectives of the RFI are to characterize the nature and extent of contaminants associated with releases from SWMUs and AOCs, to evaluate contaminant migration pathways, and to identify both actual and potential receptors. The ultimate goal is to determine the need for interim corrective measures (ICMs) or a corrective measures study (CMS). This need will be 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

Thirteen sites were identified in Zone F through the RCRA Facility Assessment (RFA) process. Each site in Zone F is discussed in detail in the *Final RCRA Facility Assessment for Naval Base Charleston* (E/A&H, June 6, 1995), and the *Final Zones D, F, and G RFI Work Plan* (E/A&H 1996b). Investigative approaches for each site were developed and proposed based on the best available information at that time and were subject to modification based on additional site information availability and/or site conditions. The RCRA investigatory designations used are defined below:



(K)
(NON CONTIGUOUS)
(L)

(BASE WIDE SEWER AND RAILWAY)
2000 0 2000
SCALE FEET

LEGEND
[J] - STUDY ZONES



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

FIGURE 1-1
INVESTIGATIVE
ZONE BOUNDARIES

- *No Further Investigation (NFI)* – This designation was applied to AOCs or SWMUs with sufficient data to thoroughly assess the potential hazards associated with the site and to determine that it does not pose a threat to human health or the environment.

- *Confirmatory Sampling Investigation (CSI)* – This designation was applied AOCs or SWMUs for which insufficient data was available to thoroughly assess the potential site hazards. Generally, a limited amount of "confirmatory" samples were needed to determine whether a hazard exists. The result of the CSI determines whether no further investigation is appropriate or a full-scale RFI is warranted.

- *RFI* – This designation was applied to AOCs or SWMUs if visual evidence, historical information such as spill reports, or analytical data indicated that a release of hazardous substances to the environment has occurred. A complete characterization of the site is needed to determine the nature and extent of contamination, to identify migration pathways, to identify actual and potential receptors, and to evaluate the ecological and human health risks posed by the site.

The approved final RFI work plan outlined an investigative strategy for each of the 13 Zone F sites reported on herein. Table 1.1 summarizes each Zone F AOC and SWMU requiring investigation. Figure 1-2 identifies each site's location.

1.5 Previous Investigations

In addition to data generated during this investigation, pertinent data from previous investigations of Zone F sites have been incorporated, along with other historical information.

Table 1.1
Zone F
AOC and SWMU Summary

AOCs and SWMUs	Site Description	Investigative Approach	Previous Investigations	Investigation Grouping
SWMU 35				AOC 619 and SWMU 35 were investigated together due to site proximity or co-location.
SWMU 36	Battery Shop, Building 68	RFI	None	AOC 620 and SWMU 36 were investigated together due to site proximity
AOC 620	Battery Shop, Building 68	RFI	None	
SWMU 67				Investigated independently
AOC 607	Dry Cleaning, Building 1189	RFI	None	Investigated independently
AOC 609	Service Station, Building 1191	RFI	1991 underground storage tank (UST) removal and flow in sump in 1993 and 1994. Waste oil UST removed in 1996.	Investigated independently
AOC 611	Grease Rack and Hobby Shop, Building 1264	CSI	None	Investigated independently
SWMU 175	Crane Painting Area Near Building 1277	RFI	None	AOCs 613/615 and SWMU 175 were investigated together due to site proximity
AOC 613	Old Locomotive Repair Shop, Former Building 1169	RFI	Areas of AOCs 613/615 were subject to a prelease evaluation of baseline environmental conditions in 1996.	
AOC 615	Old Chain Locker, Building 1191	CSI		
AOC 616	Paint Shop Former, Building 1201	CSI	None	Investigated independently
AOC 617	Galvanizing Plant, Former Building 1176	CSI	None	Investigated independently

1.6 RFI Report Organization

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:

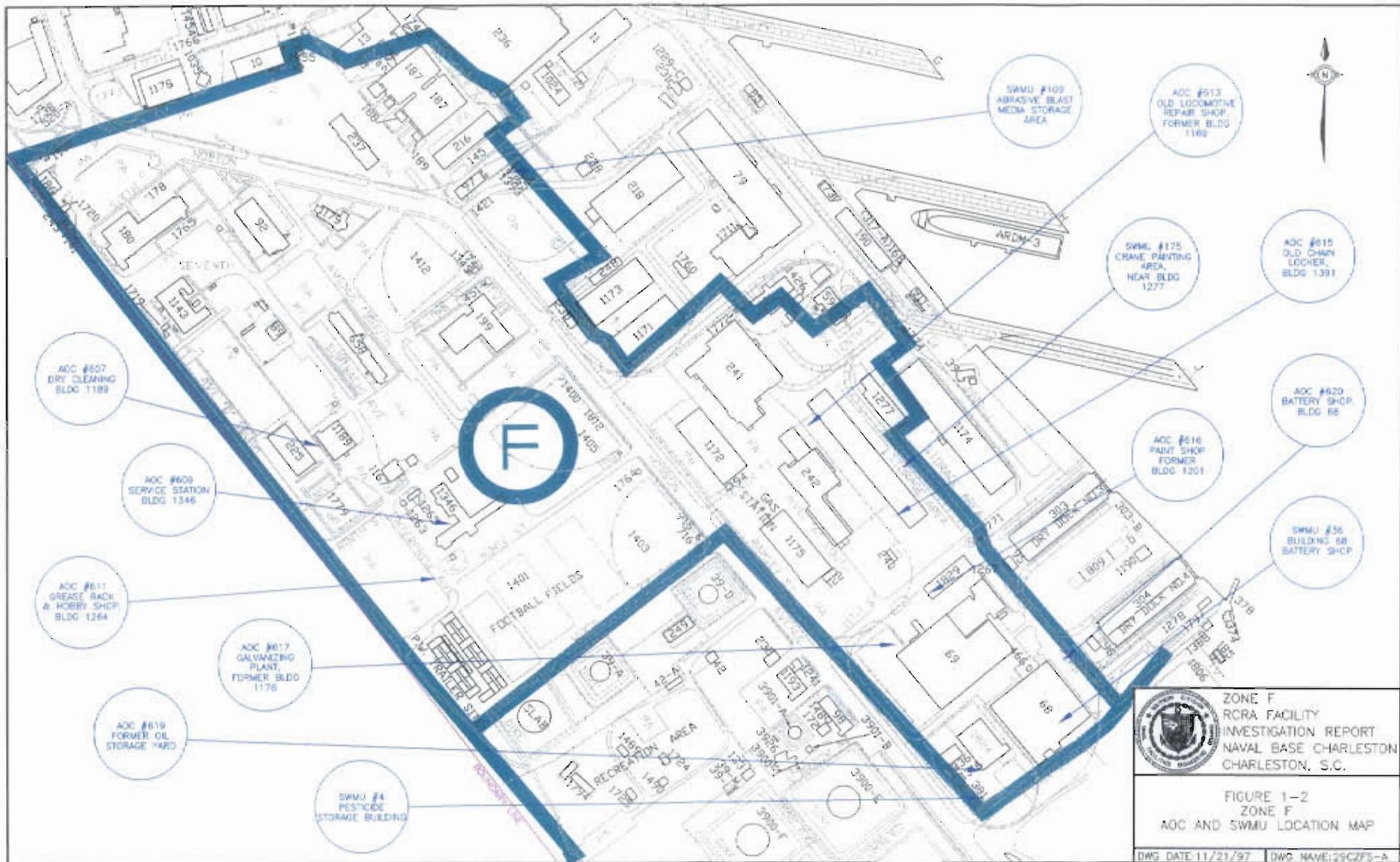
- 1.0 Introduction
- 2.0 Physical Setting
- 3.0 Field Investigation
- 4.0 Data Validation
- 5.0 Data Evaluation and Background Comparison
- 6.0 Fate and Transport
- 7.0 Human Health Risk Assessment
- 8.0 Ecological Risk Assessment
- 9.0 Corrective Measures

The site-specific sections are:

- 10.0 Site-Specific Evaluations
- 11.0 Conclusions and Preliminary Recommendations
- 12.0 References
- 13.0 Signatory Requirement

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.

2.0	PHYSICAL SETTING	1
2.1	Regional Setting	2
2.1.1	Regional Physiographic and Geologic Description	3
	The NAVBASE area regional physiographic and geologic settings are described in Section 2.1.1 of the <i>Draft Zone A RFI Report</i> .	4 5
2.1.2	Regional Hydrologic and Hydrogeologic Background	6
	Regional hydrology and hydrogeology for the NAVBASE area are described in Section 2.2.1 of the <i>Draft Zone A RFI Report</i> .	7 8
2.1.3	Regional Climate	9
	Regional climate is discussed in Section 2.3 of the <i>Draft Zone A RFI Report</i> .	10
2.2	Zone F Geologic Investigation	11
	Geologic and stratigraphic information was obtained from samples collected during soil and monitoring well boring advancement. The borings were advanced using hollow-stem auger, water rotary, and rotasonic drilling methods. Soil samples were collected with a two-foot split-spoon sampler, or continuous sampler depending on the drilling method in use. The stratigraphy was logged by an EnSafe geologist in accordance with the approved <i>Final Comprehensive Sampling and Analysis Plan (CSAP) RCRA Facility Investigation (Revision No: 02) (E/A&H 1996c)</i> .	12 13 14 15 16 17
2.2.1	Monitoring Wells	18
	Thirty six monitoring wells (23 shallow, five intermediate, and eight deep) were installed at Zone F between August 1996 and April 1997 for the groundwater investigation. Lithologic boring logs and well construction diagrams are contained in Appendix A. In addition, 15 Zone F wells drilled by other companies and several wells in adjacent zones were used to characterize the Zone F geology and hydrogeology. Zone F well locations are illustrated on Figure 2-1. Table 2.1	19 20 21 22 23




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

FIGURE 1-2
 ZONE F
 AOC AND SWMU LOCATION MAP

DWS DATE: 11/21/97 DWS NAME: 29CZFS-A

Table 2.1
 Zone F
 Monitoring Well Construction Data

Well Identifier	Date Installed	TOC Elevation (ft msl)	Ground Elevation (ft msl)	Construction Depths (ft bgs)			GW Elev.* Low Tide (ft msl)	GW Elev.* High Tide (ft msl)
				TOS	BOS	BOW		
Zone F RFI Wells								
109001	9/12/96	9.61	9.7	2.4	11.8	12.4	5.30	5.36
607001	11/2/96	10.78	8.5	7.7	9.6	10.0	5.26	5.18
607011	11/1/96	11.09	8.7	17.7	19.6	20.0	4.62	4.63
60701D	11/1/96	10.36	7.9	29.7	31.9	32.5	4.09	4.30
607002	10/29/96	8.38	8.4	7.7	9.6	10.0	5.19	5.22
60702I	10/29/96	8.60	8.6	19.2	21.1	21.5	4.88	4.92
60702D	10/29/96	8.37	8.6	29.7	31.9	32.5	4.57	NM
607003	10/31/96	7.99	8.1	8.2	10.1	10.5	5.51	5.29
60703I	10/31/96	8.05	8.0	16.5	18.4	19.0	4.37	4.47
60703D	10/31/96	7.62	7.7	29.7	31.6	32.0	3.96	4.19
607004	11/2/96	10.15	7.7	7.7	9.6	10.0	4.39	4.34
60704I	10/30/96	9.29	6.9	17.7	19.6	20.0	4.45	4.47
60704D	10/30/96	7.09	7.1	29.7	32.4	33.0	3.98	NM
60705D	11/3/96	7.42	7.5	30.8	32.7	33.0	3.88	4.03
607006	11/2/96	7.49	7.5	7.7	9.6	10.0	3.53	3.52
60706I	4/15/97	7.29	7.5	17.5	19.0	19.5	4.11	4.14

Table 2.1
 Zone F
 Monitoring Well Construction Data

Well Identifier	Date Installed	TOC Elevation (ft msl)	Ground Elevation (ft msl)	Construction Depths (ft bgs)			GW Elev.* Low Tide (ft msl)	GW Elev.* High Tide (ft msl)
				TOS	BOS	BOW		
60706D	4/16/97	7.20	7.4	29.5	31.0	31.5	6.15	4.90
607007	11/2/96	10.66	8.3	7.7	9.6	10.0	5.25	NM
607008	4/15/97	7.65	7.9	9.2	11.5	12.0	4.44	4.45
607009	4/16/97	7.19	7.5	8.5	10.0	10.5	3.76	NM
613001	10/21/96	9.48	9.5	3.3	12.7	13.3	1.99	2.28
61302D	9/4/96	9.06	9.4	26.7	35.7	36.0	3.26	3.32
613003	10/22/96	9.40	9.5	2.2	11.6	12.0	6.54	6.52
613004	10/22/96	9.44	9.6	3.7	13.1	13.5	2.46	2.98
613005	10/22/96	8.71	9.0	3.0	12.4	13.0	3.15	3.53
617001	9/30/96	10.57	8.1	2.3	11.7	12.3	3.88	3.89
617002	4/18/97	11.86	12.4	4.0	13.5	14.0	8.35	7.16
619001	8/29/96	9.73	9.8	3.0	12.4	13.0	6.06	6.18
619002	8/29/96	10.37	10.4	2.4	11.8	12.4	10.24	9.93
619003	8/29/96	6.36	6.4	2.7	12.1	12.7	4.15	4.05
620001	9/10/96	7.82	7.9	2.8	12.2	12.8	0.28	3.92
620002	9/3/96	9.58	9.8	2.6	12.0	12.6	6.26	6.14
620003	4/17/97	10.49	10.4	4.0	13.5	14.0	3.94	3.95

Table 2.1
 Zone F
 Monitoring Well Construction Data

Well Identifier	Date Installed	TOC Elevation (ft msl)	Ground Elevation (ft msl)	Construction Depths (ft bgs)			GW Elev.* Low Tide (ft msl)	GW Elev.* High Tide (ft msl)
				TOS	BOS	BOW		
620004	4/17/97	11.31	8.8	3.0	12.5	13.0	7.58	7.55
GDF001	8/27/96	9.57	9.6	3.8	13.2	13.8	4.75	4.80
GDF01D	8/29/96	9.33	9.6	18.0	22.0	22.0	3.96	4.05
Previously Constructed Wells								
240003	NA	8.93	9.3	NA	NA	NA	6.85	6.91
GEL005 ^a	6/12/96	8.55	NA	3.0	13.0	15.0	4.90	4.97
GEL006 ^a	6/13/96	8.73	NA	3.0	13.0	14.0	4.47	4.54
GEL007 ^a	6/12/96	9.70	NA	2.5	12.5	14.0	4.23	3.99
GEL008 ^a	6/12/96	8.74	NA	2.5	12.5	13.5	6.56	6.60
GEL011 ^a	6/14/96	8.35	NA	3.0	13.0	15.0	2.85	3.82
GEL012 ^a	6/13/96	9.51	NA	3.0	13.0	14.0	3.82	2.99
GEL013 ^a	6/13/96	9.11	NA	3.0	13.0	14.0	6.35	6.47
GEL014 ^a	6/14/96	7.61	NA	2.0	12.0	13.0	LNAPL: 6.61 Water: 6.11	LNAPL: 6.51 Water: 6.05
SME001 ^b	NA	7.90	NA	1.0	11.0	12.0	NM	NM
SME003 ^b	NA	7.40	NA	2.0	12.0	13.0	3.67	3.73
SME004 ^b	NA	8.00	NA	2.0	12.0	13.0	4.05	4.19

Table 2.1
 Zone F
 Monitoring Well Construction Data

Well Identifier	Date Installed	TOC Elevation (ft msl)	Ground Elevation (ft msl)	Construction Depths (ft bgs)			GW Elev.* Low Tide (ft msl)	GW Elev.* High Tide (ft msl)
				TOS	BOS	BOW		
SME005 ^b	NA	8.02	NA	2.0	12.0	13.0	3.52	3.57
SME006 ^b	NA	7.92	NA	16.0	26.0	NA	3.66	3.77
SME007 ^b	11/30/94	7.41	NA	2.0	12.0	13.0	4.06	4.04
SME008 ^b	11/30/94	7.60	NA	2.0	12.0	13.0	4.31	4.34
GDE009	10/2/95	8.61	8.8	3.9	12.9	13.5	NM	NM
GDE09D	12/12/95	8.91	8.9	21.5	31.0	31.5	NM	NM

- Notes:**
- a = Evaluation of Baseline Environmental Conditions, Proposed CPW Lease Areas, Former Charleston Naval Shipyard, North Charleston, South Carolina (General Engineering Laboratories [GEL], Inc., August 8, 1996).
 - b = Assessment Report Addendum Building No. 1346, Charleston Naval Base, Charleston, SC (S&ME, Inc., March 29, 1995).
 - TOC = Top of well casing
 - TOS = Top of screened interval
 - BOS = Bottom of screened interval
 - BOW = Bottom of well (end cap)
 - GW = Groundwater
 - ft msl = Mean sea level in feet
 - bgs = Below ground surface
 - * = Groundwater elevations vary seasonally and diurnally. The elevations presented are based on measurement data collected 4/29/97.
 - NM = Not measured
 - NA = Not available
 - LNAPL = Light non-aqueous phase liquid.

presents monitoring well construction data from Zone F wells and from selected wells in adjacent zones, which were used to support the field investigation.

2.2.2 Geotechnical Analyses

Shelby tube soil samples were collected to characterize physical properties of Zone F soils during the RFI. These samples were analyzed for porosity, bulk density, grain-size distribution, specific gravity, percent moisture, and vertical permeability. Shelby tube sample intervals were selected for geotechnical analysis based upon areal distribution and lithology. Additional geotechnical information was obtained from borings advanced at AOCs 607, 613, 620, and 109. Samples were collected from the additional locations to provide supplemental porosity and grain-size data in specific areas of interest. Zone F Shelby tube data are summarized in Table 2.2. Geotechnical data from laboratory analyses of Shelby tube samples are in Appendix B.

2.2.3 Zone F Geology

Only Quaternary and Tertiary age sediments were encountered during the Zone F RFI. The lowermost stratigraphic unit identified in Zone F is the Ashley Formation (Ta) member of the Mid-Tertiary age Cooper Group. Overlying the Ashley are younger Upper-Tertiary and Quaternary-age stratigraphic units. Stratigraphic units encountered during the RFI are presented in the following sections in ascending order. Lithologic cross sections for Zone F are presented as Figures 2-2 and 2-3. Figure 2-4 presents the topography of the top of the Ta in Zones F and G. Zone F geologic maps and cross sections were developed from split-spoon and rotasonic core lithologic sample data. The deepest borehole in Zone F (61302D) limited available stratigraphic information to the upper 40-feet of unconsolidated sediments.

Table 2.2
 Zone F
 Geotechnical Sample Data

Sample Identifier	Sample Depth (ft bgs)	Lith Type	Moisture Content (%)	Bulk Dry Density (g/cc)	Bulk Wet Density (g/cc)	Specific Gravity (g/cc)	Percent Porosity	Vertical Permeability		Grain-Size Distribution		
								cm/sec	ft/day	Percent Sand	Percent Silt	Percent Clay
109001	6-8	Qc	22.9	1.7	—	2.7	36.4	6.62E-08	1.88E-04	44	14	42
60701D	8-10	Qc	41.8	—	—	2.65	52.1	1.07E-08	3.03E-05	3	34	63
607002	8-10	Qc	29.9	—	—	2.68	45.6	3.90E-08	1.10E-04	36	27	37
60702I	19-21	Tu	29.1	—	—	2.66	49.2	—	—	48	18	34
60702D	30-32	Ta	35.1	—	—	2.7	57.4	4.50E-06	1.30E-02	66	22	12
60704D	18-20	Tu	22.9	—	—	2.7	44.4	6.20E-05	1.76E-01	69	18	13
60704D	30-32	Tu	33.1	—	—	2.74	53.8	—	—	69	19	12
607007	4-6	Qc	66.7	—	—	2.56	68.1	1.11E-07	3.15E-04	2	36	62
607007	14-16	Qc	38.1	—	—	2.75	46.2	9.76E-06	2.80E-02	45	22	33
613003	9-11	Qm	90.4	—	—	2.68	67.2	9.84E-07	2.79E-03	7	48	45
613004	5-7	Qc	67.0	—	—	2.6	83	—	—	13	27	60
613005	3-5	Fill	7.9	—	—	2.66	—	—	—	92	1	7
613014	5-7	Qundif	94.7	—	—	2.6	72.2	1.11E-07	3.14E-04	2	40	58
613014	9-11	Qundif	97.8	—	—	2.57	69.1	1.66E-07	4.70E-04	7	43	50
619001	4-6	FBI	15.9	—	1.82	2.69	43	4.10E-06	1.20E-02	68	21	11
619001	8-10	Qs	19.4	1.7	—	2.67	39.2	3.10E-05	8.80E-02	81	4	15
619002	6-8	Qm	40.0	1.1	—	2.62	68.3	2.95E-08	8.40E-05	9	34	57

Table 2.2
 Zone F
 Geotechnical Sample Data

Sample Identifier	Sample Depth (ft bgs)	Lith Type	Moisture Content (%)	Bulk Dry Density (g/cc)	Bulk Wet Density (g/cc)	Specific Gravity (g/cc)	Percent Porosity	Vertical Permeability		Grain-Size Distribution		
								cm/sec	ft/day	Percent Sand	Percent Silt	Percent Clay
620002	6-8	Qundif	27.6	—	—	2.8	37.9	1.94E-06	5.50E-03	43	15	42
620002	7-9	Qs	21.6	1.8	—	2.72	35.7	1.32E-08	3.74E-03	66	6	28
607001P1	—	—	14.4	—	—	2.65	—	—	—	86	6	10
607004P1	—	—	47.2	—	—	2.67	—	—	—	12	20	62
617003P1	—	—	5.7	—	—	2.71	—	—	—	93	2	5

Notes:
 ft bgs = feet below ground surface
 g/cc = grams per cubic centimeter
 cm/sec = centimeters per second
 ft/day = feet per day
 Qs = Quaternary sand
 Qc = Quaternary clay
 Qm = Quaternary marsh clay
 Qundif = Quaternary undifferentiated unit
 — = Parameter not measured

2.2.3.1 Tertiary-Age Sediments

Ashley Formation

The oldest sediment encountered during the Zone F RFI was the Ta, the youngest member of the Eocene-Oligocene age Cooper Group. The Ta was deposited in an open-marine shelf environment during a rise in sea level in the late Oligocene (Weems and Lemon, 1993).

The Ta was encountered throughout Zone F at elevations ranging from -12.2 feet mean sea level (ft msl) at location GDF01D to -25.1 feet msl at location 60705D (Figure 2-4). Figure 2-4 shows that the Ta is higher in the northwestern quarter of Zone F than in the remaining portion. The Ta contact with overlying Zone F sediments is undulatory, with elevations typically between -22 and -26 feet msl.

The Ta is an olive-yellow to olive-brown, tight, slightly calcareous, clayey silt with varying amounts of very fine to fine grained sand that decrease rapidly with depth. It is firm to stiff, low in plasticity, and moist to wet. Analysis of a Zone F Shelby tube sample (60702D 30 - 32 feet below ground surface [ft bgs]) of Ta sediment resulted in a grain-size distribution of 66% fine sand, 22% silt, and 12% clay, and a porosity of 57%.

Tertiary Undifferentiated Unit

According to Weems & Lemon (1993) four Tertiary age units are placed stratigraphically above the Ta. These units are (in ascending order) the Chandler Bridge, Edisto, Marks Head, and Goose Creek Limestone formations. Upper-Tertiary marine regression-transgression sequences have resulted in considerable erosion before subsequent deposition. This erosion has resulted in typically unconformable contacts, where many of the intervening stratigraphic units are no longer present. These stratigraphic units are quite difficult to identify in the field and have not been identified. For this report, these units have been grouped as undifferentiated Upper Tertiary (Tu).

Tu was encountered in all Zone F deep well borings except 61302D which lies in the eastern portion of the zone (Figure 2-2). Cross sections A-A' and C-C' (Figure 2-2) illustrate the area in the central portion of the eastern half of Zone F where Tu has been eroded and replaced by Quaternary-age sediments. Tu sediments vary from approximately two-feet thick at GDF01D to 12-feet thick at 60701D and occur at depths ranging from 16-ft bgs at 60704D to 25-ft bgs at 60702D. Three Zone F Shelby tube samples were collected at borings 60702I and 60704D. The average grain-size distribution of these Shelby tube samples was 62% sand, 18% silt, and 20% clay, with an average porosity of 49%. It is described as an olive-gray to green silt with varying amounts of clay, and very fine to fine quartz and phosphate sand. It is slightly plastic, soft, and intermixed with phosphate pebbles, shell hash, and oyster shells.

2.2.3.2 Quaternary-Age Sediments

The Quaternary Period began with the Pleistocene Epoch and continues with the Holocene (Recent) Epoch. During the Quaternary, several marine transgression-regression sequences occurred which resulted in a complex network of terraces composed of coastal depositional environments such as barrier islands, back-barrier lagoons, tidal inlets, and shallow-marine shelf systems. During the Quaternary, regional crustal uplift in the Charleston region preserved many barrier and back-barrier lagoon deposits as terraces. Succeeding transgressions reworked the shallow-marine shelf deposits on the seaward side of each older barrier ridge or island. This activity resulted in a younger sequence of sediments on the seaward side, laterally adjacent to the previous (older) coastal deposit (Weems and Lemon, 1993). Weems and Lemon (1993) have identified and correlated several formations of Quaternary age sediments. However, field identification of these formational units is difficult since many characteristics may be evident only at the microscopic level.

Throughout Zone F, Quaternary-age sediments were observed from the top of Tertiary-age sediments to the surface. These sediments range from 18-feet thick at 60703D to 35-feet thick at

61302D, including fill and other anthropogenic deposits. These sediments comprise the Pleistocene-age Wando Formation, which is overlain by Holocene-age sand and clay deposits.

According to Weems and Lemon (1993), the Wando depositional period encompasses three distinct high sea-level stands in the late Pleistocene. As a result, Wando composition consists of vertically and sometimes laterally repeating sequences of clayey sand and clay deposits overlying barrier sand deposits which, in turn, overlie fossiliferous shelf-sand deposits.

During the Holocene, rivers and streams have down cut these sediment sequences, leaving scours that have become filled with clay and silty sand deposits typical of low energy environments. These younger deposits may resemble Wando-age deposits and further complicate the interpretation of local geology. Various distinct Quaternary-age litho-stratigraphic units have been identified and correlated in the geologic cross sections prepared for the Zone F RFI report. The following three Zone F Quaternary-age units are described below: Quaternary Clay (Qc), Quaternary Marsh Clay (Qm), and Quaternary Sand (Qs).

Quaternary Clay

Qc consists of moderately plastic inorganic clays and silts, and may be sandy. Coloration is typically brown, brownish red, and gray. This unit is often interbedded with brown sandy nodules and laminae. The Qc unit comprises the predominant Quaternary lithology in Zone F's northwestern and southeastern portions, and lies stratigraphically on top of the Qs or Tu sequence (Figures 2-2 and 2-3). Cross sections A-A' and C-C' illustrate where Qc in Zone F has been removed during an erosive event and Qm deposited. Qc is typically 10- to 15-feet thick and occurs in the upper 20-feet of the shallow subsurface.

Six Shelby tube samples of Qc were collected in Zone F. From Table 2.2, the average grain-size distribution for Qc samples was 24% sand, 27% silt, and 49% clay, with an average porosity value of 55%.

Quaternary Marsh Clay

Quaternary marsh clay is dark gray to black, soft, sticky, and occasionally thinly laminated with sand, silt, and shelly lenses. It is characterized by a high organic content, often intermixed with grass and wood fragments. Qm has low plasticity and often has a distinctive hydrogen sulfide odor due to an oxygen-poor environment. Qm sediments in Zone F range from 10- to 30-feet thick, as seen in cross section B-B' (Figure 2-3). Qm occurs as a narrow deposit trending south toward Zone G from the area around 61302D. It is absent in Zone F's northwestern and western portions.

Two Shelby tube samples of Qm in Zone F were collected at locations 613003 and 619002. From Table 2.2, the average grain-size distribution for these samples was 8% sand, 41% silt, and 51% clay, with an average porosity of 67.7%.

Quaternary Sand

The Quaternary sand unit is typically very fine to medium-grained silty sand, well to moderately well sorted, with little clay, and loose. Coloration varies between gray, orange, and brown. Occasional laminae of brown to black silt, as well as small shell fragments, are often present.

In Zone F, Qs deposits occur as thin lenticular bodies ranging from 2.5-feet thick at 60701D to four-feet thick at GDE08D. Depth of Qs sediments in Zone F ranges from five-ft bgs at 60706D to 35-ft bgs at GDE08D, as illustrated in Figures 2-2 and 2-3. Two Shelby tube samples of Qs were collected at Zone F. From Table 2.2, the Qs deposits exhibit an average grain-size distribution of 73% sand, 5% silt, and 21% clay with an average porosity of 38%.

2.2.3.3 Soil

Due to extensive surface soil disturbance at NAVBASE during its operational history, approximately the upper five-feet of the subsurface are typically a mixture of artificial fill and native sediments. However, the extent of fill placement varies throughout NAVBASE. Areas of extensive excavations or areas where native soils may have been unsuitable for foundation support may have undergone more extensive fill placement. The fill includes materials dredged from the Cooper River and Shipyard Creek, which are an unsorted mixture of sands, silts, and clays.

Two Shelby tube samples were collected from fill material encountered in borings 613005 and 619001. From Table 2.2, the average grain-size distribution of these samples was 80% sand, 11% silt, and 9% clay. A porosity value of 43% was measured from four- to six-ft bgs at boring 619001.

2.3 Zone F Hydrogeology

Hydrogeological information was obtained from slug test analyses and water-level measurements conducted during the Zone F RFI. Grain-size analysis, porosity data, and estimates of vertical permeability (K_v), were determined from laboratory analysis of Zone F Shelby tube samples collected during the RFI.

2.3.1 Surficial Aquifer

The surficial aquifer extends from the water table to the top of the Ashley Formation, which serves as a regional confining unit. Aquifer thickness varies throughout Zone F, based upon water table, the elevation, and elevation of the top of the Ashley Formation (Figure 2-4). Based on deep well borings in Zone F, the surficial aquifer ranges from 21- to 35-feet thick. Figure 2-2, cross section A-A', exhibits the variable thickness and lithology of the surficial aquifer.

In the northwest portion of Zone F, the boring log for GDF01D shows that the surficial aquifer consists of approximately two-feet of basal Tu, overlain by approximately 15-feet of Qc. The Qc is overlain by five-feet of fill to ground surface. The aquifer overlying Qc in this region is probably unconfined, while Tu at the bottom of the aquifer is confined or semiconfined at location GDF01D by the 15-feet of Qc above it.

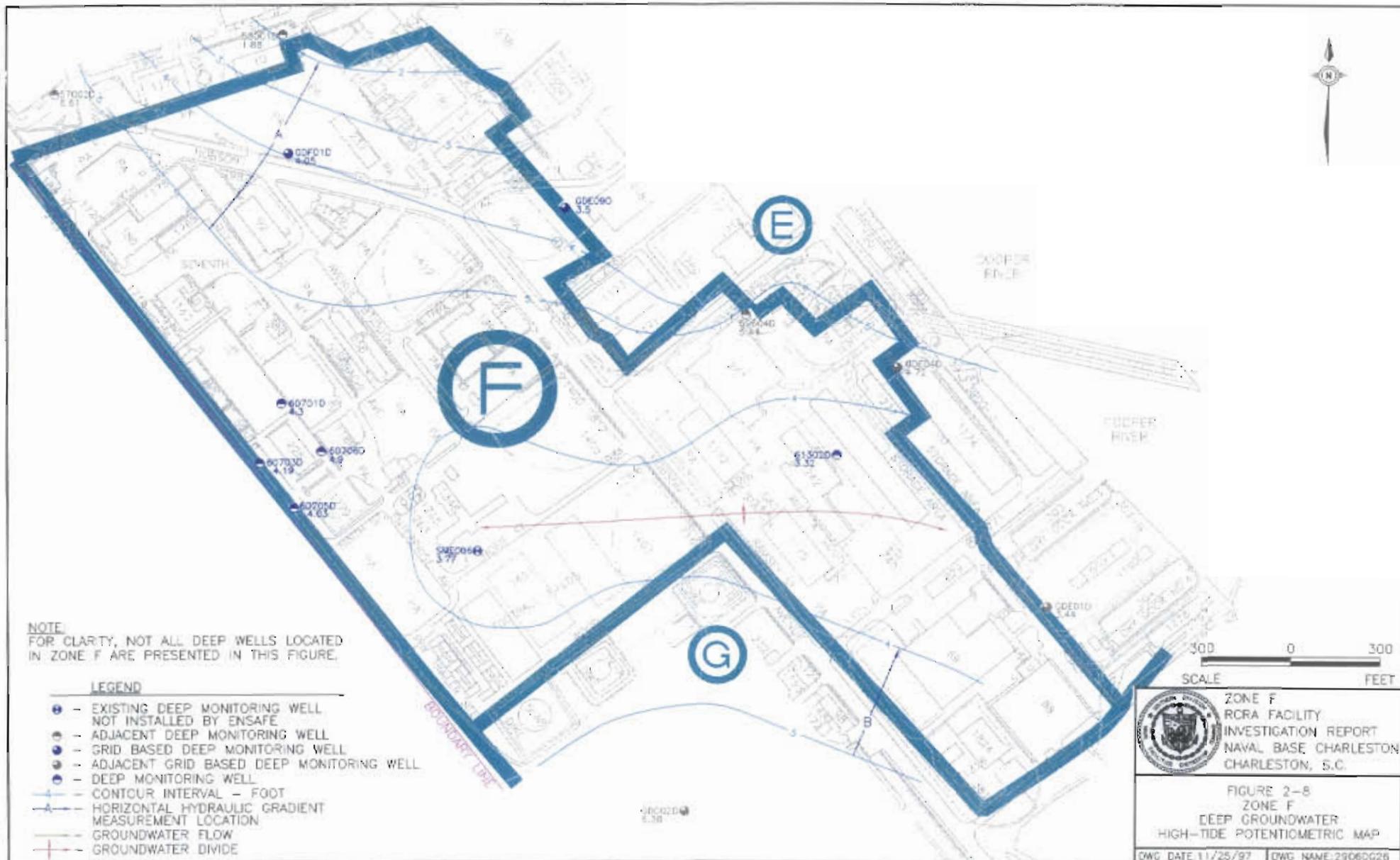
Aquifer characteristics differ somewhat in the southeastern portion of Zone F, where deep boring 61302D is located. In this region, the aquifer is composed of 35-feet of Qm, which is overlain by five-feet of gravel and sand fill. The 35-foot thick sequence of marsh clay is probably unconfined to semiconfined in the upper portions and semiconfined to confined in the lower portions.

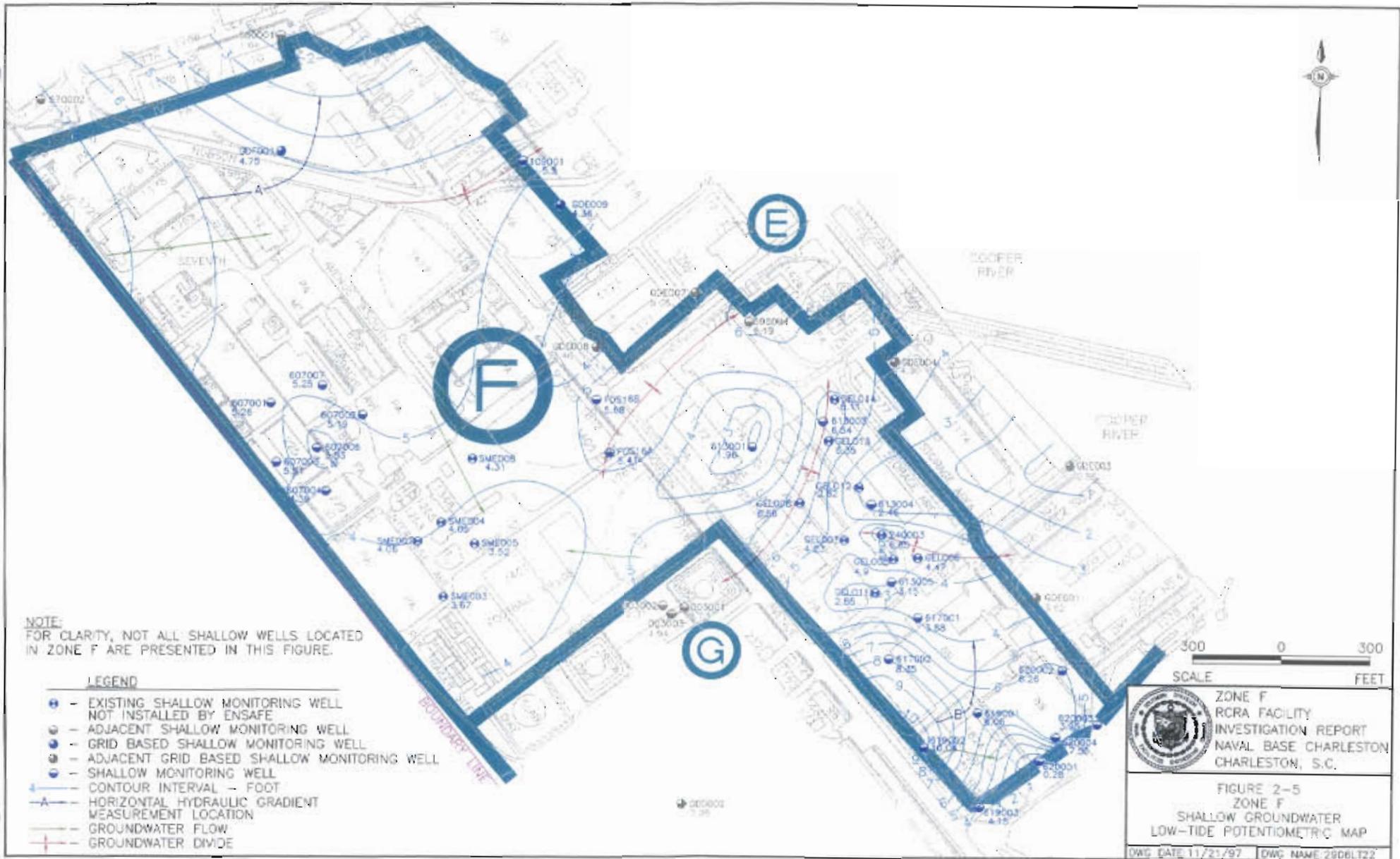
2.3.2 Groundwater Flow Direction

Water levels in the shallow and deep wells in Zone F and selected wells from surrounding zones were measured during low and high tides on April 29, 1997. Water level data were recorded by well depth and tidal stage.

Shallow Wells

Figures 2-5 and 2-6 depict groundwater elevation contours in selected shallow wells at low and high tide, respectively. These figures represent the potentiometric surface of the surficial aquifer. Little change in groundwater flow patterns occur between low and high tide events. Groundwater flow in the surficial aquifer is highly variable in gradient and direction. Both maps indicate the presence of a narrow groundwater divide which trends east to northeast from the tank farm area in Zone G. Groundwater flow south of this divide is generally in an easterly direction toward the Cooper River. Three groundwater depressions north of this divide are associated with wells 613001, SME005, and 607006. Groundwater movement north of Ninth Street is from the south and west toward the north across Hobson Avenue.





Deep Wells

Figures 2-7 and 2-8 are contour maps of groundwater elevation data from the deep wells during low and high tide, respectively. These figures depict the potentiometric surface of the water-bearing unit at the base of the surficial aquifer. Generally groundwater movement is from west to east towards the Cooper River. However, there are some changes in gradient and direction of groundwater flow from low to high tide events. A groundwater high observed at 60706D during low tide was diminished at high tide. A west-to-east trending groundwater divide not present during low tide developed during the high-tide event.

2.3.3 Horizontal Hydraulic Gradient

The horizontal hydraulic gradient (i) measures the difference in hydraulic head (Δh) (i.e., change in groundwater elevation) between two points divided by the distance between the points (Δx). It is a unitless value used to quantitatively determine the magnitude of potential groundwater flow. Groundwater elevation contour maps for shallow wells (Figures 2-5 and 2-6) and deep wells (Figures 2-7 and 2-8) were examined to find representative ranges in horizontal hydraulic gradient at both low and high tide for the shallow and deep wells. Locations used to determine these gradients were taken along groundwater flow lines labeled A or B and are depicted on Figures 2-5, 2-6, 2-7, and 2-8. The calculated hydraulic gradients for Zone F are presented in Table 2.3.

2.3.4 Horizontal Groundwater Conductivity

Slug test data were used to evaluate the horizontal hydraulic conductivity of an aquifer at a single point. The resulting horizontal hydraulic conductivity (K_h) values from these slug tests are presented in Table 2.4 for shallow, intermediate, and deep wells. Because hydraulic conductivity data are lognormally distributed, the geometric mean is the best measure of central tendency. Therefore, the representative hydraulic conductivity for each well is presented as the geometric mean of the falling and rising head values.

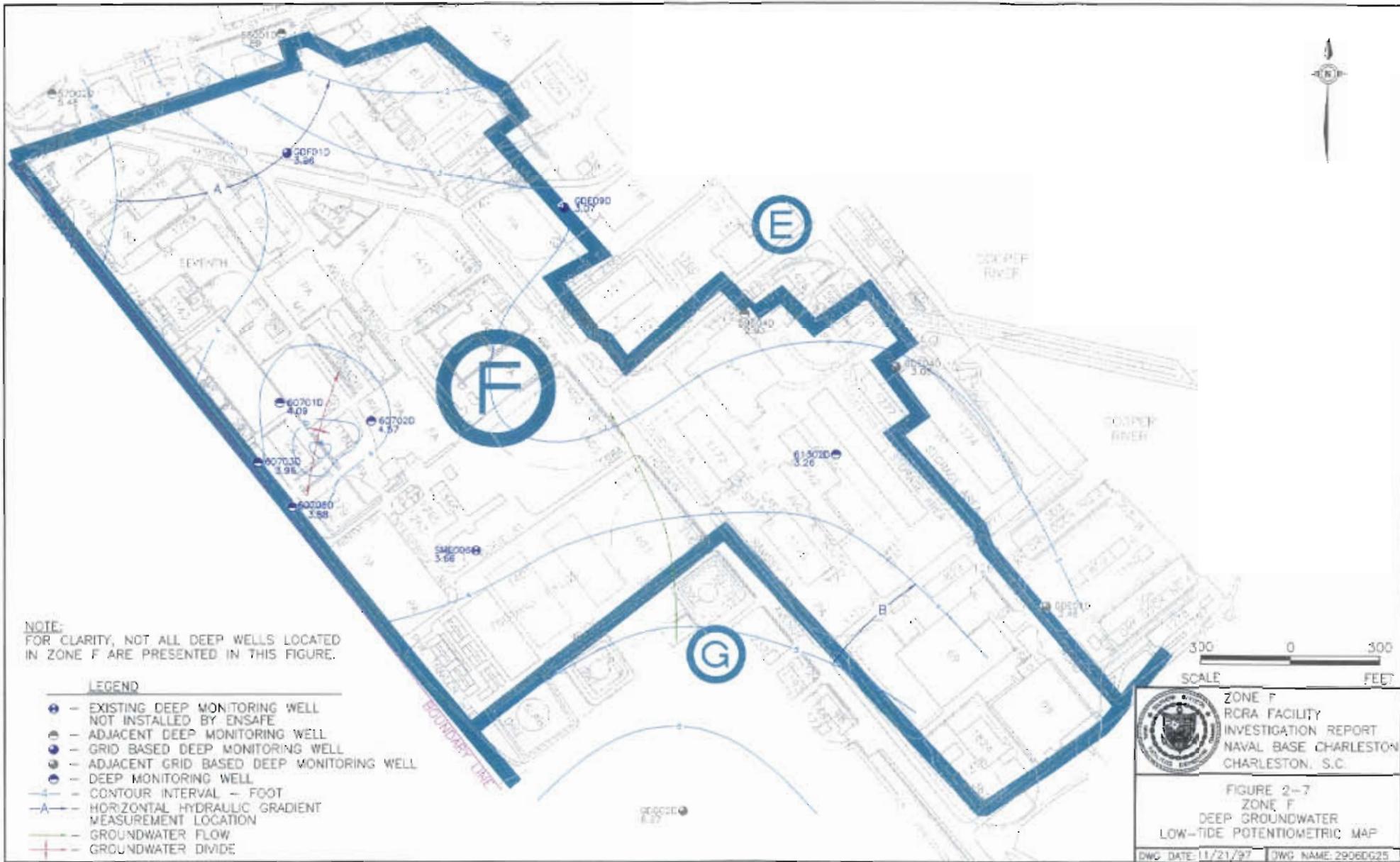


Table 2.3
Zone F
Horizontal Hydraulic Gradients

Measurement Points	Tide	Δh (ft)	Δx (ft)	i
Shallow Groundwater				
A B	Low	5	650	4.6E-03
A B	High	3 5	830 420	3.6E-03 1.19E-02
Deep Groundwater				
A B	Low	3 1	900 380	3.3E-03 2.6E-03
A B	High	3 1	660 390	4.5E-03 2.6E-03

Notes:

Water level measurements from 4/29/97 used for calculations.

- Δh (ft) = Hydraulic head difference
- Δx (ft) = Distance between points
- i = Horizontal hydraulic gradient

Table 2.4
Zone F
Horizontal Hydraulic Conductivities

Well	Falling Head Hydraulic Conductivity ^a	Rising Head Hydraulic Conductivity ^a	Geometric Mean ^b
Shallow Wells			
GDF001	6.0	8.4	7.1
607001	1.74	2.0	1.8
607002	0.42	0.62	0.51
607004	0.191	0.197	0.194
613001	0.83	1.3	1.0
613004	0.38	0.27	0.32
619002	0.11	0.11	0.11
619003	0.28	0.32	0.30
620002	0.42	0.41	0.41
GEL005	0.42	0.41	0.41

Table 2.4
Zone F
Horizontal Hydraulic Conductivities

Well	Falling Head Hydraulic Conductivity ^a	Rising Head Hydraulic Conductivity ^a	Geometric Mean ^b
GEL007	0.31	0.21	0.26
SME004	8.7E-02	9.2E-02	8.9E-02
Intermediate Wells			
60701F	1.30	1.20	1.25
60702I	0.37	0.55	0.45
60704I	0.70	0.65	0.68
Deep Wells			
GDF01D	2.7	1.7	2.14
60701D	2.7E-02	NM	2.7E-02
60702D	2.3E-02	NM	2.3E-02
60704D	8.1E-03	NM	8.1E-03
61302D	0.120	0.120	0.120

Notes:

- a = Slug test results in ft/day.
- b = Calculated using the falling and rising head values.
- NM = Not measured, well recovery was too slow to evaluate conductivity.

Data from the slug tests were compiled using the computer program AQTESOLV (Aquifer Test Solver) by the Geraghty and Miller Modeling Group (1989). AQTESOLV has several widely published and accepted analytical solutions for many different kinds of aquifer tests. Rising and falling head slug test data from shallow wells were plotted using an unconfined aquifer solution.

For this solution, time (elapsed) versus displacement (change in water level) was plotted on semi-logarithmic graph paper. Hydraulic conductivity (K) was computed by the program using an equation developed by Bouwer and Rice (1976) for unconfined aquifers. Slug test results and program printouts are included in Appendix C.

Data from deep wells were analyzed using a confined solution by Cooper, Bredehoeft, and Papadopulos (1967). This solution uses time (elapsed) plotted against changes in head on semi-logarithmic graph paper to calculate aquifer transmissivity (T) and storativity (S). Again, results and printouts are included in Appendix C.

The Bower and Rice and Cooper et al. methods assume the following conditions:

- A homogeneous, isotropic aquifer of uniform thickness
- Horizontal water table/potentiometric surface prior to test
- Instantaneous change in head
- Negligible well losses
- Well storage is not negligible and is accounted for
- Fully or partially penetrating wells
- Steady state flow

A line of best fit was matched to the plotted data that was thought to best represent the "true" aquifer response. Given all the above qualifiers, hydraulic conductivity data from these tests are presented only to two significant figures.

Transmissivities from the Cooper et al. confined solution were converted to hydraulic conductivity values with the following relationship:

$$K = \frac{T}{b}$$

where:

- K** = hydraulic conductivity
- T** = transmissivity
- b** = aquifer thickness

The aquifer thickness (b) at each tested well was obtained from the well boring log by summing the thicknesses of suspected water producing layers that intersect the well filterpack.

Figure 2-9 presents the aerial distribution of hydraulic conductivity (shallow wells/deep wells) in the surficial aquifer using values from Table 2.4. Hydraulic conductivities in the shallow portions of the aquifer are greater than those of the deep at every location. Moreover, the geometric mean hydraulic conductivity for all the shallow wells in Table 2.4 is 0.44 feet per day (ft/day), more than six times greater than the mean for the deep wells (6.6E-02 ft/day). Because intermediate wells are only associated with AOC 607, comparisons of conductivity are presented in Section 10.4.1.

2.3.5 Horizontal Groundwater Velocity

Horizontal groundwater velocity was calculated using the following formula:

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

where:

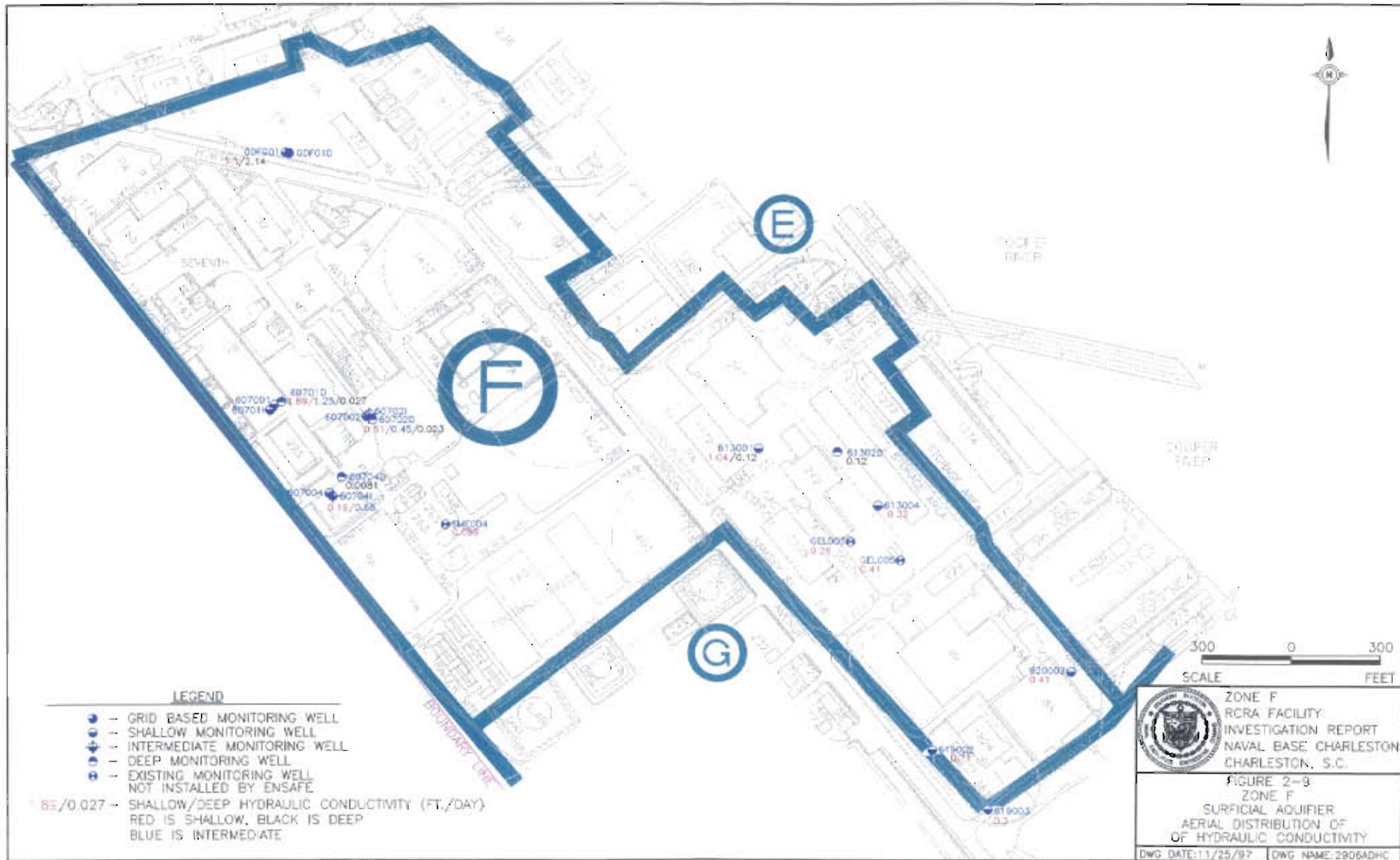
V = horizontal groundwater velocity

K = hydraulic conductivity

i = horizontal hydraulic gradient

n_e = effective porosity

Horizontal hydraulic velocities were calculated for the horizontal gradients presented in Table 2.3. The geometric means of K for shallow wells 607001, 613001, 613004, and 620002, which were completed in Quaternary sand, were used to calculate velocities. The K value for GFD01D was used as the representational value for deep well Qs hydraulic conductivity.



A laboratory measured porosity value of 35.7% was selected for shallow well groundwater velocity calculations because it was the lowest porosity of the shallow well Zone F Shelby tube sand samples. This Shelby tube sample was taken from a depth of seven- to nine-ft bgs in 620002. Similarly, a porosity value of 44.4% for the 18- to 20-foot deep sample collected at 60704D was selected for deep well groundwater velocity calculations. These porosity values were used to provide the most conservative (quickest) velocities. Table 2.5 presents the calculated groundwater flow velocities.

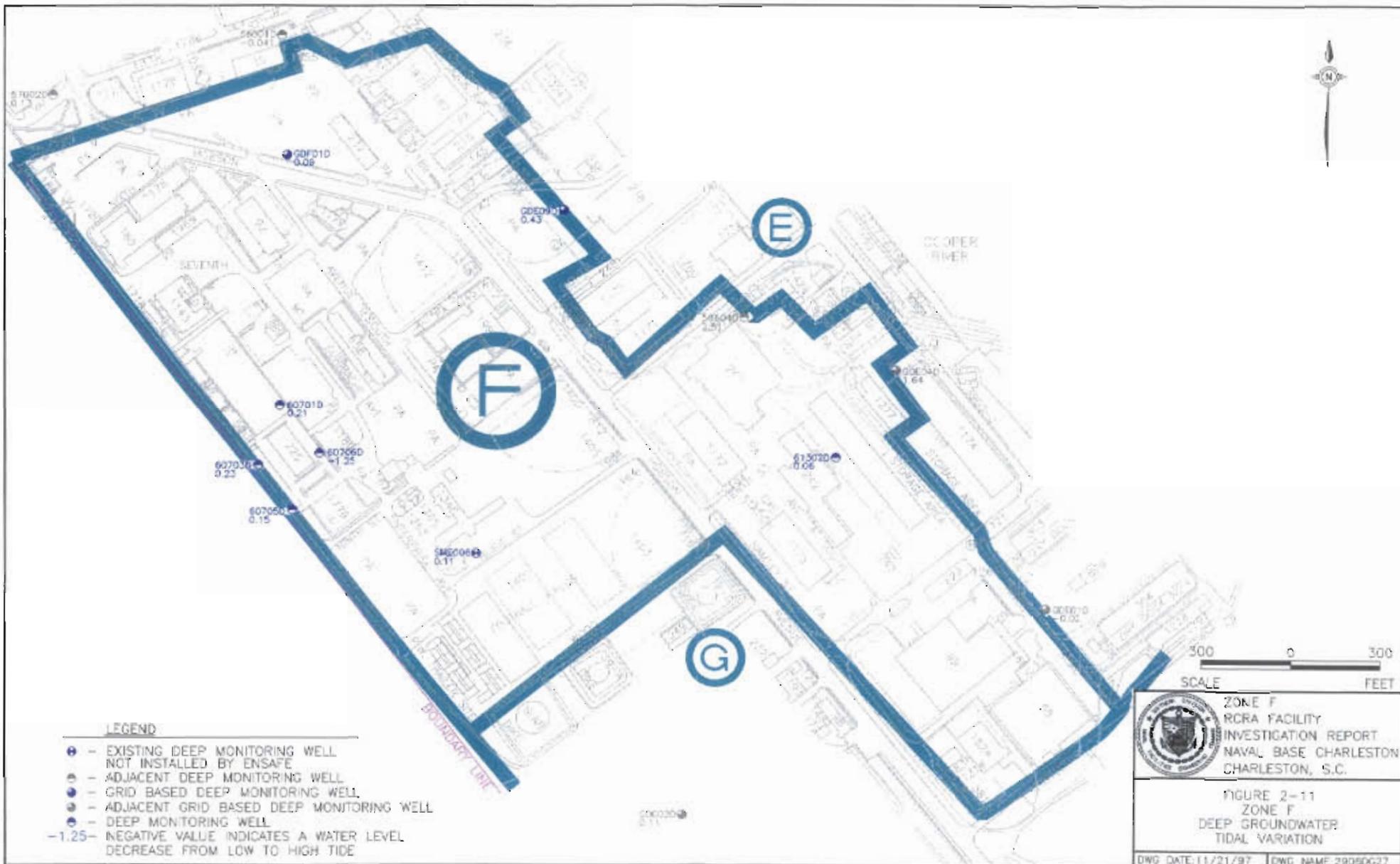
Table 2.5
Zone F
Groundwater Velocity Results

Aquifer Location	Tide	n_e	K (ft/day)	Gradient (i)	Estimated Velocity (ft/day)
Shallow Groundwater					
A	High	0.357	0.51	3.6E-03	5.1E-03
B				1.19E-02	1.69E-02
Deep Groundwater					
A	High	0.444	2.1	4.5E-03	2.13E-02
B				2.6E-03	1.23E-02

Notes:
 ft/day = Feet per day
 i = Horizontal hydraulic gradient
 n_e = Effective porosity

2.3.6 Tidal Influence

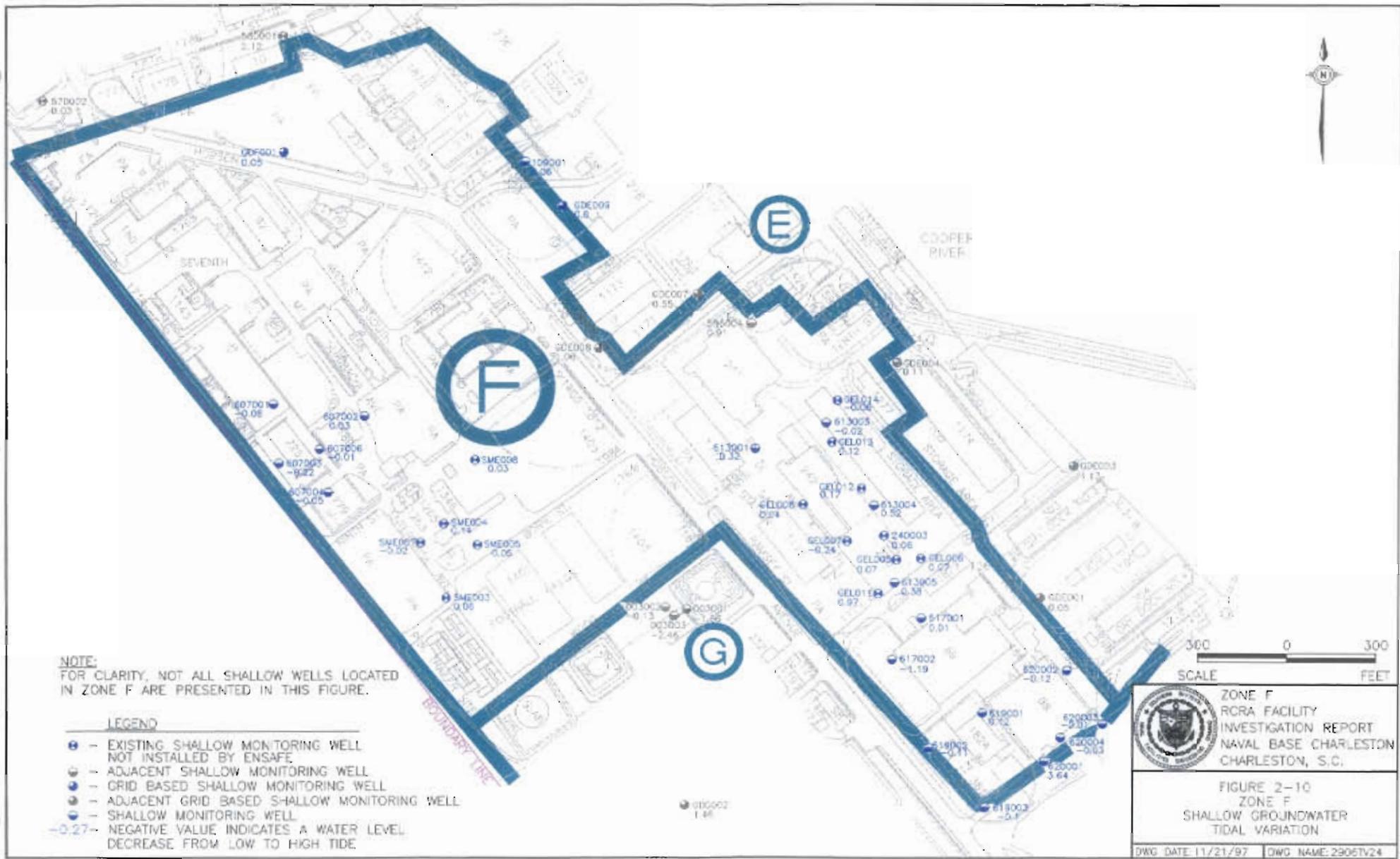
The numerical difference in groundwater elevation from low to high tide for shallow wells and deep wells are shown on Figures 2-10 and 2-11, respectively. Static water level elevations for high and low tide are presented in Table 2.1 Wells with larger tidal difference values are more highly influenced by tidal fluctuations than wells with lower values. A negative tidal variation



LEGEND

- ⊕ - EXISTING DEEP MONITORING WELL NOT INSTALLED BY ENSAFE
- ⊙ - ADJACENT DEEP MONITORING WELL
- ⊙ - GRID BASED DEEP MONITORING WELL
- ⊙ - ADJACENT GRID BASED DEEP MONITORING WELL
- ⊙ - DEEP MONITORING WELL
- 1.25- NEGATIVE VALUE INDICATES A WATER LEVEL DECREASE FROM LOW TO HIGH TIDE

	ZONE F RCRA FACILITY INVESTIGATION REPORT NAVAL BASE CHARLESTON CHARLESTON, S.C.
	FIGURE 2-11 ZONE F DEEP GROUNDWATER TIDAL VARIATION
DWG DATE: 11/21/97 DWG NAME: 29050627	



value indicates a decrease in water level elevation from low to high tide. Conversely, a positive tidal variation indicates an increase in water level from low to high tide. Wells with low or negative tidal differences may have higher tidal lag times than wells with high values. High lag times often occur in wells that have limited hydrologic connection with or are at great distances from tidal water bodies (Cooper River).

Shallow Wells

A comparison of the high and low tide potentiometric maps indicates that no significant change in the overall groundwater flow regime occurs in response to tidal changes in the shallow surficial aquifer. In general, contours at low tide (Figure 2-5) are more closely spaced than those at high tide (Figure 2-6). This indicates that horizontal hydraulic gradients decrease slightly from low to high tide. Contours presented on Figure 2-10 indicate that decreases in elevation from low to high tide occurred in several areas, and are less than one foot in magnitude. The major areas of elevation decline are associated with AOC 607 and in the south central portion of the zone where it abuts Zone G. Areas with a large increase in groundwater elevation are located at AOC 620 and in the area between GDE008 and AOC 596 in adjacent Zone E.

Deep Wells

A comparison of Figures 2-7 and 2-8 indicates that groundwater elevations generally increase slightly throughout most of the zone during high tide. An exception to this is the groundwater high at 60706D during low tide which, although present during the high tide event, is reduced in magnitude by 1.25 feet. A slight northeast trending groundwater divide appears across the middle portion of the zone during high tide. This divide temporarily modifies groundwater flow direction in this area.

2.3.7 Vertical Hydraulic Gradient

Water levels were measured in several Zone F and adjacent zone well pairs on April 29, 1997. Table 2.6 presents the calculated vertical hydraulic gradients between shallow and deep well pairs in Zone F and adjacent zone wells during low and high tide events. The vertical gradients were calculated by dividing the difference between water levels at each well pair by the vertical distance between the bottom of each well screen in the pair. Positive values indicate downward vertical gradients whereas negative values indicate an upward vertical gradient.

Vertical gradients from wells are graphically presented in Figure 2-12. This figure shows gradients measured between shallow and deep wells at low tide (red) and high tide (blue).

Vertical gradients were typically positive across Zone F, indicating a vertical flow potential from the upper portions of the surficial aquifer to the lower portions. However, only location 607006/06D demonstrated negative vertical gradients at both high and low tide. When low versus high tide values are compared, gradients at most locations were greater during low tide.

2.3.8 Lithologic Unit Summary

The following sections discuss the hydrologic properties and role of the predominant lithologic units in the groundwater flow regime at Zone F.

2.3.8.1 Tertiary Age Units

Ashley Formation

Ta is important because of its role as a confining unit between the lower members of the Cooper Group and the Eocene-age Santee Limestone and the overlying water-bearing strata of the Quaternary sediments (Park, 1985). Lithologic cross sections presented by Weems and Lemon (1993) show the Ta to have a laterally consistent overall thickness. Samples collected from this unit at NAVBASE have shown high clay and silt contents and varying sand contents, depending

3.0 FIELD INVESTIGATION

The following section lists the field investigation objectives and describes the technical sampling methods, procedures, and protocols implemented during Zone F data collection. Fieldwork was conducted in accordance with the approved final CSAP and the United States Environmental Protection Agency (USEPA) Region IV Environmental Services Division, *Standard Operating Procedures and Quality Assurance Manual* (ESDSOPQAM) (USEPA, 1996a). Any deviations from the approved work plans, such as the number of samples collected, modified locations, or procedures, etc., were documented in the field logbooks and are detailed in Section 10, Site-Specific Evaluations.

3.1 Investigation Objectives

The Zone F sampling strategy, as detailed in the approved final RFI work plan, was designed to collect sufficient environmental media data to:

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

3.2 Sampling Procedures, Protocols, and Analyses

The media sampled during the Zone F field investigation were soil, groundwater, and sediment. Sampling was conducted per the approved final RFI work plan. The media collected and the analyses varied between sites. The objective was for site-specific sampling and analyses to provide sufficient data to meet the stated investigation objectives.

Analytical Protocols

All screening and discrete site samples were analyzed per USEPA SW-846 methods at data quality objective (DQO) Level III unless otherwise noted. Analytical methods for soil, sediment, and groundwater samples were:

• Volatile organic compounds (VOCs)	USEPA Method 8260	5
• Semivolatile organic compounds (SVOCs)	USEPA Method 8270	6
• Pesticides/Polychlorinated Biphenyls (PCBs)	USEPA Method 8080	7
• Cyanide	USEPA Method 9010	8
• Metals/Mercury	USEPA Method 6010/7470	9
• Herbicides	USEPA Method 8150	10
• Organophosphorous (OP) pesticides	USEPA Method 8140	11
• pH	USEPA Method 9045	12
• Total Dissolved Solids (TDS)	USEPA Method 160.1	13
• Chlorides	USEPA Method 325.1	14
• Sulfates	USEPA Method 375.1	15

Approximately 10% of the samples collected for each medium at Zone F were duplicated and submitted for Appendix IX analytical parameters at DQO Level IV. These additional samples were collected to fulfill quality assurance/quality control (QA/QC) standards while cost-effectively analyzing additional parameters. Besides analyses for VOC, SVOC, pesticide, OP pesticide, PCB, metal, and cyanide constituents, Appendix IX samples included:

• Hexavalent chromium	USEPA Method 7196	21
• Dioxins/Dibenzofurans	USEPA Method 8290	22
• Herbicides	USEPA Method 8150	23

To support corrective measures at NAVBASE, selected soil samples in Zone F were analyzed for the following engineering parameters: cation exchange capacity (CEC), total organic carbon (TOC), and pH. Additionally, thin-walled Shelby tube soil samples were collected for physical parameters, per the approved final RFI work plan, and as described in Section 4.6.2 of the approved final CSAP. Analysis of Shelby tube soil samples varied based on type of soil, recovery of tube, location, and depth of sample. Shelby tube results were detailed in Section 2.

3.2.1 Sample Identification

All samples collected during this investigation were identified using the 10-character scheme outlined in Section 11.4 of the approved final CSAP. This scheme identifies the samples by site, sample matrix, location, and sample depth. The first three characters identify the site where the sample was collected. The fourth and fifth characters identify the medium or sample QC code. Characters six through eight designate sampling location: boring or well number, sampling station, trench number, existing well identification, and others. The ninth and tenth characters represent sample-specific identification such as depth to the nearest foot, depth interval, sampling event for water samples, and others.

The following codes were used to identify specific media for sample identification during the Zone F RFI: (1) soil boring samples – SB; (2) groundwater samples – GW (GW is not used in well location identifiers on maps and in tables in this report); (3) sediment samples – M; (4) Direct Push Technology (DPT) soil samples – SP; (5) DPT groundwater samples – GP.

3.2.2 Soil Sampling

Section 4 of the approved final CSAP describes Zone F RFI soil sampling procedures and activities. The following subsections summarize these procedures.

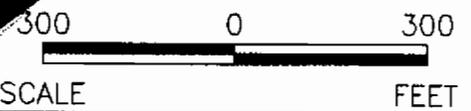
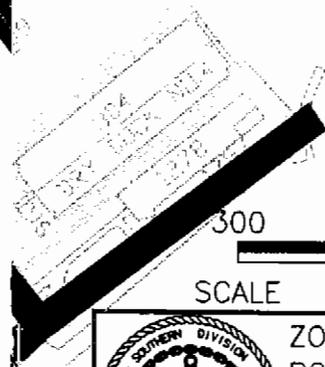
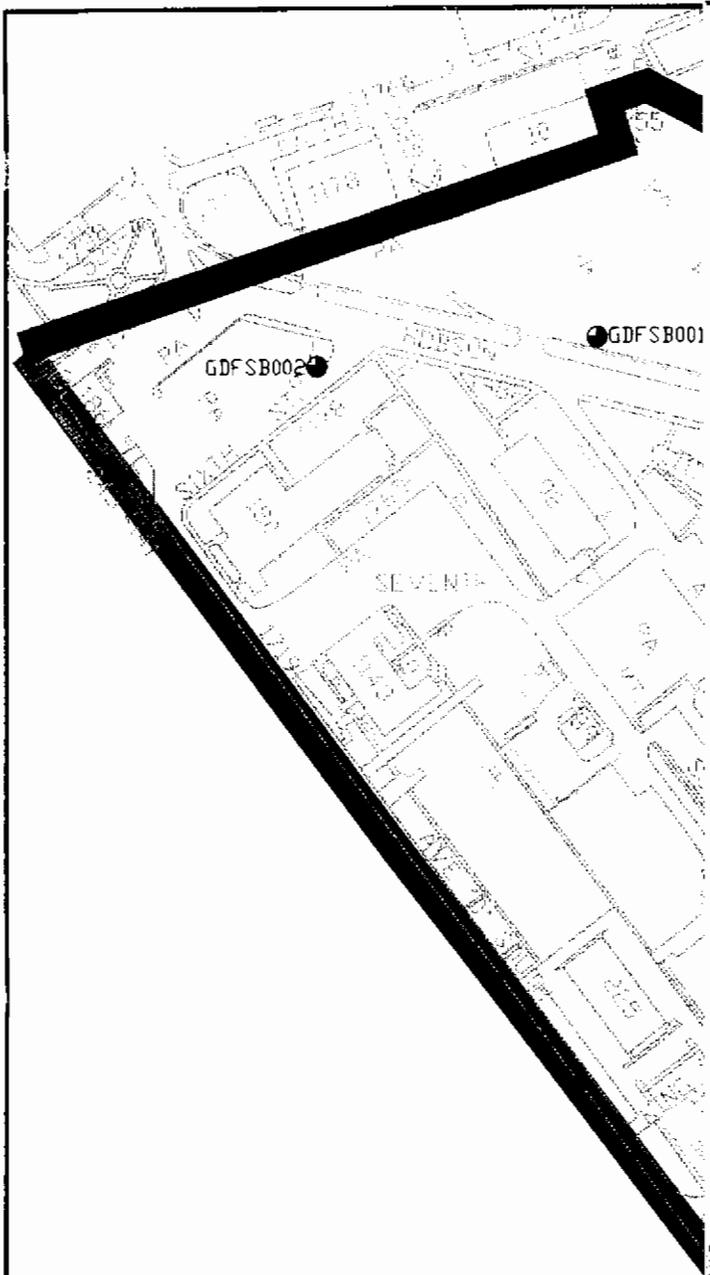
In accordance with Section 3 of the final RFI work plan, a systematic grid-based sampling approach was selected to more fully characterize background conditions, and supplement the biased sampling locations. Although six grid-based locations were proposed in the work plan, one was located along the boundary with Zone E, near a Zone E grid-based soil sample location (GDESB009). This proposed sample was not collected because the data from the Zone E grid-based sample was available to help characterize background conditions. A total of five grid-based soil borings were advanced within Zone F, as depicted on Figure 3-1. Upper and lower interval samples were collected as described in Section 3.2.2.2 of this report. Grid-based Zone F soil samples were analyzed for metals, cyanide, pesticides/PCBs, SVOCs, and VOCs, using the analytical methodologies described in Section 3.2. One of the soil samples was analyzed for the Appendix IX site parameters identified in the approved final RFI work plan

3.2.2.1 Soil Sample Locations

Soil samples were collected as proposed in the approved final RFI work plan; the locations were based on the investigation strategy outlined in Section 1.2 of that document. Each AOC and SWMU primary sampling pattern is presented in Sections 2.1 through 2.10 of the approved final RFI work plan. Some proposed sample locations were modified slightly due to utility locations or because they were inaccessible. Additional samples were required to adequately characterize contaminant distribution at some sites. After the analytical data for the initial round of soil sampling were interpreted, a second sampling round was proposed for some sites to further delineate contaminants identified during the initial sampling. Typically, additional sample locations were justified due to relatively high contaminant concentrations identified on the previous sampling pattern's perimeter. Section 10 figures detail the site-specific soil sample locations.

3.2.2.2 Soil Sample Collection

Composite soil samples were generally collected for laboratory analysis from zero- to one-foot bgs and from three- to five-feet bgs. The zero- to one-foot bgs interval is referred to in this report as



LEGEND
 ● - GRID BASED SOIL SAMPLE


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

FIGURE 3-1
 ZONE F
 GRID-BASED SOIL SAMPLE
 LOCATION MAP

DWG DATE: 11/14/97 DWG NAME: 29CZFSBL

the first or upper-interval sample. At soil sample locations overlain by pavement, the upper interval was collected from the base of the pavement to one-foot below the base of the pavement. The three- to five-foot bgs interval is referred to as the second or lower-interval sample. No other intervals were sampled due to the relatively shallow depth to groundwater in Zone F, typically from four- to six-foot bgs. No saturated soil samples were retained for laboratory analysis.

Stainless-steel hand augers were used to collect soil samples, as detailed in Section 4.5 of the approved final CSAP. At sodded locations, the sod (generally less than two-inches thick) overlying the soil sample at the upper interval was removed before augering to one-foot bgs. A coring machine was used to gain access to soil covered by concrete and/or asphalt pavement. At AOC 607 and AOCs 613/615 and SWMU 175, soil samples were collected using DPT. All DPT soil sampling was performed in accordance with Section 4.3.3 of the approved final CSAP.

3.2.2.3 Soil Sample Preparation, Packaging, and Shipment

Section 3.2.2.3 of the *Draft Zone A RFI Report* details soil sample preparation, packaging, and shipment as conducted for the Zone F RFI.

3.2.2.4 Soil Sample Analysis

Section 3.2.2.4 of the *Draft Zone A RFI Report* details soil sample analysis as performed for the Zone F RFI. Analytical protocols specific to the Zone F RFI are described in Section 3.2 of this report.

3.2.3 Monitoring Well Installation and Development

Monitoring wells were installed and sampled at Zone F per the approved final RFI work plan. Following analysis and interpretation of initial groundwater analytical data, additional wells and/or subsequent sampling were required at some sites to determine the extent of groundwater contamination (round two). Typically, these additional samples were justified due to relatively

high concentrations of contaminants on the perimeter of the previous sample pattern. Section 10
figures detail the site-specific groundwater sample locations.

Additionally, per the approved final RFI work plan, a systematic grid-based groundwater sampling
approach was selected to more fully characterize background conditions, and to supplement the
biased sampling locations. For Zone F, a shallow/deep grid well pair (GDF001/GDF01D) was
installed along Hobson Avenue in the northern portion of Zone F. These wells were supplemented
by a Zone E grid well pair (GDE009/GDE09D) near SWMU 109. Grid-based groundwater
samples at Zone F were analyzed for metals, cyanide, pesticides /PCBs, SVOCs, VOCs, sulfates,
chlorides, and TDS as described in Section 3.2, above. The Zone E grid wells used for the
Zone F investigation were sampled for the same constituents at an earlier date. Figure 3-2 shows
the grid-based groundwater sample locations for Zone F.

Section 5 of the approved final CSAP describes the methods used during monitoring well
installation. All monitoring wells were permitted by the SCDHEC, and installed according to
South Carolina Well Standards and Regulations (R.61-71.11). In general, all shallow and deep
monitoring wells were constructed of an appropriate length of two-inch inside diameter polyvinyl
chloride (PVC) riser pipe attached to a 10-foot section of 0.010-inch slotted PVC well screen. At
AOC 607, all shallow, intermediate, and deep monitoring wells were constructed with two-foot
long screens. The following subsections briefly describe Zone F site-specific methods. All
identification numbers for monitoring wells installed during the Zone F investigation consist of
six characters. The first three characters identify the site where the monitoring wells were
installed. Characters four through six identify the individual well number. For Zone F grid-based
monitoring wells, the first three characters are GDF. The grid-based well pair from Zone E uses
the characters GDE. Appendix A includes the lithologic boring logs and Zone F monitoring well
construction diagrams.

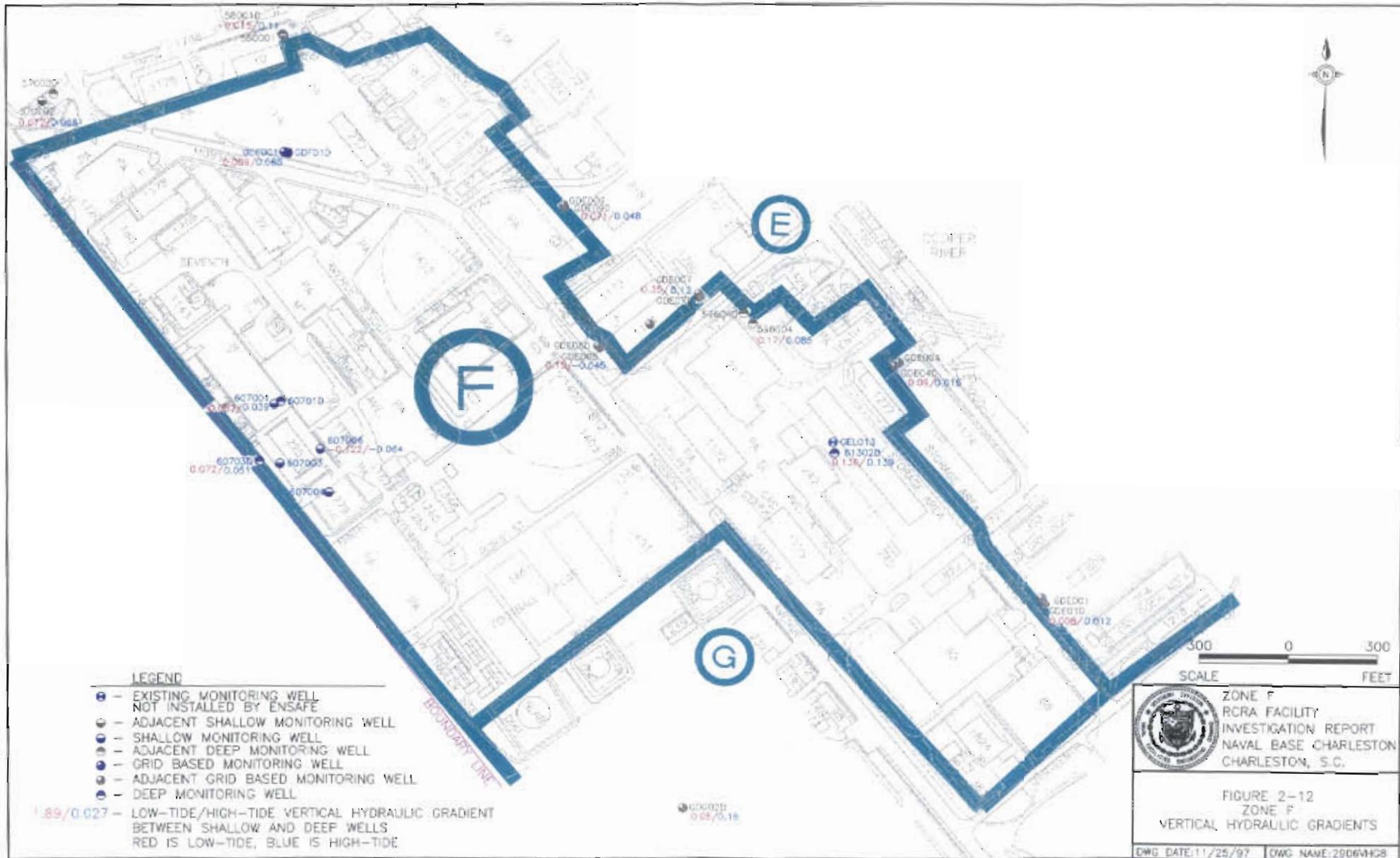


Table 2.6
Zone F
Vertical Hydraulic Gradients^a

Well Pair	Vertical Distance (ft)	Date	Low Tide		High Tide	
			Groundwater Elevation Difference (ft)	Vertical Hydraulic gradient	Groundwater Elevation Difference (ft)	Vertical Hydraulic gradient
GDE001/01D	22.3	4/29/97	0.79	3.9E-02	0.75	3.5E-02
607001/01D	22.3	4/29/97	1.17	5.2E-02	0.88	3.9E-02
607002/02D	22.3	4/29/97	0.62	2.7E-02	NM	NM
607003/03D	21.5	4/29/97	1.55	7.2E-02	1.1	5.1E-02
607004/04D	22.3	4/29/97	0.44	1.9E-02	NM	NM
607006/06D	21.4	4/29/97	-2.62	-0.122	-1.38	-6.4E-02
GEL013/61302D	22.7	4/29/97	3.09	0.136	3.15	0.139
NBCE570002/2D	22.4	4/29/97	1.62	7.2E-02	1.52	6.8E-02
NBCE580001/1D	17.1	4/29/97	-0.25	-1.5E-02	1.88	0.11
GDE009/9D	18.1	4/29/97	1.29	7.1E-02	0.86	4.8E-02
NBCE596004/4D	19.6	4/29/97	3.26	0.17	1.66	8.5E-02
NBCEGDE004/4D	20.0	4/29/97	1.82	9E-02	0.29	1.5E-02
NBCEGDE001/1D	19.4	4/29/97	0.16	8E-03	0.23	1.2E-02
GDG002/2D	13.5	4/29/97	0.81	6E-02	2.16	0.16

Notes:

NM = Not measured
a = Measured 4/29/97

greatly upon depth. One Shelby tube sample collected from the Ta in Zone F (60702D) exhibited a vertical permeability of 4.5E-06 centimeters per second (cm/sec) (1.3E-02 ft/day). According to Fetter (1988), sediments with vertical permeabilities of 1E-05 cm/sec (3E-02 ft/day) or less can be considered confining units.

Upper Tertiary Undifferentiated

As shown on Table 2.2, the K_v measured from Tu sediment samples collected in Zone F was $6.2E-05$ cm/sec ($1.76E-01$ ft/day), indicating that Tu deposits act as an aquitard to vertical migration. Slug test data from wells installed in Tu sediments had K_h values ranging from $8.1E-03$ ft/day at 60704D to $2.7E-02$ ft/day at 60701D. This data suggest that Tu sediments in Zone F are not effective groundwater transport media.

2.3.8.2 Quaternary Age Sediments

During the field investigation, Shelby tubes were collected from the Qc, Qm, and Qs units beneath Zone F. The results of laboratory vertical permeability testing are provided in Table 2.2. This section discusses the viability of these lithologic units as aquifers.

Quaternary Clay

Five Shelby tube samples from the Qc displayed a vertical hydraulic conductivity geometric mean of $3.5E-04$ ft/day. Based upon K_v values, Qc should be an effective barrier to vertical groundwater flow where it is present. If Qc sediments are interbedded with sand, Qc may act as a leaky confining unit if the sand interbeds are connected vertically. Qc sediments have typically low K_h values. These low K_h values suggest very limited potential for horizontal groundwater movement through these sediments. However, Qc sediments are often interbedded with thin sand units which may act as preferential flow paths for lateral groundwater movement.

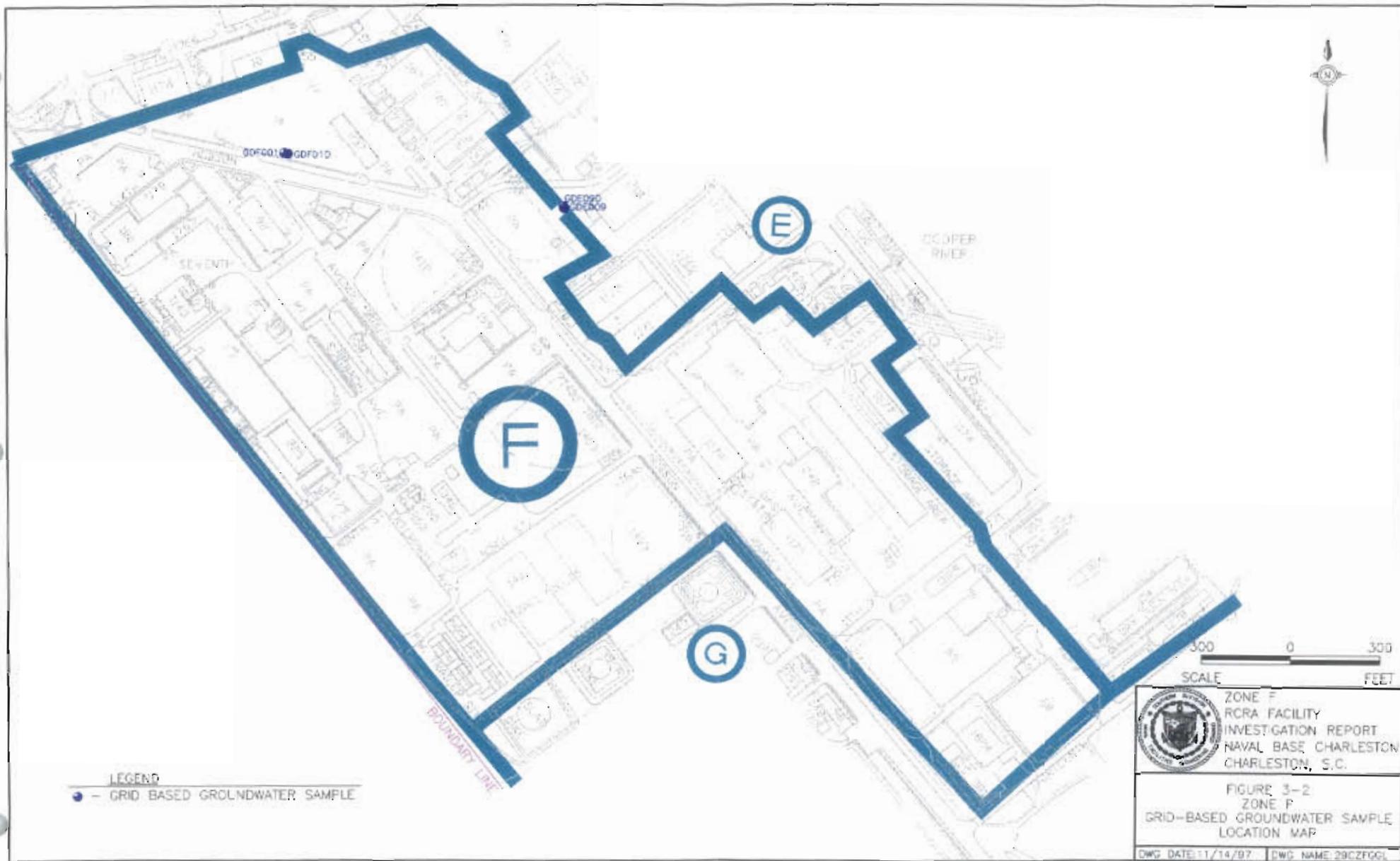
Quaternary Marsh Clay

Two Shelby tube samples of Qm from Zone F exhibited a vertical hydraulic conductivity geometric mean of $4.5E-04$ ft/day. Based on this data, Qm sediments would be expected to act as an aquitard to vertical groundwater migration. However, Qm may allow limited horizontal groundwater movement due to the increased conductivity of occasional thin interbedded sand units.

Quaternary Sand

Two Shelby tube samples of Qs from Zone F exhibited a K_v geometric mean of 1.8E-03 ft/day. The low K_v values observed are likely the result of thin horizontal clay laminae. Consequently, Qs deposits may act as a vertical aquitard in very limited local areas. However, this unit should not be considered an aquitard at all locations in Zone F due to the sporadic nature of the clay interbeds. This variability is dictated by the episodic erosion and deposition of Qs. Heterogeneities in Qs may provide intervals of preferential flow within the Qs unit and as interbeds within Qm and Qc. These intervals of preferential flow within the groundwater system may affect flow direction and velocity. Qs is primarily observed as a basal unit to Qm. However, Qs occurs elsewhere in the zone as thin lenticular beds at higher elevations where it is typically overlain by Qc deposits. K_h values for Qs are in the 0.28 ft/day range supporting their role as a local aquifer.

1
2
3
4
5
6
7
8
9
10
11
12



LEGEND
 ● - GRID-BASED GROUNDWATER SAMPLE

300 0 300
 SCALE FEET


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

FIGURE 3-2
 ZONE F
 GRID-BASED GROUNDWATER SAMPLE
 LOCATION MAP

DWG DATE: 11/14/97 DWG NAME: 29CZF001

3.2.3.1 Shallow Monitoring Well Installation

Shallow monitoring wells at Zone F were installed to facilitate groundwater sampling in the upper water-bearing zone of the shallow aquifer. These monitoring wells were installed using hollow-stem auger drilling method, in accordance with procedures set forth in Section 5 of the approved final CSAP. A total of 18 shallow monitoring wells were installed within the Zone F area during the first sampling phase of the field investigation. Five additional shallow monitoring wells were installed (AOC 607 — two wells, AOC 617 — one well, and AOC 620 — two wells) to further delineate affected groundwater identified during earlier groundwater sampling phases. The total depth of the shallow wells depended primarily on depth to groundwater, because these wells were installed to bracket the water table surface at each location. Because groundwater is encountered at approximately four- to six-foot bgs across Zone F, the average shallow monitoring well depth was approximately 12-foot bgs. Additionally, 15 previously installed shallow monitoring wells (AOC 609 — six wells, AOCs 613/615 and SWMU 175 — nine wells) were redeveloped and sampled during the first sampling phase at Zone F. Since previous data from Zone E grid well GDE009 were available, this well was not resampled.

3.2.3.2 Intermediate Monitoring Well Installation

Intermediate depth monitoring wells were used at AOC 607 only. In all four intermediate depth wells were installed during the field investigation's first sampling phase. One additional intermediate well was later installed to determine the vertical extent of groundwater contamination in the secure area. Hollow-stem auger drilling procedures were used to install most intermediate depth wells, as specified in Section 5 of the approved final CSAP. A surface casing and wet rotary drilling method were used to drill and install the intermediate well (60706I) in the source area at AOC 607. The average total depth of these wells was 22-foot bgs.

3.2.3.3 Deep Monitoring Well Installation

Deep monitoring wells were installed to sample groundwater at the shallow aquifer's base. In all seven deep wells (AOC 607 — five wells, AOCs 613/615 and SWMU 175 — one well, and GDF01D) were installed during the field investigation's first sampling phase. One additional deep well was installed at AOC 607 to further delineate the vertical extent of affected groundwater identified during earlier sampling phases. Additionally, one previously installed deep monitoring (SME006 at AOC 609) well was redeveloped and sampled during the first sampling phase at Zone F. Since previous data from Zone E grid well GDE09D were available, this well was not resampled. Per Section 5.5 of the approved final CSAP, rotasonic drilling methods were used to install the deep monitoring wells, except for the deep wells at AOC 607. The original five deep wells at AOC 607 were installed using hollow-stem auger methods because the locations had been screened earlier using DPT, thus eliminating the concern of cross contamination between water-bearing units. Monitoring well 60706D was drilled using wet rotary drilling methods and telescoping casing to preclude cross contamination while drilling in the source area. The average total depth of the deep wells at AOC 607 was 32.4-feet bgs. The other zone deep wells ranged in depth from 22-to 36-feet bgs.

3.2.3.4 Monitoring Well Protector Construction

Section 3.2.3.4 of the *Draft Zone A RFI Report* details the monitoring well protector construction process as constructed for the Zone F RFI. Monitoring wells were completed with either flush-mount, manhole type well protectors or above-grade protective casings, depending upon well location.

3.2.3.5 Monitoring Well Development

Section 3.2.3.5 of the *Draft Zone A RFI Report* details monitoring well development procedures as conducted for the Zone F RFI.

3.2.4 Groundwater Sampling

Section 3.2.4 of the *Draft Zone A RFI Report* details groundwater sampling as conducted for the Zone F RFI.

3.2.4.1 Groundwater Sampling Locations

At Zone F, installation of monitoring wells were based on the locations identified in the approved final RFI work plan. Some proposed locations were adjusted due to inaccessibility or obstructing utilities. Section 10 figures detail the site-specific soil sample locations.

3.2.4.2 Groundwater Sample Collection

Section 3.2.4.2 of the *Draft Zone A RFI Report* details the groundwater sample collection process as conducted for the Zone F RFI. At Zone F, peristaltic pump procedures were used as set forth in Section 6 of the approved final CSAP. In addition to the permanent monitoring wells, groundwater samples were collected for screening purposes using DPT at AOC 607, AOCs 613/615 and SWMU 175. DPT groundwater samples were collected in accordance with Section 6.1.3 of the approved final CSAP.

3.2.4.3 Groundwater Sample Preparation, Packaging, and Shipment

Section 3.2.4.3 of the *Draft Zone A RFI Report* details groundwater sample preparation, packaging, and shipment as performed for the Zone F RFI.

3.2.4.4 Groundwater Sample Analysis

Section 3.2.4.4 of the *Draft Zone A RFI Report* details groundwater sample analysis as conducted for the Zone F RFI. Analytical protocols specific to the Zone F RFI are described in Section 3.2 of this report.

3.2.5 Sediment Sampling

Section 7 of the approved final CSAP describes the procedures used for sediment sample collection at Zone F.

3.2.5.1 Sediment Sample Locations

The investigation strategy proposed in the approved final RFI work plan included the collection of sediment samples from four site groupings in Zone F (AOC 607, AOCs 613/615 and SWMU 175, SWMU 4 and AOC 619, and SWMU 109). The purpose was to determine the impact of site contaminants on the storm sewer system adjacent these sites. A total of 13 sediment samples from these sites were called for in the approved final RFI work plan. Because four storm sewer drop basins proposed for sampling at these sites were washed clean of sediments, only nine sediment samples were actually collected. Section 10 figures detail site-specific sediment sample locations.

3.2.5.2 Sediment Sample Collection

At Zone F, sediment samples were collected for laboratory analysis from zero- to six-inches bgs using the scoop sampling method outlined in Section 7.2.3 of the approved final CSAP.

3.2.5.3 Sediment Sample Preparation, Packaging, and Shipment

Guidelines in Section 11 of the approved final CSAP were followed for the preparation, packaging, and shipment of sediment samples collected during the Zone F RFI.

3.2.5.4 Sediment Sample Analysis

Sediment samples were analyzed per USEPA SW-846 at DQO Level III unless otherwise noted. Analytical protocols specific to the Zone F RFI are described in Section 3.2 of this report.

3.2.6 DPT Screening Surveys

The approved final RFI work plan proposed DPT screening surveys at two site groupings within Zone F (AOC 607 and AOCs 613/615 and SWMU 175). These surveys were conducted to identify the extent that soil and shallow groundwater may have been impacted. DPT screening results were used to optimize the discrete soil and groundwater sampling locations proposed in the approved final RFI work plan for these sites. Samples of unsaturated soil were collected at each grid node. Groundwater samples were collected at nodes that yielded groundwater.

Soil screening data for AOCs 613/615 and SWMU 175 were of sufficient quality, and site coverage extensive enough for the DPT soil data to be used in lieu of discrete soil sampling. Therefore, no discrete soil samples were collected at this combined site. Groundwater screening data at AOCs 613/615 and SWMU 175 were used for monitoring well placement as planned.

3.2.6.1 DPT Screening Locations

DPT points were spaced on 50-foot square grids, dependent on the layout of the site (buildings, obstructions, etc.). Sampling grids were densified as necessary to determine the extent of contamination identified through the screening process.

3.2.6.2 DPT Sample Collection

Soil and groundwater were sampled using a DPT rig, as described in Sections 4.3.3 and 6.1.3 of the approved final CSAP.

3.2.6.3 DPT Sample Preparation, Packaging, and Shipment

Guidelines in Section 11 of the approved final CSAP were followed for preparing, packaging, and shipping DPT samples collected at these sites. Samples from AOCs 613/615 and SWMU 175 were submitted to the contract laboratory, while an onsite, mobile laboratory analyzed DPT samples for AOC 607.

3.2.6.4 DPT Sample Analysis

DPT samples for AOCs 613/615 and SWMU 175 were submitted to the contracted laboratory for analysis at DQO Level III. The mobile laboratory used for AOC 607 was able to produce data at DQO Level IV. Analytical protocols specific to the Zone F RFI are described in Section 3.2 of this report.

3.2.7 Vertical and Horizontal Surveying

Section 3.2.7 of the *Draft Zone A RFI Report* discusses the procedures for vertical and horizontal surveying used for the Zone F RFI.

3.2.8 Aquifer Characterization

Section 3.2.8 of the *Draft Zone A RFI Report* details aquifer characterization procedures as conducted for the Zone F RFI.

3.2.9 Decontamination Procedures

Section 3.2.9 of the *Draft Zone A RFI Report* details decontamination procedures as conducted for the Zone F RFI.

3.2.9.1 Decontamination Area Setup

Section 3.2.9.1 of the *Draft Zone A RFI Report* details decontamination area setup as conducted for the Zone F RFI.

3.2.9.2 Cross-Contamination Prevention

Section 3.2.9.2 of the *Draft Zone A RFI Report* details cross-contamination prevention as conducted for the Zone F RFI.

3.2.9.3 Nonsampling Equipment

1

Section 3.2.9.3 of the *Draft Zone A RFI Report* details decontamination procedures for nonsampling equipment as conducted for the Zone F RFI.

2

3

3.2.9.4 Sampling Equipment

4

Section 3.2.9.4 of the *Draft Zone A RFI Report* details decontamination procedures for sampling equipment as conducted for the Zone F RFI.

5

6

4.0 DATA VALIDATION

4.1 Introduction

Section 4.1 of the *Draft Zone A RFI Report* defines the DQOs used for the Zone F investigation. For Zone F, analytical Level III data with 10% analyses for Appendix IX at Level IV were deemed appropriate for the following data uses: (1) site screening, (2) site characterization, (3) risk assessment, and (4) determinations/design of corrective measures. Site screening data for Zone F was accomplished by obtaining environmental samples through the use of DPT collection techniques. Site screening samples from AOCs 613/615 and SWMU 175 were submitted to the contract laboratory (Southwest Laboratories, Inc.) to be analyzed at Level III for metals, SVOCs, and VOCs. A total of 191 DPT samples were analyzed at the contract laboratory. For site screening at AOC 607, an onsite mobile laboratory was used. Hydrologic, Inc. analyzed 213 DPT soil and groundwater samples at AOC 607 for VOCs, providing Level IV data for these samples. The mobile laboratory followed EPA SW-846 Method 8260 QC requirements, which included daily gas chromatography/mass spectroscopy (GC/MS) tuning specifications, initial and daily calibrations, and analysis of method blanks.

Appendix D includes the complete copy of the analytical dataset for Zone F.

4.2 Validation Summary

Section 4.2 of the *Draft Zone A RFI Report* discusses the NAVBASE analytical program, including the analytical methods used, as well as the QA/QC evaluation for the definitive data produced during the Zone F RFI.

Field samples were collected at Zone F from August 1996 to August 1997, per the approved work plan. All non-screening samples were analyzed by Southwest Laboratory of Oklahoma. In accordance with the approved final CSAP, sample analyses followed the guidance in *Test Methods for Evaluating Solid Waste*, SW-846 (USEPA, November 1986) and Title 40 CFR Part 264.

Third-party independent data validation of all analytical work performed under the CSAP was conducted by Heartland Environmental Services, Inc. of St. Charles, Missouri based on the QC criteria developed for the Contract Laboratory Program (CLP). The third-party validator's function was to assess and summarize the quality and reliability of the data to determine their usability and to document any factors affecting data usability, such as compliance with methods, possible matrix interferences, and laboratory blank contamination.

4.2.1 Organic Evaluation Criteria

Section 4.2.1 of the *Draft Zone A RFI Report* discusses the organic evaluation criteria as they apply to the Zone F RFI. Appendix D includes the complete analytical dataset for Zone F.

4.2.1.1 Holding Times

Section 4.2.1.1 of the *Draft Zone A RFI Report* discusses organic sample holding times as they apply to the Zone F RFI.

4.2.1.2 GC/MS Instrument Performance Checks

Section 4.2.1.2 of the *Draft Zone A RFI Report* discusses performance standards for VOC and SVOC analyses as they apply to the Zone F RFI.

4.2.1.3 Surrogate Spike Recoveries

Section 4.2.1.3 of the *Draft Zone A RFI Report* discusses organic surrogate compounds as they apply to the Zone F RFI.

4.2.1.4 Instrument Calibration

Section 4.2.1.4 of the *Draft Zone A RFI Report* discusses instrument calibration as it applies to the organic data evaluation for the Zone F RFI.

4.2.1.5 Matrix Spike/Matrix Spike Duplicate 1

Section 4.2.1.5 of the *Draft Zone A RFI Report* discusses matrix spikes/duplicates as they apply 2
to the organic data evaluation for the Zone F RFI. 3

4.2.1.6 Laboratory Control Samples and Laboratory Duplicates 4

Section 4.2.1.6 of the *Draft Zone A RFI Report* discusses laboratory control samples and 5
laboratory duplicates as they apply to the organic data evaluation for the Zone F RFI. 6

4.2.1.7 Blank Analysis 7

Section 4.2.1.7 of the *Draft Zone A RFI Report* discusses blank analysis as it applies to the organic 8
data evaluation for the Zone F RFI. 9

4.2.1.8 Field-Derived Blanks 10

Section 4.2.1.8 of the *Draft Zone A RFI Report* discusses field-derived blank analyses as they 11
apply to the organic data evaluation for the Zone F RFI. 12

4.2.1.9 Internal Standard Performance 13

Section 4.2.1.9 of the *Draft Zone A RFI Report* discusses internal performance standards as they 14
apply to the organic data evaluation for the Zone F RFI. 15

4.2.1.10 Diluted Samples 16

A special evaluation was performed for diluted samples to determine if method detection limits 17
(MDLs) were low enough to be compared to reference concentrations (e.g., Maximum 18
Contaminant Levels [MCLs], Risk-Based Concentrations [RBCs], etc.). Tables 4.1 through 4.3 19
list the diluted samples for Zone F (for DPT, soil and sediment, and groundwater, respectively). 20

Table 4.1
 Zone F
 DPT Diluted Samples

Method	Parameter	Sample ID	Result	VQUAL
SW846-SVOC	Acenaphthene	613SP02202	43,000	D
SW846-SVOC	Acenaphthene	613SP02202	55,000	D
SW846-SVOC	Anthracene	613SP02202	26,000	D
SW846-SVOC	Dibenzofuran	613SP02202	46,000	D
SW846-SVOC	Fluoranthene	613SP02202	32,000	D
SW846-SVOC	Fluorene	613SP02202	60,000	D
SW846-SVOC	Naphthalene	613SP02202	38,000	D
SW846-SVOC	Phenanthrene	613SP02202	110,000	D
SW846-SVOC	Pyrene	613SP02202	18,000	D
SW846-SVOC	Pyrene	613SP05101	8,500	D

Notes:

All results are in $\mu\text{g}/\text{kg}$.

VQUAL = Validation Qualifier

D = Diluted Sample

Table 4.2
 Zone F
 Soil Diluted Samples

Method	Parameter	Sample ID	Result	VQUAL
APX9 PEST	alpha-Chlordane	004CB00201	33	DJ
APX9 PEST	gamma-Chlordane	004CB00201	86	D
APX9 PEST	4,4'-DDE	609CB00201	84	D
APX9 PEST	gamma-Chlordane	619CB00501	24	D
SW846-PEST	gamma-Chlordane	619SB00501	28	DJ
SW846-PEST	4,4'-DDD	619SB01101	110	DJ
SW846-PEST	4,4'-DDD	619SB01301	200	D
SW846-PEST	4,4'-DDE	619SB01301	530	D
SW846-PEST	gamma-Chlordane	619SB01501	34	D
SW846-PEST	4,4'-DDE	620SB00401	58	DJ
SW846-PEST	4,4'-DDT	620SB00401	120	DJ
SW846-PEST	4,4'-DDE	620SB00701	140	D
SW846-PEST	4,4'-DDT	620SB00701	150	D

Table 4.2
 Zone F
 Soil Diluted Samples

Method	Parameter	Sample ID	Result	VQUAL
SW846-PEST	gamma-Chlordane	620SB00701	24	D
SW846-PEST	4,4'-DDT	620SB00802	400	D
SW846-PEST	4,4'-DDT	620SB00802	75	D
SW846-SVOC	Acenaphthene	607M000301	27,000	D
SW846-SVOC	Anthracene	607M000301	32,000	DJ
SW846-SVOC	Benzo(a)anthracene	607M000301	51,000	DJ
SW846-SVOC	Benzo(a)pyrene	607M000301	36,000	DJ
SW846-SVOC	Benzo(b)fluoranthene	607M000301	52,000	DJ
SW846-SVOC	Benzo(g,h,i)perylene	607M000301	15,000	DJ
SW846-SVOC	Chrysene	607M000301	55,000	DJ
SW846-SVOC	Dibenz(a,h)anthracene	607M000301	9,100	DJ
SW846-SVOC	Fluoranthene	607M000301	130,000	DJ
SW846-SVOC	Fluorene	607M000301	27,000	D
SW846-SVOC	Indeno(1,2,3-cd)pyrene	607M000301	16,000	DJ
SW846-SVOC	Phenanthrene	607M000301	110,000	DJ
SW846-SVOC	Pyrene	607M000301	70,000	DJ
SW846-SVOC	Benzo(a)anthracene	607M000401	3,700	DJ
SW846-SVOC	Benzo(b)fluoranthene	607M000401	3,500	DJ
SW846-SVOC	Chrysene	607M000401	4,200	DJ
SW846-SVOC	Fluoranthene	607M000401	7,100	D
SW846-SVOC	Phenanthrene	607M000401	5,900	DJ
SW846-SVOC	Pyrene	607M000401	8,400	DJ
SW846-SVOC	2-Methylnaphthalene	611SB00502	12,000	D
SW846-SVOC	Naphthalene	611SB00502	7,400	D
SW846-SVOC	Benzo(a)anthracene	617SB00302	5,900	D
SW846-SVOC	Fluoranthene	617SB00302	14,000	D
SW846-SVOC	Naphthalene	617SB00302	240	DJ
SW846-SVOC	Phenanthrene	617SB00302	11,000	D
SW846-SVOC	Pyrene	617SB00302	10,000	D

Table 4.2
 Zone F
 Soil Diluted Samples

Method	Parameter	Sample ID	Result	VQUAL
SW846-SVOC	2-Methylphenol	617SB00402	280	D
SW846-SVOC	Benzo(k)fluoranthene	617SB00402	6,200	D
SW846-SVOC	Chrysene	617SB00402	5,000	D
SW846-SVOC	Fluoranthene	617SB00402	13,000	D
SW846-SVOC	Phenanthrene	617SB00402	12,000	D
SW846-SVOC	Pyrene	617SB00402	10,000	D
SW846-VOC	Aroclor	607SB00202	4,000	DJ
SW846-VOC	Tetrachloroethene	607SB00402	710	D

Notes:

All results are in $\mu\text{g}/\text{kg}$.

VQUAL = Validation Qualifier.

D = Diluted sample.

DJ = Diluted sample, results estimated.

Table 4.3
 Zone F
 Water Diluted Samples

Method	Parameter	Sample ID	Result	VQUAL
SW846-SVOC	2,4-Dimethylphenol	SME00501	380	D
SW846-SVOC	2-Methylphenol (o-Cresol)	SME00501	1,000	D
SW846-SVOC	4-Methylphenol (p-Cresol)	SME00501	970	D
SW846-SVOC	Benzoic acid	SME00501	420	D
SW846-SVOC	Naphthalene	SME00501	540	D
SW846-SVOC	Phenol	SME00501	810	D
SW846-VOC	1,2-Dichloroethene (total)	60700601	840	D
SW846-VOC	Tetrachloroethene	60700601	45,000	D
SW846-VOC	Trichloroethene	60700601	1,300	D

Notes:

All results are in $\mu\text{g}/\text{L}$.

VQUAL = Validation Qualifier.

D = Diluted sample.

4.2.2 Inorganic Evaluation Criteria	1
Section 4.2.2 of the <i>Draft Zone A RFI Report</i> discusses the inorganic evaluation criteria as they apply to the Zone F RFI. Appendix D includes the complete analytical data set for Zone F.	2 3
4.2.2.1 Holding Times	4
Section 4.2.2.1 of the <i>Draft Zone A RFI Report</i> discusses inorganic holding times as they apply to the Zone F RFI.	5 6
4.2.2.2 Instrument Calibration	7
Section 4.2.2.2 of the <i>Draft Zone A RFI Report</i> discusses instrument calibration as it applies to the Zone F RFI.	8 9
4.2.2.3 Blank Analysis	10
Section 4.2.2.3 of the <i>Draft Zone A RFI Report</i> discusses blank analysis as it applies to the Zone F RFI.	11 12
4.2.2.4 Inductively Coupled Argon Plasma Interference Check Samples	13
Section 4.2.2.4 of the <i>Draft Zone A RFI Report</i> discusses inductively coupled argon plasma (ICAP) interference check samples as they apply to the Zone F RFI.	14 15
4.2.2.5 Laboratory Control Samples	16
Section 4.2.2.5 of the <i>Draft Zone A RFI Report</i> discusses laboratory control samples (LCS) as they apply to the Zone F RFI.	17 18
4.2.2.6 Spike Sample Analysis	19
Section 4.2.2.6 of the <i>Draft Zone A RFI Report</i> discusses spike sample analyses as they apply to the Zone F RFI.	20 21

4.2.2.7 Laboratory Duplicates	1
Section 4.2.2.7 of the <i>Draft Zone A RFI Report</i> discusses laboratory duplicates as they apply to the Zone F RFI.	2 3
4.2.2.8 ICAP Serial Dilutions	4
Section 4.2.2.8 of the <i>Draft Zone A RFI Report</i> discusses ICAP serial dilutions as they apply to the Zone F RFI.	5 6
4.2.2.9 Atomic Absorption Duplicate Injections and Postdigestion Spike Recoveries	7
Section 4.2.2.9 of the <i>Draft Zone A RFI Report</i> discusses atomic absorption (AA) analysis, duplicate injections, and postdigestion spikes as they apply to the Zone F RFI.	8 9
4.3 Zone F Data Validation Reports	10
A complete copy of the Zone F data validation reports along with a table of validation qualifiers, is included in Appendix E for review. These reports are the outcome of the evaluations described above and are specific to the analytical data collected during the Zone F RFI. During data validation review of Zone F soil and groundwater analyses, the following per-site deficiencies and/or problems were noted in the volatile, semivolatile, and metals methods. Although field blanks were site specific, trip, equipment, and distilled water blanks were not necessarily specific to the site.	11 12 13 14 15 16 17
4.3.1 Soil Blanks	18
SWMU 4 – Soil blanks numbered for SWMU 4 for the volatile method contained detectable:	19
• 2-butanone and xylene in the trip blanks,	20
• Carbon disulfide in the equipment and trip blanks,	21
• Methylene chloride and 1,2-dichloroethene in equipment, trip and method blanks, and	22
• Acetone and chloroform in the trip, method, distilled water, and equipment blanks.	23

Blanks for the semivolatile method contained detectable bis(2-ethylhexyl)phthalate detected in the method blank. Blanks for the metals method contained detectable antimony, selenium, sodium, and tin in the method blank.

AOC 619 – Soil blanks numbered for AOC 619 for the volatile method contained detectable:

- Methylene chloride and 2-butanone in the method blank, and
- Acetone in the method and trip blanks.

Blanks for the semivolatile method contained detectable:

- Butylbenzylphthalate in the method blank, and
- Bis(2-ethylhexyl)phthalate in the distilled water and equipment blanks.

Blanks for the metals method contained detectable:

- Zinc in the equipment blank,
- Antimony, beryllium, cobalt, selenium, thallium, and tin in the method blanks,
- Cyanide and silver in the distilled water and method blanks,
- Sodium in the distilled water and equipment blanks, and
- Copper in the method, distilled, and equipment blanks.

SWMU 36 – Soil blanks numbered for SWMU 36 for the volatile method contained detectable:

- Acetone in the method blank, and
- Chloroform and methylene chloride in the method, distilled water, equipment, and trip blanks.

Blanks for the semivolatile method contained detectable bis(2-ethylhexyl)phthalate in the equipment and method blanks. Blanks for the metals method contained detectable:

- Tin in the distilled water blank,
- Copper and sodium in the distilled water and equipment blanks, and
- Beryllium in the distilled water, equipment, and method blanks.

AOC 620 — Soil blanks numbered for AOC 620 for the volatile method contained detectable:

- Acetone in the method and trip blanks,
- Methylene chloride in the method, distilled water, and equipment blanks, and
- Chloroform in the distilled water, equipment, trip, and method blanks.

Blanks for the semivolatile method contained detectable bis(2-ethylhexyl)phthalate in the distilled water, equipment, and method blanks. Blanks for the metals method contained detectable:

- Tin in the method blank,
- Zinc in the equipment blanks,
- Copper and sodium in the distilled water and equipment blanks, and
- Cyanide in the method, distilled water, and equipment blanks.

SWMU 109 — Soil blanks numbered for SWMU 109 for the volatile method contained detectable acetone and methylene chloride in the method blanks. Blanks for the semivolatile method contained detectable bis(2-ethylhexyl)phthalate in the distilled water and equipment blanks. Blanks for the metals method contained detectable:

- Silver and tin detected in the method blanks,

• Sodium in the distilled blank, and	1
• Copper, nickel, and zinc in the method and equipment blanks.	2
AOC 607 — Soil blanks numbered for AOC 607 for the volatile method contained detectable:	3
• 2-butanone in the distilled water blank, and	4
• Acetone and methylene chloride in the method, distilled water, equipment, and trip blanks.	5
Blanks for the semivolatile method contained detectable bis(2-ethylhexyl)phthalate in the method	6
blank. Blanks for the metals method contained detectable:	7
• Sodium in the method blank, and	8
• Beryllium and tin in the method and distilled water blanks.	9
AOC 609 — Soil blanks numbered for AOC 609 for the volatile method contained detectable:	10
• Methylene chloride in the method blank,	11
• Acetone in the method and trip blanks, and	12
• Chloroform in the distilled and equipment blanks.	13
Blanks for the semivolatile method contained detectable bis(2-ethylhexyl)phthalate in the method	14
blank. Blanks for the metals method contained detectable:	15
• Beryllium in the method blank,	16
• Antimony and selenium in the equipment blank,	17
• Cobalt, nickel, silver, sodium, and zinc in the distilled water and equipment blanks,	18
• Thallium and tin in the distilled and method blanks, and	19
• Copper in the distilled, equipment, and method blanks.	20

AOC 611 — Soil blanks numbered for AOC 611 for the volatile method contained detectable acetone and methylene chloride in the trip and method blanks. Blanks for the semivolatile method contained detectable butylbenzylphthalate and bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable:

- Beryllium and tin in the method blank, and
- Sodium in the distilled and equipment blanks.

AOC 613 — Soil blanks numbered for the DPT soil samples at AOC 613 for the volatile method contained detectable:

- 2-butanone and xylene in the trip blank,
- Carbon disulfide in the equipment and trip blanks,
- Methylene chloride and 1,2-dichloroethene in the equipment, trip, and method blanks, and
- Acetone and chloroform in the distilled water, equipment, trip, and method blanks.

Blanks for the semivolatile method contained detectable di-n-butylphthalate and bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable:

- Cadmium, mercury, and selenium in the method blank,
- Beryllium, cyanide, and sodium in the distilled and equipment blanks,
- Nickel and thallium in the equipment and method blanks, and
- Antimony, copper, silver, tin, and zinc in the distilled water, equipment, and method blanks.

Note: DPT samples collected at AOC 607 were analyzed by a mobile laboratory and were not validated.

AOC 613 — Soil blanks numbered for AOC 613 for the volatile method contained detectable acetone in the trip and method blanks. Blanks for the semivolatile method contained detectable butylbenzylphthalate and bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable antimony, beryllium, copper, and tin.

AOC 616 — Soil blanks numbered for AOC 616 for the volatile method contained detectable acetone and methylene chloride in the method and trip blanks. Blanks for the metals method contained detectable cobalt, copper, lead, thallium, and tin in the method blank.

AOC 617 — Soil blanks numbered for AOC 617 for the volatile method contained detectable:

- Acetone in the method blank, and
- Methylene chloride in the method and trip blanks.

Blanks for the metals method contained detectable antimony, copper, cyanide, lead, silver, tin, and zinc in the method blank.

Grid Based — Soil blanks numbered for the grid soil samples for the volatile method contained detectable:

- 2-butanone in the method blank,
- Methylene chloride in the trip blank, and
- Acetone and chloroform in the method and trip blanks.

Blanks for the metals method contained detectable: 1

- Beryllium, nickel, and tin in the method blank, and 2
- Sodium and zinc in the equipment blank. 3

4.3.2 Groundwater Blanks 4

AOC 619 – Groundwater blanks numbered for AOC 619 for the volatile method contained 5
detectable acetone in the distilled water, equipment, and field blanks. Blanks for the metals method 6
contained detectable: 7

- Beryllium in the distilled water blank, 8
- Cobalt and copper in the method blank, 9
- Nickel in the distilled water and field blanks, 10
- Silver in the equipment and method blanks, 11
- Zinc in the distilled water and method blanks, 12
- Selenium in the distilled water, equipment, and method blanks, and 13
- Tin in the distilled water, equipment, field, and method blanks. 14

AOC 620 – Groundwater blanks numbered for AOC 620 for the volatile method contained 15
detectable acetone in the distilled water, equipment, trip, and method blanks. Blanks for the 16
semivolatile method contained detectable bis(2-ethylhexyl)phthalate in the distilled water, 17
equipment, and method blanks. Blanks for the metals method contained detectable: 18

- Antimony in the equipment blank, 19
- Beryllium in the distilled water blank, 20
- Selenium and tin in the method blank, and 21
- Silver in the distilled water and equipment blanks. 22

SWMU 109 — Groundwater blanks numbered for SWMU 109 for the metals method contained detectable: 1
2

- Antimony, selenium, silver, and zinc in the method blank, and 3
- Cobalt in the method and the equipment blanks. 4

AOC 607 — Groundwater blanks numbered for AOC 607 for the volatile method contained detectable: 5
6

- Acetone and tetrachloroethene in the trip blank, 7
- Methylene chloride in the field and trip blanks, and 8
- Chloroform in the distilled water, field, and the equipment blanks. 9

Blanks for the semivolatile method contained detectable bis (2-ethylhexyl)phthalate in the field and method blanks. Blanks for the metals method contained detectable: 10
11

- Cyanide, vanadium, and zinc in the method blank, 12
- Cobalt in the equipment and method blanks, 13
- Thallium in the field and method blanks, 14
- Mercury in the distilled water and equipment blanks, and 15
- Antimony and silver in the distilled water, equipment, and method blanks. 16

AOC 609 — Groundwater blanks numbered for the S&ME samples (located at AOC 609) for the volatile method contained detectable: 17
18

- Acetone in the trip blank, and 19
- Methylene chloride in the method and trip blanks. 20

Blanks for the metals method contained detectable antimony, beryllium, chromium, copper, thallium, tin, and zinc in the method blank. 1
2

AOC 613 – Groundwater blanks numbered for AOC 613 for the volatile method contained detectable: 3
4

- Acetone in the trip blank, 5
- Methylene chloride in the field and trip blanks, and 6
- Chloroform in the distilled water, equipment, and field blanks. 7

Blanks for the semivolatile method contained detectable bis (2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable: 8
9

- Copper, tin, vanadium, and zinc in the method blank, 10
- Antimony, cobalt, and thallium in the field and method blanks, 11
- Mercury in the distilled and equipment blanks, and 12
- Beryllium in the distilled water, equipment, field, and method blanks. 13

GEL Samples – Groundwater blanks numbered for the GEL samples (located at AOCs 613/615 and SWMU 175) for the volatile method contained detectable: 14
15

- Methylene chloride in the field, trip, and method blanks, and 16
- Acetone in the distilled water, equipment, field and method blanks. 17

Blanks for the semivolatile method contained detected bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable: 18
19

- Beryllium, copper, silver, and thallium in the method blank, 1
- Cobalt in the distilled water blank, 2
- Nickel in the distilled water and field blanks, 3
- Selenium in the distilled water and equipment blanks, 4
- Zinc in the field and method blanks, and 5
- Tin in the distilled water, equipment, field, and method blanks. 6

Location 240 — Groundwater blanks numbered for location 240 (located at AOCs 613/615 and 7
SWMU 175) for the volatile method contained detectable methylene chloride in the distilled water 8
and equipment blanks. Blanks for the metals method contained detectable: 9

- Cobalt, silver, thallium, and zinc were detected in the method blank, 10
- Mercury in the distilled water and equipment blanks, 11
- Vanadium in the equipment and method blanks, and 12
- Antimony in the distilled water, equipment, and method blanks. 13

AOC 617 — Groundwater blanks numbered for AOC 617 for the volatile method contained 14
detectable acetone and methylene chloride in the method and trip blanks. Blanks for the 15
semivolatile method contained detectable bis(2-ethylhexyl)phthalate in the method blank. Blanks 16
for the metals method contained detectable beryllium, copper, silver, and tin in the method blank. 17

Grid Based — Groundwater blanks numbered for the grid groundwater samples contained 18
detectable acetone in the trip blank. Blanks for the semivolatile method contained detectable 19
bis(2-ethylhexyl)phthalate in the equipment and method blanks. Blanks for the metals method 20
contained detectable: 21

- Beryllium in the distilled water blank, 1
- Silver in the method blank, 2
- Nickel and selenium in the distilled water and the field blanks, 3
- Zinc in the field and method blanks, and 4
- Tin in the distilled water, equipment, field, and method blanks. 5

4.4 Method Detection Limits 6

Tables 4.4 through 4.13 contain Southwest Laboratory of Oklahoma’s MDL study. 7

Table 4.4
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Dioxins

Compound	CAS Number	MDL	
		Water (pg/L)	Soil (ng/kg)
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		
2378-TCDD	1746-01-6	6.79	0.17
12378-PeCDD	40321-76-4	6.64	0.74
123478-HxCDD	39227-28-6	17.63	0.82
123678-HxCDD	57653-85-7	13.56	0.89
123789-HxCDD	19408-74-3	15.35	0.96
1234678-HpCDD	35822-39-4	14.44	0.41
OCDD	3268-87-9	21.46	0.59
2378-TCDF	51207-31-9	2.96	0.39
12378-PeCDF	57117-41-6	5.58	0.27
23478-PeCDF	57117-31-4	13.26	0.60
123478-HxCDF	70648-26-9	7.96	0.54
123678-HxCDF	57117-44-9	8.68	0.57
123789-Hx-CDF	72918-21-9	17.87	0.69
234678-HxCDF	60851-34-5	16.00	0.88
1234678-HpCDF	67562-39-4	10.99	0.26
1234789-HpCDF	5563-89-7	17.98	0.53
OCDF	39001-02-0	10.63	0.32

Notes:

MDL = Method detection limit
 pg/L = picograms per liter
 ng/kg = nanograms per kilogram
 ng/mL = nanograms per milliliter

Table 4.5
Zone F
Southwest Laboratory of Oklahoma's Method Detection Limit Study for VOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Volatiles			
Test Code:	MS300		
Method:	SW846 8240, 3rd Edition, Nov. 1986/Sept. 1994		
Matrix:	Soil-Water		
Sample Volume:	5 g - 5 mL		
Initial Calibration:	5-20-50-100-200 ppb, %RSD < 30% for CCC compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100		
Continuing Calibration:	50 ppb, %D < 20% for CCC Compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100		
Chloromethane	74-87-3	0.96	1.6
Vinyl Chloride	75-01-4	1.4	1.8
Bromomethane	74-83-9	1.8	2.0
Chloroethane	75-00-3	1.4	2.1
1,1-Dichloroethene	75-35-4	1.4	1.8
Acetone	67-64-1	1.6	2.6
Carbon Disulfide	75-15-0	1.5	2.0
Methylene Chloride	75-09-2	3.0	1.8
1,2-Dichloroethene (total)	540-59-0	0.97	2.1
trans-1,2-Dichloroethene	56-60-5	0.97	2.1
1,1-Dichloroethane	75-34-3	0.97	2.0
Vinyl Acetate	108-05-4	0.92	1.6
cis-1,2-Dichloroethene	156-59-2	0.93	1.9
2-Butanone	78-93-3	0.88	1.6
Chloroform	67-77-3	0.85	1.9
1,1,1-Trichloroethane	71-55-6	1.3	1.8
Carbon Tetrachloride	56-23-5	1.2	1.9
Benzene	71-43-2	15	1.7
1,2-Dichloroethane	107-06-2	0.44	2.0
Trichloroethene	79-01-6	1.0	1.9
1,2-Dichloropropane	78-87-5	0.76	1.9
Bromodichloromethane	75-27-4	0.68	1.9

Table 4.5
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for VOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
2-Chloroethyl Vinyl Ether	110-75-8	0.54	4.4
cis-1,3-Dichloropropene	10061-01-5	0.58	2.0
4-Methyl-2-Pentanone	108-10-1	1.8	1.9
Toluene	108-88-3	1.0	1.7
trans-1,2-Dichloropropene	10061-02-6	0.60	1.8
1,1,2-Trichloroethane	79-00-5	0.45	1.9
Tetrachloroethene	127-18-4	1.2	2.2
2-Hexanone	591-78-6	0.62	2.4
Dibromochloromethane	124-48-1	0.78	1.6
Chlorobenzene	108-90-7	0.83	1.9
Ethylbenzene	100-31-4	1.2	1.9
m,p-Xylene	13-302-07	2.2	3.9
Xylene (Total)	1330-20-7	2.2	3.9
o-Xylene	95-47-6	0.93	1.9
Styrene	100-42-5	0.8	2.1
Bromoform	75-25-2	1.0	1.7
1,1,2,2-Tetrachloroethane	79-34-5	1.3	1.7

Notes:

- CCC = Calibration Check Compounds
- %D = Percent difference
- RRF = Relative Response Factor
- %RSD = Percent Relative Standard Deviation
- SPCC = Spill Prevention, Control and Countermeasures
- MDL = Method Detection Limit
- $\mu\text{g/L}$ = micrograms per liter
- $\mu\text{g/kg}$ = micrograms per kilogram

Table 4.6
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Semivolatile			
Test Code:	MS500		
Method:	SW846 8270, 823rd Edition, Nov. 1986, PQL Table II, Rev.0, Sept. 1986		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	20-50-100-120-160 ng, %RSD for CCC compounds=30%, SPCC=97RF > 0.05		
Continuing Calibration:	50 ng, %D = 25% for CCC Compounds, SPCC = RF > 0.05100		
Phenol	108-95-2	3.3	100
bis(2-chloroethyl)ether	111-44-4	3.4	100
2-Chlorophenol	95-57-8	3.3	97
1,3-Dichlorobenzene	541-73-1	2.6	100
1,4-Dichlorobenzene	106-46-7	2.8	120
Benzyl alcohol	100-51-6	3.6	82
1,2-Dichlorobenzene	95-50-1	3.0	100
2-Methylphenol	95-48-7	2.9	130
bis(2-chloroisopropyl)ether	108-60-1	3.5	89
4-Methylphenol	106-44-5	6.4	94
N-Nitroso-di-n-propylamine	621-64-7	2.8	87
Hexachloroethane	67-72-1	2.3	94
Isophorone	78-59-1	3.0	100
Nitrobenzene	98-95-3	3.5	100
2-Nitrophenol	88-75-5	3.4	99
2,4-Dimethylphenol	105-67-9	3.9	160
bis(2-chloroethoxy)methane	111-91-1	3.3	99
2,4-Dichlorophenol	120-83-2	2.6	110
Benzoic acid	65-85-0	9.2	150
1,2,4-Trichlorobenzene	120-82-1	2.9	94
Naphthalene	91-20-3	2.6	110
4-Chloroaniline	106-47-8	3.3	210

Table 4.6
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Hexachlorobutadiene	87-68-3	3.0	90
4-Chloro-3-methylphenol	59-50-7	2.6	90
2-Methylnaphthalene	91-57-6	2.4	85
Hexachlorocyclopentadiene	77-47-4	NA	75
2,4,6-Trichlorophenol	88-06-2	2.6	110
2,4,5-Trichlorophenol	95-95-4	2.7	110
2-Chloronaphthalene	91-58-7	2.1	110
2-Nitroaniline	88-74-4	2.8	110
Dimethylphthalate	131-11-3	0.8	120
Acenaphthylene	208-96-8	2.4	120
2,6-Dinitrotoluene	606-20-2	4.0	110
3-Nitroaniline	99-09-2	3.6	150
Acenaphthene	83-32-9	2.2	100
2,4-Dinitrophenol	51-28-5	2.9	100
4-Nitrophenol	100-02-7	2.6	93
Dibenzofuran	132-64-9	1.9	110
2,4-Dinitrotoluene	121-14-2	3.9	100
Diethylphthalate	84-66-2	1.2	120
Fluorene	86-73-7	1.8	100
4-Chlorophenyl-phenylether	7005-72-3	2.2	120
4-Nitroaniline	100-01-6	2.8	150
4,6-Dinitro-2-methylphenol	534-52-1	2.4	100
N-nitrosodiphenylamine	86-30-6	2.4	110
4-Bromophenyl-phenylether	101-55-3	2.3	86
Hexachlorobenzene	118-74-1	2.6	84
Pentachlorophenol	87-86-5	2.3	76

Table 4.6
Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Phenanthrene	85-01-8	2.6	110
Anthracene	120-12-7	2.6	100
Di-n-butylphthalate	84-74-2	2.0	110
Fluoranthene	206-44-0	1.9	100
Pyrene	129-00-0	1.2	120
Butylbenzylphthalate	85-68-7	1.1	120
Benzo(a)anthracene	56-55-3	1.0	100
3,3'-Dichlorobenzidine	91-94-1	2.4	120
Chrysene	218-1-9	0.9	100
bis(2-ethylhexyl)phthalate	117-81-7	3.5	140
Di-n-octylphthalate	117-84-0	2.0	110
Benzo(b)fluoranthene	205-99-2	1.8	120
Benzo(k)fluoranthene	207-08-9	2.1	100
Benzo(a)pyrene	50-32-8	1.6	83
Indeno(1,2,3-cd)pyrene	193-39-5	1.6	110
Dibenz(a,h)anthracene	53-70-3	1.6	120
Benzo(g,h,i)perylene	191-24-2	1.6	130

Notes:

- CCC = Calibration Check Compounds
- %D = Percent difference
- RRF = Relative Response Factor
- %RSD = Percent Relative Standard Deviation
- SPCC = Spill Prevention, Control, and Countermeasures
- MDL = Method Detection Limit
- $\mu\text{g/L}$ = micrograms per liter
- $\mu\text{g/kg}$ = micrograms per kilogram
- NA = Not applicable

Table 4.7
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Pesticides/PCB

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Pesticide/PCB			
Test Code:	GC800		
Method:	SW846 8080A, 3rd Edition, Nov. 1986		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	5 point calibration, %RSD=20%		
Continuing Calibration:	Single point calibration, %D = 15%		
alpha-BHC	319-84-6	2E-03	0.130
beta-BHC	319-85-7	1E-03	0.120
delta-BHC	319-86-8	6E-03	8.6E-02
gamma-BHC(Lindane)	58-89-9	2E-03	6.8E-02
Heptachlor	76-44-8	1.9E-02	9.5E-02
Aldrin	309-00-2	1E-03	6.2E-02
Heptachlor epoxide	1024-57-3	4E-03	5.1E-02
Endosulfan I	959-98-8	3E-03	9.8E-02
Dieldrin	60-57-1	4E-03	0.170
4,4-DDE	72-55-9	6E-03	0.150
Endrin	72-20-8	8E-03	0.120
Endosulfan II	33213-65-9	6E-03	0.110
4'4'-DDD	72-54-8	4E-03	0.100
Endosulfan sulfate	1031-07-8	2E-03	0.250
4'4'-DDT	50-29-3	9E-03	0.250
Methoxychlor	72-43-5	2.1E-02	0.390
Endrin ketone	53494-70-5	4E-03	0.110
Endrin aldehyde	7421-36-3	8E-03	0.220
alpha-Chlordane	5193-71-9	2E-03	0.250
gamma-Chlordane	5103-74-2	2E-03	0.130
Toxaphene	8001-35-2	1.6E-03	2.000
Aroclor-1016	12674-11-2	0.210	2.600

Table 4.7
Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Pesticides/PCB

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Aroclor-1221	11104-28-2	6.2E-02	2.300
Aroclor-1232	11141-16-5	0.280	1.800
Aroclor-1242	53469-21-9	2.4E-02	1.600
Aroclor-1248	12672-29-6	9.6E-02	2.200
Aroclor-1254	11097-69-1	0.140	3.200
Aroclor-1260	11096-82-5	0.170	2.700

Notes:

- %D = Percent difference
- %RSD = Percent Relative Standard Deviation
- MDL = Method Detection Limit
- $\mu\text{g/L}$ = micrograms per liter
- $\mu\text{g/kg}$ = micrograms per kilogram

Table 4.8
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Pesticides, Organophosphorus

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Pesticides, Organophosphorus			
Test Code:	GC880		
Method:	SW846-8140, EPA methodology		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	5 point calibration, %RSD=20%		
Continuing Calibration:	Single point calibration, %D = 15%		
Dichlorvos	62-73-7	0.29	17.0
Mevinphos	7786-34-7	0.47	30.0
Demeton S	8065-48-3	0.27	19.0
Ethoprop	13194-48-4	0.23	17.0
Naled	300-76-5	0.50	60.0
Phorate	298-02-2	0.18	11.0
Diazinon	333-41-5	0.33	19.0
Disulfoton	298-04-4	0.22	12.0
Parathion-methyl	298-00-0	0.04	3.5
Ronnel	299-84-3	0.41	22.0
Fenthion	55-38-9	0.20	6.9
Chlorpyrifos	2921-88-2	0.20	9.9
Trichloroanate	327-98-0	0.20	9.5
Stirophos	22248-79-9	0.57	79.0
Tokuthion	34643-46-4	0.34	16.0
Merphos	150-50-5	0.29	15.0
Fensulfothion	115-90-2	0.60	78.0
Bolstar	35400-43-2	0.20	9.2
Azinphos-methyl	86-50-0	0.26	85.0
Coumaphos	56-72-4	0.41	100.0

Notes:

- %D = Percent difference
- %RSD = Percent Relative Standard Deviation
- MDL = Method Detection Limit
- $\mu\text{g/L}$ = micrograms per liter
- $\mu\text{g/kg}$ = micrograms per kilogram

Table 4.9
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Herbicides

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Acid Herbicides			
Test Code:	GC570		
Method:	SW846-8150, EPA methodology		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	5 point calibration, %RSD=20%		
Continuing Calibration:	Single point calibration, %D = 15%		
Dalapon	75-99-0	1.30	24
Dicamba	1918-00-9	0.11	4.89
MCPP	93-65-2	7.4	535
MCPA	94-74-6	12.0	627
Dichloroprop	120-36-5	0.19	8.26
2,4-D	94-75-7	0.29	9.51
2,4,5-TP (Silvex)	93-72-1	8.8E-02	6.15
2,4,5-T	93-76-5	0.18	2.28
2,4-DB	94-82-6	0.70	12.46
Dinoseb	88-85-7	0.49	2.76

Notes:

- %D = Percent difference
- %RSD = Percent Relative Standard Deviation
- MDL = Method Detection Limit
- $\mu\text{g/L}$ = micrograms per liter
- $\mu\text{g/kg}$ = micrograms per kilogram

Table 4.10
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by Low-Level ICP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Metals reporting limits by Low Level ICP			
Method:	SW846 Third Edition, Nov. 1986, Method 6010A		
Matrix:	Water-Soil		
Extract Volume:	100mL - 1g		
Initial Calibration:	0-500ug/L - varies		
Continuing Calibration:	1/2 high std		
Aluminum	7429-90-5	8.0	1.30
Antimony	7440-36-0	1.6	0.27
Arsenic	7440-38-2	2.1	0.31
Barium	7440-39-3	0.3	6E-02
Beryllium	7440-41-7	0.2	3E-02
Boron	7440-42-8	11.0	2.60
Cadmium	7440-43-9	0.3	5.1E-02
Calcium	7440-70-2	43.0	1.90
Chromium	7440-47-3	1.0	7E-02
Cobalt	7440-48-4	0.8	6E-02
Copper	7440-50-8	1.4	0.26
Iron	7439-89-6	20.0	1.60
Lead	7439-92-1	0.9	0.18
Magnesium	7439-95-4	43.0	4.70
Manganese	7439-96-5	0.3	4E-02
Molybdenum	7439-98-7	0.9	0.18
Nickel	7440-02-0	0.7	0.12
Potassium	7440-09-7	55.0	7.00
Selenium	7782-49-2	3.4	0.24
Scandium	440-20-2	0.1	2E-02
Strontium	7440-24-6	0.2	7E-02
Silicon	7440-21-3	35.0	15.00
Silver	7440-22-4	1.0	0.17

Table 4.10
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by Low-Level ICP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Sodium	7440-23-5	19.0	4.90
Thallium	7440-28-0	5.0	0.46
Tin	7440-31-5	14.0	0.45
Titanium	7440-32-6	0.7	0.05
Vanadium	7440-62-2	1.1	0.13
Zinc	744-66-6	5.8	1.10

Notes:
 $\mu\text{g/L}$ = micrograms per liter
 mg/kg = milligrams per kilogram

Table 4.11
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by ICP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Metals reporting limits by ICP			
Method:	SW846 Third Edition, Nov. 1986, Method 6010		
Matrix:	Water-Soil		
Extract Volume:	100mL - 1g		
Initial Calibration:	0-1000 $\mu\text{g/L}$ -varies		
Continuing Calibration:	1/2 high std		
Aluminum	7429-90-5	14	2.8
Antimony	7440-36-0	12	1.7
Arsenic	7440-38-2	32	3.1
Barium	7440-39-3	1.0	0.19
Beryllium	7440-41-7	1.0	0.10
Boron	7440-42-8	17	2.5
Cadmium	7440-43-9	1.3	0.11
Calcium	7440-70-2	39	23.0
Chromium	7440-47-3	1.9	0.38
Cobalt	7440-48-4	2.8	0.46

Table 4.11
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by ICP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Copper	7440-50-8	8.3	0.73
Iron	7439-89-6	18	1.7
Lead	7439-92-1	12	1.5
Magnesium	7439-95-4	25	6.1
Manganese	7439-96-5	1.2	0.10
Molybdenum	7439-98-7	5.7	25
Nickel	7440-02-0	6.5	5.9E-02
Potassium	7440-09-7	560	57.0
Selenium	7782-49-2	28	3.1
Silicon	7440-21-3	70	23.0
Silver	7440-22-4	1.4	0.25
Sodium	7440-23-5	27	50.0
Thallium	7440-28-0	48	4.6
Tin	7440-31-5	17	2.1
Titanium	7440-32-6	1.0	0.14
Vanadium	7440-62-2	2.2	0.27
Zinc	744-66-6	11	1.1

Notes:

$\mu\text{g/L}$ = micrograms per liter
 mg/kg = milligrams per kilogram

Table 4.12
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Mercury by Cold Vapors

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Mercury by Cold Vapors			
Test Code:	MT310		
Method:	SW846 Third Edition, Nov. 1986		
Matrix:	Water-Soil		
Extract Volume:	100mL - 0.6g		
Initial Calibration:	0 - 10.0 $\mu\text{g/L}$		
Continuing Calibration:	1/4 HIGH STD		
Mercury	7439-97-6	0.12	3E-02

Notes:
 $\mu\text{g/L}$ = micrograms per liter
 mg/kg = milligrams per kilogram

Table 4.13
 Zone F
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Miscellaneous Inorganics

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Miscellaneous Inorganic Analyses			
Test Code:	Methods various		
Method:			
Matrix:	Water-Soil		
Extract Volume:			
Initial Calibration:			
Continuing Calibration:			
Chloride (IC)	EPA300.0	7E-02	0.7
Cyanide (Total)	SW846-9010	2.0	0.5
Hexavalent Chromium	SW846-7196	5E-03	0.20
Sulfate (IC)	EPA300.0	0.1	0.9
Total Dissolved Solids	EPA160.1	4	—

Notes:
 $\mu\text{g/L}$ = micrograms per liter
 mg/kg = milligrams per kilogram

5.0 DATA EVALUATION AND BACKGROUND COMPARISON

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

Types of compounds detected in Zone F included VOCs, SVOCs, pesticides, PCBs, herbicides, dioxins and inorganics. Detected concentrations were compared to corresponding RBCs listed in the USEPA Region III *Risk-Based Concentration Table, January-June 1996* (USEPA 1996b), to: (1) evaluate the significance of the detections; (2) determine the need for additional sampling for defining the extent of contamination; and (3) develop investigative endpoints. Detected inorganic concentrations were also compared to corresponding background (or reference) concentrations. The comparisons pertain only to the protection of human health and do not address protection of ecological receptors. Excess risk to the ecosystem from the contaminants onsite is addressed in Section 8.

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

5.1 Organic Compound Analytical Results Evaluation

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

For screening purposes, concentrations of dioxin congeners and carcinogenic polynuclear aromatic hydrocarbons (cPAHs) were converted to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

equivalency quotients (TEQs) and benzo(a)pyrene equivalents (BEQs), respectively, in accordance with recent EPA guidance. Section 5.1 of the *Draft Zone A RFI Report* details the guidance and procedures followed during the Zone F RFI.

5.2 Inorganic Analytical Results Evaluation

Inorganics sample analytical results are often difficult to evaluate because inorganics are ubiquitous, naturally occurring in soil and frequently present in groundwater as well. Further, NAVBASE was predominantly built on artificially placed dredge/fill material, compounding the difficulty of assessing natural site conditions. The following describes the step-by-step procedures used to determine background for Zone F inorganics in soil and groundwater and the approach for comparing background data to site data.

Many chemicals, particularly carcinogenic metals such as arsenic and beryllium, are typically detected at concentrations higher than their corresponding risk-based screening levels. It is usually necessary to supplement site-specific sampling efforts by determining the non-site-related concentrations of these chemicals. Reference (or background) concentrations must be determined, along with how much higher than background a specific site parameter must be before it is of concern. USEPA Region IV guidance recommends using twice the mean of the background data values as an upper bound, considering any site-related values higher than this bound to represent contamination. Although more sophisticated statistical tests can be used when larger datasets are available, the smaller site and background datasets of Zone F mandated use of the "twice the mean" approach for comparing site values to background.

Where possible, EnSafe used a dual testing procedure to compare site-specific values for inorganics with results from a grid-based background dataset. Background reference values for surface soil, subsurface soil, shallow groundwater, and deep groundwater were calculated as described above, in accordance with established NAVBASE procedures, and approved by the

project team technical subcommittee. Approved background reference values were used in combination with Wilcoxon rank sum tests to make background comparisons for soil. Because groundwater datasets did not support use of the Wilcoxon rank sum test (see Section 5.2.6 below), background comparisons for groundwater were performed using “twice the mean” reference concentrations only.

5.2.1 Grid-Based Background Dataset

The background datasets for Zone F soil were derived from upper and lower interval samples collected from six grid-based soil borings (GDFSB001 to GDFSB005 and GDESB009). The background datasets for shallow and deep groundwater were derived from the first two sampling rounds from two grid-based well pairs (GDF001/GDF01D and GDE009/GDE09D). Figures 3-1 and 3-2 depict the Zone F grid-based soil and groundwater sample locations.

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

5.2.2 Nondetect Data

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

5.2.3 Developing Datasets for Sites

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

5.2.4 Comparing Site Values to Background

Section 5.2.4 of the *Draft Zone A RFI Report* discusses statistical hypothesis testing for comparing site concentrations to background. It presents USEPA's suggested "twice the mean" approach and compares it to more powerful statistical approaches that can be used in its place. It also recommends a dual testing strategy to detect different types of site contamination, involving a reference concentration comparison and the Wilcoxon rank sum test.

5.2.5 Reference Concentration Test

As discussed above, background reference values were determined for each inorganic in each environmental medium by calculating twice the mean of the background sample concentrations. Analytical results for each site sample were then compared to the corresponding reference concentrations to identify individual samples with concentrations significantly higher than background. If the results from the test were positive (i.e., significantly higher than background), sample values were compared to the corresponding USEPA RBCs for soil and tap water and, where appropriate, carried forward into detailed human health risk assessment (HHRA).

5.2.6 Wilcoxon Rank Sum Test

To identify onsite contamination when the majority of a site's sample values are higher than the mean background value (but not dramatically higher), as a group, the site samples must be shown to be significantly higher than the group of background samples.

The most commonly prescribed method for comparing two populations is the Student's *t*-test, which determines whether the two population means differ significantly. The *t*-test was not used in this investigation to compare site values to background because it is parametric. A nonparametric counterpart to the *t*-test is the Wilcoxon rank sum test, also known as the Mann-Whitney U test. Since it is nonparametric, the two datasets that are compared need not be drawn from normal or even symmetric distributions, and the test can accommodate a moderate number of nondetect values by treating them as ties (Gilbert 1987). Each dataset (representing site samples or background samples) should contain at least four data values. Because groundwater datasets for Zone F sites were not this large, the Wilcoxon rank sum test was used for soils only. Section 5.2.6 of the *Draft Zone A RFI Report* contains additional description of the Wilcoxon rank sum test and justification for its use.

5.2.7 Summary of Techniques Used

Methods used for soil sample results are capable of detecting situations where (a) individual site values are much higher than background, or (b) site values are generally higher than background. For situation (a), site values were compared to reference concentrations consisting of twice the mean of background sample values. To account for situation (b), the Wilcoxon rank sum test was applied to compare each group of site values to background. For groundwater, site values were compared to reference concentrations only. Loss of the Wilcoxon rank sum test results was not considered detrimental to background comparisons. It was found that comparing individual sample results to twice the mean of the background samples is an arbitrary method that is inherently more conservative than using the statistical tests (upper tolerance limits) that are possible with larger datasets. The added conservatism of the "twice the mean" reference concentration test made up for the loss of the Wilcoxon rank sum test for groundwater.

5.2.8 Combined Results of the Reference Concentration and Wilcoxon Rank Sum Tests 1

Methods described in Section 5.2.5 identify individual site samples with concentrations 2
significantly higher than background, while the method in Section 5.2.6 identifies entire sites. If 3
the outcome of either test was positive (i.e., higher than background), sample values were 4
compared to the corresponding USEPA RBCs for soil and tap water, where appropriate, and 5
carried forward into detailed HHRA. Where background comparisons could not be carried out 6
for a chemical due to lack of detections in background samples, site concentrations were screened 7
against risk-based concentrations only. 8

5.2.9 Conclusion 9

The overall approach documented here is conservative for three reasons: 10

- Following procedures described in Section 5.2.1, high values were removed from the 11
background datasets whether or not they were true outliers in the conventional sense, 12
thereby lowering the total background concentrations to which the site values were 13
compared; 14

- The use of two complementary tests for soil sample results increased the likelihood that 15
any contamination would be identified and addressed further. A positive result from either 16
test triggered a detailed HHRA whenever site concentrations exceeded corresponding 17
USEPA RBC values; and 18

- The use of twice the mean of background sample concentrations as reference 19
concentrations generally results in lower background values than are justified by more 20
sophisticated statistical tests. The effect of these factors is to increase the rate of false- 21
positive test results while minimizing the rate of false negatives, as explained in 22
Section 5.2.4 of the *Draft Zone A RFI Report*. 23

In other words, some samples will be considered contaminated when they reflect nothing more than the high end of the range of background concentrations, and will trigger a detailed HHRA if their concentrations also exceed corresponding USEPA RBC values.

5.2.10 Background Reference Values

Table 5.1 presents background reference values (reference concentrations) derived from grid-based soil and groundwater samples from Zone F.

**Table 5.1
 Zone F
 Background Reference Values**

Inorganic Chemical	Surface Soil [mg/kg](n = 6)	Subsurface Soil [mg/kg](n = 6)	Shallow Groundwater [µg/L](n = 4)	Deep Groundwater [µg/L](n = 4)
Aluminum	18,500	17,100	224	77.7
Antimony	0.79	ND	ND	ND
Arsenic	19.9	18.2	16.7	16.2
Barium	61.5	51.8	94.3	200
Beryllium	1.05	1.20	0.66	0.46
Cadmium	0.26	9E-02	0.82	0.77
Chromium (total)	34.8	32.2	2.05	1.31
Cobalt	15.1	6.85	10.9	67.0
Copper	48.2	30.4	ND	ND
Lead	180	51.7	ND	ND
Manganese	307	469	2,010	1,260
Mercury	0.62	0.23	ND	ND
Nickel	12.6	8.85	5.55	61.1
Selenium	1.15	1.24	ND	ND
Silver	1.85	ND	ND	2.70
Thallium	ND	1.24	5.58*	8.18*

**Table 5.1
 Zone F
 Background Reference Values**

Inorganic Chemical	Surface Soil [mg/kg](n = 6)	Subsurface Soil [mg/kg](n = 6)	Shallow Groundwater [µg/L](n = 4)	Deep Groundwater [µg/L](n = 4)
Tin	9.38	ND	ND	ND
Vanadium	48.9	49.4	1.58	1.13
Zinc	198	84.2	ND	ND
Cyanide	0.29	0.24	3.30	4.30

Notes:

- ND = Not detected
- mg/kg = Milligrams per kilogram
- µg/L = Micrograms per liter
- * = Thallium values are subject to revision pending results of basewide study of thallium in groundwater
- n=6 = number of background soil samples analyzed
- n=4 = number of background groundwater samples analyzed

6.0 FATE AND TRANSPORT

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

Zone F AOCs and SWMUs are located on flat, low-lying land, mostly covered with buildings and pavement. Precipitation falling on impervious surfaces drains into storm sewers, where it is transported to outfalls on the Cooper River. The relatively small amount of rainwater that infiltrates the soil percolates into the upper, unconfined portion of the surficial aquifer, which is the uppermost unit of the regional Wando Formation. After evaluating Zone F for the characteristics discussed in the previous paragraph, four potential routes of constituent migration have been identified for further investigation:

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

Definitions:

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

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

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

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

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

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 controlled by their vapor pressures and Henry's Law Constants (HLs).

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 (VP), density (D), solubility, half-life ($T_{1/2}$), HL, organic carbon/water partitioning coefficient (K_{oc}), and molecular weight (MW). Table 6.1 provides an overview of chemical properties and expected behavior in environmental media based on these properties.

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

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

6.1.2 Media Properties Affecting Fate and Transport

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

Table 6.1
Zone F
Constituent Characteristics Based On
Chemical and Physical Properties

Property	Critical Value ^a	High (>)	Low (<)
Vapor Pressure	10E-03 mm Hg	volatile	nonvolatile
Density	1.0 g/cm ³	sinks/falls	floats/rises
Solubility	0 to 100 mg/L	leaches from soil; mobile in water; does not readily volatilize from water	sorbs to soil; immobile in water; volatilizes from water
Henry's Law Constant	5E-06 to 5E-03 atm-m ³ /mole	resistance to mass transfer in the aqueous phase	resistance to mass transfer in the gas phase
Half-life	biologically dependent	does not degrade readily	degrades readily
Organic Carbon/Water Partitioning Coefficient (K _{oc})	10 to 10,000 kg _{oc} /L _{water}	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	characteristics listed above may not hold true; more detailed evaluation necessary	all of the above generally hold true

Notes:

- ^a = Critical values were based on literature review and professional judgment
- mm Hg = Millimeters of mercury
- atm-m³/mole = Atmosphere cubic meters per mole
- kg_{oc}/L_{water} = Kilograms of organic carbon per liter of water
- g/cm³ = grams per cubic centimeter
- mg/L = milligrams per liter
- g/mole = grams per mole

Total Organic Carbon

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

Normalized Partitioning Coefficient

K_d 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 K_{oc} is adjusted by the soil's TOC: $K_d = f_{oc}$. Soil/constituent combinations with higher K_d s have a higher potential to sorb.

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. The process also depends on soil pH. Soils with high CEC values have the potential to adsorb inorganic ions and organic compounds with dipole moments.

Redox Conditions

Redox is the process which includes oxidation (the loss of electrons), and reduction (the gain of electrons). The resultant change in oxidation state generates 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

The R is a measure of the ability of an aquifer matrix to inhibit the movement of a chemical by preferentially binding contaminants with high K_{oc} . R is calculated as follows:

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

where:

R = Retardation factor

K_d = Normalized partitioning coefficient (L/kg)

ρ_b = Dry soil bulk density (kg/L)

n = Soil total porosity

Table 6.2 summarizes the soil parameters used to evaluate fate and transport for Zone F. The geometric mean CEC value for Zone F soil is 24.4 meq/100g, with a range of CEC values from 9.10 to 39.30 meq/100g. The geometric mean of the pH for Zone F soil is 6.85, with a range of pH values from 4.47 to 7.97. Sixteen of the 23 soil pH values were greater than 7.0. These soil conditions indicate limited mobility for inorganics by the processes of desorption, increased solubility, and consequent advection, diffusion, and dispersion, except in localized areas of low pH. The geometric mean of the TOC concentrations for Zone F soil samples was 4,570 mg/kg (the arithmetic mean was 8,833 mg/kg). The range of TOC values for Zone F soil is 745 to 36,900 mg/kg. TOC measurements indicate a relatively high organic content that will inhibit the

movement of contaminants, particularly those with high K_{oc} values, due to increased soil adsorption.

Table 6.2
Zone F
Soil Parameters Used to Evaluate Fate and Transport

Parameter	Number of Soil Samples	Zone F Minimum Value	Zone F Maximum Value	Zone F Geometric Mean Value	Units
CEC ^a	8	9.1	39.3	24.4	meq/100g
TOC ^a	8	745	36,900	4,570	mg/kg
pH ^a	23	4.47	7.97	6.85	—
Total Porosity ^b	18	.357	.83	.559	—
Hydraulic Conductivity^c					
Shallow Wells		8.9E-02	7.10	1.04	
Intermediate Wells		0.45	1.25	0.79	ft/day
Deep Wells		8.1E-03	2.14	0.46	

Notes:

- a = Values are from discrete soil sample data
- b = Values are from Zone F Shelby tube samples collected from the vadose zone and surficial aquifer
- c = Values are geometric means of rising head and falling head slug test results
- ft/day = feet per day
- meq/100g = milliequivalent per 100 grams
- mg/kg = milligrams per kilogram

The geometric mean of total porosity of the vadose zone and surficial aquifer in Zone F is 55.9%, as determined through analysis of 18 Shelby tube samples collected from depths ranging from 3 feet to 32 feet bgs. The elevated total porosity values reflect the high clay content of many of the samples. Hydraulic conductivity values for individual wells are reported as the geometric means of the rising head and falling head slug test results, as shown in Table 2.4. The average (arithmetic mean) of the geometric mean hydraulic conductivities for the Zone F shallow aquifer, as determined by slug test data analysis from 12 shallow monitoring wells is 1.04 ft/day. The

average geometric mean hydraulic conductivity for the Zone F intermediate aquifer, as determined by slug test data analysis from three intermediate monitoring wells (all at AOC 607) is 0.79 ft/day. The average geometric mean hydraulic conductivity for the Zone F deep aquifer, as determined by slug test data analysis from five deep monitoring wells (three of which were from AOC 607) is 0.46 ft/day. The averages for shallow and deep groundwater were each affected by one particularly large value; for comparison, geometric means of the geometric mean hydraulic conductivities were 0.44 ft/day for shallow groundwater, 0.74 ft/day for intermediate groundwater, and 6.6E-02 ft/day for deep groundwater.

Horizontal hydraulic gradients were calculated for shallow and deep groundwater at Zone F. For shallow groundwater, the average gradient varies from 9.3E-03 at low tide to 7.8E-03 at high tide. For deep groundwater, the average gradient varies from 3.0E-03 at low tide to 3.6E-03 at high tide. The estimated maximum horizontal groundwater velocity calculated for shallow groundwater at Zone F is 1.98E-02 ft/day. For deep groundwater, the calculated maximum velocity is 2.1E-02 ft/day.

Table 6.3 lists the calculated approximate travel times for advective groundwater from AOCs 613/615 and SWMU 175 and AOC 617. Based on Figures 2-5 and 2-6, these are the only two sites that exhibit flow in the general direction of the Cooper River. Groundwater levels in Zone F are typically within 5 feet of the surface. A river gauging station at the Army Depot in North Charleston at mile 10.5 of the Cooper River, upstream from Zone F, reported a mean river stage of 1.06 feet for the year October 1992 - September 1993. Downstream from NAVBASE at the gauging station at Charleston Harbor (mile 0.6), mean river stage is roughly zero. Calculation of travel times was based on an assumption of 0.5 ft msl local elevation for water in the Cooper River.

Table 6.3
Zone F
Travel Time Analysis

Site Area	Hydraulic Conductivity (ft/day) ^a	Horizontal Gradient (-)	Total Porosity (-) ^b	Horizontal Velocity (ft/yr)	Horizontal Distance (ft) ^c	Travel Time (years)
AOCs 613/615, SWMU 175 (Well GEL008 → Cooper River)	0.30	7.6E-03	.357	3.89	800	205.6
AOC 617 (Well 617002 → Cooper River)	0.11	8.3E-03	.357	0.93	950	1,021.5

Notes:

- a = Based on slug test data from adjacent monitoring wells
- b = Total porosity is based on the lowest porosity from Shelby tube samples collected in the upper sand
- c = Horizontal distance is based on the direct distance from the well to the surface water body, not the indirect path of groundwater flow
For advective groundwater only

6.2 Fate and Transport Approach for Zone F

Each site-specific fate and transport discussion in Section 10 describes site characteristics that can affect constituent migration. As presented earlier in this section, four potential routes of constituent migration have been identified for Zone F. Each site area has been evaluated for site conditions that promote these migration pathways.

Evaluation of an individual constituent's ability to migrate considers four cross-media transfer mechanisms: (1) soil-to-groundwater, (2) groundwater-to-surface water, (3) surface soil-to-air, and (4) surface soil-to-sediment. Cases can be made for each of these potential transfer mechanisms based on empirical data available for each environmental medium sampled. For example, if a constituent is found in soil as well as in groundwater, it is reasonable to conclude that the soil constituent may be leaching to the groundwater. In support of such conclusions, Zone F fate and transport phenomena were evaluated using constituent-specific chemical and physical properties, RBCs, and grid-based background reference values.

The following sections describe the methods used to evaluate the potential migration of constituents identified at each AOC/SWMU. 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) or 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 AOC/SWMU operations, it might be assumed that any compounds with the potential to migrate from soil into the surficial aquifer would have done so already. This assumption would also be appropriate in light of the thin, relatively permeable soil present above the static water table in Zone F. 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 AOC/SWMU (or group thereof) were compared to the greater of:

- Leachability-based generic soil-to-groundwater screening levels (SSLs) as presented in the USEPA *Soil Screening Guidance: Technical Background Document*, May 1996 (USEPA 1996c) (primary source) or USEPA Region III *Risk-Based Concentration Table, January-June 1996* (USEPA 1996b), (secondary source). Leachability-based SSLs were used directly from the *Technical Background Document* (USEPA 1996c), modified from those in the RBC table, or calculated independently, as described below, assuming a dilution attenuation factor (DAF) of 20.

- Soil background reference values for inorganics in Zone F, determined in consultation with the project team technical subcommittee; selected as described below.

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

- Tap water risk-based screening concentrations as presented in USEPA Region III *Risk-Based Concentration Table, January-June 1996* (USEPA 1996b), assuming a target hazard quotient (THQ) of 1.0.
- Groundwater background reference values for inorganics in Zone F, determined in consultation with the project team technical subcommittee; selected as described below.

Quantitative screening defines the list of chemicals to be considered for detailed fate and transport assessment. It reveals constituents in soil having the potential to impact the surficial aquifer. A conservative screening approach was employed using generic soil screening levels (SSLs) to provide the most comprehensive list of constituents with the potential to impact groundwater. It was assumed that if soil concentrations do not exceed conservative leachability-based screening levels or background, no significant migration potential exists. Likewise, if current groundwater concentrations do not exceed risk-based screening values or background, it was concluded that existing soil/groundwater equilibria are sufficiently protective of 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 20, rather than site-specific SSLs. DAFs significantly higher than 20 would be justified for Zone F AOCs and SWMUs, based on site-specific values of hydraulic conductivity, hydraulic gradient, aquifer thickness, and estimated infiltration rate (to estimate dilution), as well as soil type

and organic content (to estimate attenuation). Higher DAF values translate into higher SSLs. Section 6.3 compares assumptions underlying the fate and transport screening process with site-specific conditions. As a screening tool, generic SSLs are used to compile a list of potential fate and transport concerns; detailed fate and transport assessments evaluate the identified concerns to facilitate risk management decisions.

Table 6.4 contains physical site characteristics along with chemical and physical properties and regulatory standards for each constituent detected in Zone F soil and groundwater samples, enabling calculation of soil screening levels for protection of groundwater. Where generic SSLs for organics were not listed in the *Technical Background Document* (USEPA 1996c) or the *Region III Risk-Based Concentration Table, January-June 1996* (USEPA 1996b) they were calculated using the values shown in Table 6.4. Values of HL and K_{oc} not available in the *Technical Background Document* or the *USEPA Soil Screening Guidance: User's Guide* (USEPA 1996d), were obtained from various standard references. Where calculated SSLs in Table 6.4 differed from USEPA's generic values, the USEPA values were used. Differences in the two types of SSL were generally due to USEPA's use of nonstandard target leachate concentrations as starting points for their calculations: rather than starting with listed RBCs or MCLs, USEPA sometimes rounds them off to one or two significant figures. USEPA's starting-point values are listed in Attachment D, "Regulatory and Human Health Benchmarks for SSL Development," of the *User's Guide* (USEPA 1996d). Where no generic SSLs were listed for inorganics, generic SSLs were calculated based on default values for K_d taken from the TERRA model (Baes, C.S. III, et al., September 1984).

The SSL used for total chromium was 38 mg/kg, as recommended in the *Technical Background Document* (USEPA 1996c). EPA's prescribed value of 38 mg/kg is equal to the SSL for hexavalent chromium (or hexachrome) on the conservative assumption that any detected chromium

Table 6.4
 Calculation of Soil to Groundwater Soil Screening Levels
 NAVBASE Charleston: Zone F
 Charleston, South Carolina

Site-Specific Parameters:								
Fraction Organic Carbon (--) :	0.002							
Dilution Factor (--) :	20							
Dry Soil Bulk Density (kg/L) :	1.5	Dimension- less Henry's Law Constant (--)	Organic Carbon Water Part. Coeff. (L/kg)	Tap Water RBC (mg/L)	Unadjusted MCL/ MCLG (mg/L)	Target Leachate Conc. (mg/L)	Target Leachate Conc. (mg/L)	Soil to Groundwater SSL (mg/kg)
Water-filled Soil Porosity (--) :	0.3							
Air-filled Soil Porosity (--) :	0.13							
Soil Porosity (--) :	0.43							
Volatile Organic Compounds								
Acetone	1.59E-03	5.75E-01	3.7	NA	3.7	74	14.90	
Acrolein	1.80E-04	5.25E-01	0.73	NA	0.73	14.6	2.94	
Benzene	2.28E-01	5.89E+01	0.00036	0.005	0.005	0.1	0.0338	
Bromomethane	2.56E-01	NDA	0.0087	NA	0.0087	0.174	NDA	
2-Butanone	1.90E-03	3.88E+00	1.9	NA	1.9	38	7.90	
Carbon disulfide	1.24E+00	4.57E+01	1	NA	1	20	7.98	
Chlorobenzene	1.52E-01	2.19E+02	0.039	NA	0.039	0.78	0.508	
2-Chloroethyl vinyl ether	1.03E-02	2.20E+01	0.15	NA	0.15	3	0.735	
Chloromethane	3.60E-01	1.40E+00	0.0014	NA	0.0014	0.028	0.00655	
Dichlorodifluoromethane	9.23E+00	2.00E+02	0.39	NA	0.39	7.8	10.92	
1,1-Dichloroethane	2.30E-01	3.16E+01	0.81	NA	0.81	16.2	4.59	
1,2-Dichloroethane	4.01E-02	1.74E+01	0.00012	0.005	0.005	0.1	0.0238	
1,1-Dichloroethene	1.07E+00	5.89E+01	4.4E-05	0.007	0.007	0.14	0.0575	
cis-1,2-Dichloroethene	1.67E-01	3.55E+01	0.061	0.07	0.07	1.4	0.400	
trans-1,2-Dichloroethene	3.85E-01	5.25E+01	0.12	0.1	0.1	2	0.677	
Ethylbenzene	3.23E-01	3.63E+02	1.3	0.7	0.7	14	13.36	
2-Hexanone	NDA	NDA	NDA	NA	NDA	0	NDA	
4-Methyl-2-pentanone	1.61E-04	6.17E+00	2.9	NA	2.9	58	12.32	
Methylene chloride	8.98E-02	1.17E+01	0.0041	NA	0.0041	0.082	0.01896	
1,1,2,2-Tetrachloroethane	1.41E-02	9.33E+01	5.2E-05	NA	5.2E-05	0.00104	0.000403	
Tetrachloroethene	7.54E-01	1.55E+02	0.011	0.005	0.005	0.1	0.0575	
Toluene	2.72E-01	1.82E+02	0.75	1	1	20	11.75	
1,1,1-Trichloroethane	7.05E-01	1.10E+02	0.79	0.2	0.2	4	1.92	
Trichloroethene	4.22E-01	1.66E+02	0.0016	0.005	0.005	0.1	0.0569	
Trichlorofluoromethane	4.51E+00	1.58E+02	1.3	NA			ND	
Vinyl chloride	1.11E+00	1.86E+01	1.9E-05	0.002	0.002	0.04	0.01334	
Xylene (total)	2.91E-01	2.43E+02	12	10	10	200	142.2	
o-Xylene	2.13E-01	3.63E+02	1.4	10	10	200	188.9	
m-Xylene	3.01E-01	4.07E+02	1.4	10	10	200	208	
Semivolatile Organic Compounds								
Acenaphthene	6.36E-03	7.08E+03	2.2	NA	2.2	44	632	
Acenaphthylene	8.20E-03	4.79E+03	1.5	NA	1.5	30	293	
Anthracene	2.67E-03	2.95E+04	11	NA	11	220	13024	
Benzo(a)pyrene	4.63E-05	1.02E+06	9.2E-06	0.002	0.002	0.04	81.6	
Benzo(a)anthracene	1.37E-04	3.98E+05	9.2E-05	NA	9.2E-05	0.00184	1.465	
Benzo(b)fluoranthene	4.55E-03	1.23E+06	9.2E-05	NA	9.2E-05	0.00184	4.53	
Benzo(k)fluoranthene	3.40E-05	1.23E+06	0.00092	NA	0.00092	0.0184	45.3	
Benzo(g,h,i)perylene	5.74E-06	7.76E+06	1.5	NA	1.5	30	465606	
Benzyl alcohol	9.35E-06	5.00E+00	11	NA	11	220	46.2	
4-Bromophenyl-phenylether	4.80E-03	1.70E+04	2.1	NA	2.1	42	1436	
Butylbenzylphthalate	5.17E-05	5.75E+04	7.3	NA	7.3	146	16819	
Carbazole	6.26E-07	3.39E+03	0.0034	NA	0.0034	0.068	0.475	
4-Chloro-3-methylphenol	7.30E-05	7.76E+02	180	NA	180	3600	6307	
Chrysene	3.88E-03	3.98E+05	0.0092	NA	0.0092	0.184	146.5	
Dibenzo(a,h)anthracene	6.03E-07	3.80E+06	9.2E-06	NA	9.2E-06	0.000184	1.398	
Dibenzofuran	NDA	NDA	0.15	NA	0.15	3	NDA	
1,2-Dichlorobenzene	7.79E-02	6.17E+02	0.27	0.6	0.6	12	17.29	
1,3-Dichlorobenzene	1.48E-01	1.70E+02	0.54	NA	0.54	10.8	5.97	
1,4-Dichlorobenzene	9.96E-02	6.17E+02	0.00044	0.075	0.075	1.5	2.16	
Dimethylphthalate	2.17E-03	4.40E+01	370	NA	370	7400	2133	

Table 6.4
 Calculation of Soil to Groundwater Soil Screening Levels
 NAVBASE Charleston: Zone F
 Charleston, South Carolina

Site-Specific Parameters:								
Fraction Organic Carbon (--):	0.002							
Dilution Factor (--):	20							
Dry Soil Bulk Density (kg/L):	1.5	Dimension-	Organic					
Water-filled Soil Porosity (--):	0.3	less	Carbon			Unadjusted		
Air-filled Soil Porosity (--):	0.13	Henry's	Water	Tap		Target		
Soil Porosity (--):	0.43	Law	Part.	RBC	MCL/	Leachate	Target	Soil to
		Constant	Coeff.	(mg/L)	MCLG	Conc.	Conc.	Groundwater
		(--)	(L/kg)		(mg/L)	(mg/L)	(mg/L)	SSL
								(mg/kg)
Di-n-octylphthalate	2.74E-03	8.32E+07	0.73	NA	0.73	14.6	2.43E+06	
bis(2-Ethylhexyl)phthalate	4.18E-06	1.51E+07	0.0048	0.006	0.006	0.12	3624	
Fluoranthene	6.60E-04	1.07E+05	1.5	NA	1.5	30	6426	
Fluorene	2.61E-03	1.38E+04	1.5	NA	1.5	30	834	
Indeno(1,2,3-cd)pyrene	6.56E-05	3.47E+06	9.2E-05	NA	9.2E-05	0.00184	12.77	
2-Methylnaphthalene	1.98E-02	2.00E+03	1.5	NA	1.5	30	126.1	
4-Methylphenol (p-cresol)	4.92E-05	9.12E+01	0.18	NA	0.18	3.6	1.38	
Naphthalene	1.98E-02	2.00E+03	1.5	NA	1.5	30	126.1	
N-Nitroso-methylethylamine	1.74E-05	4.00E+00	3.1E-06	NA	3.1E-06	6.2E-05	0.0000	
Phenanthrene	1.60E-03	2.29E+04	1.5	NA	1.5	30	1381	
Pyrene	4.51E-04	1.05E+05	1.1	NA	1.1	22	4624	
1,2,4,5-Tetrachlorobenzene	4.00E-09	6.65E+03	0.0018	NA	0.0018	0.036	0	
1,2,4-Trichlorobenzene	5.82E-02	1.78E+03	0.19	0.07	0.07	1.4	5.27	
Polychlorinated dibenzodioxins/dibenzofurans								
TCDD Equivalents	1.31E-03	1.58E+06	4E-10	3E-08	3E-08	6E-07	0.001902	
Pesticide/PCB Compounds								
Aldrin	6.97E-03	2.45E+06	4E-06	NA	4E-06	8E-05	0.392	
Aroclor 1260	NA	3.09E+05	8.7E-06	0.0005	NA	NA	1.00	
delta-BHC	3.05E-05	1.26E+03	3.7E-05	NA	3.7E-05	0.00074	0.00201	
gamma-BHC (Lindane)	5.74E-04	1.07E+03	5.2E-05	0.0002	0.0002	0.004	0.00936	
alpha-Chlordane	1.99E-03	1.20E+05	5.2E-05	0.002	0.002	0.04	9.61	
gamma-Chlordane	1.99E-03	1.20E+05	5.2E-05	0.002	0.002	0.04	9.61	
4,4'-DDD	1.64E-04	1.00E+06	0.00028	NA	0.00028	0.0056	11.20	
4,4'-DDE	8.61E-04	4.47E+06	0.0002	NA	0.0002	0.004	35.8	
4,4'-DDT	3.32E-04	2.63E+06	0.0002	NA	0.0002	0.004	21.0	
Dieldrin	6.19E-04	2.14E+04	4.2E-06	NA	4.2E-06	8.4E-05	0.00361	
Endosulfan	4.59E-04	2.14E+03	0.22	NA	0.22	4.4	19.71	
Endrin	3.08E-04	1.23E+04	0.011	0.002	0.002	0.04	0.992	
Heptachlor	6.07E+01	1.41E+06	2.3E-06	0.0004	0.0004	0.008	22.6	
Inorganic Compounds								
		<i>Kd (6.8 pH)</i>						
Aluminum	NA	1.50E+03	37	NA	37	740	1.11E+06	
Antimony	NA	4.50E+01	0.015	0.006	0.006	0.12	5.42	
Arsenic	NA	2.90E+01	4.5E-05	0.05	0.05	1	29.2	
Barium	NA	4.10E+01	2.6	2	2	40	1648	
Beryllium	NA	7.90E+02	1.6E-05	0.004	0.004	0.08	63.2	
Cadmium	NA	7.50E+01	0.018	0.005	0.005	0.1	7.52	
Chromium (III)	NA	1.80E+06	37	0.1	0.1	2	3.60E+06	
Chromium (VI)	NA	1.90E+01	0.18	0.1	0.1	2	38.4	
Cobalt	NA	4.50E+01	2.2	NA	2.2	44	1989	
Copper	NA	3.50E+01	1.5	1.3	1.3	26	915.2	
Lead	NA	NA	0.015	NA	0.015	0.3	Background	
Manganese	NA	6.50E+01	0.84	NA	0.84	16.8	1095	
Mercury	4.67E-01	5.20E+01	0.011	0.002	0.002	0.04	2.090	
Nickel	NA	6.50E+01	0.73	0.1	0.1	2	130.4	
Selenium	NA	5.00E+00	0.18	0.05	0.05	1	5.20	
Silver	NA	8.30E+00	0.18	NA	0.18	3.6	30.6	
Thallium	NA	7.10E+01	0.0029	0.0005	0.0005	0.01	0.712	
Tin	NA	2.50E+01	22	NA	22	440	11088	
Vanadium	NA	1.00E+03	0.26	NA	0.26	5.2	5201	

Table 6.4
 Calculation of Soil to Groundwater Soil Screening Levels
 NAVBASE Charleston: Zone F
 Charleston, South Carolina

Site-Specific Parameters:		Dimension- less	Organic Carbon	Tap Water	MCL/ MCLG	Unadjusted Target Leachate Conc.	Target Leachate Conc.	Soil to Groundwater SSL
		Henry's Law Constant (-)	Water Part. Coeff. (L/kg)	RBC (mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg)
Fraction Organic Carbon (-):	0.002							
Dilution Factor (-):	20							
Dry Soil Bulk Density (kg/L):	1.5							
Water-filled Soil Porosity (-):	0.3							
Air-filled Soil Porosity (-):	0.13							
Soil Porosity (-):	0.43							
Zinc		NA	6.20E+01	11	NA	11	220	13684

Notes:
 NA - Not applicable
 NDA - No data available
 kg/L - Kilograms per liter
 L/kg - Liters per kilogram
 mg/kg - Milligrams per kilogram
 mg/L - Milligrams per liter

may be hexachrome. Although none of the 12 Zone F duplicate soil samples that were analyzed for hexachrome reported a detection, the number of hexachrome analyses was not considered large enough to rule out the possibility of hexachrome as a contributor to reported total chromium concentrations. According to the *Technical Background Document* (USEPA 1996c), trivalent chromium as a contaminant in soil is not considered a threat to groundwater at any concentration.

The greater of the background reference values for surface soil or subsurface soil was used as the screening alternative to SSLs for inorganics. Since constituent migration is from surface or near-surface soil downward through subsurface soil to the aquifer, and since the SSL methodology assumes zero attenuation of constituents during migration, the higher of the two background values is always appropriate for comparison to SSLs. Similarly, the greater of the background reference values for shallow and deep groundwater was used as the screening alternative to tap water RBCs. The lithology of the surficial aquifer in Zone F is complex. Over distances involved in migration from AOCs/SWMUs to surface water, aquifer units at all depths down to the confining unit (Ashley Formation) are assumed to be interconnected, so that the higher background value is always relevant.

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

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. Surface water was not sampled as part of the Zone F RFI. Therefore, potential impacts to surface water were evaluated by comparing groundwater constituent concentrations to surface water screening standards, as described below. The screening process may be summarized as follows:

Quantitative — Chemicals present in groundwater were compared to appropriate screening values. Relative to human health evaluation, maximum shallow and deep groundwater analytical results for each AOC/SWMU (or group thereof) were compared to the greater of:

- Tap water risk-based screening levels as presented in USEPA Region III *Risk-Based Concentration Table, January-June 1996* (USEPA 1996b).
- Groundwater background reference values for inorganics in Zone F, determined in consultation with the project team technical subcommittee; selected as described above in Section 6.2.1.

To evaluate potential impact on ecological receptors, maximum shallow and deep groundwater analytical results for each AOC/SWMU (or group thereof) were compared to USEPA saltwater surface water chronic screening values for hazardous waste sites, from *Supplemental Guidance*

to RAGS: *Region IV Bulletins, Ecological Risk Assessment*, (USEPA 1995b). Since surface water 1
samples were not collected as part of the Zone F RFI, no background values for surface water 2
constituents could be determined for use as alternatives to surface water screening standards. 3

The quantitative assessment identifies chemicals detected in groundwater having the potential to 4
disperse within the aquifer, increasing the areal extent of groundwater concentrations that exceed 5
human-health-based standards, or impacting surface water via groundwater migration and 6
discharge. If groundwater concentrations do not exceed tap water risk-based screening levels or 7
background concentrations, no significant threat relative to migration potential exists. If reported 8
concentrations in groundwater do not exceed saltwater surface water chronic screening levels, no 9
threat exists relative to ecological impacts resulting from groundwater discharge to surface water. 10
This screening assessment purposely does not consider effects of dilution and attenuation on 11
transport between the affected well and the surface water discharge point, or the dilutional capacity 12
of the receiving water body. Omitting these factors from the quantitative screening ensures that 13
a conservative list of potential groundwater to surface water concerns is developed. 14

Detailed Assessment — Upon completion of the quantitative screening process, detailed 15
assessments were performed to delineate the magnitude and areal extent of groundwater impacts 16
that may adversely affect human or ecological receptors. Maximum constituent concentrations in 17
shallow groundwater were compared to those in deep groundwater to estimate the extent of 18
downward migration. The number and spatial distribution of exceedances were noted. 19

The detailed assessments helped to determine the significance of groundwater impacts and potential 20
impacts. In addition, inferences were drawn about the potential for significant impacts on surface 21
water. The Zone J RFI results will be used to confirm or refute preliminary conclusions. Detailed 22
assessments were also used to determine which areas of groundwater contamination may require 23

supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

6.2.3 Surface Soil-to-Sediment Cross-Media Transport

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

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

Sediments are formed by surface soil erosion, with accumulation in depositional areas. Normally, site topography and ground cover would be used to identify areas with erosional potential and the corresponding expected areas of deposition. Because erosional/depositional processes within Zone F are limited at most locations due to the widespread presence of buildings or paved surfaces, migration of constituents from surface soil to sediment has been rare. Zone F sediment samples were all collected from storm sewer catch basins. Nevertheless, sediment results were compared to data for proximate surface soil representing possible points of origin for sediment contaminants. This process clearly disregards those constituents that have accumulated in catch basins onsite but were derived from an upgradient source and transported through the sewer system. At most sites, it was concluded that constituents present in both surface soil and sediment likely came from a common or similar source.

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

Evaluation of fate and transport for sediments in Zone F was limited to sediments as contaminant receptors. Fate and transport for constituents originating in Zone F catch-basin sediments will be provided in the RFI report for Zone L.

6.2.4 Soil-to-Air Cross-Media Transport

To evaluate the soil-to-air migration pathway for volatile contaminants, a screening approach focused on volatile chemicals possessing the greatest potential to create a human health threat in ambient air. The screening process may be summarized as follows:

Quantitative — The maximum concentrations of volatile organics detected in surface soil at each AOC/SWMU were compared to soil-to-air screening concentrations as presented in the USEPA Region III *Soil Screening Guidance: Technical Background Document* (USEPA 1996c) (primary source) or *Risk-Based Concentration Table, January-June 1996* (USEPA 1996b) (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, no significant migration potential exists, and current soil conditions would be 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 volatiles into the air.

The outcome of the detailed assessments was used to determine the significance of soil impacts relative to ambient air. In some instances, isolated areas of soil contamination above soil-to-air

volatilization-based concentrations could have the potential for localized ambient air impacts but not be of a magnitude to pose a long-term or widespread threat through inhalation pathways. The detailed assessment 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. The screening tables identify the constituents, while the detailed assessments evaluate their significance. This procedure depends heavily on USEPA's soil screening methodology, and makes many simplifying assumptions that come directly from the 1996 *Soil Screening Guidance* (USEPA 1996c,d). This section compares some of the assumptions of the screening procedure with actual conditions encountered at AOCs and SWMUs in Zone F in an attempt to demonstrate the conservative nature of the method. The screening assumptions are shown in italics, followed by commentary.

1. *The contaminant source is infinite (i.e., steady-state concentrations are maintained during the exposure period).* At virtually every site, the original source of the soil contamination (process/spill) — prior to soil contamination — has been discontinued. As constituent molecules migrate through the system or degrade, they are generally not replaced from the original source.
2. *Each soil contaminant is uniformly distributed from the surface to the top of the aquifer, at a concentration equal to the maximum value reported from any of the samples.* Site conditions vary greatly, as seen in sample analytical results. Most often, screening

exceedances are reported from a relatively small percentage of samples, as presented in the detailed assessments.

3. *There is no contaminant attenuation (i.e., adsorption, biodegradation, chemical degradation) as leachate moves downward through soil.* Dissolved organic compounds and metallic ions originating in the upper soil horizons are not particularly mobile, due to sorption. Because of their origins in back-barrier, lagoonal, and other low-energy environments (Section 2.2.3.2), many NAVBASE soils and lithologic units exhibit clay content varying from moderate to very high. The geometric mean of the CEC values for eight Zone F soil samples was 24.4 meq/100g. For comparison, CEC for pure montmorillonite clay (smectite) ranges from 80 to 150 meq/100g. Other clays such as illite (10-40 meq/100g) and kaolinite (3-15 meq/100g) have lower values (Boulding 1995). The relatively high clay content and corresponding high CEC values of Zone F soil should result in extensive attenuation of migrating site constituents, especially inorganics.

The geometric mean of the TOC values for the same eight soil samples was 4,570 mg/kg ($K_{oc} = 4.6E-03$), while the arithmetic mean was 8,830 mg/kg ($K_{oc} = 8.8E-03$). The default value of K_{oc} used by USEPA to calculate generic SSLs is $2E-02$, indicating that Zone F soils have on average two to four times the organic carbon available to bind contaminants to soil particles, versus the soils assumed in the generic model's partitioning equation for migration to groundwater.

USEPA's generic SSLs are based on reference values of K_{oc} for ionizing organics and K_d for inorganics. The listed reference values assume a soil pH of 6.8. For Zone F, the geometric mean pH for 23 soil samples is 6.85, indicating that the assumption for this factor has been met. Values of K_d for most metals would be higher in local areas with

higher pHs and lower in areas with lower pHs. The effect of pH variations on ionizing organics is reversed, but is weaker than for inorganics.

4. *The generic SSLs used in the screening tables are based on a DAF of 20. Since EPA’s methodology unrealistically assumes zero attenuation for migration of leachate through the vadose zone and groundwater through the aquifer, the default DAF of 20 recommended in the 1996 User’s Guide (USEPA 1996d) is actually a dilution factor only. Using equations presented therein, a site-specific dilution factor of 14 was calculated for leachate and shallow groundwater at AOC 607. The calculation assumes a rainfall infiltration rate of 0.3 inches per year, equal to the rate assigned by the ongoing USGS groundwater modeling study to the semi-industrial areas of the base (Zones A, H, and I). Considering the high clay content (Table 2.2) and corresponding low hydraulic conductivity values (Table 2.4) in Zone F soil and aquifer sediments, a default DAF of 20 is suitable conservative for initial screening purposes.*
5. *There is no contaminant attenuation as groundwater moves through the aquifer. Although Zone F aquifer sediments were not sampled for hydrogeochemical parameters, the lithology and the CEC and TOC values of the soil samples in the vadose zone indicate the potential for attenuation, as discussed above in item three:*
- *Substantial amounts of clay minerals present*
 - *Geometric mean of the CEC values for eight samples is similar to those of illite*
 - *Geometric mean of the TOC values for eight samples are two to four times higher than the EPA’s default values*
6. *The 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 20:1 by groundwater, or (b) maximum groundwater concentration. This assumption should be compared to analytical results from soil and groundwater samples collected at each AOC/SWMU and from groundwater samples collected downgradient from each site. High constituent concentrations in Zone F 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 assessments for each site.

- 7. An appropriate human health screen for groundwater is EPA's Region III tap water RBCs (USEPA 1996b) using a THQ of 1.0. Since the focus of the fate and transport analysis was on individual chemical concentrations and behavior rather than risk, a THQ of 1.0 was considered appropriate. The many built-in conservatisms discussed above should more than make up for any possible compounding effects of multiple contaminants in environmental media.*

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

7.0 HUMAN HEALTH RISK ASSESSMENT

7.1 Introduction

Section 7.1 of the *Draft Zone A RFI Report* discusses the purpose of the HHRA as it applies to the Zone F RFI.

Chemical contamination at the site must be adequately characterized before a HHRA can determine whether detected concentrations are potentially toxic and cause increased cancer incidences, and before it becomes useful for making remedial decisions. Characterizing the study area includes determining the amount, type, and location of contaminant sources. Variables include exposure pathways such as media type and migration routes; and the type, sensitivities, exposure duration, and dynamics of the exposed populations (receptors); as well as the toxicological properties of identified contaminants.

7.2 Objectives

The objectives of the HHRA are to: (1) characterize the source media and determine the chemicals of potential concern (COPCs) for affected environmental media; (2) identify potential receptors, quantifying potential exposures under current and future conditions for all affected environmental media; (3) qualitatively and quantitatively evaluate the adverse effects associated with the site-specific COPCs in each medium; (4) characterize the potential baseline carcinogenic risk and noncarcinogenic hazards associated with exposure to impacted environmental media at Zone F under current and future conditions; (5) evaluate uncertainties related to exposure predictions, toxicological data, and resultant carcinogenic risk and noncarcinogenic hazard predictions; and (6) establish Remedial Goal Options (RGOs) for chemicals of concern (COCs) in each environmental medium based on risk/hazard for risk management decision-making.

The focus of each investigation is detailed in the field investigation approach section for each site. Comprehensive tables list the sample identification numbers and analytical methods applied to each

sample. At most AOCs and SWMUs, sampling activities consisted of collecting surface (upper interval) and subsurface (lower interval) soil samples, and groundwater samples from monitoring wells installed in the shallow and deep portions of the surficial aquifer underlying the zone (as well as intermediate depth groundwater at AOC 607). Analytical results from surface soils and groundwater were used to assess possible exposure to environmental contaminants.

Organization

A HHRA, as defined by Risk Assessment Guidance for Superfund (RAGS) Part A, includes the following steps:

- *Site characterization:* Evaluation of site geography, geology, hydrogeology, climate, and demographics.
- *Data collection:* Analysis of environmental media samples, including background/reference samples.
- *Data evaluation:* Statistical analysis of analytical data to identify the nature and extent of contamination and to establish a preliminary list of COPCs based on risk-based and background screening. This list will subsequently be refined to identify COCs.
- *Exposure assessment:* Identification of potential receptors under current and predicted conditions, visualization of potential exposure pathways, calculation of exposure point concentrations (EPCs), and quantification of chemical intakes.
- *Toxicity assessment:* Qualitative evaluation of the adverse effects of the COPCs, and quantitative estimate of the relationship between exposure and severity or probability of effect.

- *Risk characterization:* A combination of the outputs of the exposure assessment and the toxicity assessment to quantify the total cancer and noncancer risk to the hypothetical receptors. 1
2
3

- *Uncertainty:* Discussion and evaluation of the areas of recognized uncertainty in human health risk assessments in addition to medium- and exposure pathway-specific influences. 4
5

- *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. 6
7
8

- *RGOs:* Computation of exposure concentrations corresponding to risk projections within the USEPA target risk range of 1E-06 to 1E-04 for carcinogenic COCs and Hazard Quotient (HQ) goals of 0.1, 1, and 3 for noncarcinogenic COCs. 9
10
11

This general process was followed in preparing the HHRA for each Zone F AOC and SWMU or groups of sites at NAVBASE. 12
13

7.3 Human Health Risk Assessment Methods 14

Section 7.3 of the *Draft Zone A RFI Report* discusses HHRA methods as these apply to the Zone F RFI. 15
16

7.3.1 Data Sources 17

Section 7.3.1 of the *Draft Zone A RFI Report* discusses data sources as they apply to the Zone F RFI. 18
19

7.3.2 Data Validation

Section 7.3.2 of the *Draft Zone A RFI Report* discusses data validation as it applies to the Zone F RFI.

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: (1) analytical methods not specific for a particular chemical such as TOC or total organic halogen; and (2) field screening instruments, including total organic vapor monitoring units and organic vapor analyzers.

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 the duplicate and primary sample results were used as the applicable value, unless the analyte was detected in only the duplicate or primary sample. In such cases, the detected results were used.

In addition, the HHRA's 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), as 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. Because the estimated values of *J*-qualified hits were frequently much lower than the sample quantitation limits of *U*-qualified nondetects for organic compounds, one-half of each *U* value was compared to one-half of the lowest hit (normally *J*-qualified) at the same site. The lesser of these two values

was used as the best estimate of the concentration that was potentially present below the sample quantitation limit, and was inserted into the adjusted dataset.

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

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

- *RAGS, Volume I – Human Health Evaluation Manual (Part A)*, (USEPA 1989), (RAGS Part A).
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert 1987).
- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (USEPA 1992).

Microsoft FoxPro, Borland Quattro Pro, and SPlus for Windows¹ were used to manage data and calculate statistics. For each set of data describing the concentration of chemicals in a contaminated area, the following information was tabulated: frequency of detection, range of detected values, average of detected concentrations, and the calculated 95% upper confidence limit (UCL) for the mean of log transformed values of the concentration. In accordance with RAGS, either the maximum concentration detected or the UCL was used to quantify potential exposure, depending on which one was the lesser value.

7.3.4 Selection of Chemicals of Potential Concern

The objective of this step was to screen the available information on the CPSS at each AOC or SWMU 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 COPCs 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 1E-06 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 1E-06 or an HQ greater than 0.1 ILCR.

Before evaluating the potential risks/hazards associated with site media, it was first necessary to delineate onsite contamination by noting the chemicals detected in environmental media. These chemicals represent the CPSS for each AOC or SWMU. The nature and general extent of CPSS at each site are detailed 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.

¹ Reference to specific software products are not to be construed as an endorsement by the U.S. Navy or EnSafe Inc.

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 the *Risk-Based Concentration Table, January — June 1996* (USEPA 1996b). According to this guidance, USEPA used a target HQ of 0.1 and a risk goal of 1E-06 to calculate screening concentrations for noncarcinogens and carcinogens, respectively. Noncarcinogenic chemical values were adjusted to equate to 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 USEPA Office of Solid Waste and Emergency Response directives considering protection of a hypothetical child resident (USEPA 1994a); the lead groundwater screening value used was the USEPA Office of Water treatment technique action level (AL) of 15 µg/L (USEPA 1996e).

A soil screening value of 1,000 ng/kg (as 2,3,7,8-TCDD TEQs) was applied to chlorinated dibenzo-p-dioxin (CDDs) and dibenzofurans, based on a worker/industrial scenario and a target risk of 1E-04. USEPA Region IV has determined this value to be an appropriate cleanup level although normally a residential scenario and a target risk of 1E-06 serve as the basis for screening values. For dioxin, USEPA Region IV considers this target risk more appropriate because of the high level of uncertainty associated with dioxin exposure. For groundwater, the TEQ value computed for each sample was compared to the 2,3,7,8-TCDD tap water screening level of 4E-04 pg/L.

In accordance with recent cPAH guidance (USEPA, 1993), BEQs were computed, where appropriate, by multiplying the reported concentration of each cPAH by its corresponding toxicity equivalency factor (TEF). The BEQ values were then summed for each sample, and the total was compared to the benzo(a)pyrene RBC value during the screening process. Subsequent exposure

quantification and risk/hazard projections for cPAHs in soil and groundwater 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. The selection of surrogate compounds was based on structural, chemical, or toxicological similarities.

Because shallow and deep groundwater beneath most Zone F areas contain chlorides and/or TDS exceeding South Carolina potable source criteria, water from these aquifers is not appropriate for domestic use. Consequently, screening the concentrations of compounds detected in groundwater against tap water RBCs assesses the significance of groundwater impacts very conservatively.

For CPSS present in all depths of soil and shallow groundwater, an additional risk-based screening was 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 were determined for Zone F using results from the grid-based soil and groundwater background sampling. Surface soil, subsurface soil, shallow groundwater, and deep groundwater were all addressed separately for determining background concentrations. After risk- and hazard-based screening values were compared, CPSS were retained for further consideration as COPCs in the HHRA on an AOC- or SWMU-specific basis under the following conditions: if their maximum detected concentrations exceeded corresponding background concentrations, or if overall site concentrations were significantly greater than corresponding overall background concentrations as determined by Wilcoxon rank sum test

procedures. The two statistical background comparisons were conducted as parallel analyses. If either method suggested that site-specific concentrations deviated from naturally occurring levels, the chemical was retained for formal risk assessment. These comparisons help account for chemicals common in nature, such as aluminum, manganese, and arsenic. By virtue of this process, risk and/or hazard associated with naturally occurring chemicals is not addressed where concentrations do not exceed corresponding background values. The statistical methods used to determine background concentrations and the rationale used to compare site concentrations are discussed in Section 5 of this report.

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

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

In accordance with RAGS Part A, essential elements that are potentially toxic only at extremely high concentrations may be eliminated from further consideration as COPCs in a risk assessment. Specifically, an essential nutrient may be screened out of a risk assessment if it is present at

concentrations 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: (1) calcium, (2) iron, (3) magnesium, (4) potassium, and (5) sodium.

Summary of COPCs

Screening evaluation results are presented on a medium-specific basis in each HHRA in Section 10. In summary, the risk information obtained from the Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST) is necessary to calculate risk, hazard estimates, and risk-based screening values. This information is based on toxicological and epidemiological data critiqued and approved by the scientific and regulatory community (i.e., listed in IRIS and/or HEAST). Risk information was not available for some CPSS; therefore, it was not possible to calculate risk and/or hazard for those chemicals. For each environmental medium sampled at an AOC or SWMU, the data were screened using risk-based and background values. Screening process results are presented in tables in each HHRA. Those chemicals determined to be COPCs through the screening process are designated with an asterisk. Total isomer concentrations reported for CDDs and dibenzofurans (e.g., Total HxCDD) were not specifically used in formal assessment per USEPA protocol. No risk-based screening values are available for the generic group total petroleum hydrocarbons (TPH). As a result, TPH assessment was consistent with the NAVBASE screening level of 100 mg/kg for soil. If no groundwater impacts were identified, the current soil concentrations were considered sufficiently protective of the underlying aquifer.

7.3.5 Calculation of Risk and Hazard

Section 7.3.5 of the *Draft Zone A RFI Report* discusses the calculation of risk and hazard as it applies to the Zone F RFI.

7.3.6 Exposure Assessment	1
Section 7.3.6 of the <i>Draft Zone A RFI Report</i> discusses exposure assessment for the Zone F RFI HHRA.	2 3
7.3.7 Toxicity Assessment	4
Section 7.3.7 of the <i>Draft Zone A RFI Report</i> discusses the toxicity assessment procedures for the Zone F RFI HHRA.	5 6
7.3.8 Risk Characterization	7
Section 7.3.8 of the <i>Draft Zone A RFI Report</i> discusses the risk characterization procedures used for the Zone F RFI.	8 9
7.3.9 Risk Uncertainty	10
This section of the HHRA discusses the uncertainty and/or variability inherent in the risk assessment process, along with medium and exposure pathway-specific influences. Risk assessment sections are discussed separately below; specific examples of uncertainty sources are included where appropriate.	11 12 13 14
General	15
Uncertainty factors into each step of the exposure and toxicity assessments summarized above. Combined with other uncertainties, initial uncertainties associated with the first stages of the risk assessment process become magnified. Using high-end estimates of potential exposure concentrations, frequencies, durations, and rates leads to conservative chronic daily intake (CDI) estimates. Toxicological values for chemicals derived from USEPA databases and other sources are generally derived from animal studies. To predict potential human responses, uncertainty and modifying factors are applied to extrapolate the results of these studies, and provide a margin of safety based upon confidence in the studies. During the risk characterization, individual chemical	16 17 18 19 20 21 22 23

risk is added to determine the incremental excess cancer risk for each exposure pathway. If calculations of individual exposure predictions were 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. All uncertainties or potential variability cannot be eliminated from the risk assessment process. However, recognizing the influences of these factors is fundamental to understanding and subsequently using risk assessment results.

The risk uncertainty portion of the HHRA presents factors influencing the uncertainty of the calculated incremental excess cancer risks and HQs/HIs. It also discusses, the uncertainty and/or variability of site-specific and medium/pathway-specific factors introduced in the risk assessment process. Calculated risk/hazard levels reflect the underlying variability of the analytical results upon which they are based. These levels also embody uncertainty about potentially unsampled maxima and minima in the analytes. The exposure pathways considered in the exposure assessment section of the HHRA are extremely conservative.

During the risk assessment process, assumptions are based on population studies and USEPA guidance. This guidance divides the assumptions into two basic categories: (1) the upper bound (90 to 95th percentile), and (2) the mean or 50th percentile central tendency (CT) exposure assumptions. As discussed in the exposure assessment section, the reasonable maximum exposure (RME) is based on the upper-bound assumptions, while CT exposure is based on mean assumptions. Therefore, risks and hazards calculated using RME 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 F investigation are presented in Section 10 of this RFI, which includes results from AOC and SWMU sites. The QA/QC of those data is addressed in Section 4. The purpose of the data evaluation is to verify that the QC requirements of the dataset have been met and to characterize questionable data.

Most analytical results for environmental samples have inherent uncertainty. This uncertainty is a function of: (1) the matrix characteristics and heterogeneity, (2) the precision and accuracy of sampling, and (3) 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 actually 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 that individually exceed 1E-06 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. Potential cumulative effects associated with multiple chemicals dismissed through this process are a valid concern. However, since maximum detected concentrations were used in the screening comparison with low range risk/hazard goals, much uncertainty is alleviated. A large number (i.e., greater than 10) of constituents would have to be present at near-RBC concentrations to substantiate cumulative effects concerns. Although conservative screening methods are used, inhalation and dermal exposure are not incorporated into

the soil screening values calculated by USEPA. If these pathways were the primary concern (as opposed to the ingestion pathway), the screening method could eliminate contaminants that should otherwise be considered COPCs. Zone F surface soil data are compared to soil-to-air cross-media transport via volatilization in the fate and transport discussion of this report. Constituents that can significantly contribute to risk via other exposure pathways, but were omitted based on comparison to residential RBCs, were added back to the list of COPCs.

Comparison to Reference Concentrations (Background)

Because the HHRA estimates the excess cancer risk or health hazard posed by COPCs, individual sample data values for inorganic chemicals were compared to background reference concentrations in the Zone F RFI, after being compared to the risk-based screening values. As a corollary background screening method, the Wilcoxon rank sum test was used to compare site inorganic COPC data populations to corresponding reference data populations. The outcomes of the fixed point and Wilcoxon tests determined whether concentrations differed significantly between onsite and background locations, as detailed in Section 7.3.4. The dual approach to background screening reduces the probability for a COPC to be improperly dismissed from formal assessment.

Additional uncertainty is introduced by comparing site data to nonspecific screening reference data. Although the background concentrations are specific to Zone F, they are not specific to individual AOCs or SWMUs. The use of zone-specific background reference standards, however, decreases the uncertainty normally resulting from using a single set of standards for the entire base.

Elimination of Essential Nutrients

In accordance with RAGS, the following nutrients were eliminated from the Zone F HHRA: (1) calcium, (2) sodium, (3) potassium, (4) magnesium, and (5) iron. Toxicity from overexposure to these nutrients is only possible 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

Because of the highly conservative assumptions (e.g., future residential use) recommended by USEPA Region IV, high bias potential is introduced through the exposure setting and pathway selection when assessing potential future and current exposure. The assumptions made in the site worker scenario are also conservative and 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 could not be expected to stay 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 F sites is not likely, based on uses, the nature of surrounding areas, and potential reuse plans. If this area ever became residential, most of the present buildings would be demolished and the surface soil conditions would likely change. The area 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. 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 F location as a source of potable or process water. A basewide potable water system provides drinking and process water to buildings throughout Zone F. This system is to remain in operation under the current base reuse plan. Accordingly,

use of shallow groundwater would not be expected under future use scenarios. Therefore, the projected risk/hazard scenario associated with shallow groundwater exposure is highly conservative, and associated pathways are not expected to be completed in the future.

Additionally, the shallow aquifer monitored during the RFI naturally contains significant concentrations of chlorides and TDS. As such, 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 (USEPA, 1992), 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 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 (estimated) 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 as a way to interpolate the statistic for each COPC addressed in the 1
HHRAs. 2

Linear interpolation provides a good estimate of the H -statistic; however, both the UCL formula 3
and H are natural log values. The effect of multiplying natural log numbers is not equivalent to 4
multiplying untransformed values. When data are log transformed, adding two numbers is the 5
equivalent of multiplying the two numbers if they were not transformed. The effect of multiplying 6
a number while in log form is exponential; and here, H is applied as a multiplier. In summary, 7
using this method to calculate the UCL has the effect of overestimating, and often provides 8
concentrations greater than the maximum detected onsite. For all datasets with fewer than 10 total 9
samples for a specific medium, the maximum concentrations detected were used as EPCs. The 10
limited number of soil and groundwater samples used to assess site conditions often resulted in 11
considerable variability between data points, and thus relatively high standard deviations about the 12
mean. The high standard deviation elevates UCL projections. 13

Although RAGS advocates using neither worst-case scenarios nor maximum concentrations as 14
EPCs, the use of the H -statistic often necessitates using the reported maximum concentration as 15
the EPC. In accordance with RAGS, the lesser of either the maximum concentration or the UCL 16
is used as the EPC. As reviewed above, summation of risk based on maximum concentrations 17
leads to overestimation of exposure, especially in the case of low detection frequency or spatially 18
segregated COPCs. This concept is further discussed below. 19

Frequency of Detection and Spatial Distribution 20

Because of the influence of standard deviation on EPC, low frequency of detection can cause 21
COPCs to be addressed inappropriately in the risk assessment. More specifically, COPCs detected 22
only once or twice in all samples analyzed (having concentrations exceeding the RBCs and 23
reference concentrations) would be expected to show relatively higher standard deviations as 24

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, use of the UCL or maximum concentration detected as the EPC (or possibly the inclusion of the COPC in question a COC) may not be appropriate, if the EPC can be assumed to be widely distributed spatially. A receptor cannot feasibly be exposed simultaneously 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/hazard could be skewed upward due to the low frequency of detection.

In some instances, hot spots can be defined within the investigation area. A hot spot is an isolated area of concentrated contamination, within a larger area not impacted, or much less so. Exposure quantification in the presence of a hot spot may be achieved by calculating a fraction ingested/fraction contacted (FI/FC) from a contaminated source factor. This calculation is based on the percentage of the total exposure area encompassed by the hot spot, modifying the maximum (or restricted area average) contaminant concentration to derive the EPC.

Toxicity Assessment Information

Uncertainty is generally recognized in developing human toxicological risk from experimental data. This is primarily due to 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 occurs mainly in the degree of accuracy of the exposure assumptions. Most of these assumptions cannot be 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. Among other factors, the uncertainty assigned to these values account for: (1) acute to chronic dose extrapolation, (2) study inadequacies, and

(3) sensitive subpopulations. Although uncertainty factors for a specific compound may be 1,000 or higher, these safety factors are applied by USEPA to help guarantee a conservative overall assessment for risk/hazard, relative to human health concerns. The possibility of uncertainty obligates the USEPA and the risk assessor to make conservative assumptions to eliminate actual health risk to be greater than that determined via the risk assessment process. Alternatively, the process is not intended to be overly conservative so risk values have no basis in actual conditions. This balance was considered in developing exposure assumptions and pathways, and in interpreting data and guidance for Zone F site HHRA.

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

Where CDDs and dibenzofurans (dioxins) were detected in soil, TEQs were derived by multiplying the concentration of each dioxin congener by its corresponding USEPA TEF. The resulting TEQs were then summed for each sample, comparing the total to the 1,000 ng/kg AL. If the total TEQ value was less than 1,000 ng/kg, then soil dioxins do not pose an unacceptable risk. Groundwater exposure quantification used TEQ values computed for each monitoring point.

Evaluation of Chemicals for Which No Toxicity Values Are Available

Parameters not having corresponding RBCs due to the lack of approved toxicological values were not included in the CDI calculation data. However, 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 discusses potential sources of uncertainty or variability not covered in preceding sections. Each exposure medium identified in the formal risk assessment process is discussed briefly.

Mapping Risk/Hazard

Risk and hazard maps presenting site-specific HHRA results are in Section 10. For selected sites, point maps were constructed showing the cumulative risk/hazard computed at specific locations. Location-specific data were summed and plotted to illustrate ranges of total risk and/or total hazard at sites where such presentations could be supported.

Risk and hazard point mapping is a useful risk assessment tool for determining whether hot spots (or isolated areas of gross contamination) are present in an otherwise unimpacted area. This is important because heterogeneous contaminant concentrations can affect how receptors are exposed to the affected media. 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, as well as easier estimation of 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 RGOs

Section 7.3.11 of the *Draft Zone A RFI Report* discusses RGOs as they apply to the HHRA for Zone F RFI.

8.0 ECOLOGICAL RISK ASSESSMENT

Zone F is within a heavily disturbed, industrial portion of NAVBASE. Several grass fields containing small trees and shrubs are within Zone F. Passerine birds and seasonally occurring flocks of cattle egrets and white ibis have been occasionally observed within these fields, but actual use of these areas within Zone F is unknown. Small mammals such as shrews, voles, or mice could also be expected to occur in these grassy areas. The limited habitat and significant volume of human activity in and around this zone severely restricts area use by ecological receptor species. Although surface water runoff to the storm water sewer system from Zone F sites may provide a potential transport pathway to offsite areas, these sites do not present risk to ecological receptors.

1
2
3
4
5
6
7
8
9
10

9.0 CORRECTIVE MEASURES

9.1 Introduction

According to condition IV.E.1 of the NAVBASE RCRA Part B Permit (SCDHEC, May 4, 1990), SCDHEC will review the final RFI report and notify NAVBASE of the need for further investigations, corrective actions, corrective action studies, or plans to meet the requirements of R.61-79.264.101, South Carolina Hazardous Waste Rules, which outline regulations for correction actions for SWMUs. This section of the RFI report is in response to SCDHEC's comment that "the RFI report should discuss whether the extent of contamination has been defined, and proposed recommended actions for the AOCs and SWMUs, such as collection of additional samples, proceed into a CMS, or NFI, whichever is appropriate." The NAVBASE project team established ALs to assess whether to conduct a CMS at 1E-06 residential risk. The following discusses the overall approach for evaluating a CMS, lists potential remedies, and outlines the steps to be conducted during a CMS. The sites that will require a CMS are discussed in Section 10, Site-Specific Evaluations.

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

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

Report Outline

- Introduction/Purpose

- Description of Current Conditions 1
- Corrective Action Objectives 2
- Identification, Screening, and Development of Corrective Measures Alternatives 3
- Evaluation of a Final Corrective Measures Alternative 4
- Recommendation by a Permittee/Respondent for a Final Corrective Measures Alternative 5
- Public Involvement Plan 6

Each required element will be detailed in the CMS work plan to: 7

- Identify minimum requirements for CMS reports in each area. 8
- Define the base pool of technologies to be evaluated for each medium. 9
- Define the evaluation process. 10
- Identify selection criteria for the final corrective measures alternative. 11

Issues to be discussed under each element are: 12

- An activity-specific description of the overall purpose of the CMS for NAVBASE. 13

AOCs and SWMUs at NAVBASE 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), and the subsequent cleanup goals. 14
15
16
17
18

- A description of the corrective action objectives for NAVBASE, including how target media cleanup standards, points of compliance, or risk assessments will be established and performed for each site, zone, and activity. 19
20
21

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

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

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

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

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

- A description of the general approach to investigating and evaluating potential corrective action measures. 1
2

Corrective measures alternatives will be evaluated using four primary and five secondary criteria, listed below: 3
4

Primary 5

1. *Protect human health and the environment.* 6
2. *Attain media cleanup standards set by the implementing agency.* 7
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.* 8
9
4. *Comply with any applicable waste management standards.* 10

Secondary 11

1. *Long-term reliability and effectiveness* 12
2. *Reduction in the toxicity, mobility, or volume of waste* 13
3. *Short-term effectiveness* 14
4. *Implementability* 15
5. *Cost* 16

Alternatives will be discussed and compared according to these criteria, which are used to gauge their relative effectiveness and implementability. 17
18

- A detailed description of how pilot, laboratory, and/or bench-scale studies will be selected, performed, evaluated, reported on, and transferred to full scale. 19
20

Treatability studies will be implemented when more involved treatment units are being considered. For example, air stripping technologies usually do not require treatability studies to determine optimal 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 a statement of basis or response to comments or permit modifications will be processed.

Statement of basis/response to comments will be handled through NAVBASE and Southern Division, Naval Facilities Engineering Command (SOUTHDIV). The Comprehensive Long-term Environmental Action Navy (CLEAN) contractor, EnSafe, will assist the Navy in preparing the statement of basis or response to comments. Permit modifications will be managed through NAVBASE as the permit holder until the base is closed. Upon closure, SOUTHDIV and NAVBASE's caretaker will manage permit modifications. According to the RCRA permit issued May 4, 1990, Appendix C, Facility Submission Summary, a permit modification is required to prepare and conduct a Corrective Action Study/Plan.

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

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

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

EnSafe will use trained qualified and/or registered geologists and engineers of South Carolina, where required.

9.2 Remedy Selection Approach

As agreed in the *Final Comprehensive Project Management Plan* (E/A&H, August 30, 1994), remedies will be selected in accordance with statutory and RCRA CMS criteria. Particular attention will be given to the following items when evaluating alternatives:

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

CAMUs and temporary units will be used, where necessary, to facilitate storage and treatment during remediation activities. 1
2

9.3 Proposed Remedy 3

Section 9.3 of the *Draft Zone A RFI Report* discusses the proposed remedy process for NAVBASE Charleston. 4
5

9.4 Development of Target Media Cleanup Goals 6

Section 9.4 of the *Draft Zone A RFI Report* discusses the development of target media cleanup goals for soil, groundwater, sediment, surface water, and air. 7
8

9.5 Identification, Screening, and Development of Corrective Measures Technologies 9

The initial step in assembling corrective measures alternatives is to identify, screen, and develop corrective measures technologies that apply to the site. Technologies are typically screened using waste-, media-, and site-specific characteristics. This section addresses the range of technologies which may be assessed for each site, the screening process, and screening criteria. 10
11
12
13

9.5.1 Identification of Corrective Measure Technologies 14

Each site will be assessed using the methodology described in Section 9.2. Impacted media and COCs were initially identified in the RFI. The site-specific BRAs in Section 10 identify soil and groundwater as the contaminated media of concern. For each site, the major contaminants present have been grouped into one or more of the following categories: 15
16
17
18

- Chlorinated VOCs 19
- Nonchlorinated VOCs 20
- Chlorinated SVOCs 21
- Nonchlorinated SVOCs 22

- Pesticides/herbicides 1
- PCBs 2
- Dioxins 3
- Inorganic compounds (includes metals) 4
- Petroleum hydrocarbons 5

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

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

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

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

Table 9.1
Zone F
Removal/Containment/Disposal Options

Action	Soil	Groundwater/ Leachate	Sediment	Surface Water	Air
Removal	Excavation	Groundwater extraction Leachate collection	Dredging	Diversion Pumping	NA
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	NA
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
- NA = Not Applicable

Table 9.2
Zone F
Treatment Technology Options

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

Table 9.2
 Zone F
 Treatment Technology Options

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

9.5.2 Description of Prescreened Technologies

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

In-Situ Soil

Bioremediation

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

likely to be a good candidate for some compounds. Typically nonchlorinated VOCs and SVOCs are good candidates for this technology.

Solidification/Stabilization

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

Ex-Situ Treatment of Soils

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

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 with incineration or some other type of offgas treatment. Soil is excavated and put in the treatment systems for both high- and low-temperature desorption to separate the contaminants from the soil, not to destroy the chemicals. The

volatilized contaminants enter an airstream and travel to some type of gas treatment for the
contaminant destruction. Low-temperature (200°F to 600°F) thermal desorption (LTTD) is used
only for VOCs while high-temperature (600°F to 1,000 °F) thermal desorption (HTTD) is used
for SVOCs, polynuclear aromatic hydrocarbons (PAHs), PCBs, and pesticides.

Thermal Destruction/Incineration

This technology is used with ex-situ soil technologies. Typically the contaminant is removed from
the soil matrix and transferred to an airstream. The airstream is then treated with the thermal
destruction on a catalyst or burned in an incinerator, or a combination of the two. High
temperatures (1,800°F to 2,000°F) are required to destroy organics such as PCBs, dioxins, furans,
pesticides, and others.

Solidification/Stabilization

This technology is similar to the in-situ methods; however, 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 such as phosphate or nitrate
and an electron acceptor such as oxygen or nitrate 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. The site may be monitored to observe the contaminant reduction, 1
Many case studies have demonstrated this technology on TPH. 2

Ex-Situ Treatment of Groundwater 3

Any ex-situ treatment of groundwater requires a system of extraction wells and pumps to deliver 4
the groundwater to the treatment location. 5

Chemical Precipitation 6

The solubility of many metals is a function of pH. As a result, chemical agents can be added to 7
change the pH of the water, which results in the metals becoming insoluble. In other cases, a 8
chemical can be added to chelate the metal and precipitate it out of the solution. Either way, the 9
contaminants can then be removed by filtering. 10

Air Stripping 11

Groundwater can be extracted from the subsurface and pumped to a nearby publicly owned 12
treatment works (POTW). While the contaminated groundwater is in the aeration basin of the 13
water treatment plant, the volatile compounds (compounds with a high HL) will mass-transfer 14
from the water to the air. Steam can also be used to heat the groundwater, causing organics to 15
volatilize. These air vapors can be treated with an appropriate technology or can be permitted as 16
an air emissions source. 17

Chemical Oxidation/UV-Ozone 18

Ozone, one of the strongest chemical oxidizers, can be generated with UV light sources. Almost 19
any organic compound can be oxidized. When water passes through a flowstream surrounded by 20
UV lights, oxygen in the water is converted to ozone and the organics are oxidized into harmless 21
by-products. Compounds that typically are recalcitrant to biological oxidation, such as chlorinated 22

organics, can be easily oxidized with ozone. Good light transmission is essential; therefore, very turbid water is not a good candidate for UV ozonation.

Activated Sludge

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

9.5.3 Screening Criteria

When more than one technology applies to a specific site, it is necessary to evaluate the limitations to show why certain CMS technologies may not be feasible to implement waste- and site-specific conditions. Therefore, for each technology, the following criteria will be discussed:

- Site characteristics
- Waste characteristics
- Technology limitations

Site Characteristics

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

Waste Characteristics

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

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 feasibility of implementing 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 limitation to be assessed include effectiveness in meeting treatment goals and remedial time frame. Technologies meeting this screening criterion may differ from residential to BRAC-specified use scenarios due to the differences in cleanup goals for each scenario.

9.6 Identification of Corrective Measures Alternatives

Section 9.6 of the *Draft Zone A RFI Report* discusses identification of corrective measures alternatives as these apply to the Zone F RFI.

9.7 Evaluation of Corrective Measures Alternatives 1

Section 9.7 of the *Draft Zone A RFI Report* discusses evaluation of corrective measures 2
alternatives as they apply to the Zone F RFI. 3

9.8 Ranking the Corrective Measures Alternatives 4

Section 9.8 of the *Draft Zone A RFI Report* discusses ranking the corrective measures alternatives, 5
as they apply to the Zone F RFI. 6