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RESOURCE CONSERVATION AND RECOVERY ACT FACILITY INVESTIGATION REPORT
ZONE I VOLUME I OF VII SECTION 1 TO 9 CNC CHARLESTON SC

3/1/1999
ENSAFE

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

ZONE I
RCRA FACILITY INVESTIGATION REPORT

VOLUME I OF VII
SECTIONS 1 TO 9

SOUTHDIV CONTRACT
NUMBER: N62467-89-D-0318

Prepared for:

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

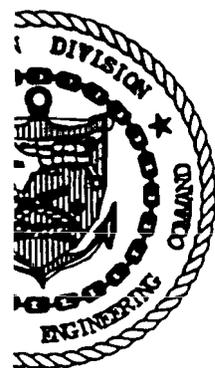
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March 1, 1999

Revision: 0

Page Changes: July 30, 1999



document requires prior notification of the Commanding Officer of the
sion, Naval Facilities Engineering Command, North Charleston,



DEPARTMENT OF THE NAVY

SOUTHERN DIVISION

NAVAL FACILITIES ENGINEERING COMMAND

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5090/11

Code 18710

17-Jun-99

Mr. John Litton, P.E.
Director, Division of Hazardous and Infectious Waste Management
SCDHEC-Bureau of Land and Waste Management
2600 Bull Street
Columbia, SC 29201

Subj: SUBMITTAL OF THE REVISED ZONE I RCRA FACILITY INVESTIGATION
REPORT

Dear Mr. Litton:

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

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

Sincerely,

DAVID P. DODDS

Remedial Project Manager
Environmental Department

Encl:

(1) Revised Zone I RFI Report, EnSafe, dated 28 May 1999

Copy to:

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

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

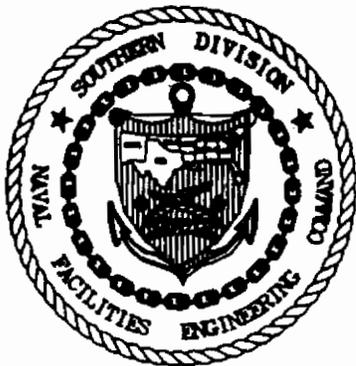


RESPONSE TO COMMENTS FOR

**DRAFT ZONE I
RCRA FACILITY INVESTIGATION REPORT
(Dated January 1996)**

Prepared for:

**Department of the Navy
Southern Division
Naval Facilities Engineering Command
Charleston, South Carolina**



**SOUTHDIV Contract Number:
N62467-89-D-0318**

Prepared by:

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

**March 1, 1999
Revision: 0**

**SCDHEC Comments on Risk Assessment Portion of The
Zone I RCRA Facility Investigation Report
(dated January 1996) NAVBASE Charleston**

Comment 1:

Section 7, page 7-18. Please explain the statement "...A large number (i.e. greater than 10) of constituents would have to be present at near RBC concentrations to substantiate a concern for cumulative effects". It is very difficult to determine the cumulative effect on human and ecological health from exposure to a mixture of chemicals. EPA is trying to determine how complex mixture behave, how these interactions affect the overall toxicity of the mixture, and how to incorporate this information into risk assessments of chemical mixtures. There has been considerable effort in this area since the publication of the US Environmental Protection Agency's guidelines for risk assessment of chemical mixtures in 1986. Synergistic or antagonistic effects, not readily predicted from the mechanisms of action of the individual components, are possible when the mixture components are present at levels equal to or above their individual thresholds. For noncancer endpoints, adverse effects are unlikely to occur when the individual components in the mixture are present at levels well below their respective thresholds. *Synergistic carcinogenic effects have, however, been observed in animal studies of mixtures even at relatively low doses.* Epidemiological studies which have considered the simultaneous effect of *two chemical* carcinogens have been reviewed, and shown to provide examples of additivity, multiplicativity and interaction both intermediate between the two and greater than multiplicative.

Response 1:

RAGS suggests that risk and hazard quotients for individual chemicals be summed to provide a cumulative risk or hazard index for any given pathway of exposure. The Navy would require specific guidance from SCDHEC that provides alternatives to the RAGS solution for dealing with the health effects of chemical mixtures. The statement referenced in comment 1 stems from the screening process used to select COPCs. For noncarcinogenic chemicals, the screening concentrations used equate with a target hazard quotient of 0.1. This is done to prevent screening out chemicals whose individual hazard quotients may be below 1 but when assessed in the context of many chemicals whose hazard quotients are below 1 could ultimately translate into a cumulative hazard index above 1.

Comment 2:

Please explain why only 2 soil sample were used for ecological risk assessment (Section 8) in Zone I-1 (DMA) where as 5 soil samples were considered for the human health risk assessment under the site specific evaluation (Section 10) for the same site.

Response 2:

Samples selected for inclusion in the human health risk assessment are determined on a site (AOC or SWMU) basis. Samples selected for the ERA are based on their occurrence in different habitats, called subzones, due to differences in potential ecological receptors. These

subzones do not necessarily parallel site boundaries such as the case with the DMA, which consists of both early- and mid-succession habitats. Therefore, the number of samples may differ between ecological and human health risk assessments. The number of samples used for both of these risk assessments remains the same.

Comment 3:

Please explain why the reference concentrations for inorganics used in the ecological risk assessment section (section 8) are different from the reference concentration for inorganics used for site specific evaluation section (section 10). Where the backgrounds for the ecological area of concern derived separately? if yes, was a part of the data set, that was used to determine the reference concentration for the entire site for site specific evaluation, was used to determine the reference concentration for the ecological risk assessment.

Response 3:

The reference concentrations for inorganics used in Section 8 have been updated.

Comment 4:

Section 8, page 8.14, table 8.3a. Please explain why Endrin is not an ECPC even though it was detected in more than 5% (4 out of 69) of the samples and met the selection criterion for an ECPC.

Response 4:

Endrin has been added as an ECPC and its associated HQ values added to both the lethal and sublethal HIs.

Comment 5:

The reference concentration for the inorganics have been revised according to the proposed background reference value for soil and groundwater of June 9, 1997. Please use the revised values for screening for COPCs.

Response 5:

The reference concentrations for inorganics used in Section 8 have been updated. The revised background reference values have been used for all screening comparisons in the final report.

Comment 6:

Since the reference concentrations for the inorganics has been changed, would not the results of Wilcoxon rank sum test change too? Please verify the results of Wilcoxon rank sum test for each site to make sure that all the COPCs are identified.

Response 6:

Where reference concentrations changed due to removal of high values from background data sets, results of the Wilcoxon rank sum test may have changed as well. Inclusion of values from recent site samples into the site data sets could also affect Wilcoxon results. Consequently, all Wilcoxon rank sum tests for surface soil and shallow groundwater were re-run where the test was justified (i.e., a minimum of four samples in each data set, with no more than approximately 80% nondetects). The Wilcoxon test was not run for subsurface soil results because those data are not used for risk assessment; it was not run for deep groundwater because the only deep wells in Zone I are grid wells.

Comment 7:

Section 10 AOC 671. Even though As is below the reference concentration, it is above the risk based concentration at 7 out of 8 sampling sites. The carcinogenic risk from the sum of all pathways to potential future residents from As alone is $1.12E-5$ which is considerably higher than the carcinogenic risk of $5E-6$ from combined sum of all pathway from all identified COCs. The COCs that were identified at AOC 671 are Benzo (a) pyrene and Nitroso-di-n-propylamine. In the calculation of the exposure term for As, the FI factor was conservatively assumed to be 0.5. The maximum detected concentration of As was 8.3 mg/kg and this was used as the exposure point concentration. Considering such high risk numbers from As, it should be discussed separately in the uncertainties section of the risk assessment.

Response 7:

It is not unusual to find background levels of arsenic that are associated with relatively high risk estimates. A conservative process is used to separate arsenic concentrations that are associated with background conditions and those that are site related. These tests include direct comparisons maximum concentrations to background reference concentrations and Wilcoxon rank sum tests. Since the submittal of the Draft Zone I RFI, new background concentrations have been developed. Each Zone I site has been reevaluated based on these new background concentrations.

Comment 8:

Section 10 AOC 672 and 673 Table 10.2.5. Beta-BHC has been listed as NA under the column titled 'range of detection'. The detection of $3.2 \mu\text{g}/\text{kg}$ should be mentioned under this column.

Response 8:
Noted.

Comment 9:

Section 10 AOC 672 Table 10.2.9. The exposure pathway summary excludes groundwater as a possible exposure pathway on the basis that no groundwater sampling was performed at AOC 672, 673. A exposure pathway can not be excluded on this basis especially when an identified COPC (As) is present above its risk based concentration as well as above its reference concentration. The maximum concentration of As in soil was 42.9 mg/kg which is greater than the UTL of 21.6 mg/kg (proposed background reference value for soil and groundwater dated June 9, 1997). The maximum detected concentration of arsenic is also above 0.37 mg/kg which is the risk based concentration for residential soil ingestion.

Response 9:

The decision whether of not to sample groundwater at a given site is not made in the risk assessment. In the absence of groundwater data for AOCs 672 and 673, no risk assessment was performed for the groundwater pathways. Chemicals that exceed RBCs in the soil have no bearing on potential impacts to groundwater. However, should the fate and transport assessment indicate that soil concentrations of a given chemical are sufficient to cause an adverse impact to groundwater then modeling can be performed to provide data for evaluating the groundwater pathway in the risk assessment.

Comment 10:

Considering the possibility of As migration to groundwater (refer to comment 15) please carry out appropriate sampling and analysis procedure for arsenic and other inorganics and organics in groundwater at AOCs 672, 673.

Response 10:
See Response 9.

Comment 11:

Section 10.3. Though materials of concern at AOC 675 and 677 include residual fuel, diesel fuel and aviation gasoline (paragraph 2) analytical procedure for total petroleum hydrocarbon (TPH) was not included for soil and groundwater samples. Sampling for TPH is required especially at AOC 677, which is the site of a number of petroleum spills.

Response 11:

TPH analyses usually determine the total amount of hydrocarbons present as a single number and give little or no indication of the types of hydrocarbons present. These analyses are useful for site characterization, but are not suitable for risk assessments because the general measure of TPH does not provide sufficient information about the amounts of individual compounds present. Consequently, the risk assessment community has focused on assessing the impacts of a select group of indicator compounds that are inherently assumed to represent a significant fraction of the overall potential risk associated with petroleum hydrocarbons. These indicator compounds are included in the analysis for VOCs and SVOCs, and to a lesser extent, metals analysis. For additional discussion on this subject, please refer to the position paper titled "*Use of TPH and TIC Analytical Results for RFI Evaluation at CNC*" submitted as part of the Zone C work plan.

Comment 12:

Section 10.3.7.2. The concentration of dimethoate in shallow groundwater does exceed the risk based concentration for dimethoate in tap water (refer to table 10.3.10) therefore please correct your statement that "... combined AOC 675 shallow groundwater concentration did not exceed the tap water RBCs or the reference concentrations.

Response 12:

This statement has been corrected.

Comment 13:

Section 10 AOC 678. Though petroleum hydrocarbons are among the material of concern for this site, TPH analysis was not carried out at this site. Please provide an explanation.

Response 13:

Site specific discussion on AOC 678 will be provided as an addendum to the RFI report and as such, comments will be addressed and submitted with that addendum.

Comment 14:

Section 10 Table 10.4.27. Aroclor has an oral RfD (refer to section 10.4.6.4). Why the HQ for this chemical has not been calculated (refer to table 10.4.22). Please explain how a hazard based remedial goal for Aroclor was derived (refer to table 10.4.27) in the absence of a hazard quotient for Aroclor.

Response 14:

As noted above, site specific discussion on AOC 678 will be provided as an addendum to the RFI report and as such, comments will be addressed and submitted with that addendum.

Comment 15:

Section 10.6.5.1 AOC 681. When discussing the fate and transport of all the ten organic constituents detected above their RBCs, at this site, it will be helpful to include a discussion on soil type, groundwater depth and meteorological (weather) conditions. According to Section 8.4 the soil type is sandy and the soil is low in organic carbon. The above mentioned factors, beside the Koc value of each constituents, are important in determining the fate and transport of each constituents. The possibility of soil-to-groundwater cross-media transport should be carefully analyzed in the absence of groundwater sampling. On the other hand, groundwater samples could be collected to demonstrate that this media has not been impacted.

Response 15:

Site specific discussion on AOC 681 will be provided as an addendum to the RFI report and as such, comments will be addressed and submitted with that addendum.

Comment 16:

Section 10 AOC 681. Considering the fact that so many organic chemicals are detected above their soil water protection SSL and that Benzo (a) pyrene was recognized as a COPC, based on the result of Wilcoxon rank sum test, a groundwater sampling is recommended at this site with analysis for VOCs and SVOCs.

Response 16:

Site specific discussion on AOC 681 will be provided as an addendum to the RFI report and as such, comments will be addressed and submitted with that addendum.

Comment 17:

Section 10.6.6.1. Please note that an USEPA report by Technical Review Workgroup for Lead (December 1996) provides recommendations for an interim approach to assessing risk associated with adult exposure to lead in soil. Under the light of above fact please reconsider the statement "...USEPA does not currently sanction any risk characterization model or approach for predicting the adverse health effects of lead in adults".

Response 17:

Site specific discussion on AOC 681 will be provided as an addendum to the RFI report and as such, comments will be addressed and submitted with that addendum.

Comment 18:

Section 10.6.6.2. Under the 'COPC identification' section TPH is not mentioned as a COPC whereas table 10.6.10 identifies TPH as a COPC. TPH has not been discussed under exposure assessment and toxicity assessment. A qualitative risk discussion on TPH is required if TPH is recognized as a COPC.

Response 18:

Site specific discussion on AOC 681 will be provided as an addendum to the RFI report and as such, comments will be addressed and submitted with that addendum.

Comment 19:

Section 10.7 AOC 685. Please revise table 10.7.4 using the proposed reference concentration for inorganics (6.9.97). Beryllium exceeds its revised reference concentration of 0.95 mg/kg with a maximum detection of 1.2 mg/kg. If was not considered as a COPC before it should now.

Response 19:

Any changes in the background concentrations have been reflected in the Final RFI.

Comment 20:

Section 10.7.2 AOC 685. The last line under the paragraph titled 'Inorganics in Soil' is not clear. It is mentioned that 6 samples exceeded the reference concentration for 'Zinc' but the data (Appendix D) and Table 10.7.4 indicate that 6 samples exceed the reference concentration of nickel.

Response 20:

The reference concentrations have been revised for the final RFI report and there are no exceedances for nickel or zinc above the revised reference concentrations.

Comment 21:

Section 10.7 AOC 685 Table 10.7.9. Please explain why vanadium was recognized as a COPC. Vanadium has a frequency of detection of 9/15 but appears above its screening concentration in only one of the samples. The maximum detected concentration (55.5 mg/kg) of vanadium is less

than its reference concentration (113 mg/kg). Table 10.7.9 does not identify vanadium as a COPC by placing an asterisk beside it yet it is discussed under risk assessment.

Response 21:

The maximum vanadium concentration did not exceed its background concentration and therefore should not be considered a COPC. Changes in background concentrations are reflected in the Final RFI. The HHRA has been revised accordingly.

Comment 22:

Section 10.7 AOC 685 Table 10.7.9. This table identifies thallium as a COPC but thallium is not discussed under exposure assessment, toxicity assessment and risk characterization sections. No risk/hazard number was calculated for thallium.

Response 22:

The HHRA has been revised for the final RFI and thallium is discussed as applicable.

Comment 23:

Section 10.7 AOC 685 Table 10.7.10. Shallow groundwater ingestion and inhalation of contaminants can not be ruled out from a possible exposure pathway, without extensive sampling of groundwater or without sufficient evidence that support that groundwater is not impacted. Detection of number of inorganics and organics above their reference concentration and screening concentration in soil at this site warrants that groundwater sampling and monitoring at this site may be highly desirable.

Response 23:

See Response 9.

Comment 24:

Section 10.8.2 This section does not include all the inorganics that were detected above their reference concentration (refer table 10.8.3). Co, Pb, Mn, Va, Zn, Al, Ar and Be were detected above their proposed reference concentration (6.9.97) in the subsurface soil.

Response 24:

Section 10.8.2 and Table 10.8.3 have been revised to reflect the reference concentrations agreed on in June 1997.

Comment 25:

Section 10.8.7.2. Please state clearly what is meant by "qualitative screening identified arsenic's published AWQC".

Response 25:

The above referenced statement has been deleted and the text has been revised as applicable.

Comment 26:

Section 10.8.8.3. Please explain clearly the meaning of second paragraph of this section which states "...because surface soil samples collected around the combined AOC 687 failed to identify any COPCs, there is reason to expect widespread presence of BEQs, heptachlor epoxide or chlordane".

Response 26:

The section has been revised and the referenced statement is no longer applicable.

Comment 27:

Section 10.8.8.2. Since the new proposed reference concentrations of inorganics, for soil and groundwater (6.9.97), are considerably different from the previously used reference concentrations for inorganics, it is suggested that the Wilcoxon rank sum test analysis be carried out again for the inorganics in soil, groundwater and sediments. It is important since Al and Be exceeded their risk based concentrations at 3 out of 4 soil sampling sites and As and Mn exceed their risk based concentrations at all the 4 soil sampling sites.

Response 27:

Wilcoxon rank sum tests were re-run for all surface soil and shallow groundwater data sets where they were appropriate. Wilcoxon tests were not run on sediment data because background have not been established for sediment.

Comment 28:

Section 10.8 AOC 687 Table 10.8.18. If heptachlor epoxide is below its screening concentration how was it identified as a COPC.

Response 28:

Heptachlor epoxide should not have been identified as a COPC. This has been corrected in the Final RFI.

Comment 29:

Section 10.9.5.2 AOC 688. A minimum of 4 samples (sample size=4) are required for Wilcoxon rank sum test. Please explain how the Wilcoxon rank sum test carried on 2 sediment samples to identify COPCs.

Response 29:

This statement was in error. No Wilcoxon rank sum tests were carried out on sediment samples, as explained above in the response to Comment 27.

Comment 30:

Section 10.9 AOC 688 Table 10.9.5. The table does not have the column of UTLs and SSLs. No comparison was made between the maximum detected concentrations of organics and inorganics and their respective SSLs/UTLs.

Response 30:

Surface soil and subsurface soil samples were collected at two AOC 688 locations in April 1998. The revised versions of Table 10.9.5 include soil and sediment analytical results and comparisons of soil results to soil SSLs and background reference values (for inorganics). Sediment analytical results are compared qualitatively to soil results in revised Section 10.9.8. Sediment results were not compared to UTLs because no sediment background values were determined for Zone I.

Comment 31:

In spite of a RfD for Aroclor (refer section 10.9.5.4 - toxicity assessment) the noncarcinogenic risk (hazard) from this chemical was not derived under the risk characterization section.

Response 31:

The text has been clarified (note that the HHRA is now found in section 10.9.8). Only certain Aroclor congeners have RfDs, Aroclor 1260 does not. The hazard-based RGOs for Aroclor 1260 were calculated in error. This has been corrected in the Final RFI.

Comment 32:

Section 10 AOC 689 and 690. Table 10.10.10 (Exposure pathway summary) excludes groundwater as a possible exposure pathway on the basis that no groundwater sampling was performed at AOC 689 and 690. An exposure pathway can not be excluded on this basis especially when COPCs such as chromium and copper may have a marked potential to migrate to ground water. Provide an explanation.

Response 32:
See Response 9.

Comment 33:

Section 10 SWMU 12. Please revise table 10.11.4 using the proposed reference concentrations for inorganics dated 6.9.97. The frequency of detection of selenium above its reference concentration increases from 5 to 7 on considering the revised reference concentration for selenium. Does the increase on frequency of detection merit selenium to be a COPC?

Response 33:

Table 10.11.4 (now Table 10.11.3) has been revised as requested. Selenium has not been identified as a COPC because its maximum detected concentration of 1.8 mg/kg is below selenium's RBC of 39 mg/kg (THQ = 0.1).

Comment 34:

Section 10 SWMU 12. Please explain why TPH was not included in the list of analytes to be tested considering the fact that petroleum hydrocarbon figures as one of the materials of concern under Section 10.11.

Response 34:
See Response 11.

Comment 35:

Section 10 SWMU 12. Please revise Table 10.11.7 using the proposed reference concentrations for inorganics dated 6.9.97. Ba, Pb and Zn exceed their proposed reference concentrations.

Response 35:

Table 10.11.7 has been revised as requested.

Comment 36:

Section 10.13.4 RTC. Please explain why hazard quotient (HQ) for PCB Aroclors was not calculated even though a reference dose for PCB Aroclor is available and mentioned under Section 10.13.4.4.

Response 36:

Only certain Aroclor congeners have RfDs, Aroclor 1260 does not. The hazard-based RGOs for Aroclor 1260 were calculated in error. This has been corrected in the Final RFI.

Comment 37:

Section 10.14 DMA. Please explain why tables 10.14.2, 10.14.3, 10.14.5 and 10.14.6 did not have columns for 'RBC/UTL' and 'number of samples exceeding RBC/UTL'.

Response 37:

It would be inappropriate to compare chemical concentrations of recently dredged river-bottom sediments to RBCs and background reference values developed for in-place soils.

Comment 38:

Section 10.14 DMA Table 10.14.3. On comparison of surface and subsurface concentrations of inorganics with their respective UTLs, many inorganics exceed their reference concentrations. Al, Be, Cd, Co, Mn, Se and Va exceed their reference concentration in both surface and subsurface soil where as As, Ba, Cu, Pb, Ni and Zn exceed their subsurface reference concentrations. The inorganics were compared to their proposed reference concentrations for inorganics in soil and groundwater dated 6.9.97. The results of this comparison should be included under Section 10.14.2. Identify COPCs accordingly.

Response 38:

Table 10.13.3 (formerly Table 10.14.3) has been updated with revised reference concentrations. Inorganics in soil are compared to RBCs (upper-interval) and SSLs (lower-interval) and discussed as appropriate in Section 10.13.2.

Comment 39:

Section 10.14 DMA Table 10.14.6. Al, Be, Co, Mn and Se exceed their proposed reference concentrations in sediment.

Response 39:

See response 37.

Comment 40:

Section 10.14 DMA Table 10.14.3 and 10.14.6. The average concentration of As in soil and sediment at this site is 12.55 and 12.74 mg/kg respectively. These concentrations of As are considerably higher than the risk based number of 0.37 mg/kg. The frequency of detection of As

in soil and sediment is high. As also exceeds its risk based number (tap water RBC) in surface water (refer Table 10.14.16). The risk from exposure to high concentrations of As to humans should be considered at this site.

Response 40:

The risk from exposure to arsenic was considered at this site. However, arsenic was not identified as a COC for the DMA.

Comment 41:

Section 10.14 DMA Table 10.14.9. The maximum concentration of lead detected at this site (36.05 µg/L), exceeds 15 µg/L. 15 µg/L is the action level for lead in water. Please note the above comment and include under appropriate section.

Response 41:

Lead was considered under the HHRA. Please reference section 10.14.9 of the revised RFI.

Comment 42:

Section 10.14 DMA Table 10.14.11. Based on the proposed UTLs for inorganics (6.9.97), Al, Co and Mn exceed their respective UTLs and therefore have a potential to contaminate groundwater. Please revise Table 10.14.11 using the proposed reference concentrations for inorganics dated 6.9.97.

Response 42:

The tables have been revised to include the appropriate reference concentrations. The DMA discussion is now found in Section 10.13.

Comment 43:

Please correct the following typographical errors:

- Section 3.2.2.4, page 3-5. First line uses the word "tube" twice.
- Section 5.2.5, Tolerance-Interval or Reference Concentration Test, page 5-10. The line "... Where 50% > ND > 90%" is not clear. The sentence should be rewritten as "50% < ND < 90%" to fit the context.
- Section 6, page 6-18. The last line on this page can be written without the word "made" just before the word "determined" on the next page.

- Section 10.2 AOC 672. Please complete the last line in the 3rd paragraph by adding the word "sites" at the end.
- Section 10.3. Please rewrite the first line of the first paragraph to link each designated AOC with its respective location.
- Section 10. Figure 10.3.1 does not indicate the location of the tank NS-4. Please include it in the figure.
- AOC 685 Table 10.7.4. Please correct the upper range of detection for Barium. The upper range for barium is 47.7 instead of 126.
- Section 10.8 AOC 687 Line 20. Please correct the word 'were' at the beginning of the line.
- Section 10.13.2 RTC pg 10-7. Under the paragraph titled "Pesticides and PCBs in soil" please correct the RBC value for PCBs. The RBC value for PCBs is 83 $\mu\text{g}/\text{kg}$ and not 0.083 $\mu\text{g}/\text{kg}$ as mentioned under this section.

Response 43:

The revisions and changes as requested above have been made as applicable and appropriate.

Comment 44:

Please revise and update the following tables with the new approved background reference concentrations. Identify COPCs and carry through the risk assessment if applicable:

- Section 10 AOC 672. Please revise tables 10.2.3, 10.2.5 and table 10.2.8 to include the revised reference concentrations for inorganics.
- Section 10. Please revise tables 10.3.3, 10.3.6, 10.3.9, 10.3.10, 10.3.16 10.3.17 and 10.3.18 according to the revised reference concentrations for inorganics. Screening for COPCs, using the revised UTLs for inorganics, is recommended.
- Please revise tables 10.6.4, 10.6.7 and 10.6.10 by using the proposed background reference concentration for inorganics in soil and groundwater dated. 6.9.97.
- Section 10.7 AOC 685. Please revise tables 10.7.6 and 10.7.9 using the proposed reference concentration for the inorganics (6.9.97). According to the recently proposed reference concentration for inorganics, Al and Co should be included in the list of chemicals exceeding their reference concentration.

- Section 10.8 AOC 687. Please revise table 10.8.3 according to the proposed reference concentration for inorganics in soil and groundwater (6.9.97).
- Section 10.8 AOC 687 Table 10.8.10. On considering the proposed reference concentration for inorganics in soil and groundwater, dated 6.9.97, Al and Mn are additional chemicals that were detected above their reference concentration in groundwater. Please revise table 10.8.10 using the most recent proposed reference concentration for inorganics.
- Please revise tables 10.8.9, 10.8.12, 10.8.17 and 10.8.18 using the proposed reference concentration for inorganics in soil and groundwater dated 6.9.97.
- Section 10.8 AOC 687 Table 10.8.6. Please revise table 10.8.6 using the proposed reference concentration for inorganics in soil and groundwater dated 6.9.97. Mn and Zn exceed their new proposed reference concentrations and should be included as the inorganics detected above their reference concentration, besides nickel (Ni).
- Section 10.9 AOC 688. Please revise table 10.9.3 using the proposed reference concentration for inorganics in soil and groundwater dated 6.9.97.
- Section 10 AOC 689 and 690. Please revise table 10.10.4 using the proposed reference concentration for inorganics in soil and groundwater dated 6.9.97. As, Cd, Hg and Zn exceed their revised reference concentration.
- Section 10 AOC 689 and 690. Please provide a footnote for the abbreviations used in table 10.10.8.
- Section 10 AOC 689 and 690. Please revise table 10.10. 9 using the proposed reference concentration for inorganics in soil and groundwater dated 6.9.97. Considering the revised reference concentrations for inorganics, As appears above its screening and reference concentration. As should be designated as a COPC.
- Section 10 SWMU 12. Please revise table 10.11.8 using the proposed reference concentration for inorganics in soil and groundwater dated 6.9.97.
- Section 10 RTC. Please revise table 10.13.3 and 10.13.4 using the proposed reference concentration for inorganics dated 6.9.97.
- Section 10.14 DMA Table 10.14.10.2. Please identify COPCs for this site based on the proposed reference concentrations for inorganics dated 6.9.97.

Response 44:

All tables have been revised to reflect the modified background reference values. COPCs are identified and carried through the respective HHRAs.

**SCDHEC (Paul Bergstrand) Comments on The
Zone I RCRA Facility Investigation Report
(dated January 1996) NAVBASE Charleston
November 5, 1997**

General Comments

Comment 1:

This report deals with an area that was formerly used as a Naval Air Station. In fact, some tanks and structures remain from that former use. This report needs maps of the former Naval Air Station with the current base structures indicated in a light grey or provided as an overlay.

Response 1:

All engineering drawings and specifications (both old and new) that were available have been used to update the base maps and drawings used for figures in this report.

Comment 2:

RFI surface soil samples are collected from 0 to 1 foot. Surface soil samples collected at SWMUs or AOCs based on former base used must account for disruption or reworking during construction of subsequent structures. This is particularly important when sub-surface soil samples were not collected due to high water table.

Response 2:

During project team discussions regarding this comment, it was pointed out that the reason subsurface soil samples were not collected below the water table is the validity of the results becomes questionable in terms of whether the contamination detected is representative of soil conditions or if it is contamination associated with groundwater in the pore space. An agreement was reached for all remaining soil sampling to be performed during the RFI regardless of zone, subsurface soil samples would be collected regardless of depth to groundwater. In the instances where groundwater is encountered and there are no site monitoring wells, the analytical data can be used to make reasonable assumptions as to whether a shallow groundwater problem exists and if monitoring well installations are necessary.

Comment 3:

The RFI Work Plan included Grid well locations on SWMU and AOC site maps. The RFI report, however, apparently did not consider or discuss analytical results from those wells. The final report should include this data.

Response 3:

Grid well sampling data has been considered and is included in site specific discussions as applicable.

Comment 4:

The Zone I RFI Report should include data available from other nearby or adjoining sources such as Zone H grid wells and SWMUs and Zone K, Shipyard Creek soil, sediment and water samples.

Response 4:

The Zone I RFI Report will include, summarize, or reference validated and pertinent data from other zone investigations depending on the degree to which such data is addressed in the zone-specific RFI report it was generated for.

Comment 5:

Ground water flow maps based on the quarterly sampling events should be included on the final report.

Response 5:

Water level data were acquired at each well during quarterly sampling events; however, these data were not collected synoptically since the wells were sampled over a period of several weeks. As a result, these water level data are not suitable for developing quarterly groundwater flow maps.

A synoptic groundwater level event for the entire southern end of the peninsula (all wells in Zones H and I and a portion of those in Zone G) was conducted in mid summer 1998 as part of the Zone H CMS work. These data will be used for zone-wide groundwater flow maps as well as site-specific groundwater flow maps that may be included in the Zone I Final RFI Report.

Comment 6:

Sites such as RTC and DMA should be assigned a SWMU or AOC number.

Response 6:

The assignment of an AOC or SWMU number is a decision to be made by project team consensus. The 177/RTC site has been identified as a SWMU. The DMA has not been identified as either a AOC or a SWMU since it was created and regulated under the Clean Water Act.

Comment 7:

This RFI report must conclude if the vertical and horizontal extent of contamination has been detected and defined for each SWMU and AOC. This is very important before moving a site into the CMS process.

Response 7:

Acknowledged

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
671	Meter House, AvGas Concrete USTs (2)	a) Metals in Grid Well 17 & 17D > MCLs; b) Mercury in well 03 > MCL (37 ppb) c) Thallium in wells 17S, 17D, 01, 01 > MCL d) What is GW flow near the wall? e) Piping Runs are not indicated on the maps and may require sampling. f) Has site been addressed by UST Program? Where is the data? g) Dioxin "hot spots" in soils? Consider IM.

Response: Due to the unique format of these comments, a conference call was held by project team members on 20 January 1998 to clarify which specific comments required only text clarification and which comments identified data gaps requiring additional samples to be collected. In general it was agreed that this site was adequately characterized and no further sampling is required pending final risk management decisions.

Comments "a-c", the presence of metals in these wells is acknowledged and exceedances have been discussed with respect to whether the concentrations are suspected to be related to site operations or are more appropriately discussed as part of the basewide groundwater quality evaluation.

Comment "d", the impact of the quay wall on groundwater flow is not fully understood; however, sufficient data (Figures 2.11 through 2.14) is available to determine predominant groundwater flow direction is toward the Cooper River.

Comment "e", figures for all sites in Zone I have been revised as applicable and/or as data was available to show pertinent site features. As noted above, the project team agreed that no further sampling was required pending final risk management decisions.

Comment "f", This site is not currently included in the UST Program.

Comment "g", the method used by Ted Simon (Simon to Britain, 2 March 1995) to calculate a theoretical hotspot was applied to the Zone I surface soil data set to determine a worst case scenario. Basically the maximum detection of each congener, regardless of sample location, is multiplied by the appropriate TCDD toxicity equivalency factor to determine a toxicity equivalent (TEQ). The TEQs are summed to calculate a total dioxin TEQ. The calculated values are well below respective screening levels. Based on this observation the Navy feels the risk posed by dioxins in Zone I are negligible and interim measures are not warranted.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
672	Electrical Substation	a) Metals, VOC & SVOC are in soils & Grid Well.
673	Storage Paint, Oils & Solvents	b) No site wells. c) No GW flow maps. d) What is GW flow near the wall? e) Thallium in Grid Well 18D (3 rounds of sampling) > MCL f) Grid Well data not incorporated into report. g) May need to address site contamination not directly attributed to the AOCs.

Response:

Comment "a", As discussed in the report, a number of organic and inorganic compounds were detected at these sites. Of those detected, arsenic is the sole COC and therefore, the primary risk driver. A review of the data collected prior to 20 January 1998 conference call indicated the extent of arsenic had not been defined in accordance with criteria provided in the Comprehensive RFI Work Plan. As a result, soil samples were collected at 4 additional locations in April, 1998.

Comments "b-d", As indicated in the Zone I RFI work plan, the objective of the investigation was to perform confirmatory soil sampling to determine if a release had occurred. A grid-based well pair were installed down gradient of the subject site and the result of samples collected from these wells is discussed. The impact of the quay wall on groundwater flow is not fully understood; however, sufficient data (Figures 2.11 through 2.14) is available to determine predominant groundwater flow direction is toward the Cooper River.

Comments "e-f", grid wells 18 and 18D are approximately 60 feet down gradient of the sites. The data from these wells has been discussed with respect to aiding in the characterization of groundwater in the vicinity of these sites. The presence of thallium in the grid well is acknowledged and will be discussed with respect to whether the concentrations are suspected to be related to site operations or are more appropriately discussed as part of the basewide groundwater quality evaluation.

Comment "g", the risk assessment evaluates CPSSs irrespective of whether or not it is known that the compounds detected can be attributed to historical site activities.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
675	OWS NS-4	a) 675 is actually a Oil Water Separator (OWS).
676	Incinerator NS-2	b) Where does the OWS drain? Storm water or Sewer?
677	Grounds	c) Need to show OWS pipe runs (in and out). d) Describe the system that feeds into OWS. e) What process generated the need for the OWS? f) How old is the OWS? g) What is GW flow near the wall? h) What is the source of gas and naphtha contamination in Grid Well at 675-02? i) 676 only has one monitoring well. j) What is the groundwater flow near the wall? k) SB 03 and 06 have high SVOC < RBC. l) Grid Well 15D has Thallium > MCL. m) MW-02 has Thallium > MCL. n) SB03 has Thallium > SSL of 400. NOTE! Is this the only soil sample on base > SSL for Thallium? o) SBs 03, 06, 09 and 10 have high SVOC < RBC. p) What is the source? q) What is the full extent?

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
		<p>Response: During the 20 January 1998 conference call it was discussed that these sites are being addressed by the petroleum program and that USTs have been removed. Team members agreed with the recommendation that no further sampling occur under the RFI.</p>
		<p>Comments "a-f", The RFA, EBS, and historical base maps will be reviewed and a more detailed description of historical site operations provide in the revised report as available and/or appropriate.</p>
		<p>Comments "g and j", the impact of the quay wall on groundwater flow is not fully understood; however, sufficient data (Figures 2.11 through 2.14) is available to determine predominant groundwater flow direction is toward the Cooper River.</p>
		<p>Comment "h", the source of gasoline and naptha is likely former UST NS-4 which was closed by removal in September 1996. These constituents were only detected in one sampling round and in the same time frame as the UST removal. No detections of naptha or gasoline was noted in the monitoring well located downgradient of the former UST.</p>
		<p>Comment "i", only one well has the "676" prefix however, there are a total of 6 wells at these sites which were investigated as one contiguous site.</p>
		<p>Comments "k, o-q", the presence of SVOCs is acknowledged and discussed with respect to protocol established in the Comprehensive RFI Work Plan.</p>
		<p>Comments "l-n", Thallium has been identified as a COC for this site. Additionally, the presence of thallium in groundwater (and potential sources) is being addressed as part of a basewide groundwater quality evaluation.</p>

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
678	Fire Fighting School	a) Provide air photos to locate former structures.
679	Wash Rack	b) Figures in report must show site in relation to sample locations and monitoring wells. c) No GW flow maps. What is GW flow near the wall? d) Grid well 14 reported Aroclor > MCL and pentachlorophenol = MCL e) Grid well 14D reported chloroethane at 200 ppb which is a breakdown product of TCA. Is this a result of the Fire Fighting School or the Washrack? f) Monitoring well 002 reported Methylene Chloride < MCL. Is this the leading edge, the training edge or the center of contamination? g) Was a OWS used at the wash rack? If so where did the piping run to OWS? If so where did the OWS discharge, into the sanitary sewer or the Cooper River? h) Other questions as in 678.

Response: Site specific discussion on this combined AOC will be provided as an addendum to the revised RFI report and as such response to comments will be addressed and submitted with the addendum.

680	Grinding Room	a) No data was submitted for this AOC. b) What was former use of building? The last use was an Administration Office. (NS 26) c) What other mechanical repair besides brake work occurred in this building? NOTE. Nearby buildings 680 and 681 are studied in this report as sandblasting and Fleet service. d) Was an OWS associated with this site? e) Was degreasing a part of a former activity? Brakes are always very clean. f) Was liquid waste discharged to sewer?
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Response: Site specific discussion on this AOC will be provided as an addendum to the revised RFI report and as such response to comments will be addressed and submitted with the addendum.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
681	Blast Booth & Cyclone	<ul style="list-style-type: none"> a) Soils: PAH, TPH (no 2nd interval samples taken), b) Lead 2nd interval > background. c) Was an OWS a part of this site? d) No wells at this AOC.
<p>Response: Site specific discussion on this combined AOC will be provided as an addendum to the revised RFI report and as such response to comments will be addressed and submitted with the addendum.</p>		
685	Smoke Drum	<ul style="list-style-type: none"> a) Second round soil samples reported higher values than the first round. The extent of the surface soil contamination has not been defined. b) No subsurface soil samples were collected due to high water table. c) Provide air photos during period of operation 1941 - 1953. d) What is ground water flow? What is the ditch flow? e) DEHP levels in soil increased to the east. f) Grid well 10S reports Lead, MEK, DDT, DDE, CI Pesticides and Dioxins in Shallow GW. g) Grid Well 10D reports Lead, Thallium > MCL and mercury < MCL in deep GW.

Response:

Comment "a, b, and e", per the 20 January 1998 conference call, twenty-one surface and eighteen subsurface soil samples were collected from an additional 21 locations during March and April, 1998 to further define the extent of COPCs.

Comment "c", No aerial photos from the specified time period were available for inclusion in the revised RFI report. **Comment "d",** groundwater flows easterly or toward the Cooper River. Surface water in the ditch flows to the south.

Comment "e", While DEHP does increase in detection level towards the east side of the site, all detections are well below respective guidance levels. Further, DEHP was not identified as a COC as a result of the HHRA.

Comments "f and g", the groundwater data from grid well pair 10 will be used along with a qualitative assessment of the subsurface soil samples (which were all collected from below the water table) to evaluate whether AOC 685 is a source of groundwater contamination. The significance of the groundwater data will be evaluated using frequency of detection, concentration vs. MCLs, etc.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
687	Ammo Storage Bunker	a) Were explosives analyzed in soil or GW?
16	Paint Storage	b) Figures of 687/16 show GW 7 & 7D. Should be Grid Well 8 & 8D. Navy did not include grid well data in report discussion. NOTE! Values > MCL in GW 8 & 8D. c) Where is sediment analytical data? d) What is the direction of water flow in ditch? e) What is GW flow? How does it interact with the river? f) Provide GW flow maps for the four quarters of data. g) RFI WP states SWMU 16 had paint, paint thinner and other haz material LIKE..... h) Air photos should be provided. i) Navy must explain VOCs in GW. Is it the leading edge, the trailing edge or the center? j) Is the Arsenic above background. How is this addressed? k) Who made the personal statement that "No paint was ever stored at 16"? Were they in the Navy since 1942 and working at this bunker the entire time? l) Based on the maps, the area west of X-55 where paint, solvents and other hazardous materials were stored were not sampled. This area should be sampled for soils and groundwater.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
		Response:
		Comment "a" , The soil and groundwater were not analyzed for explosives since this area was used for storage, not disposal and there is no indication that explosives were spilled or released from this facility.
		Comment "b" , The figure has been corrected and the text has been revised to include a discussion of the grid well results as they relate to the results from the 4 site wells.
		Comment "c" , The sediment results are discussed in Section 10.8.5 of the report.
		Comment "d" , surface water flow in the ditch is toward the south.
		Comment "e" , Groundwater flows easterly or toward the Cooper River. As for interaction, the river serves as a discharge boundary and due to the fine grain nature of the shallow sediments in which the monitoring wells are screened, it is unlikely the flow direction is significantly influenced by the changing tides. There have been several "tidal influence" studies at various locations around the base to confirm this hypothesis.
		Comment "f" , groundwater flow maps have been prepared over time on a larger basewide scale (using the vast majority of wells across the base as data points) rather than for a small number of wells at individual sites. Figures 2.11 through 2.14 provide groundwater flow maps for two different time periods.
		Comment "g" , this comment lacks specificity therefore the Navy is unsure exactly what is meant. The materials of concern listed in the work plan were a "best guess" by project team members at that time. The analyses performed for confirmation purposes included all compounds on the USEPA TCL/TAL list.
		Comment "h" , No aerial photos are available which provide additional information.
		Comments "i and j" , per the 20 January 1998 conference call it was agreed that 2 additional quarters of groundwater samples would be collected for VOCs and metals. VOCs were not detected in subsequent sampling rounds. No VOCs were identified as COCs as a result of the HHRA. Arsenic detections are addressed in full in the HHRA and is identified as a COC.
		Comments "k and l" , It is the Navy's position that the empty paint containers found at AOC 687 represented a one time storage and were not

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
688	Ammo Bunker, Paint Storage	<ul style="list-style-type: none">a) NOTE. Use GW 7 & 7D.b) Grid wells GW 7S reports Lead and Thallium > MCL. Grid well 7D reports DEHP > MCL. Grid well hits were not addressed in report.c) No shallow wells associated with site.d) How long was 3420 gallons of paint stored during 1987?e) Air photos should be provided for the paint storage period.f) Was RDX included in analysis of soils and GW?g) Where is the Sed data?h) 2-Butanone (MEK) is associated with paint and paint solvents. RFI calls this a common laboratory contaminant. Navy must prove CLC.i) Aroclor is in seds at 98 ppb. The RBC is 88. What is the source of PCBs. What is the extent of the PCBs?j) Soil sample should be collected at this site.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
		<p>Response:</p> <p>Comments "a-c", The data from grid well pair 7 has been incorporated into this site discussion as appropriate. Per the 20 January 1998 conference call it was agreed that 2 more quarters of groundwater samples would be collected and analyzed for SVOCs and metals. The additional sampling was accomplished and the resulting data has been included in the report as appropriate.</p> <p>Comment "d", No data is available regarding the length of time paint was stored at the facility. There is no available data that indicates that any of the stored paint was spilled or released from the bunker.</p> <p>Comment "e", There are no aerial photos available that will provide additional information regarding this site.</p> <p>Comment "f", analysis for explosives was not included during the work plan scoping since it is highly unlikely disposal of these types of material ever occurred since this unit was used for storage of live ammunition.</p> <p>Comments "g, i, and j", discussions regarding these sites during the 20 January 1998 conference call focused primarily on the sediment data and the presence of PCBs. Because the ditch only contains water intermittently, it was felt the samples are more indicative of soil than sediment. It was agreed that 2 more soil samples would be collected from within the ditch at locations topographically upgradient and downgradient. The results of these samples (only analyzed for pest/PCBs as agreed) are presented in the revised RFI report.</p> <p>Comment "h", statements referring to these types of compounds as common laboratory artifacts have been deleted from the revised RFI report.</p>

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
689	Marina Parking	<ul style="list-style-type: none">a) The parking area was included because of suspected unauthorized disposal. However only 3 surface soil samples were collected for the entire area. Subsurface samples were not collected. The surface would be the would be the area most disrupted by construction of the parking lot. Only one well pair GD 19 is associated with this site. Could this be representative? What is the groundwater flow for this area?b) Provide air photos of this area over a wide time period.c) Additional samples may be required.

Response:

Comments "a and c", During the 20 January 1998 conference call it was pointed out that soil samples were collected from 10 locations (actually 11) instead of 3 as stated in the comment. There are also 2 grid well pairs within the boundary of the site. The conference call participants agreed no further sampling was needed at this time.

Comment "b", No aerial photos are available which provide additional information for the subject site.

Comment "c", As noted above, the project team agreed that no further sampling was required for the marina parking area.

690	DMA Roads	<ul style="list-style-type: none">a) Which areas are proposed for CMS? Were any contaminated areas identified?b) SB 02 and SB 10 had a high number of low level hits. This may indicate dumping areas. Additional sampling is necessary at these and possibly other areas to determine if the edge or the center of contamination has been discovered.c) Metals were not analyzed for soil samples 1-10. Please explain why.d) The Naval Detachment found and removed drums along the perimeter road. The description of the drums indicated waste solvents. Samples were analyzed only for TCLP metals. Additional full scan sampling is necessary at this location.e) Samples collected in Shipyard Creek for Zone J should be considered for a big picture view of this AOC.
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SPECIFIC COMMENTS

S/A Number	Site Name	Notes
Response:		
<p>Comment "a", Several areas with risk estimates above guidance levels were identified in the combined AOC 689/690. Also, a number of COCs were identified as a result of the HHRA. This information is provided in the revised RFI report.</p>		
<p>Comments "b and d", two additional samples were collected at both the SB 02 and SB 10 locations. Five confirmation samples were collected at the drum removal site. The text has been revised to include the new data.</p>		
<p>Comment "c", the subject samples were analyzed for metals. The data tables and text in Section 10 include the data; however, it appears the complete data set printouts for these samples were not included in the appendices. The complete data set can be found in Appendix D of the revised report.</p>		
<p>Comment "d", As noted above, five additional samples were collected from the drum removal site. These samples were analyzed for VOCs, SVOCs, and metals. The results of these additional samples has been included in the revised RFI report.</p>		
<p>Comment "e", this type of evaluation will be performed as part of Zone J RFI which has not be completed. Any hot spots identified along the road will be noted as potential point sources for sediment/surface water contamination and any required assessment will be performed in the Zone J RFI. However, due to the large number of variables potentially influencing Zone J, it would be premature to speculate on the significance of the upland samples from this one area.</p>		
SWMU 12	Fire Fighter Training	<ul style="list-style-type: none"> a) Need air photos from the time this area was used for fire training. b) Need quarterly GW flow maps. c) Note no 2nd interval soil samples were collected. d) DEHP was reported above the MCL in well #3. e) Arsenic was reported above the MCL for four quarters in well #2. f) Thallium was reported above the MCL in well #3. g) No site deep wells were installed. h. Dioxins were reported in shallow groundwater.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
Response:		
<p>Comment "a", Preparation of the work plan included a review of air photos, base maps, and a site visit with the USEPA RPM. There are no aerial photos that provide any additional information on the subject site.</p>		
<p>Comment "b", groundwater flow maps have been prepared over time on a larger basewide scale (using the vast majority of wells across the base as data points) rather than for a small number of wells at individual sites. Figures 2.11 through 2.14 provide basewide GW flow maps for two separate time periods.</p>		
<p>Comment "c", no second interval soil samples were collected due to the shallow water table.</p>		
<p>Comments "d-f, h", all CPSSs were evaluated relative to the completion of the HHRA for the subject site and is included in the revised RFI report.</p>		
<p>Comment "g", one grid-based deep well (GDI03D) is located adjacent to SWMU 12 and results from sampling of this well are discussed in the revised RFI report.</p>		
RTC	Reserve Training Center	<ul style="list-style-type: none"> a) NOTE! Not in Work Plan b) This site needs a SWMU or AOC number. c) What guided the sampling protocol? d) No wells on site. e) Across from Fire Training S-13. Is this site influenced by S-13? f) What was site history before RTC? g) Upper soils reworked to build RTC etc. which may influence surface soil complex. h) Navy must prove Acetone & DEHP are Common Laboratory Contaminants (CLC). i) Pest & Dioxin hot spots at 10, 3, 5, & 8. How does this affect risk? An IM may be useful here. j) Grid wells GW16 & 16D adjacent to site. Was data from these wells included in the discussion? k) Methylene Chloride > MCL. Explain. l) Need deeper soil and GW samples.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
Response:		
<p>Comments "a-l", This was never identified or designated as a site and samples were collected at the urging of USEPA simply as a precautionary measure because NOAA was performing site improvements prior to completion of the RFI at nearby sites. The team already rendered an opinion once that the concentrations of what was detected were insignificant and that no further action was warranted.</p>		
177	RTC Storage Building	<ul style="list-style-type: none"> a) Presently Bldg. RTC #4, for NOAA use. b) No site map. No sample locations. c) No wells on the site. d) What direction does groundwater flow? e) How does the wall affect groundwater flow? f) Surface soils: Dioxins, Pest, VOC, SVOCs g) Subsurface Soils: Dioxins SVOCs h) Navy must prove Acetone & DEHP are CLC. i) Three surface soils with TCE and two with breakdown products. j) This site needs a closer look and wells on site.
Response:		
<p>Comments "a-j", this site was inadvertently omitted from the original RFI work plan and was addressed by an addendum that was submitted later. Consequently a draft RFI report for this site was not submitted. Soil samples have been collected from 19 locations and 2 monitoring wells were recently installed at this site per the 20 January 1998 conference call. The revised RFI report will include a full evaluation of this site which should address the comments noted above.</p>		
DMA	Dredge Materials Area	<ul style="list-style-type: none"> a) This site needs a SWMU or AOC number. b) What guided the sampling protocol? c) No wells on site. d) Dike relocated? Show how has it changed over time and explain the significance. e) Five samples collected. 1 outside dike, 3 inside dike, 2, 4, & 5 on the dike. Were the dike sample on top, on the side or inside the dike? 1, 3, & 5 did not collect subsurface samples. Explain why. f) Explain or define any interaction with SWMU 12. g) Wells surrounding the DMA were not included in any discussion. h) This site needs a closer look and possible wells on the site.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
Response:		<p>Comments "a-h", at the time the work plan was written the project team members agreed that this area should not be assigned a site number since it was created and regulated under the Clean Water Act. The team agreed it would be appropriate to simply extend the base wide grid pattern over the areas and collect soil, sediment, and/or surface water samples. In addition, there are nine shallow/deep grid well pairs that surround the DMA which should provide sufficient data to, at a minimum, detect any significant groundwater contamination in the area. The RFI report has been revised to further explain the rationale for why/where samples were collected and to evaluate the data with respect to screening against the appropriate risk thresholds. The DMA discussion is being completely re-written to address the concerns listed in the comments. This discussion is provided in the revised RFI report.</p>

**Zone I
 Summary Sheet**

S/A #	Site Name	SCDHEC	EPA	Navy	Final
671	Meter House, AvGas Concrete USTs (2)	CMS Surface Soils + GW		CMS Surface Soils	
672	Electrical Substation	CS 2		CMS S Soils	
673	Storage Paint Oils & Solvents	CS 2		CMS S Soils	
675	OWS NS-4	CS 2 GW		NFA	
676	Incinerator NS-2	CS 2 GW		NFA	
677	Grounds	CS 2 S Soils, GW		NFA	
678	Fire Fighting School	*CMS		CMS S Soil + Shallow GW	* = CS 2 Soils + Shallow and Deep GW
679	Wash Rack	*CMS		CMS S Soils + Shallow GW	* = CS 2 Soils + Shallow and Deep GW
680	Grinding Room	INFO		NFA	
681	Blast Booth & Cyclone	CS 2		NFA	
685	Smoke Drum	CS 2 Soils + Sh/Deep GW		CMS Seds + Shallow GW	
687	Ammo Bunker	INFO		CMS Seds +	
16	Paint Storage	CS 2		Shallow GW	
688	Ammo Bunker	INFO		NFA	
	Paint Storage	CS 2			
689	Marina Parking	CS 2		CMS S Soils	
690	DMA Roads	CS 2		CMS S Soils	

*Response to SCDHEC (Paul Bergstrand) Comments
 Draft RCRA Facility Investigation Zone I
 Dated January 26, 1996*

**Zone I
 Summary Sheet**

S/A #	Site Name	SCDHEC	EPA	Navy	Final
S 12	Fire Fighting Training	CS 2		CMS Shallow GW	
RTC	Reserve Training Center	CS 2		NFA	
177	RTC Storage Building	CS 2			
DMA	Dredge Materials Area	CS 2		NFA	

**Zone I RFI
 Comment Resolution for Additional Field Work**

Proposed Recommendations

Site Name	Proposed Recommendations	Rationale
AOC 671, Meter House, AvGas Concrete USTs	NFI - CMS	The site is adequately characterized to tentatively recommend CMS. Due to the relative low risk posed by the site of 5E-06, the team should make a risk management decision to determine if further action is even warranted. Metals is GW should be discussed on a larger scale.
AOC 672, Electrical Substation AOC 673, Storage - Paint, oils, and solvents	Collect 3 additional SS samples for arsenic analysis.	At AOC 673, arsenic concentrations exceed background at 5 of 6 locations. Even though exceedances are marginal, samples from AOC 672 are lower and provide contrast. Based on a risk of 1E-04, CMS will be recommended and the lack of arsenic extent definition will be a data gap.

**Zone I RFI
 Comment Resolution for Additional Field Work**

Site Name	Proposed Recommendations	Rationale
AOC 675, OWS NS-4 AOC 676, Incinerator NS-2 AOC 677, Grounds	NFI	Petroleum contamination was detected in groundwater; however, the DET has performed a tank removal which was the likely source. The EBS identified the following tanks in this area: AOC 676, 2 - 25,000 fuel, 1- 495 gallon waste oil; AOC 677, near NS-3 were 2 of unknown capacity. Cumulative risk 8E-07. This area already being addressed by the tank program.
AOC 678, Fire Fighting School AOC 679, Wash Rack	Collect 3 additional GW samples using DPT. Resample grid 14 & 14D	Consistent detections of petroleum compounds and random detections of other compounds (primarily VOCs). No USTs or ASTs are listed at NS-1 so there is currently insufficient data to identify source.
AOC 680, Grinding Room	Confirmation sampling for both soil & GW (DPT)	NFI with respect to asbestos based on detect results. However, the EBS states the site historical operations included seaplane refueling, oil storage, parts cleaning, and a 6000 gallon oil/sludge UST associated with an OWS. None of this info was cited in the RFA and therefore appears to have been over looked during work plan scoping.
AOC 681, Blast Booth and Cyclone	NFI	Cumulative risk for surface soil is 3E-07. For Zone L RFI, 3 GW samples were collected nearby in association with an OWS and piping. The VOC results were non-detect. Only CMS concern (may more appropriately be a process closure type concern) appears to be lead residue on interior walls.
AOC 685, Smoke Drum	Additional surface soil sampling	The site will be recommended for CMS based on a 4E-05 cumulative risk. Data gap concern will be the fact COCs are fairly ubiquitous across area sampled and a boundary cannot be defined.

**Zone I RFI
 Comment Resolution for Additional Field Work**

Site Name	Proposed Recommendations	Rationale
AOC 687, Ammo Bunker SWMU 16, Paint Storage	NFI	The site will be recommended for CMS based on a 9E-04 cumulative risk. Primary driver is arsenic in shallow GW (8.7E-04). Arsenic was detected in one well, one time above MCL (73.7 ug/L). Otherwise, the maximum hit is 39.3 ug/L. The hits in grid wells 08 & 08D are very minor and an MCL was only exceeded once - thallium in 08D at 5.5 ug/L.
AOC 688, Ammo Bunker, Paint Storage	NFI	The relative significance of metals hits in grid wells is more appropriate to address on a larger scale. The hits of metals and DEHP above MCL were all a one time occurrence.
AOC 689, Marina Parking	NFI	The site is adequately characterized to tentatively recommend CMS. DHEC comments only refer to 3 sample locations when 10 were sampled. Due to the relative low risk posed by the site of 7E-06, the team should make a risk management decision to determine if further action is even warranted
AOC 690, DMA Roads	Confirmation sampling at drum removal locations.	If confirmation samples were not already collected at ISM locations they should be.
SWMU 12, Fire Fighter Training	NFI	This site is tentatively recommended for CMS on the basis arsenic in shallow groundwater drives a 4E-3 risk. The arsenic concentrations in the problem well were consistently very high but no down gradient locations came close to exceeding MCLs. Maximum arsenic concentrations in soil is 14.2 ppm.

**Zone I RFI
Comment Resolution for Additional Field Work**

Site Name	Proposed Recommendations	Rationale
RTC, Reserve Training Center	NFI	This was never a site and samples were collectively at the urging of EPA simply as a precautionary measure because NOAA was performing site improvements prior to completion of the RFI at nearby sites. The team already rendered an opinion once that the concentrations of what was detected were insignificant.
SWMU 177, RTC Storage Building	Collect 4 additional soil samples - both intervals	The subsurface sample collected from boring location 07 contained elevated levels of SVOCs. The extent of these compounds should be delineated further and sampling may need to be expanded to include groundwater screening.
DMA, Dredge Materials Area	NFI	Data to characterize the site currently exists but was never compiled in a format to easily allow a thorough review by the team.

Notes:

- CMS = Corrective measures study
- CS = Confirmatory sampling
- ISM = Interim stabilization measure
- NFA = No further action
- NFI = No further investigation

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**Environmental Protection Agency Comments On
Draft RCRA Facility Investigation Report for Zone I
Dated January 26, 1996**

GENERAL

Comment 1:

Human health risk assessment comments specific for the Zone I RFI Report are identified below. General human health risk assessment comments, which EPA submitted on the procedure in conjunction with the Zone H RFI Report, are not repeated here but should be considered herein.

Response 1:

Acknowledged

Comment 2:

Throughout the Zone I RFI Report the statement is made that various chemicals:

--- are considered a common lab artifact by the USEPA National Functional Guidelines, February 1994.

Examples include:

Site	Page	Chemical(s)
AOC 671	10-9	Acetone
AOCs 675, 676, 677	10-17	Acetone
AOCs 678, 679	10-9	Acetone, Freon - 113
	10-14	Methylene Chloride
AOC 687, SWMU 16	10-6	Acetone, Methylene Chloride
	10-10	Acetone, Methylene Chloride
	10-16	Methylene Chloride
	10-52	Methylene Chloride
SWMU 12	10-13	Methylene Chloride, Phthalates
GRID	10-8	Acetone
	10-16	Acetone, Methylene Chloride
RTC	10-6	Acetone
DMA	10-6	Acetone, Toluene
	10-10	Acetone, 2-butanone
	10-14	Acetone

This raises three points:

- a. Good laboratory practice has ways of avoiding, or at least minimizing, lab artifacts.
- b. Good laboratory practice has ways of identifying when a chemical in a sample is a true sample ingredient and when it is a laboratory artifact.
- c. Simply identifying that a chemical is sometimes found as a lab artifact does not explain the chemical in the samples collected at Naval Base Charleston. Should such a lab artifact question arise, EPA would expect the laboratory to identify and resolve the issue or the Contractor to collect additional samples for analysis in a different laboratory. Fact rather than conjecture is needed here.

Response 2:

A comprehensive site-by-site discussion of all problems/deficiencies found in the laboratory and field blank data will be included in Section 4.0. Compounds detected in blanks will be grouped by analytical methods and sampling events and will be discussed as requested. In addition, the subject statement has been deleted from the site specific discussions.

Comment 3:

The format used for Sections 5.0 (Nature and Extent of Contamination) and 10.0 (Site-Specific Evaluations) makes the text difficult to follow. Except for a discussion of data related to background comparisons, the actual nature and extent of contamination are not presented until Section 10.0, after the presentation of the risk assessments. It would be better to incorporate Section 10.0 in Section 5.0 for the Final Zone I RFI Report.

Response 3:

The title of Section 5 has been changed to "Data Evaluation and Background Comparison" to more accurately reflect the contents. Section 10 includes all of the site-specific data and analysis: nature and extent, fate and transport, human health risk assessment, and corrective measures considerations, in that order. Ecological risk is discussed earlier, in Section 8, because it is more appropriately addressed zonewide.

Comment 4:

In the context of ecological risk assessment, receptors are considered to be the potentially affected biota - not surface water bodies such as the Cooper River. For Section 10.1, Page 10-1, and similar sections for all SWMUs and AOCs, revise the references to potential receptors accordingly.

Response 4:

References to the surface water bodies as receptors have been revised as requested.

SPECIFIC

Comment 1:

Page vii, List of Tables, Table 2.5 - The footnote is missing.

Response 1:

The List of Tables has been revised and the reference to footnote for Table 2.5 has been deleted. The footnote will remain with Table 2.5 in the body of the report where it is intended.

Comment 2:

Page 2-1, Section 2.1.1 - Add a figure showing the locations of the Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) in Zone I.

Response 2:

This figure has been added to the report. However, it is believed this figure is better suited for Section 1.0 and will be inserted in Section 1.4 (Figure 1.3) under the paragraph discussing the field investigation scope.

Comment 3:

Page 3-1, Section 3.0 - The statement is made that field work was conducted in accordance with the *Final Comprehensive Sampling and Analysis Plan* but no mention is made of the Zone I RFI Work Plan. The Zone RFI Work Plan should be reference also.

Response 3:

Reference to the Zone I RFI Work Plan was made in Section 3.1. However, it has been added to the statement in Section 3.0 as well.

Comment 4:

Page 3-2, Section 3.2.2.1, and Page 5-1, Sections 5.0 and 5.1 - In the text, clarify that the comparison of detected chemical concentrations to the USEPA Region 3 Risk-Based Concentration (RBC) Table pertains only to the protection of human health and does not address protection of ecological receptors.

Response 4:

The above clarifying statement will be added to the appropriate sections of the Report.

Comment 5:

Page 6-1, Section 6.0 - The theory and application of Fate and Transport are discussed. The discussion leads up to, but stops short of, making a conclusion. The questions that need to be answered here are:

- a. What is the contamination, where is it coming from, where is it going, and how is it getting there? And,
- b. What is the horizontal and vertical extent of contamination?

Response 5:

Section 6 is a general discussion of fate and transport matters. The questions above are addressed on a site-by-site basis in Section 10, in the fate and transport portion of each site's subsection.

Comment 6:

Page 6-18, Section 6.2.2 - In Paragraph 2, modify Sentence 3 to read as follows:

If concentrations of chemicals present in ground water do not exceed published AWQC, it is assumed that those chemicals present no risk to ecological receptors resulting from ground water discharge to surface water.

Response 6:

The sentence has been modified as requested in Section 6.2.2.

Comment 7:

Page 6-20, Section 6.2.4 - Check the wording in the second bullet and revise as needed.

Response 7:

The wording has been corrected.

Comment 8:

Page 8-1, Section 8.0

- a. Describe the nature of Area of Ecological Concern AEC V-3, since it is not shown in Figure 8.1, Page 8-2, or in Figure 8.2, Page 8-3.
- b. Under "Zone Rationale," revise the last sentence of Paragraph 2 to indicate that the Zone I RFI Report will include an evaluation of Zone I SWMU and AOC contaminants with respect to their potential for migration to aquatic areas outside Zone I, at concentrations that might result in adverse effects to ecological receptors. If this initial valuation indicates a potential risk, further evaluation of those aquatic areas will be conducted during the Zone J investigation.

Response 8:

- a. **AEC V-3 consists of all three subzones listed for Zone I as well as contiguous habitats located in Zone H. No ecological risk-based determinations have been made based on the AEC designations. Instead, AECs were evaluated for habitats containing similar biota within each zone's boundary and likely receptors from these habitats (subzones) were identified to assess ecological risk. Rather than adding a description of AEC V-3, which would be both repetitious and unrelated to the goals of the zone-specific ERA, the text has been revised to clarify the relation of AECs to subzones.**
- b. **The text has been revised to reference Section 10, the site-specific fate and transport assessments, as well as a brief summary of the conclusions of Section 10 dealing with groundwater to surface water cross media transport.**

Comment 9:

Page 8-1, Section 8.0 - The statement is made that "This methodology is described in detail in the *Final Zone J RFI Work Plan* (submitted November 22, 1995)." This raises two points:

- a. A Comprehensive RFI Work Plan has been developed and approved for work to be done at two or more zones. Each Zone Work Plan is intended to be specific for that zone. Thus, any reference to a more detailed description of this methodology should be to either the Comprehensive RFI Work Plan or a Section in the Zone I RFI Work Plan.
- b. The Zone J RFI Work Plan is still draft and should be referred to accordingly.

Response 9:

The text has been revised to read: "This survey methodology, which is used in conjunction with the Zone I RFI Report, is also described in the Zone J RFI Work Plan."

Comment 10:

Page 8-3, Figure 8.2.

- a. In the legend, include a brief descriptive phrase for the each of the designated ecological sub-zones.
- b. Show the locations of all SWMUs and AOCs in Zone I, as listed in Table 1.1, Pages 1-12 to 1-13.

Response 10:

For Figure 8.3, the legend has been revised to include a brief description of each ecological subzone and the location of all AOCs and SWMUs located in Zone I ecological subzones. The location of all SWMUs and AOCs is more appropriately shown on Figure 1.3 (Section 1.0).

Comment 11:

Page, 8-4, Section 8.1 - Clarify whether the species noted have been observed in Sub-Zone I-1 or are just expected to occur there, based upon the nature of the habitat present.

Response 11:

The text has been revised to clearly indicate which species have been observed and those which may occur within this habitat as stated in literature.

Comment 12:

Page 8-9, Section 8.2 and 8.3 - Mention that a preliminary evaluation of ground water contaminants will be conducted with respect to potential migration and discharge to surface water bodies.

Response 12:

The text has been revised to reference Section 10, the site-specific fate and transport assessments, as well as a brief summary in Section 8.3 of the conclusions of Section 10 dealing with groundwater to surface water cross media transport.

Comment 13:

Page 8-9, Section 8.3 - The last sentence in Paragraph 2 (concerning depth to ground water and ecological impacts) is true. However, considering the location of Zone I adjacent to the Cooper River and Shipyard Creek, Zone I ground water contaminants must be evaluated with respect to their potential to migrate and discharge into those water bodies at concentrations presenting a potential risk to aquatic receptors.

Response 13:
See Response 12.

Comment 14:
Page 8-12, Table 8.2b - Since the maximum surface soil concentration of iron (216,000 mg/kg) exceeds the upper tolerance limit of background (30,910 mg/kg), include iron as an Ecological Chemical of Potential Concern (ECPC) for Sub-Zone I-1.

Response 14:
Since iron is a naturally occurring nutrient, there are no known toxicity benchmarks for iron in soil and it has been excluded from the current UTL list (11/97) for Zone I. This information has been added to the text.

Comment 15:
Pages 8-27 to 8-31, Section 8.4 - Although this section on "Stressor Characteristics" is under the heading "Contaminant Fate and Transport," it includes some information on ecological effects. In future RFI reports for other zones, it would be better to include all of the effects information in the same section.

Response 15:
The text of the Zone I RFI and the ERA format have been revised so section headings are more consistent with the text provided below them.

Comment 16:
Page 8-31, Section 8.5.1 - Revise the last line to read "measured by comparing literature data on toxic effects to actual soil concentrations."

Response 16:
The text has been revised as requested.

Comment 17:
Page 8-34, Section 8.6.2 - although Sub-Zone I-3 "lacks significant terrestrial habitat," wetland contaminants should be evaluated for risks to bird and mammal species, which feed in the wetland.

Response 17:
The lack of terrestrial habitat in Subzone I-3 very much limits the exposure potential of contaminants in sediment to foraging terrestrial wildlife. However, as noted in the text, the

terrestrial wildlife which may forage in Subzone I-3 would likely forage in Subzone I-2 and risk estimates from Subzone I-2 could potentially apply to terrestrial species which occur in Subzone I-3.

Comment 18:

Page 8-35, Section 8.7

- a. The point made in Paragraph 1 about the use of different concentration units is understandable.

However, since the analytical data are presented in units of ug/kg or mg/kg (for example), rather than in ppb or ppm, it is preferred that the former units be used in future discussions.

- b. If ecological effects data are not available for particular ECPCs, say so in the text. The lack of effects data is an uncertainty with respect to the risk characterization, as mentioned in Page 8-64, Section 8.8.

Response 18:

- c. **The units have been converted as requested. The statement regarding different concentration units has been deleted since a "standardized" convention is now being used.**
- b. **Those ECPCs lacking ecotoxicological benchmarks have been identified and this benchmark deficiency will included as an uncertainty which my underestimate potential risk.**

Comment 19:

Page 8-35, Section 8.7; Pages 8-36 to 8-41; Section 8.7.1; Pages 8-59 to 8-61, Section 8.7.3 - Most of the information in these sections pertain to ecological effects and, therefore, would be more appropriate in Section 8.6 (Ecological Effects Assessment), beginning on Page 8-34. Risk characterization actually begins on Page 8-41 for terrestrial infaunal invertebrates and Page 8-62 for terrestrial vegetation.

Response 19:

This format discrepancy is noted and revisions have been made to Section 8 as requested.

Comment 20:

Pages 8-41 to 8-42, Section 8.7.1 - For the three sub-zones, be consistent in stating the locations of the chemical concentrations (e.g., Tables 8.2a and 8.2b) and the effects data (e.g., Table 8.9 or text?) used to characterize risk to terrestrial infaunal invertebrates.

Response 20:

The format in which sample locations, concentrations, and effects data are presented have been revised to be more consistent and easier to reference and review.

Comment 21:

Page 8-43, Section 8.7.2 - See the comment given above concerning evaluation of Sub-Zone I-3 with respect to terrestrial wildlife.

Response 21:

See Response 17.

Comment 22:

Pages 8-51 and 8-52, Tables 8.13a and 8.13b.

- a. Include the Volatile Organic Chemicals (VOCs) shown as ECPCs in Page 8-11, Table 8.2a, or explain why they are not included in the evaluation.
- b. Include iron in the evaluation, based upon the comment given above.

Response 22:

- a. The omission of the VOC concentrations is noted. However, there are no data available to calculate the effects or potential dietary uptake of the three VOCs detected at this site to terrestrial receptors. Acetone evaporates very quickly in the environment (vapor pressure 231 mm Hg at 25°C) and is subject to biodegradation under both aerobic and anaerobic conditions. Tetrachloroethene will also evaporate fairly rapidly due to its high vapor pressure (18.49 mm Hg at 25°C). Toluene, with a vapor pressure of 28.4 mm Hg at 25°C, also evaporates very quickly and will biodegrade as well. K_{oc} values for toluene in sandy soils have been reported at 178, indicating high mobility and high potential to leach to groundwater, away from potential receptors (*Handbook of Environmental Fate and Exposure Data*, Sage et al., 1990). Based on these factors, the VOCs detected at the site are not expected to stress ecological receptors and will not be incorporated into the risk assessment. This information has been added to the report.
- b. As stated earlier, iron is a naturally occurring nutrient and will not be included as an ECPC.

Comment 23:

Page 8-54, Table 8.14a - Check the series of U.S. Fish and Wildlife Service Contaminant Hazard Reviews by Ronald Eisler for reference toxicity values (RTVs) for the inorganics for birds (e.g., Eisler, Ronald. 1988. Arsenic Hazards to Fish, Wildlife, and Invertebrates: A synoptic Review. USFWS Contaminant Hazard Reviews, Report, Report No. 12.)

Response 23:

Additional ecotoxicological benchmarks has been reviewed, including Eisler's RTVs, and have been included in the Zone I RFI as appropriate.

Comment 24:

Page 8-59, Section 8.7.2 - Food chain calculations based upon maximum surface soil contaminant concentrations show a potential risk (sublethal effects) for terrestrial wildlife. Therefore, it is recommended that mean contaminant concentrations also be used in determining potential dietary exposure, to give a risk range and to determine whether risk is related to localized vs widespread areas of high contaminant concentrations. This would help determine the need for collecting site-specific ecological data.

Response 24:

For those parameters which, when using the maximum concentration, indicates risk, the potential dietary exposure and risk range has been calculated using both the maximum and mean concentration.

Comment 25:

Page 8-62, Section 8.7.3

- a. Include a statement indicating how risk to terrestrial vegetation was characterized (e.g., comparison of chemical concentrations to effects data in Page 8-60, Table 8.15, and in the text).
- b. For Sub-Zone I-2, explain why "Effects from organic concentrations could not be assessed."

Response 25:

- a. Text has been added to explain how risk to terrestrial vegetation was characterized.
- b. Text has been added to explain why effects from organic concentrations could not be assessed.

Comment 26:

Page 8-62, Section 8.7.4

- a. In Paragraph 1, last line, change "surface water quality" to "aquatic receptors."
- b. For surface water, include a reference to Table 8.4, Pages 8-17 to 8-18.

Response 26:

- a. The text has been revised as requested.
- b. The text has been revised as requested.

Comment 27:

Page 8-63, Section 8.7.4 - For Sub-Zone I-2, also include 4,4'-DDE since it has a hazard quotient (HQ) of 80 (Page 8-23, Table 8.6).

Response 27:

The omission of this compound is noted. The text will be revised to indicate 4,4'-DDE is an ECPC.

Comment 28:

Pages 8-64 to 8-65, Section 8.9

- a. As written, the ecological risk assessment does not present sufficient information to make a decision concerning the possible need for corrective action at different AOCs or SWMUs. Several data gaps are mentioned in the text of the draft Zone I RFI Report and related EPA comments. These data gaps must be addressed in order to finalize the ecological risk assessment. This again points out the apparent lack of a mechanism for proceeding from Phases I and II to Phase III of the ecological risk assessment prior to submission of a draft RFI Report.
- b. Revise this section, based upon EPA comments given above.
- c. Risk was not evaluated for terrestrial wildlife in Sub-Zone I-3. (See Page 8-34, Section 8.6.2). Therefore, change the statement about no risk potential for terrestrial wildlife species within Sub-Zone I-3.

Response 28:

- a. **With the revisions requested, the Zone I ecological risk assessment provides sufficient information to adequately support risk management decisions.**
- b. **Section 8.9 has been revised as per regulatory comments.**
- c. **This statement regarding risk to terrestrial wildlife has been revised.**

Comment 29:

Pages 9-1 and 9-3, Sections 9.0 and 9.1; and Page 9-7, Section 9.4. The wording in these sections erroneously implies that only human health concerns will be the basis for determining the need for a Corrective Measures Study. While EPA is concerned about human health, EPA is also concerned with other life forms. Depending upon the final outcome of the Ecological Risk Assessment, ecological concerns might also need to be addressed through corrective action.

Response 29:

The basis for which a site is determined to be included as part of the Corrective Measures Study (CMS) will include risk and hazard, both from the human health and ecological perspective. In addition, a CMS may be warranted for sites where contaminant fate and transport pose significant concerns. However, sites with significant fate and transport issues typically pose a risk threat as well, and thus are included in the CMS from the onset. The RFI Report has been amended to reflect this.

Comment 30:

Page 9-1, Section 9.0 - It says in part that:

--- the RFI Report should discuss whether the extent of contamination has been defined, and propose recommended actions for the SWMUs and AOCs, such as collection of additional samples, proceed into a Corrective Measures Study, or No Further Investigation, whichever is appropriate.

EPA agrees with this former SCDHEC comment. Yet, Section 9.0 does not fully satisfy this comment. This section summarizes what is contained in the USEPA guidance document *RCRA Corrective Action Plan* (USEPA 1994) rather than dealing with the site specific CMS issues. Section 9.0 is a very important section which should serve as a focal point for the rest of the Zone I RFI Report. It should summarize which areas are clean and require No Further Investigation, which areas need additional samples (how many, where, what type, etc.), and which areas should proceed into the Corrective Measures Study. Further, it should identify the

boundaries of each site ("the extent of contamination"). The extent of contamination is critical to designing a CMS.

Response 30:

Section 9.0 has been written in general terms to describe the overall CMS process proposed for NAVBASE. Potential remedial technologies based on impacted media are discussed in a general sense as well. Section 11.0 is a new portion of the RFI which was not developed at the time of this comment generation. This new section summarizes and presents recommendations for sites warranting a CMS. The reasons for including or excluding a site from the CMS process are listed as well. Site-specific CMS issues such as which areas need additional samples (how many, where, what type, etc.), proposed remedial objectives, and potential remedial alternatives will be included as part of the zone-specific CMS work plan.

Comment 31:

Page 9-27, Section 9.8 - A discussion is presented of a system for ranking the corrective measure alternatives. The statement is made that:

The ranking system will apply a weighing factor selected by the Navy to determine the importance of each corrective measure criterion.

However, the use to be made of that information is not provided. It should be noted that RCRA corrective action includes a public participation process. Specifically, while the Navy can recommend corrective measure alternatives, public input will be actively solicited and weighed heavily in the decision which will be made by the RCRA Permitting Authority(i.e., SCDHEC) as to which actual corrective measure is selected for each site. This emphasizes the importance of getting and keeping the Restoration Advisory Board informed and actively involved in the decision making process throughout the RFI and CMS.

Response 31:

The weighing factor the Navy will use during the ranking process to determine the importance of each corrective measure criterion will be provided to the Restoration Advisory Board (RAB). The reasons for its development and application will be explained to the RAB. In addition, Volume I of the Comprehensive Corrective Measures Study Project Management Plan, June, 1997 contains Section 7.0, Community Involvement. This section references the Community Relations Plan (CRP) and explains the process of and the benefits that can be obtained from a CRP. Active involvement of the RAB and the local community will be sought throughout the CMS as it currently is for the RFI.

Comment 32:

Section 10 - These discussions need to conclude with a discussion of the horizontal and vertical extent of contamination which is critical to the design of a Corrective Measures Study (CMS) where a CMS is needed and to the transfer of property where an area is demonstrated to be "environmentally clean." Maps which EPA has reviewed subsequent to the submission of this RFI Report would satisfy this concern if incorporated.

Response 32:

A discussion of the horizontal and vertical extent of contamination for each SWMU and AOC will be included in Section 10.

Comment 33:

Page 10-1, DMA - The statement is made that:

Sample locations may have been changed due to inaccessibility of proposed locations.

Since the investigation has been completed, this statement can be re-worded to say that the sample locations either were or were not changed thus eliminating any uncertainty. If they were changed, say so and explain why.

Response 33:

This discussion has been revised as appropriate.

Comment 34:

Pages 10-1 to 10-2, Section 10.0, and Page 10-3, Section 10.10.1 - State that the comparison of soil analytical data to the USEPA Region 3 RBC Table pertains only to the protection of human health and does not address protection of ecological receptors.

Response 34:

The text has been revised as appropriate. In addition, this text has been revised to include discussion of ecological receptors as well.

Comment 35:

Pages 10-1 and 10-2, Section 10.14.1, and Figure 10.14.1 - According to Page 10-1, Section 10.14, the purpose of the Dredged Materials Area (DMA) soil samples was to "characterize background conditions from dredged material deposits." However, Figure 10.14.1 show that only two soil samples were collected within the dike, while one was collected on the

dike and two were collected outside the dike. Thus it is questionable whether this limited number of soil samples adequately characterize the dredged material deposits. Address this point.

Response 35:

This statement is no longer included in the discussion.

Comment 36:

Page 10-10, Section 10.8.5 - Indicate the nature of the sediment sampling locations (i.e., drainage ditch?).

Response 36:

The samples were collected from a drainage ditch immediately east of the site. The text has been revised to reflect this.

Comment 37:

Page 10-17, Section 10.14.8 - The first sentence is unsupported. Add a table summarizing the ground water analytical data.

Response 37:

No wells were specifically installed to characterize groundwater at the DMA. The final RFI work plan proposed eight grid-based well pairs (GDI001/1D through GDI008/8D) to be installed along the eastern and western boundaries of the DMA to characterize the zone perimeter groundwater. Results of these analyses are discussed in the nature and extent section and are included in Appendix H of the RFI report.

Comment 38:

Page 10-17, Section 10.14.9.1 - Since the last two sentences (about sediment and surface water) do not apply to soil-to-ground water cross-media transport, it is recommended that they be separated into a new section.

Response 38:

This section has been revised as appropriate.

Comment 39:

Page 10-18, Section 10.8.7.4, and Page 10-7, Section 10.9.4 - Explain why sediment is not expected to migrate from the sampled drainage.

Response 39:

The statement has been removed from the text and the sections have been revised accordingly.

Comment 40:

Page 10-17, Section 10.11.5.2.

- a. Check the end of Line 3 to see if it should read "to have exceeded the published AWQCs."
- b. Include a table showing the comparison of ground water data to the AWQC, to support the statement concerning arsenic and nickel.

Response 40:

The fate and transport has been revised and the screening tables have been modified to include comparisons of groundwater analytical results to corresponding AWQCs (also known as saltwater surface water chronic screening values).

Comment 41:

Page 10-15, table 10.12.6 - Check the second line for arsenic, to see if it should read "Deep" rather than "Shallow."

Response 41:

The second line was correct as written. The first line should have read "Aluminum - Shallow" rather than "Arsenic - Shallow." The table has been corrected.

Comment 42:

Page 10-21, Section 10.3.7.4. - The statement is made that:

The significance of constituents detected in AOC 675 sediment with respect to ecological receptors will be addressed as necessary in the Zone I ERA or Zone J RFI.

This needs to be worded better to identify specifically where in the Zone I RFI Report this is more fully discussed and what part will be addressed as a part of the Zone J RFI.

Response 42:

The statement has been removed from the subject text and the section revised as applicable.

Comment 43:

Page 10-56, Section 10.3.9 - The statement is made that:

Therefore, a corrective measures study was not performed.

This needs to be re-worded to reflect what is recommended for future activities rather than stating this is something that has already happened.

Response 43:

This section has been revised and the subject sentence has been deleted.

Comment 44:

Page 11-6, Section 11.9.1 - The statement is made that:

--- risk to infaunal communities from organic ECPCs appears to be low or absent.

Fact rather than conjecture are needed here.

Response 44:

Noted.

Comment 45:

Dioxin - In the description of the risk assessment, the cleanup number of 1 ppb used at Times Beach is based on the work of Kimbrough and cited. In EPA's comments on the Zone H RFI, it was indicated that the slope factor approach is now more in favor and derived a cleanup number of 1 ppb based on this approach for workers. The Navy should be aware of this distinction and should refer to EPA's most recent comments on the draft Zone H RFI Report.

Response 45:

The derivation of the 1 ppb cleanup level for dioxin, which is now based on the slope factor approach, has been included in the final RFI Report.

Comment 46:

PAHs - These chemicals are present throughout Zone I. As would be expected, PAHs would wash from land sources (asphalt, oil, cars, etc.) by surface runoff to sediment. The sediment was then dredged and used as fill material so the PAHs occur in fairly low concentrations ubiquitously.

Response 46:

Other nearby PAH sources include power plants, the municipal incinerator, cooking, and general urban activities. At the February 1997 project team meeting, EnSafe presented proposed background reference values for carcinogenic PAHs in soil, expressed as $\mu\text{g}/\text{kg}$ of BEQs. Project team members agreed that the proposed reference values would not be used to identify site COPCs, but as risk management tools, as possible sampling endpoints, and as guidelines for handling IDW. The proposed reference value for Zone I soil was $160\mu\text{g}/\text{kg}$ BEQs.

Comment 47:

AOC 678 and 679 - The PCB Arochlor 1260 was detected in groundwater at levels of concern but not in soil. A possible disconnect exists here. It is present in 1 hit out of 3 and drives risk at the site.

Response 47:

Discussion of these combined sites is not included in the revised RFI but will be submitted as an addendum to that report. The comments regarding these sites will be addressed in the addendum submittal.

Comment 48:

SWMU 12 - The groundwater risk at SWMU 12 is driven by arsenic. It is possible that the sample was turbid because metals and dioxin, all generally entrained as fines, were selected as Chemicals Of Potential Concern (COPCs). This may become important in a risk management decision regarding groundwater.

Response 48:

The Final RFI report will evaluate all four quarters of groundwater data. Any trends in the groundwater data over time perhaps will confirm or refute the presence of these constituents in the groundwater.

Comment 49:

Dredge Spoils Area - A few samples of soil, sediment and surface water were taken in the Dredge Spoils area (referred to in the draft Zone I RFI Report as the DMA). Of the data reported, the soil and sediment were clean. Surface water had only metals contamination. The document claims that a risk assessment is unwarranted under RCRA because the area is a Clean Water Act (CWA) permitted dredge spoils area. Aluminum and manganese will probably drive any estimated risk from surface water.

This issue is a "Pandora's Box" which EPA does not see the benefit of opening at Naval Base Charleston. Rather, the environmental investigation and cleanup at Naval Base Charleston is

proceeding under the Community Environmental Response and Facilitation Act (CERFA) which is multimedia including but not limited to RCRA. Accordingly, EPA will not concur with the transfer of property until it is determined to be "CERFA clean." Therefore, EPA recommends that a sufficient number and types of samples be collected to identify the nature and extent of any contamination present, and that a risk assessment be conducted.

Response 49:

The subject statement has been removed from the text. A HHRA was conducted for the DMA and is included in the revised RFI report.

*Response to Comments From the
Environmental Protection Agency on the
Draft Zone I RCRA Facility Investigation
Dated January 26, 1998*

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



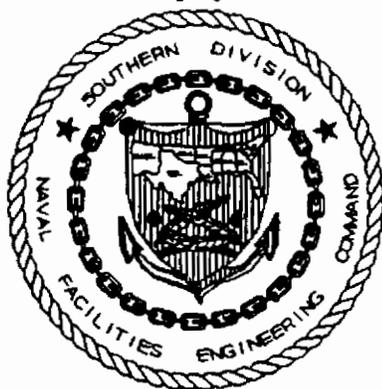
RESPONSE TO COMMENTS FOR

**ZONE I RCRA FACILITY INVESTIGATION REPORT
AOC 681
(Dated January 1996)**

Prepared for:

**Department of the Navy
Southern Division
Naval Facilities Engineering Command
Charleston, South Carolina**

**SOUTHDIV Contract Number:
N62467-89-D-0318**



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**July 30, 1999
Revision: 0**

**SCDHEC Comments on Risk Assessment Portion of The
Zone I RCRA Facility Investigation Report
(Dated January 1996) NAVBASE Charleston**

**AOC 681
RFI Report Addendum
July 30, 1999**

Comment 15:

Section 10.6.5.1 AOC 681. When discussing the fate and transport of all the ten organic constituents detected above their RBCs, at this site, it will be helpful to include a discussion on soil type, groundwater depth and meteorological (weather) conditions. According to Section 8.4 the soil type is sandy and the soil is low in organic carbon. The above mentioned factors, beside the Koc value of each constituents, are important in determining the fate and transport of each constituents. The possibility of soil-to-groundwater cross-media transport should be carefully analyzed in the absence of groundwater sampling. On the other hand, groundwater samples could be collected to demonstrate that this media has not been impacted.

Response 15:

First, please note that Section 10.6.5 of the draft document is Section 10.6.7 in the revised report addendum. Three groundwater monitoring wells were installed at AOC 681 in 1998. These wells were sampled in three rounds in late 1998 and early 1999. The results of the sampling are discussed in Section 10.6.4 as well as in the Fate and Transport Section (10.6.7). Additionally, soil and groundwater samples were collected via DPT (geoprobe sampling) at AOC 681 in March 1998. Results from this sampling event are included in revised Sections 10.6.2 and 10.6.4 as well as in revised Section 10.6.7 (Fate and Transport).

Comment 16:

Section 10 AOC 681. Considering the fact that so many organic chemicals are detected above their soil water protection SSL and that Benzo (a) pyrene was recognized as a COPC, based on the result of Wilcoxon rank sum test, a groundwater sampling is recommended at this site with analysis for VOCs and SVOCs.

Response 16:

The Wilcoxon rank sum test is not run on benzo(a)pyrene results since it is an organic compound. As noted above, three groundwater monitoring wells were installed and sampled and groundwater samples were collected from three DPT points at AOC 681. All the groundwater samples were analyzed for VOCs and SVOCs. The results of the soil sampling is presented in the Nature and Extent of Contamination discussion in Section 10.6.2 of the report addendum while the results of the groundwater sampling are discussed in Section 10.6.4 of the report addendum. PAHs were the only organics detected above SSLs in subsurface soil samples and these exceedances were only seen in boring 681SB001.

Comment 17:

Section 10.6.6.1. Please note that an USEPA report by Technical Review Workgroup for Lead (December 1996) provides recommendations for an interim approach to assessing risk associated with adult exposure to lead in soil. Under the light of above fact please reconsider the statement "...USEPA does not currently sanction any risk characterization model or approach for predicting the adverse health effects of lead in adults".

Response 17:

Please note that the HHRA which was found in Section 10.6.6 of the draft report is in Section 10.6.8 of the report addendum. The *Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil* is used to evaluate lead exposure for AOC 681. In addition, the above referenced statement has been deleted from the text.

Comment 18:

Section 10.6.6.2. Under the 'COPC identification' Section TPH is not mentioned as a COPC whereas Table 10.6.10 identifies TPH as a COPC. TPH has not been discussed under exposure assessment and toxicity assessment. A qualitative risk discussion on TPH is required if TPH is recognized as a COPC.

Response 18:

Please note that Section 10.6.6.2 is now 10.6.8.2 in the report addendum and Table 10.6.10 has been relabeled as 10.6.13. The revised Table does not identify TPH as a COPC. Typically the focus of the investigation is on RCRA regulated constituents. Where TPH has been detected, it is compared to standards provided under the State of South Carolina's UST Program. Sites where TPH concentrations are above UST standards are transferred to the Navy's Petroleum Storage Tank Program (as applicable). To date, quantitative risk assessments involving TPH exposure have not been necessary.

SPECIFIC COMMENTS

S/A Number	Site Name	Notes
681	Blast Booth & Cyclone	a) Soils: PAH, TPH (no 2 nd interval samples taken) b) Lead 2 nd interval > background c) Was an OWS a part of this site? d) No wells at this AOC

Response:

Comment "a", Multiple SVOCs were detected in soil samples (both surface and subsurface). Additional soil and groundwater samples have been collect by both EnSafe and the Detachment and the results of the additional analysis is included in the AOC 681 report addendum (Section 10.6.2 of the RFI report). TPH analyses were not performed on subsurface samples and the reason for this is not known. The point is mute however since TPH is not a RCRA regulated substance. As noted above, additional samples have been collected and analyzed for specific, regulated substances.

Comment "b", Lead was detected in the second interval above background in two samples but the detections were well below the residential action level of 400 mg/kg.

Comment "c", A 1968 sewer map indicates an oil water separator with a UST was located just off the northeast corner of Building 681, between 681 and Building NS-27. Based on a 1981 demolition map, this o/w separator and UST was closed by removal. Copies of these drawings are included as an attachment to the addendum report. There was an o/w separator and UST located on the east side of Building 681 which was closed by removal in 1997. A UST Assessment Report was complete and submitted for this removal. Also, field personnel encountered a line during soil sampling between buildings 680 and 681 that may have been associated with another oil water separator. A number of additional soil samples were collected in this area between the buildings. No additional information was discovered to indicate the nature or history of any o/w separator located between the two buildings.

Comment "d", Three groundwater monitoring wells were installed at AOC 681 in 1998 and three rounds of samples were collected from these wells. The results of the sampling are presented in Section 10.6.4 of the RFI report addendum. Grid well pair 13 is down gradient of Building 681 and is downgradient of the reported o/w separator. Per the 20 January 1998 conference call, 3 DPT samples were collected in a triangular pattern around grid well GDI013/13D. This data is also included in Section 10.6.4 of the RFI report addendum.

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



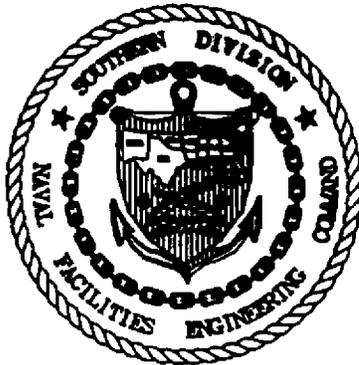
**ZONE I
RCRA FACILITY INVESTIGATION REPORT**

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

**SOUTHDIV CONTRACT
NUMBER: N62467-89-D-0318**

Prepared for:

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



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**March 1, 1999
Revision: 0
*Page Changes: July 30, 1999***

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

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR CHARLESTON NAVAL COMPLEX ZONE I

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

AA	Atomic Absorption
ABF	Absorption Factor
AEC	Area of Ecological Concern
AL	Action Level
AOC	Area of Concern
AOI	Area of Interest
AQTESOLV	Aquifer Test Solver
ARAR	Applicable or Relevant and Appropriate Requirement
AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
atm	Atmospheres
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation Factor
BAP	Benzo(a)pyrene
BDL	Below Detection Limit
BE	Barometric Efficiency
BEHP	bis(2-ethylhexyl)phthalate
BEQ	Benzo(a)pyrene Equivalent Quotient
BEST	Building Economic Solutions Together
bgs	Below ground surface
BHC	Benzenehexachloride
BOS	Bottom of Screen
BOW	Bottom of Well
BOD	Biochemical Oxygen Demand
BRA	Baseline Risk Assessment
BRAC	Base Realignment and Closure Act of 1988 and Defense Base Closure and Realignment Act of 1990, collectively
BTEX	Benzene, toluene, ethylbenzene, and xylene
BW	Receptor body weight (kg)
CAMP	Corrective Action Management Plan
CAMU	Corrective Action Management Unit
CAP	Correction Action Program
CDD	Chlorinated dibenzo-p-dioxin
CDF	Chlorinated dibenzofuran
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity

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

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Calibration Factor
CFR	Code of Federal Regulations
cm/sec	centimeters per second
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
CM	Corrective Measures
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
COD	Chemical Oxygen Demand
CNC	Charleston Naval Complex
CNS	Central Nervous System
CNSY	Charleston Naval Shipyard
COC	Chemical of Concern
COPC	Chemical of Potential Concern
cPAH	Carcinogen Polynuclear Hydrocarbon
CPSS	Chemical Present in Site Samples
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CRDL	Contract Required Detection Limit
CSAP	Comprehensive Sampling and Analysis Plan
CSI	Confirmatory Sampling Investigation
CT	Central Tendency
CV	Coefficient of Variation
CWA	Clean Water Act
DAF	Dilution Attenuation Factor
DCAA	2,4-dichlorophenylacetic acid
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyl-trichloroethane
DMA	Dredged Material Area
DNAPL	Dense Non-Aqueous Phase Liquid
DOD	Department of Defense
DPT	Direct Push Technology
DQO	Data Quality Objectives
DRO	Diesel Range Organics
DWEL	Drinking Water Equivalent Level
E/A&H	EnSafe/Allen & Hoshall
ECAO	Environmental Criteria and Assessment Office

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

ECPC	Ecological Chemical of Potential Concern
EMPC	Estimated Maximum Possible Concentration
EOD	Explosive Ordnance Disposal
EPC	Exposure Point Concentration
ERA	Environmental Risk Assessment
ESA	Ecological Study Area
ESDSOPQAM	Environmental Services Division Standard Operating Procedures and Quality Assurance Manual
FC	Fraction contracted
FFI	Focused Field Investigation
FI	Fraction Ingested
FID	Flameionization detector
ft ² /day	Square feet per day
ft bgs	Feet below ground surface
ft/day	Feet per day
ft msl	Feet above mean sea level
F _{oc}	Fraction Organic Carbon
GC/MS	Gas Chromatography/Mass Spectroscopy
gpm	Gallons per minute
GPS	Global Positioning System
GRO	Gasoline Range Organics
HASP	Health and Safety Plan
HHRA	Human Health Risk Assessment
HEAST	Health Effects Assessment Summary Table
HL	Henry's Law Constant
HMW	High Molecular Weight
HI	Hazard Index
HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments
HTTD	High-Temperature Thermal Desorption
<i>i</i>	Horizontal Hydraulic Gradient
ICAP	Inductively Coupled Argon Plasma
ICM	Interim Corrective Measure
ICP	Inductively Coupled Plasma
ID	Inside Diameter
IDL	Instrument Detection Limit
ILCR	Incremental Lifetime Excess Cancer Risk
ILO	Indeterminate Lubricating Oil
IR _{diet}	Food ingestion rate of receptor (kg of food per day)

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

IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
IS	Internal Standard
kph	Kilometers per hour
K	Hydraulic Conductivity
K_d	Normalized Partitioning Coefficient
K_h	Hydraulic Conductivity
kg/L	Kilogram per liter
K_{oc}	Organic Carbon/Water Partitioning Coefficient
K_v	Vertical Permeability
kg_{oc}/L_{water}	Kilogram of organic carbon per liter of water
$\log K_{ow}$	Octanol/Water Partitioning Coefficient
LCS	Laboratory Control Sample
LC ₅₀	Lethal Concentration to 50 percent of test population
LD ₅₀	Lethal Dose to 50 percent of test population
LMW	Low Molecular Weight
LN	Natural Logarithm
LNAPL	Light Nonaqueous Phase Liquid
LQAC	Laboratory QA Coordinator
LTTD	Low-Temperature Thermal Desorption
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
meq/L	Milliequivalent per liter
meq/100g	Milliequivalent per 100 grams
mg/kg	Milligram per kilogram
mg/kg-day	Milligram per kilogram per day
mg/L	Milligram per liter
mg/m ³	Milligram per cubic meter
ml	Milliliter
mm	Millimeter
mph	Miles per hour
msl	Mean sea level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MW	Molecular Weight
n	Soil total porosity/Number of samples collected
n_e	Effective porosity
NA	Not Applicable/Not Available
NAD	North American Datum

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

NBS	National Bureau of Standards
NCEA	National Center for Environmental Assessment
NCR	NEESA Contract Representative
ND	Not Detected
NEESA	Naval Energy and Environmental Support Activity
NFI	No Further Investigation
NGVD	National Geodetic Vertical Datum
NIOSH	National Institute for Occupational Safety and Health
NL	Not Listed
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observable Adverse Effect Level
NPDES	National Pollutant Discharge Elimination System
NR	Not Reported
NTP	National Toxicology Program
NTU	Nephelometric Turbidity Unit
OERR	Office of Emergency and Remedial Response
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OVA	Organic Vapor Analyzer
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PDE	Potential Dietary Exposure
PE	Performance Evaluation
PEM	Performance Evaluation Mixture
pg/g	Picogram per gram
pg/L	Picogram per liter
POTW	Publicly Owned Treatment Works
ppb	Parts per billion
PPE	Personal Protective Equipment
ppm	Parts per million
ppt	Parts per trillion
PRC	Preliminary Risk Characterization
PRG	Preliminary Remedial Goal
PSA	Preliminary Site Assessment
psi	Pounds per square inch
PVC	Polyvinyl Chloride
%R	Percent Recovery

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

%RSD	Percent Relative Standard Deviation
%D	Percent Difference
QA/QC	Quality Assurance/Quality Control
Qc	Quaternary Clay
Qm	Quaternary Marsh Clay
Qs	Quaternary Sand
Qs _L	Quaternary Sand/Lower
Qs _U	Quaternary Sand/Upper
R	Retardation Factor
RAB	Restoration Advisory Board
RAD	Recommended Daily Allowance
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RBSL	Risk-Based Screening Level
RCRA	Resource Conservation and Recovery Act
RDA	Charleston Naval Complex Redevelopment Authority
RFA	RCRA Facility Assessment
RfC	Reference Concentration
RfD	Reference Dose
RFI	RCRA Facility Investigation
RGO	Remedial Goal Option
RME	Reasonable Maximum Exposure
RPD	Relative Percent Difference
RRF	Relative Response Factor
RTC	Reserve Training Center
RTV	Reference Toxicity Value
SAA	Satellite Accumulation Area
SAS	Special Analytical Services
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
SDG	Sample Delivery Group
SF	Slope Factor
SFF	Site Foraging Factor
SMCL	Secondary Maximum Contaminant Level
SOP	Standard Operating Procedure
SOUTHDIV	Southern Division Naval Facilities Engineering Command
SPLP	Synthetic Precipitation Leaching Procedure

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

SQL	Sample Quantitation Limit
SSL	Soil Screening Levels
SSV	Sediment Screening Value
SVE	Soil Vapor Extraction
SVOA	Semivolatile Organic Analysis
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
Ta	Ashley Formation
$T_{1/2}$	Half Life
T_n	Food contamination concentration in mg/kg
TCDD	Tetrachlorodibenzo-p-dioxin
TD/MS	Thermal Desorption/Mass Spectrometry
TD-GS/MS	Thermal Desorption-Gas Chromatography/Mass Spectrometry
TDS	Total Dissolved Solids
TEF	Toxic Equivalency Factor
TEM	Transmission Electron Microscopy
TEQ	TCDD Equivalency Quotient
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act
TU	Temporary Unit
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
UTL	Upper Tolerance Limit
UV	Ultraviolet
UXO	Unexploded Ordinance
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
WBZ	Water-Bearing Zone
WOHL	Wisconsin Occupational Health Laboratory
WQC	Water Quality Control
Δx	Distance Between Points
Δh	Hydraulic Head
ρ_b	Dry soil bulk density

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

$\mu\text{g}/\text{cm}^2$	Microgram per square centimeter
$\mu\text{g}/\text{kg}$	Microgram per kilogram
$\mu\text{g}/\text{L}$	Microgram per liter
$\mu\text{g}/\text{m}^3$	Microgram per cubic meter
ng/kg	Nanogram per kilogram
pg/L	Picogram per liter
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DB	2,4-dichlorophenoxybutyric acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4,5-TP	Silvex

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Front Covers and Spines	Volume I to VI	Volume I to VI
Table of Contents - updated.	✓ 1 to xxvi	✓ i to xxx
 Volume II of VI – Section 10		
Section 10.3, AOC 675	✓ 10.3.1 to 10.3.34	10.3.1 to 10.3.34
Section 10.4, AOC 678/679	✓ 10.4.1	✓ 10.4.1 to 10.4.98
Section 10.5, AOC 680	✓ 10.5.1	✓ 10.5.1 to 10.5.88
Section 10.11, SWMU 12	10.11.1 to 10.11.46	10.11.1 to 10.11.46
 Volume III of VI		
Section 11.0	✓ 11.1 to 11.12	✓ 11.1 to 11.16
Section 12.0	✓ 12.1 to 12.21	✓ 12.1 to 12.22
 Volume V of VI – Appendix D to E		
Appendix D	—	Add to the back
 Volume VI of VI – Appendix E to H		
Appendix E	✓ —	✓ Add to the back
Appendix H	✓ —	✓ Add tab and drawings

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Front Covers and Spines	Volume I to VI	Volume I to VI ✓
Volume I of VI — Sections 1 to 9 Table of Contents - updated.	i to xxvi	i to xxxii ✓
Volume II of VI — Section 10 Section 10.6, AOC 681	10.6.1 to 10.6.2	10.6.1 to 10.6.108 ✓
Volume III of VI Section 11.0	11.1 to 11.12	11.1 to 11.18 ✓
Volume IV of VI Volume V of VI - Appendix D to E Appendix D 2 2.	FRONT COVER & SPINES —	FRONT COVER & SPINES Add to the back ✓
Volume VI of VI - Appendix E to H Appendix E Appendix H Appendix I	— — —	Add to the back ✓ Add drawings ✓ Add tab and data ✓

1.0 INTRODUCTION

The environmental investigation and remediation at Charleston Naval Complex (CNC) are required by the Hazardous and Solid Waste Amendments (HSWA) portion of the Resource Conservation and Recovery Act (RCRA) Part B permit (Permit Number: SCO 170022560) (South Carolina Department of Health and Environmental Control [SCDHEC], May 4, 1990). These conditions are consistent with the RCRA Corrective Action Program (CAP), with the objectives to evaluate the nature and extent of any hazardous waste or constituent releases, and to identify, develop, and implement appropriate corrective measures to protect human health and the environment. The scope of the RCRA Facility Investigation (RFI) includes the entire naval base, which has been divided into Zones A through L to accelerate the RFI process. This Zone I 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 Charleston Naval Complex 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 CNC. Several facilities within Zone I 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 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 I 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, CNC has been divided into 12 investigative zones (A through L), 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 I is in the southern portion of the peninsula formed by Shipyard Creek to the south; Cooper River to the north and east; and Hobson Avenue, Osprey Street, and C.B. Lane to the west (Figure 1.2). Zone I contains properties that will be transferred to the State Department as well as naval support, training, and administrative areas.

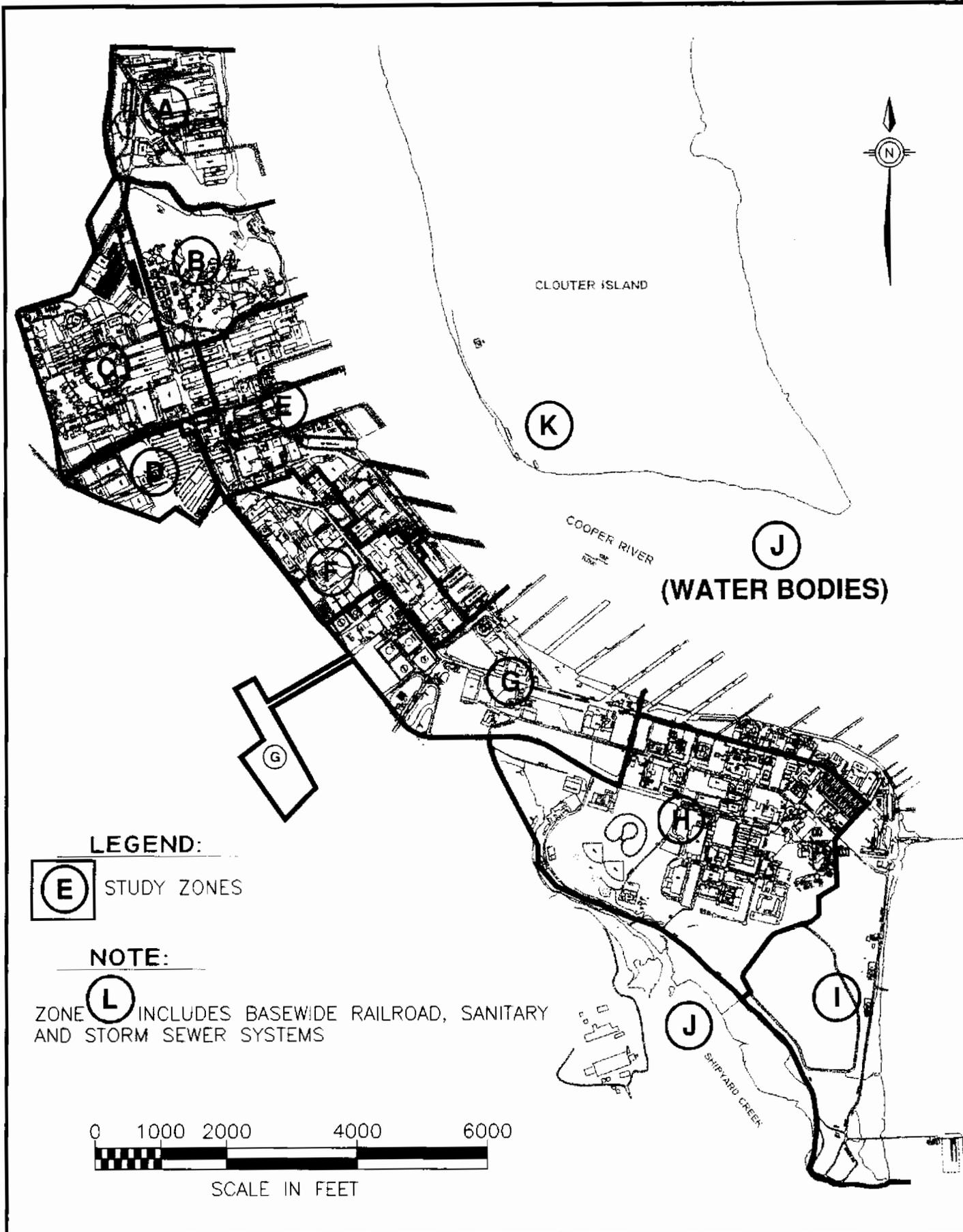
1.4 Current Investigation

Objective

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

Field Investigation Scope

Eighteen AOCs and SWMUs plus the Dredged Materials Area (DMA) were identified in Zone I through the RCRA Facility Assessment (RFA) process. Each Zone I site is discussed in detail in the *Final RCRA Facility Assessment* (E/A&H, 1995a) and the *Final Zone I RFI Work Plan* (E/A&H, 1996b). The Final RFA designated AOC 684, the Pistol Range, for investigation along with Zone I. However, due to its proximity to SWMU 14 in Zone H, this AOC was investigated under and reported in the *Zone H RFI Report* (E/A&H 1996c). SWMU 177, an oil spill at the

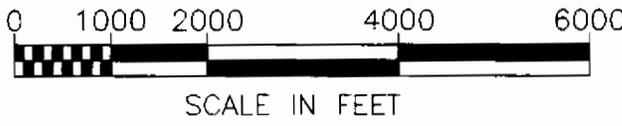


LEGEND:

(E) STUDY ZONES

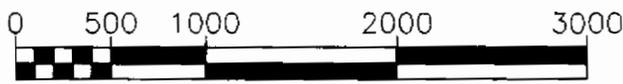
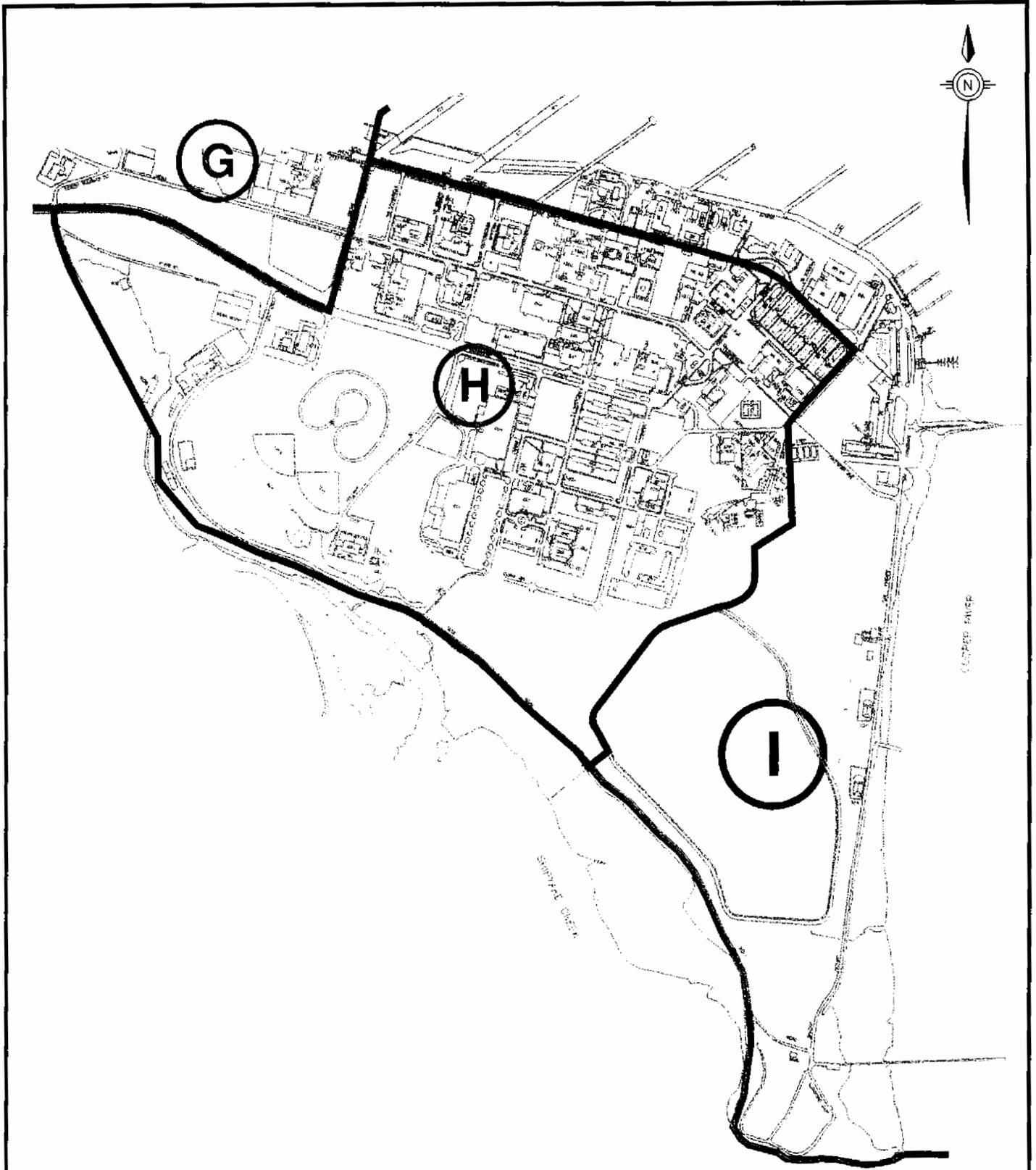
NOTE:

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



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FIGURE 1.1
INVESTIGATIVE ZONE BOUNDARIES



SCALE IN FEET



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 INVESTIGATION REPORT
 NAVAL BASE CHARLESTON
 CHARLESTON, SC

FIGURE 1.2
 SOUTHERN TIP OF NAVAL BASE

Reserve Training Center (RTC) Building 4 in Zone I, was designated for confirmatory sampling following completion of RFI field activities. Subsequent to the confirmatory sampling, the SWMU 177/RTC area underwent an RFI characterization.

The RFA noted that much of Charleston Naval Complex, particularly the southern end that includes Zone I, is built upon a series of dredged material deposits. The DMA was included in the Zone I RFI to provide a baseline data set for calculating risk at other areas of Charleston Naval Complex filled by dredge spoils.

Investigative approaches for each site were developed and proposed based on the best available information. The RCRA investigatory designations used in this process are defined below:

- *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 determine that it does not pose a threat to human health or the environment.
- *Confirmatory Sampling Investigation (CSI)* – This designation was applied to AOCs or SWMUs with insufficient data to thoroughly assess the potential hazards. Generally, a limited number of confirmatory samples are needed to determine whether a hazard exists. Results of the CSI will determine whether NFI 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 hazardous substances had been released to the environment. A complete site characterization is needed to determine the nature and extent of contamination, identify migration pathways, identify actual and potential receptors, and evaluate the ecological and human health risks posed by the site.

Nineteen sites in Zone I were listed for either RFIs or CSIs. Investigative strategies for these sites are outlined in the approved Final RFI Work Plan. Table 1.1 summarizes each AOC or SWMU to be investigated, and Figure 1.3 identifies the site locations.

1.5 Previous Investigations

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

1.6 RFI Report Organization

To facilitate review, the RFI Report has been formatted to first discuss zone-wide information, overall technical approach, and evaluation methodologies. These general informational 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

Table I.1
 Site Summary

Site	Site Description	Investigative Approach	Previous Investigations	Investigatory Grouping
AOC 671	Metering House, Former Building 3905G	CSI		Investigated independently.
AOC 672	Substation, Building 126	CSI		Investigated together due to proximity.
AOC 673	Paint and Oil Storehouse, Building 169	CSI		
AOC 675	Fuel Oil Storage, Building NS-4	CSI		Investigated together due to proximity.
AOC 676	Former Incinerator, Building NS-2	CSI		
AOC 677	Grounds, Building NS-2	RFI		
AOC 678	Firefighting School, Building 2-V	CSI		Investigated together due to proximity.
AOC 679	Former Wash Rack	CSI		
AOC 680	Brake Repair and Welding Area, Northeast side of Building NS-26	CSI		Investigated independently.
AOC 681	Abrasive Blast Booth, Building 681	RFI		Investigated independently.
AOC 685	Former Smoke Drum	CSI		Investigated independently.
AOC 687	Ammunition Storage, Building X-55	CSI	Environmental Incident Report #87-79 reported that Building X-55 had been used for unauthorized storage of paint containers. Minor spills were cleaned and containers removed the same day they were discovered.	Investigated together due to proximity.
SWMU 16	Paint Storage Bunker	RFI		
AOC 688	Ammunition Storage, Building X-56	CSI	Environmental Incident Report #87-61 revealed that Building X-56 was once used as temporary storage for approximately 3,420 gallons of paint, and that spills and leaks occurred during this time. The Environmental Baseline Survey for Building X-56 found evidence of paint spills on the floor.	Investigated independently.

*Zone I RCRA Facility Investigation Report
 Charleston Naval Complex
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**Table 1.1
 Site Summary**

Site	Site Description	Investigative Approach	Previous Investigations	Investigatory Grouping
AOC 689	Southern Tip of Base (Marina Parking Area)	RFI	In 1992, the U.S. Army Corps of Engineers sampled sediment in the AOC 689 area to determine the suitability of ocean disposal for dredge spoils deposited here. Two of six samples collected revealed concentrations of dioxins (1.3 to 2.7 parts per trillion). Ocean disposal was not recommended without further investigation.	Investigated together due to proximity.
AOC 690	Dredged Materials Area (DMA) Road	CSI		
SWMU 12	Old Firefighter Training Area	RFI	The training pit was cited by the U.S. Coast Guard in 1971 for releasing oil into Shipyard Creek following a heavy rainfall. A 1992 Confirmation Study collected soil samples in and along the pit. Sample results were not available, but no visual evidence of oil was found in any of the borings. During 1994, a visual site inspection revealed a 4-foot diameter oil spill in the construction lay-down yard. It is uncertain whether the spill was related to the firefighter training or more recent activities.	Investigated independently.
SWMU 177	RTC-4 Oil Spill	CSI		Investigated independently.
DMA		CSI		Investigated independently.

Notes:
 Site descriptions are taken from the approved Final RFI Work Plan.

The site-specific sections are:	1
• 10.0 Site-Specific (SWMU and AOC) Evaluations	2
• 11.0 Conclusions	3
and:	4
• 12.0 References	5
• 13.0 Signatory Requirements	6
Section 8 of the RFI addresses zone-wide ecological risk. Where applicable, surface soil and sediment data potentially affecting Zone I ecological areas are presented to determine overall ecological risk.	7 8 9
Section 10 follows the same zone-wide outline as Sections 1 through 9, but on a site-specific basis. The section is subdivided by specific AOCs or SWMUs, or site groupings, and includes actual data summaries, risk calculations, and corrective measures considerations specific to each area. In this manner, the entire investigation sequence is contained within a site-specific section for easy reference.	10 11 12 13 14
Section 11 summarizes the conclusions from each Section 10 site summary. This format makes it easy to determine which sites have been recommended for a CMS and which are recommended for no further action. Section 12 is a compilation of references.	15 16 17

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2.0 PHYSICAL SETTING

2.1 Geology

2.1.1 Regional Physiographic and Geologic Setting

The regional physiographic and geologic setting for the CNC area is described in Section 2.1.1 of the *Draft Zone A RFI Report*. Local topography is presented in Figure 2.1. Regional geologic relationships across a regional plan view map (Figure 2.2) are shown in cross sections in Figure 2.3.

2.1.2 Regional Hydrology and Hydrogeology

The regional hydrology and hydrogeology for the CNC area is described in Section 2.2.1 of the *Draft Zone A RFI Report*. Major surface water features are presented on Figure 2.1.

2.2 Zone I Geologic Investigation

Geologic and hydrogeologic information has been obtained from soil and monitoring well borings installed during the Zone I RFI. Because Zones I and H share a common boundary, much of the geologic information from the Zone H RFI is necessary for interpreting Zone I geology. The geologic cross sections presented in this report have been refined slightly from those in the *Final Zone H RFI Report* (E/A&H, 1996c) to reflect the increased understanding of CNC geology from previous Zone RFIs. Lithologic samples acquired using hollow-stem auger, wet rotary, and rotasonic drilling methods were classified and logged by an E/A&H geologist as described in the *Final Comprehensive Sampling and Analysis Plan (CSAP) RCRA Facility Investigation* (E/A&H, 1996d).

2.2.1 Monitoring Wells

RFI activities in Zone I included installation of 65 monitoring wells and one deep soil boring (see Figure 2.4). Deep and shallow well pairs were installed at 19 nonbiased (grid-based) locations. Twenty-seven shallow monitoring wells were installed at biased (AOC/SWMU) locations.

Stratigraphic information in Zone I is limited to 75 feet below ground surface (feet bgs), which is the depth of the deepest well boring NBCIGDI15D. Table 2.1 lists the monitoring wells and summarizes well construction data. Monitoring well boring stratigraphy and well construction logs are presented in Appendix A.

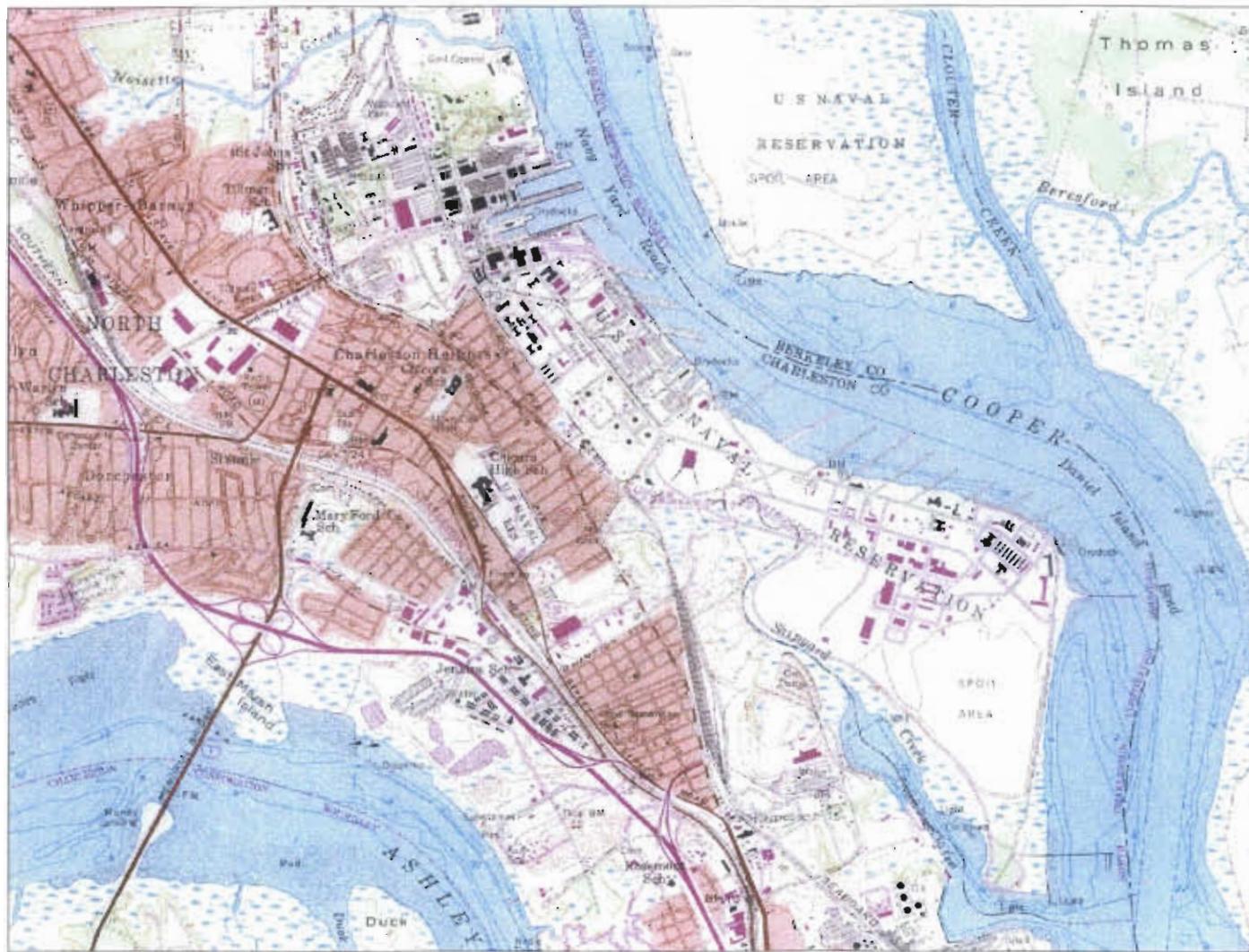
2.2.2 Geotechnical

Shelby tube samples were collected as part of the RFI drilling program and analyzed for porosity, bulk density, grain size distribution, specific gravity, percent moisture, and vertical permeability. Thin-walled steel Shelby tubes were pushed into undisturbed soil with a truck-mounted drill rig. The steel tubes were recovered, sealed, labeled, and retained onsite until transported to the laboratory for analysis. Samples were collected in plastic bags from two additional deep well locations to provide supplemental porosity and grain size data for deeper sediments.

Shelby tube sample laboratory data reports are presented in Appendix B. Table 2.2 summarizes Zone I Shelby tube data. These data, discussed in Section 2.2.3, are sorted on the basis of stratigraphic units which have been delineated in subsequent zone RFIs completed to date.

2.2.3 Zone I Geology

All Zone I deep well borings were drilled to the top of the Cooper Formation for the purpose of monitoring the deeper portions of the surficial aquifer (Figure 2.3). As a result, only Quaternary and Tertiary- age sediments were encountered during this investigation. The lowermost stratigraphic unit identified in Zone I is the Ashley Formation (Ta) of the Mid-Tertiary-age Cooper Group.

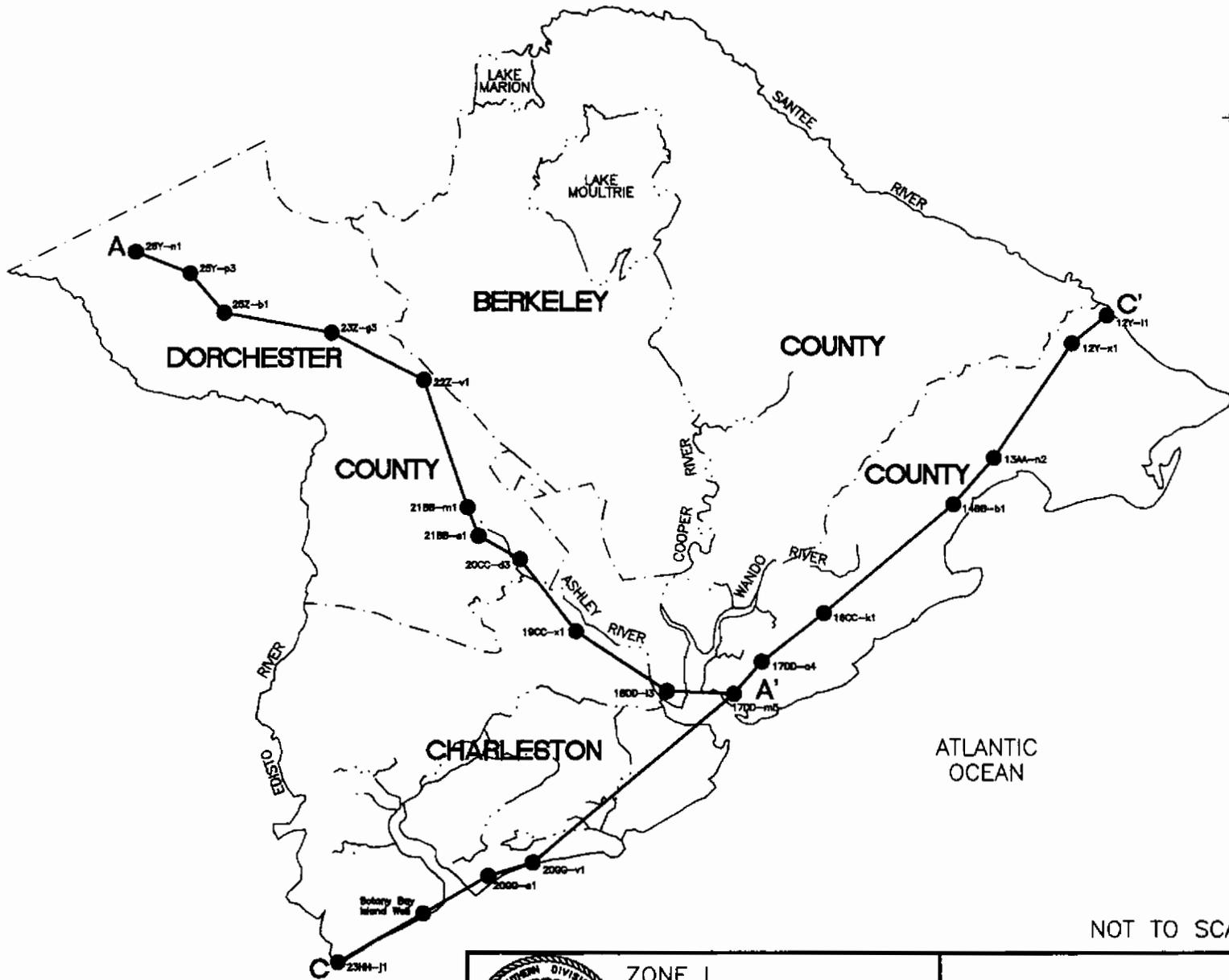


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FIGURE 2.1
TOPOGRAPHY OF
NAVAL BASE CHARLESTON
AND
SURROUNDING AREAS

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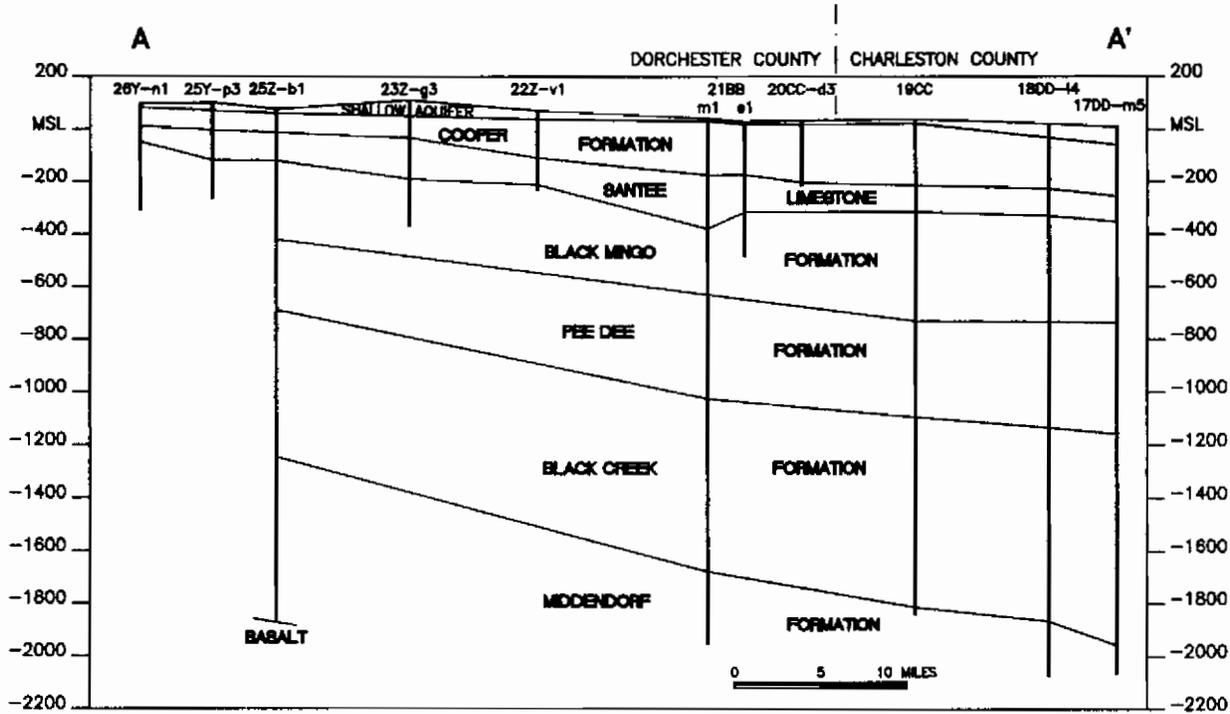


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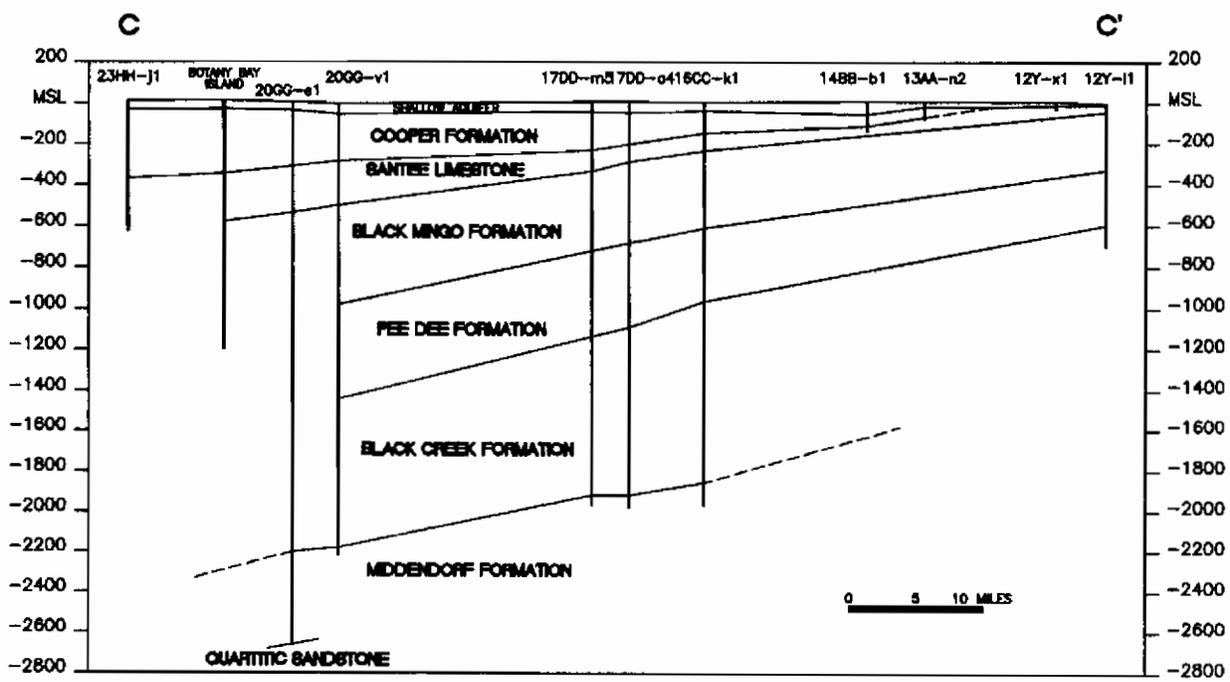
FIGURE 2.2
 PLAN VIEW OF REGIONAL
 GEOLOGIC CROSS SECTION

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CROSS SECTION A-A'



CROSS SECTION C-C'
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NAVAL BASE CHARLESTON
CHARLESTON, S.C.

FIGURE 2.3
REGIONAL GEOLOGIC
CROSS SECTIONS

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Table 2.1
Monitoring Well Construction Data

Well Identifier	Date Installed	Stateplane Coordinates		TOC elev (ft msl)	Ground elev (ft msl)	Construction Depths (ft bgs)			DTW * (ft TOC)	GW elev (ft msl)
		Northing	Easting			TOS	BOS	BOW		
NBCI012001	4/10/95	366357.11	2325579.24	8.09	5.9	2.5	12.0	12.5	4.23	3.86
NBCI012002	4/10/95	366345.97	2325708.89	8.71	6.5	3.0	12.5	13.0	4.30	4.41
NBCI012003	4/10/95	366253.93	2325756.38	8.31	6.2	2.5	12.0	12.5	4.41	3.90
NBCI177001	3/17/98	371613.50	2324646.43	5.57	5.9	2.5	12.0	12.5	3.39	2.18
NBCI177002	3/17/98	371549.09	2324677.13	6.82	7.0	2.5	12.0	12.5	4.04	2.78
NBCI671001	4/3/95	371544.78	2323968.34	8.43	8.5	3.0	12.5	13.0	5.90	2.53
NBCI671002	4/3/05	371609.01	2324020.33	7.81	7.9	2.5	12.0	12.5	5.61	2.20
NBCI671003	4/4/95	371546.95	2324230.42	8.76	8.8	2.5	12.0	12.5	5.54	3.22
NBCI671004	4/4/95	371468.61	2324203.46	8.73	8.8	2.5	12.0	12.5	5.44	3.29
NBCI675001	4/4/95	371316.15	2325605.91	10.90	8.0	2.5	12.0	12.5	6.72	4.18
NBCI675002	4/11/95	371253.96	2325568.42	11.52	8.8	2.5	12.0	12.5	11.30	0.22
NBCI676001	4/4/95	371236.90	2325607.59	10.98	8.1	2.5	12.0	12.5	8.55	2.43
NBCI677002	4/11/95	371351.98	2325655.28	7.53	7.8	2.5	12.0	12.5	3.95	3.58
NBCI678001	4/11/95	371200.50	2325929.34	8.81	8.7	2.5	12.0	12.5	5.58	3.23
NBCI678002	4/11/95	371252.86	2326067.82	8.10	8.3	2.5	12.0	12.5	5.07	3.03
NBCI679001	9/23/98	371077.64	2325710.93	12.04	9.2	4.0	13.5	14.0	8.02	1.18
NBCI680001	3/16/98	370851.04	2326375.40	9.47	9.6	3.0	12.5	13.0	5.61	3.86
NBCI680002	3/17/98	371002.10	2326415.20	9.32	9.6	3.0	12.5	13.0	5.96	3.36
NBCI680003	3/16/98	370948.37	2326520.20	9.32	9.6	2.5	12.0	12.5	5.72	3.60
NBCI680004	9/24/98	371024.71	2326378.12	9.22	9.4	4.0	13.5	14.0	5.55	3.67
NBCI681001	9/24/98	370701.87	2326441.98	9.54	9.8	4.0	13.5	14.0	5.12	4.42
NBCI681002	9/24/98	370606.35	2326573.09	9.83	9.9	4.0	13.5	14.0	5.82	4.01
NBCI681003	9/23/98	370780.31	2326690.61	9.72	9.9	4.0	13.5	14.0	5.48	4.24

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Table 2.1
 Monitoring Well Construction Data

Well Identifier	Date Installed	Stateplane Coordinates		TOC elev (ft msl)	Ground elev (ft msl)	Construction Depths (ft bgs)			DTW * (ft TOC)	GW elev (ft msl)
		Northing	Easting			TOS	BOS	BOW		
NBCI687001	4/12/95	367902.37	2326568.37	12.07	9.3	2.5	12.0	12.5	8.12	3.95
NBCI687002	4/12/95	367896.60	2326611.55	11.99	9.3	2.5	12.0	12.5	7.85	4.14
NBCI687003	4/12/95	367767.52	2326587.97	11.99	9.3	2.5	12.0	12.5	7.92	4.07
NBCI687004	4/12/95	367775.10	2326544.48	11.32	8.7	2.3	11.9	12.4	7.42	3.90
NBCIGDI001	3/13/95	367397.60	2324652.29	8.58	6.2	2.4	12.0	12.5	4.90	3.68
NBCIGDI01D	4/11/95	367391.37	2324656.68	8.74	6.4	44	53.5	54	3.90	4.84
NBCIGDI002	3/14/95	366909.47	2325177.18	11.69	9.4	2.9	12.4	12.9	7.73	3.96
NBCIGDI02D	4/12/95	366901.12	2325183.06	11.77	9.3	59.0	68.5	69.0	9.95	1.82
NBCIGDI003	3/16/95	366260.57	2325571.56	8.87	6.6	2.5	12.0	12.5	5.14	3.73
NBCIGDI03D	4/12/95	366254.69	2325574.65	9.13	6.3	52.0	61.5	62.0	2.55	6.58
NBCIGDI004	3/20/95	365450.88	2326154.49	8.62	6.2	2.5	12.0	12.5	4.76	3.86
NBCIGDI04D	4/13/95	365459.92	2326159.26	8.68	6.1	35.0	44.5	45.0	1.70	6.98
NBCIGDI005	3/27/95	366009.24	2326382.90	6.40	4.3	2.6	12.1	12.6	3.40	3.00
NBCIGDI05D	4/13/95	365995.70	2326380.40	6.62	4.0	57.0	66.5	67.0	1.83	4.79
NBCIGDI006	3/27/95	366555.27	2326451.29	7.73	5.3	2.5	12.0	12.5	3.99	3.74
NBCIGDI06D	4/14/95	366548.54	2326450.45	7.54	5.1	40.0	49.5	50.0	6.58	0.96
NBCIGDI007	3/21/95	367181.64	2326453.50	10.45	7.8	2.5	12.0	12.5	6.35	4.10
NBCIGDI07D	4/10/95	367191.97	2326453.46	10.58	8.0	34.4	43.9	44.4	8.54	2.04
NBCIGDI008	3/21/95	367772.20	2326479.29	11.57	9.0	2.5	12.0	12.5	7.86	3.71
NBCIGDI08D	4/10/95	367776.42	2326486.78	11.73	9.0	43.0	52.5	53.0	10.30	1.43
NBCIGDI009	3/16/95	368419.81	2326505.09	11.30	8.7	3.5	13.0	13.5	5.41	5.89
NBCIGDI09D	4/11/95	368414.46	2326508.88	11.38	8.7	47.0	56.5	57.0	8.69	2.69

Table 2.1
 Monitoring Well Construction Data

Well Identifier	Date Installed	Stateplane Coordinates		TOC elev (ft msl)	Ground elev (ft msl)	Construction Depths (ft bgs)			DTW * (ft TOC)	GW elev (ft msl)
		Northing	Easting			TOS	BOS	BOW		
NBCIGDI010	3/15/95	368729.36	2326743.35	8.06	5.0	2.0	11.5	12.0	5.06	3.00
NBCIGDI10D	4/13/95	368723.60	2326743.02	7.98	5.2	27.0	36.5	37.0	8.67	-0.69
NBCIGDI011	3/21/95	369617.77	2326637.69	8.77	6.1	2.5	12.0	12.5	6.26	2.51
NBCIGDI11D	4/8/95	369617.05	2326646.86	8.93	6.2	33.0	41.5	42.0	3.95	4.98
NBCIGDI012	3/22/95	370206.26	2326720.53	10.91	8.2	2.5	12.0	12.5	10.88	0.03
NBCIGDI12D	4/8/95	370200.98	2326725.40	10.81	8.1	40.5	50.0	50.5	9.62	1.19
NBCIGDI013	3/22/95	370827.24	2326724.24	11.85	9.3	2.5	12.0	15.0	8.30	3.55
NBCIGDI13D	4/9/95	370815.77	2326727.69	11.86	9.3	29.0	38.5	39.0	12.59	-0.73
NBCIGDI014	3/23/95	371168.46	2326133.79	8.72	7.1	2.5	12.0	12.5	5.60	3.12
NBCIGDI14D	4/6/95	371164.81	2326139.09	8.53	8.9	27.5	37.0	37.5	7.02	1.51
NBCIGDI015	3/27/95	371203.07	2325532.77	10.96	8.3	2.5	12.0	12.5	8.41	2.55
NBCIGDI15D	4/4/95	371206.86	2325525.87	10.77	8.2	65.0	74.5	75.0	11.19	-0.42
NBCIGDI016	3/23/95	371480.21	2324903.31	5.99	6.1	3.0	12.5	13.0	3.44	2.55
NBCIGDI16D	4/8/95	371474.34	2324899.63	5.90	6.1	54.5	64.0	64.5	6.88	-0.98
NBCIGDI017	3/22/95	371634.45	2324125.25	10.14	7.6	2.5	12.0	12.5	7.05	3.09
NBCIGDI17D	4/6/95	371635.40	2324116.71	10.15	7.6	36.0	45.5	46.0	9.84	0.31
NBCIGDI018	3/14/95	371634.54	2323772.22	7.02	7.3	2.5	12.0	12.5	4.21	2.81
NBCIGDI18D	4/6/95	371647.96	2323769.94	7.00	7.2	34.0	43.5	44.0	6.01	0.99
NBCIGDI019	3/20/95	364743.29	2326255.55	8.76	6.2	2.5	12.0	12.5	5.37	3.39
NBCIGDI19D	4/9/95	364750.17	2326260.13	9.10	6.3	23.0	25.4	25.5	10.37	-1.27

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Notes:

TOC = Top of well casing

msl = Mean sea level

bgs = Below ground surface

TOS = Top of screened interval

BOS = Bottom of screened interval

BOW = Bottom of well (end cap)

DTW = Depth to groundwater from TOC

* = The only comprehensive data set for all Zone I wells, collected 7/21/98, is presented above. These data are not used anywhere else in this report.

Table 2.2
Geotechnical Results from Shelby Tube Samples

Type	Location ID	Depth (ft bgs)	USCS	STRAT	n	SG (g/cm ³)	Vertical Permeability		% Moisture Content		Grain Size Distribution		
							(cm/sec)	(ft/day)	Composite*	Range	% sand	% silt	% clay
ST	NBCIGDI004	15-17	CH	Qm	55.5	2.66	9.87E-08	2.80E-04	105.1	65.7-133.3	2	56	42
ST	NBCIGDI007	15-17	CH/OH	Qm	74.4	2.65	2.41E-07	6.82E-04	106.5	91.9-114.8	4.5	54.5	41
ST	NBCIGDI016	15-17	OH	Qm	66.0	2.61	6.48E-08	1.84E-04	78.6	71.2-84.6	4	47	49
ST	NBCIGDI001	15-17	OH	Qm	84.7	2.54	4.50E-05	1.28E-01	138.6	89.9-219.9	3	59	38
ST	NBCIGDI005	15-17	OH	Qm	59.7	2.47	1.71E-07	4.85E-04	116.7	103.2-124.4	4	54	42
ST	NBCIGDI006	15-17	OH	Qm	73.9	2.55	1.97E-05	5.59E-02	107	97.8-115.1	17	44	39
ST	NBCIGDI008	15-17	OH	Qm	69.3	2.57	4.33E-07	1.23E-03	109.3	80.5-156.4	7	49	44
ST	NBCIGDI009	14-16	OH	Qm	47.5	2.66	1.48E-07	4.21E-04	110.2	95.4-137.2	9	52.5	38.5
ST	NBCIGDI010	15-17	OH	Qm	65.1	2.58	3.81E-07	1.08E-03	70.7	61-80.4	23	44	33
ST	NBCIGDI011	15-17	OH	Qm	76.9	2.60	2.14E-07	6.06E-04	107.9	85.2-126.9	1.5	49	49.5
ST	NBCIGDI012	15-17	OH	Qm	70.8	2.60	8.69E-08	2.46E-04	72.8	32.8-96.5	2.5	55.5	42
ST	NBCIGDI013	15-17	OH	Qm	52.2	2.69	9.72E-07	2.76E-03	47.6	21.7-95.5	36	39	25
ST	NBCIGDI014	20-22	OH	Qm	73.2	2.60	4.16E-07	1.18E-03	90.7	70.1-105	2	50	48
ST	NBCIGDI015	15-17	OH	Qm	73.1	2.60	7.90E-08	2.24E-04	98.3	86.5-113	3	51	46
ST	NBCIGDI017	15-17	OH	Qm	55.4	2.65	1.59E-05	4.50E-02	112.4	100-119.6	4	46	50
ST	NBCIGDI018	20-22	OH	Qm	69.9	2.59	8.27E-08	2.34E-04	83.3	70.9-93.1	27	38	35
ST	NBCIGDI019	15-17	OH	Qm	71.2	2.56	4.79E-07	1.36E-03	73.6	59.6-96.3	8	54	38
ST	NBCI012001	15-17	OH	Qm	74.7	2.56	1.81E-07	5.14E-04	119.2	101-128.4	4	67	29
ST	NBCI671004	13-15	OH	Qm	75.0	2.67	5.70E-07	1.62E-03	76.6	21.9-110.2	7	57	39
ST	NBCI678001	15-17	OH	Qm	72.6	2.58	1.00E-07	2.83E-04	108	103.2-114.9	4.5	67.5	28
bag	NBCIGDI03D	45-47	SP	Qs	—	—	—	—	—	—	92.5	3	4.5

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Table 2.2
 Geotechnical Results from Shelby Tube Samples

Type	Location ID	Depth			n	SG (g/cm ³)	Vertical Permeability		% Moisture Content		Grain Size Distribution		
		(ft bgs)	USCS	STRAT			(cm/sec)	(ft/day)	Composite*	Range	% sand	% silt	% clay
bag	NBCIGDI15D	65-67	SP	Qs	—	—	—	—	—	—	96	1.5	2.5

Notes:

- * = Composite value taken from two to three moisture content readings per Shelby tube sample. Values greater than 100% are due to presence of peat and high organic content.
- n = Porosity (%)
- SG = Specific gravity
- ST = Shelby tube sample (undisturbed)
- USCS = Unified Soil Classification System (visual from laboratory)
- STRAT = CNC lithologic classification based in part on USCS description
- Qm = Quaternary marsh clay
- Qs = Quaternary sand
- g/cm³ = grams per cubic centimeter
- cm/sec = centimeters per second
- ft/day = feet per day

- CH = High Plasticity inorganic clay
- OH = High Plasticity organic clay
- bag = Samples collected in Ziploc™ bags for grain-size analyses only.
- SP = Poorly-graded sand (well-sorted sand)

Overlying the Ta are younger Upper Tertiary and Quaternary-age stratigraphic units. 1
Stratigraphic units encountered during the RFI are discussed in the following sections in ascending 2
order. 3

2.2.3.1 Tertiary-Age Sediments 4

Ashley Formation 5

The oldest sediments encountered during the Zone I RFI has been the Ta, the youngest member 6
of the Eocene-Oligocene Cooper Group. The Ta was deposited in an open-marine shelf 7
environment during a rise in sea level in the late Oligocene (Weems and Lemon, 1993). 8

Due to successive sea level transgression-regression (rise and fall) sequences during late Tertiary 9
and early Quaternary time, extensive erosion has removed many of the marine and terrigenous 10
deposits overlying the Ta (Weems and Lemon, 1993). The scoured nature of the upper Ta is 11
plainly evident in Figure 2.5, which depicts surface contours of the unit based on deep well 12
boring data throughout the southern tip of the base, and geologic cross sections (Figures 2.6 13
through 2.8). The Ta contact in Zone I ranges in elevation from -66 ft mean sea level (msl) at 14
GDI15D to -19 ft msl at GDI19D, with a mean elevation of -47 ft msl. 15

The Ta penetrated in Zone I is a mustard-yellow to olive-brown, tight, slightly calcareous, clayey 16
silt to silty clay with varying amounts of very fine-grained sand that decrease rapidly with depth. 17
It is generally dry, stiff, and brittle and may contain fragments of oyster shells and clam molds and 18
other microfossils. Field identification of the Ta is usually aided by the presence of a lag bed of 19
phosphate nodules, phosphatic sand, and coarse-grained shell fragments that immediately overlies 20
its contact. 21

2.2.3.2 Quaternary-Age Sediments

The Quaternary Period began 1.6 million years ago with the Pleistocene Epoch and continues with the Holocene (recent) Epoch from 65,000 years ago to the present. During Quaternary time, several sea transgressions-regressions resulted in a jumbled network of terrace complexes composed of varied depositional environments such as barrier islands, back barrier lagoons, tidal inlets, and shallow-marine shelf systems. Due to regional crustal uplift in the Charleston region during the Quaternary, many barrier to back barrier deposits from high sea-level stands are preserved as terraces. However, succeeding transgressions reworked the shallow-marine shelf deposits on the seaward side of each older barrier ridge or island (Weems and Lemon, 1993). The result of this erosional and redepositional process of older sediments is that a subsequently younger sequence of deposits may exist on the seaward side, laterally adjacent to the previous (older) coastal deposit (Weems and Lemon, 1993). Although Weems and Lemon (1993) have identified and correlated several formations of Quaternary-age sediments, it can be difficult to determine discrete formational units within the Quaternary system. Field identification of these formational units is difficult since many characteristics may only be evident at the microscopic level.

Throughout Zone I, Quaternary-age sediments extend from the top of the Ta to just below ground surface. Based on the 19 deep well borings and one deep soil boring drilled in Zone I, these sediments range from approximately 75 feet thick at GDI15D to 25 feet thick at GDI19D, including anthropogenic deposits. These sediments primarily comprise the Pleistocene-age Wando Formation (deposited 70,000 to 130,000 years ago), which are in turn overlain by Holocene-age sand and clay deposits.

In general, the Wando deposition encompasses three distinct high sea-level stands in the late Pleistocene (Weems and Lemon, 1993). As a result, Wando composition consists of repeating sequences of clayey sand and clay deposits overlying barrier sand deposits which, in turn, overlie

fossiliferous shelf-sand deposits. In Holocene time, rivers and streams have down-cut these sediment sequences, leaving scours that have filled with clay and silty sand deposits typical of low-energy environments. These younger deposits may resemble Wando deposits and further complicate the interpretation of local geology.

Consequently, only two distinct Quaternary-age stratigraphic units have been correlated in the Zones H and I lithologic cross sections (Figures 2.6 through 2.8). These units, designated Qm (Quaternary marsh clay) and Qs (Quaternary sand), were selected because of their generally consistent lithologic characteristics throughout each zone.

Quaternary Marsh Clay

The Qm is the most persistent and easily identified stratigraphic unit in Zones H and I. It is found in borings as a dark brown to black, fat, silty organic clay containing plant material, oyster shells, and thin sand lenses. It has a characteristic "rotten egg" odor signifying an oxygen-poor reducing condition.

Stratigraphically, the importance of the Qm unit is that it typically intervenes between an upper and a lower layer of Qs. The Qm unit, pervasive throughout the southeastern portion of CNC as marsh clay, was encountered in all but one of the deep well borings and the deep soil boring. However, at two deep well borings, sample recovery was limited due to drilling difficulties, so the presence of marsh clay is unknown. Where present, the Qm unit varied in thickness from approximately 9 feet at GDI13D to more than 45 feet at GDI05D, averaging 31 feet thick. The Qm is also present as small, discontinuous lenses throughout the shallow subsurface.

Twenty geotechnical samples of Qm were obtained during the Zone I RFI from depths of 13 to 20 feet bgs. These data were presented and designated as Qm lithologies in Table 2.2. Arithmetic averages were calculated for total porosity and grain size distribution as 68.1, and 8.7% sand,

51.7% silt and 39.8% clay. The geometric mean of the vertical permeabilities reported for these 20 samples was determined to be 4.3E-06 centimeters per second (cm/sec) (equivalent to 1.2E-02 ft per day).

Quaternary Sand

The Qs unit is typically found in the southern peninsula of CNC as a poorly defined shallow or upper Quaternary sand (Qs_U) layer overlying thick Qm deposits and a better defined basal or lower Quaternary sand (Qs_L) unit intervening between the Qm and Ta units. The ambiguity in delineating the Qs_U lies in the highly variable nature of the fill material that covers much of the southeastern portion of the base. As a result, the Qs_U is intermixed with fill material such as gravel, inorganic clays and silts, and dredged spoils from the Cooper River (which often include clasts of Ta).

The Qs is best described as a green-gray, green to tan sand with a small percentage of fines. Grain size ranges from very fine to coarse, but is typically found as fine to medium. Shell fragments and oyster shells are found in varying percentages throughout the Qs as a whole, but tend to comprise higher percentages in the basal Qs_L. The Qs_L is easily identified in most deep well borings, but is not laterally consistent. Frequently, the Qs_L is interbedded with clay lenses and may even degrade to sandy laminae within Qm deposits that immediately overlie the Ta.

No undisturbed Shelby tube samples could be obtained from the Qs_U, but grain size data was obtained from two bagged samples taken from the Qs_L (Table 2.2). These samples had a mean grain-size distribution of 94.3% sand, 2.3% silt and 3.5%.

2.2.4 Soil

Surface soil at CNC has been extensively disturbed. Native soil was the fine-grained silt, silty sand, and clay typical of tidal marsh environments. Sand lenses present in localized areas are

generally only a few feet thick. Much of CNC, particularly the southern portion, has been filled using dredged materials from the Cooper River and Shipyard Creek. The dredged materials consist of an unsorted mixture of sand, silt, and clay. Figure 2.9 indicates that most of the remainder of Zone I has been either filled or reworked for development. Along the Cooper River, enough dredge spoil deposition and alteration has occurred to assume that much of the upper and surficial sediment encountered during soil boring is not natural. Granite boulders, concrete slabs, and wood pilings were occasionally encountered, indicating former waterfront development had been covered and built upon.

2.3 Zone I Hydrogeology

Hydrogeology information was obtained from slug tests, specific capacity tests, and water level measurements conducted during the Zone H and I RFIs. Estimates of vertical permeability, grain size distribution, and porosity were obtained from analysis of Shelby tube samples collected during drilling (Table 2.2). Only data pertinent to the Quaternary and Tertiary Ta deposits are discussed since they were the only deposits encountered in Zone I.

2.3.1 Tertiary-Age Sediments

2.3.1.1 Ashley Formation

The Ta is important because of its role as a confining unit between the lower members of the Cooper Group and Eocene-age Santee Limestone, and the overlying water-bearing Quaternary-age sediments (Park, 1985). Lithologic cross sections presented by Weems and Lemon (1993) show the Ta as having a laterally consistent overall thickness. Samples from this unit at CNC have shown high clay and silt and varying sand contents depending greatly upon depth. Five Shelby tube samples, collected from the Ta during the Zone H RFI, averaged a very low vertical permeability of 1E-06 cm/sec (0.0027 ft/day) (E/A&H, 1996c). According to Fetter (1988), sediments with permeabilities of 1E-05 cm/sec (0.03 ft/day) or less can be considered confining units. All deep well borings in Zone I were terminated when the Ta was encountered.

2.3.2 Quaternary-Age Sediments

The hydrogeologic role of the Quaternary-age sediments is as a single surficial aquifer overlying the Ta. However, hydraulic conditions within the surficial aquifer vary significantly at the local scale. This is largely influenced by the range of stratigraphic units that comprise the Quaternary-age sediments, as previously discussed in Section 2.2.3.2.

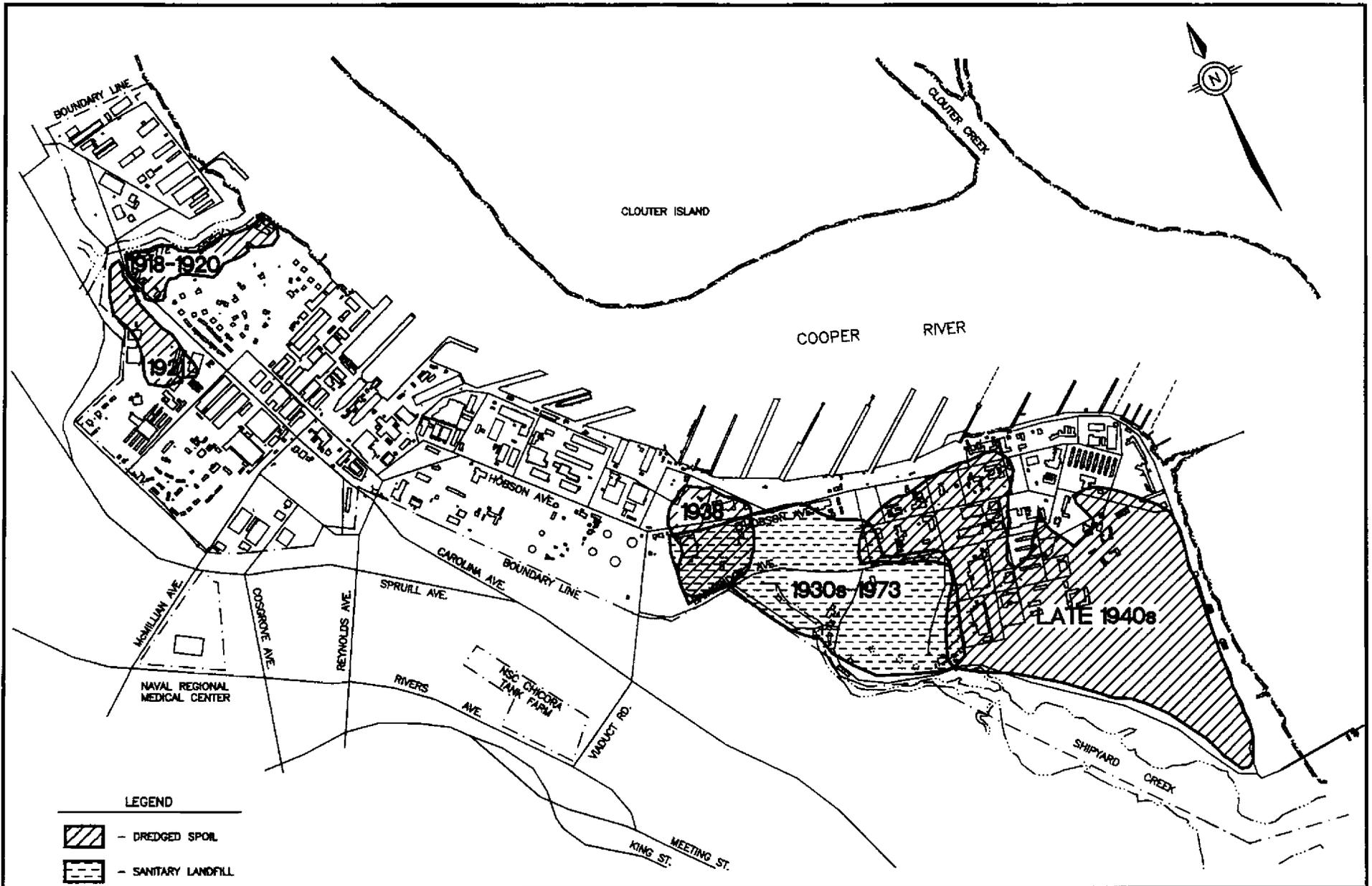
The two distinct water-bearing units in the surficial aquifer are the Q_{sU} and the Q_{sL} . Several characteristics of the Q_m – its high silt and clay content, laterally consistent overall thickness throughout Zones H and I, and its low vertical permeability – suggest that the Q_m behaves as an aquitard between the Q_{sU} and Q_{sL} units. An average vertical permeability for the Q_m of $4.3E-06$ cm/sec ($1.2E-02$ ft/day) was based on the 20 Shelby tube samples obtained in Zone I. Although no vertical permeability data for the Q_{sU} or Q_{sL} units were obtained during the Zone I RFI, a mean vertical permeability for the Q_s unit as a whole in Zone A was reported as $5.7E-04$ cm/sec (1.6 ft/day) (E/A&H, 1996a).

2.3.3 Groundwater Flow in the Surficial Aquifer

Although the surficial aquifer as a whole extends from the water table to the top of the Ta, groundwater primarily flows within the Q_{sU} and Q_{sL} units. These units will be discussed individually, as they are considered hydraulically separate.

2.3.3.1 Q_{sU}

The Q_{sU} is considered to act as an unconfined aquifer with its upper boundary as the water table surface and its bottom boundary roughly corresponding to the top of the Q_m aquitard. Due to the presence of fill material, dredged spoils and other anthropogenic influences, flow direction and magnitude within the Q_{sU} are highly variable. In some cases, the presence of clayey and silty fill material may act to semi-confine portions of the Q_{sU} . An example of such a condition exists at shallow well location GDI005 where water levels are frequently above the top of the well casings



LEGEND

-  - DREDGED SPILL
-  - SANITARY LANDFILL



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FIGURE 2.9
 AREAS FILLED AND
 APPROXIMATE DATES
 OF FILLING OPERATIONS

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1

because of artesian pressure, likely exerted from marsh clay deposits throughout the upper subsurface. In general, however, the water levels in all Zones I and H shallow wells are considered representative of the hydraulic conditions within the Q_{sU} unit.

Water levels range several feet within the Q_{sU} , but can generally average 4 to 6 feet bgs. Water level measurements, taken May 11, 1995 in a select subset of Zones H and I shallow monitoring wells, were used to develop a contour map of groundwater elevations in the Q_{sU} (Figure 2.10). Groundwater elevation highs exist in the central portion of the southeastern CNC peninsula, coinciding with much of Zone H and flow radially outwards toward Shipyard Creek and the Cooper River. Local groundwater highs in Zone I are found at GDI009 and GDI011 and reflect the heterogeneity of the Q_{sU} unit.

2.3.3.2 Q_{sL}

The Q_{sL} unit is considered semiconfined to confined by the overlying Q_m unit because water levels in wells screened across the Q_{sL} rise above the top of the aquifer. The Q_{sL} is not laterally consistent in Zones H and I and was not evident in several deep well borings. In other cases, the unit is frequently interbedded with clay lenses or degrades to sandy laminae within the Q_m immediately overlying the T_a . As a result, hydraulic head values from deep wells in Zones H and I may not be entirely indicative of the Q_{sL} unit, but represent hydraulic conditions coinciding with the top of the T_a .

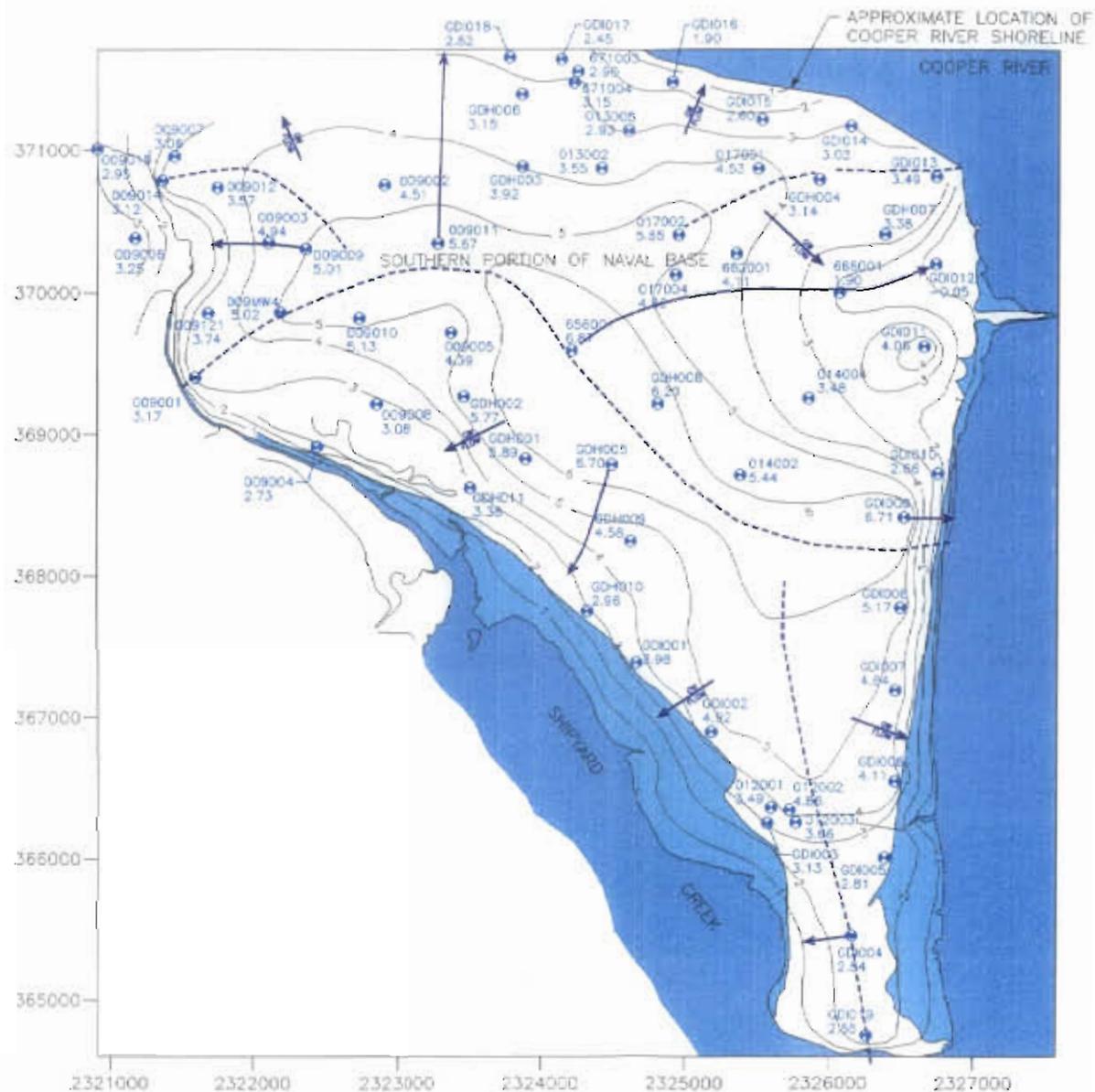
Generally, potentiometric head levels in this unit are within 10 feet of ground surface. In one Zone I well, GDI05D, and several Zone H wells (00903D, 00905D, 00908D, and GDH05D) the potentiometric head level is above ground surface. Water level measurements, taken May 11, 1995 in a select subset of Zones H and I deep monitoring wells, were used to contour groundwater elevations in the Q_{sL} (Figure 2.11).

As the figure depicts, a groundwater elevation high exists in the center of Zone H and extends all the way east to GDI08D near the eastern boundary of the peninsula. South of this high, groundwater flows southwest toward Shipyard Creek. As the peninsula becomes thinner between GDI01D and GDI08D, the dominant flow direction gradually becomes southeast to south, although localized groundwater highs are evident at GDI05D, and at GDI06D and GDI07D which have more easterly groundwater components. Groundwater north and east of the major groundwater high flows north to northeast to the Cooper River. Groundwater elevations in the Zone I deep wells along the northern portion of the peninsula tend to be lower than those along the peninsula's eastern and southwestern edge.

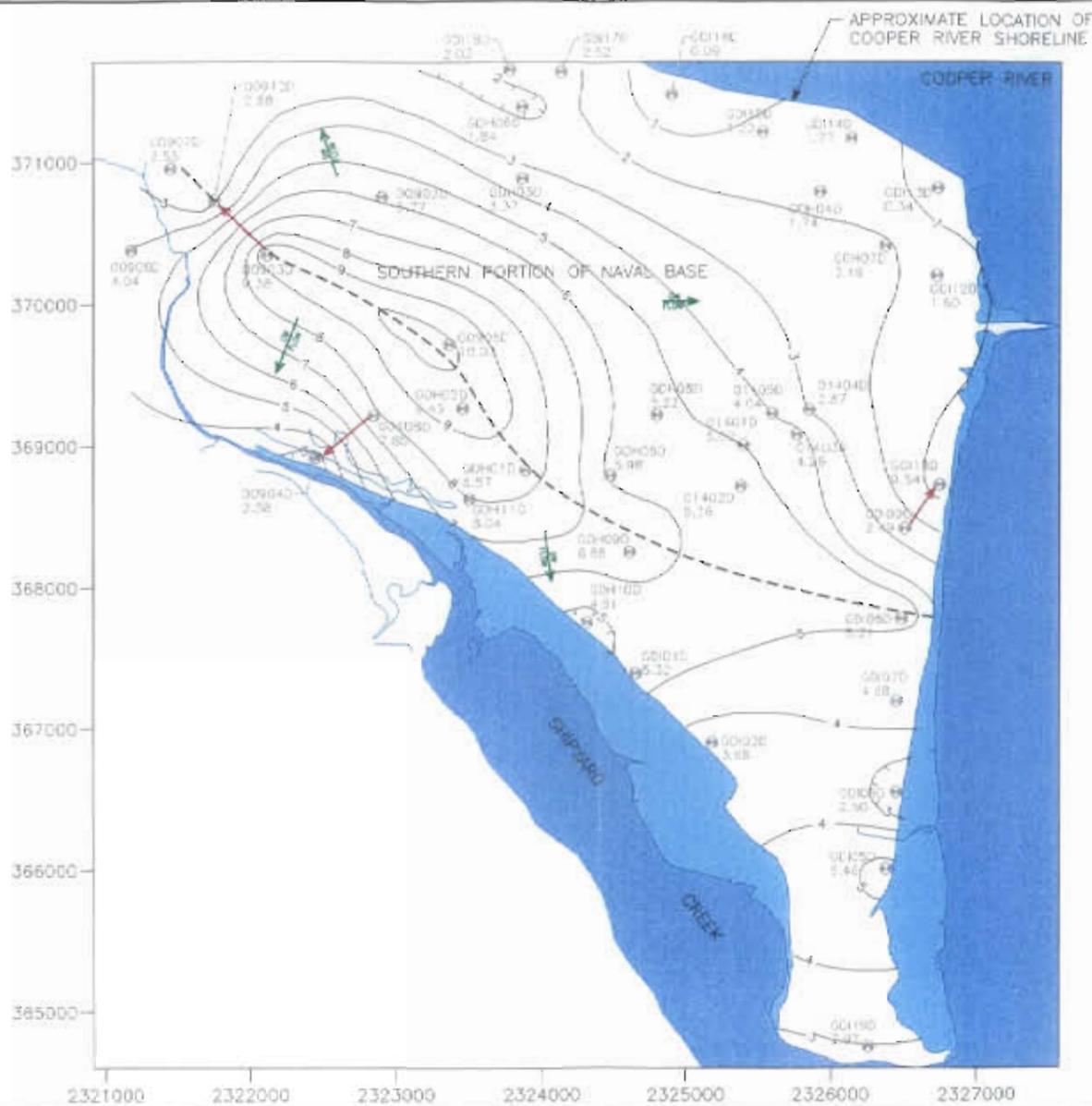
Additional water level data was collected from Zone I shallow and deep wells as part of a water level measurement event for the entire CNC southern peninsula in July, 1998. The intention of this event was to measure every well available or accessible instead of a select subset. Figures 2.12 and 2.13 are the resulting groundwater elevation contour maps for the Q_{S_U} and Q_{S_L} units, respectively. The primary difference evident when comparing Figures 2.12 and 2.10 is the sizes and shapes of the recharge zones within Zones H and I, resulting in some minor changes in groundwater flow direction. Although recharge zone morphology is influenced by seasonal fluctuations in the water table, it is likely that greater data coverage in the July 1998 event allowed for increased resolution of recharge zone morphology. Comparison of Figures 2.13 and 2.11 reveals no discernible differences in groundwater flow direction in the Q_{S_L} .

2.3.4 Vertical Hydraulic Gradient

The vertical hydraulic gradient is a mathematical expression that indicates the potential for vertical groundwater flow. Vertical gradients were calculated by dividing the differences between shallow and deep water level elevations by the vertical distance between aquifers at each well pair. In cases where the upper sand layer was not present, the elevation of the bottom of the shallow-well screen was used. Similarly, if the lower sand was absent, the elevation of the top of the deep-well




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 FIGURE 2.10
 GROUNDWATER ELEVATION CONTOURS
 OF THE Qs UNIT IN THE
 SURFICIAL AQUIFER
 (05/11/95)



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FIGURE 2.11
GROUNDWATER ELEVATION CONTOURS
OF THE Q_{sL} UNIT IN THE
SURFICIAL AQUIFER
(5/11/95)

DWG DATE: 02/03/99 | DWG NAME: 29095004

screen was used. Positive gradients indicate a downward potential for vertical flow whereas negative gradients indicate potential for upward flow.

Table 2.3 presents the calculated vertical hydraulic gradients between each of the shallow/deep well pairs in Zones I and H for water level data collected June 20, 1995. Figure 2.14 presents the distribution of vertical gradients across the site using the results presented in Table 2.3.

Most of the well pairs have a positive hydraulic gradient, indicating the potential for groundwater to flow downward from the Q_{s_U} to Q_{s_L} . This does not necessarily mean that the aquifers are hydraulically connected beneath the site, but it does indicate the direction of flow if a connection exists. However, no connection between the Q_{s_U} and Q_{s_L} was observed in any of the Zone H or I boreholes. At some lateral distance from Zones H and I, a connection between the two sands could exist in association with the Cooper River and/or Shipyard Creek.

Table 2.3
 Vertical Hydraulic Gradients

Well Pair	Groundwater Elevation Difference (ft)	Vertical Distance (ft)	Vertical Hydraulic Gradient (ft/ft)
Zone I Monitoring Wells			
GDI001/GDI01D	-1.15	45.5	-0.025
GDI002/GDI02D	1.61	58.5	0.028
GDI003/GDI03D	-1.88	39	-0.048
GDI004/GDI04D	-3.66	26.5	-0.138
GDI005/GDI05D	0.16	44	0.0036
GDI006/GDI06D	1.81	27	0.067
GDI007/GDI07D	1.78	31	0.057
GDI008/GDI08D	2.58	41	0.063
GDI009/GDI09D	3.55	39	0.091
GDI010/GDI10D	3.95	20.5	0.193
GDI011/GDI11D	1.66	23	0.072
GDI012/GDI12D	-0.97	27.5	-0.035
GDI013/GDI13D	3.63	16	0.227

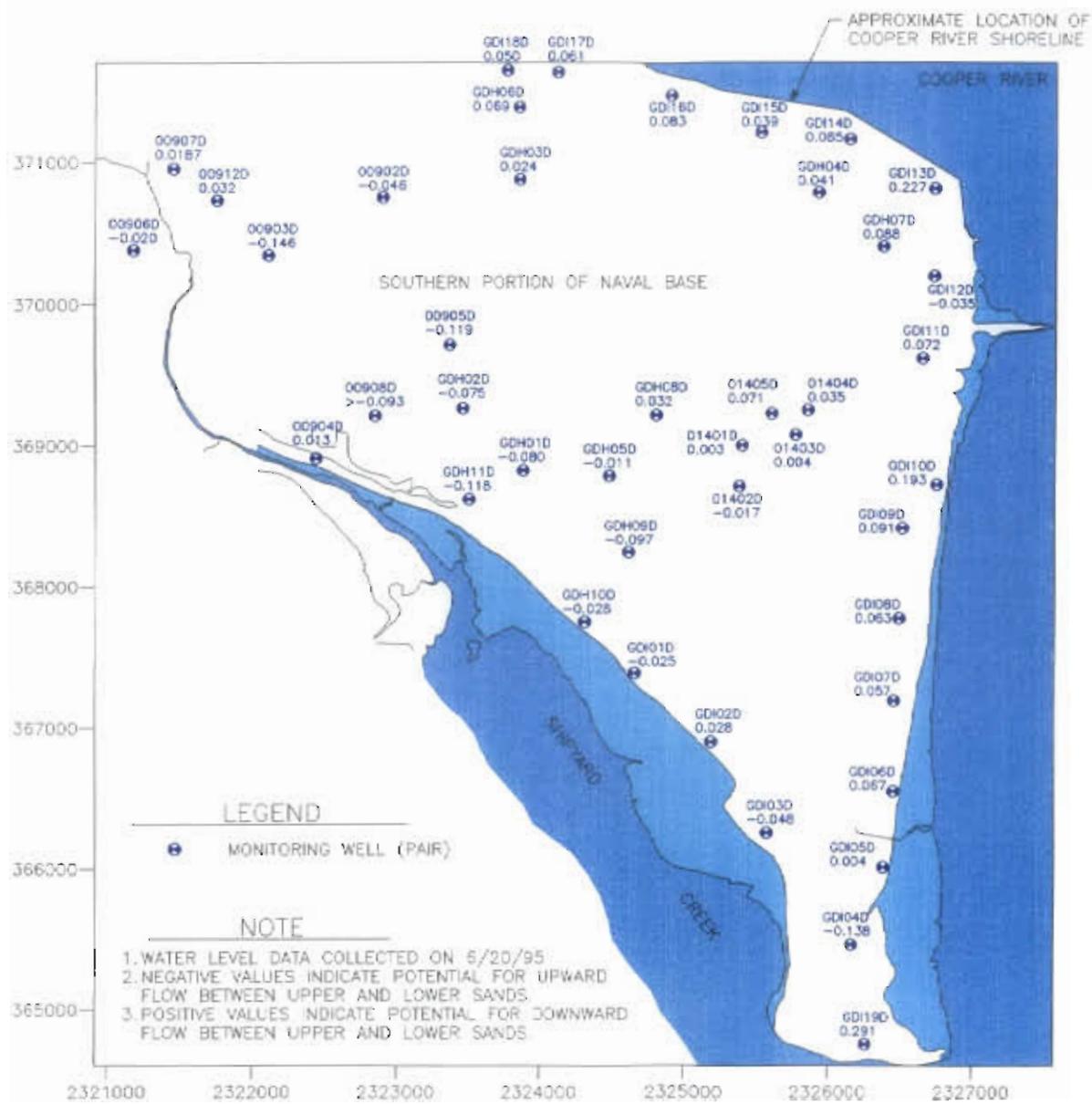
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Table 2.3
 Vertical Hydraulic Gradients

Well Pair	Groundwater Elevation Difference (ft)	Vertical Distance (ft)	Vertical Hydraulic Gradient (ft/ft)
GDI014/GDI14D	1.62	19	0.085
GDI015/GDI15D	1.85	47	0.039
GDI016/GDI16D	2.98	36	0.083
GDI017/GDI17D	1.61	26.5	0.061
GDI018/GDI18D	1.56	31	0.050
GDI019/GDI19D	3.49	12	0.291
Zone H Monitoring Wells			
009002/00902D	-1.32	29	-0.046
009003/00903D	-4.22	29	-0.146
009004/00904D	0.24	18	0.013
009005/00905D	-5.01	42	-0.119
009006/00906D	-0.36	18	-0.020
009007/00907D	0.81	48	0.017
009008/00908D	> -3.82	41	> -0.093
009012/00912D	1.12	35	0.032
014001/01401D	0.07	21	0.003
014002/01402D	-0.59	34	-0.017
014003/01403D	0.09	20	0.004
014004/01404D	0.77	22	0.035
014005/01405D	0.78	11	0.071
GDH001/GDH01D	-3.28	41	-0.080
GDH002/GDH02D	-3.73	50	-0.075
GDH003/GDH03D	0.59	25	0.024
GDH004/GDH04D	1.59	39	0.041
GDH005/GDH05D	-0.41	39	-0.011
GDH006/GDH06D	1.38	20	0.069
GDH007/GDH07D	1.59	18	0.088
GDH008/GDH08D	0.79	25	0.032
GDH009/GDH09D	-2.43	25	-0.097
GDH010/GDH10D	-1.27	45	-0.028
GDH011/GDH11D	-4.24	36	-0.118

Notes:

— = Upward potential
 ft/ft = feet per foot




ZONE 1
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FIGURE 2-14
 VERTICAL HYDRAULIC
 GRADIENTS

Date: 02/18/99 | DWG. No.: 2909C038

Well pairs that exhibit negative vertical gradients indicate a potential for upward vertical flow between the Q_{sL} and Q_{sU} . Most of these well pairs are along the southwestern shore of the peninsula near Shipyard Creek. This area roughly corresponds with one of the erosional surface lows indicated on the paleogeologic map of the Ta (Figure 2.5).

2.3.5 Horizontal Hydraulic Gradient

The horizontal hydraulic gradient (i) is a measurement of the change in hydraulic head (Δh) (i.e., change in groundwater elevation) of two points over the distance between the points (Δx). It is a dimensionless value generally used to quantitatively determine the magnitude of groundwater flow in a given region. Groundwater contour maps for the surficial aquifer (Figures 2.10 and 2.11) were examined to find groundwater flowpaths exhibiting a range of gradients throughout Zones H and I.

Because monitoring well placement during the Zone I RFI was based solely on AOC and SWMU locations and historical land uses at CNC, it is coincidental when monitoring wells are aligned with one another along a groundwater flowpath. Since groundwater flowpath lines must be perpendicular to groundwater contours or equipotential lines (lines of equal hydraulic head), the contour pattern of hydraulic head dictates the orientation of groundwater flowpaths.

Table 2.4 presents horizontal hydraulic gradients for specific groundwater flowpaths shown on Figures 2.10 and 2.11. Generally, the well pairs were selected to show the maximum and minimum horizontal gradients measured perpendicular to the groundwater elevation contours.

Table 2.4
 Horizontal Hydraulic Gradients in the Q_{s_U} and Q_{s_L} Units

Shallow Aquifer	Groundwater Flowpath	Δh (ft)	Δx (ft)	i (ft/ft)
Q _{s_U}	GDI009 to 1 ft contour adjacent to Cooper River	6.71 - 1 = 5.71	340	0.0168
	656001 to GDI012	6.87 - (-0.05) = 6.92	2600	0.0027
	GDH005 to 3 ft contour near GDH010	6.70 - 3.00 = 3.70	800	0.0046
	GDI004 to 1 ft contour adjacent to Shipyard Creek	2.84 - 1.00 = 1.84	360	0.0051
	009009 to 2 ft contour to west	5.01 - 2.00 = 3.01	640	0.0047
	009011 to 3 ft contour south of GDI018	5.67 - 3.00 = 2.67	1320	0.0020
Q _{s_L}	00903D to 00912D	9.38 - 2.88 = 6.50	520	0.0125
	GDI09D to GDI10D	2.49 - 0.54 = 1.95	400	0.0049
	00908D to 00904D	7.85 - 2.58 = 5.27	500	0.0105
	00905D to GDI16D	10.03 - 0.09 = 9.94	2420	0.0041

Notes:

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

2.3.6 Hydraulic Conductivity

Slug tests were used to evaluate the horizontal hydraulic conductivity of an aquifer at a single point. A slug test is initiated by inserting a 1-7/8" diameter Teflon cylinder below the static water level in the well, creating an instantaneous change in the water level. The change in water level over time is monitored as the aquifer attempts to reach equilibrium in response to the perturbation. This procedure is known as a falling head slug test since the water level (hydraulic head) declines back to its original static level. Once equilibrium is re-established, the slug is quickly removed, dropping the static water level. This procedure is a rising head slug test since the water level in the well rises back to its original static level as the test progresses.

Data from the slug tests were first compiled using the computer program AQTESOLV (Aquifer Test Solver) ver. 1.1 by Geraghty and Miller Modeling Group (1989). Rising and falling head slug test data were evaluated using the Bouwer and Rice Method (1976), which provided the best curve fits for both the shallow and deep wells. For this solution, elapsed time versus displacement (change in water levels) was plotted on a semilogarithmic graph. Horizontal hydraulic conductivity (K_h) was computed by the program using a straight-line of best fit. The Bouwer and Rice Method was developed for unconfined, semiconfined, and leaky aquifers. It is ideal for use in tests from wells that partially penetrate unconfined aquifers (i.e., the well does not fully screen the saturated interval). The method assumes that the aquifer is homogeneous, isotropic (vertical hydraulic conductivity equals horizontal hydraulic conductivity), in steady-state equilibrium, and that flow into the well is solely through the well screen. While this analysis results in a more reliable estimate of the aquifer's true hydraulic conductivity, it is important to recognize that these values are estimates of aquifer characteristics only at that specific well location and depth, and should be used carefully in discussing the overall aquifer characteristics. Some data sets did not provide adequate responses for evaluation, and thus were not used in the slug test analyses.

Hydraulic conductivities for the shallow and deep wells are presented in Tables 2.5 and 2.6, respectively. Stratigraphic units that are considered responsible for the test response are included. Aquifer characterization plots for groundwater in Zone I are included as Appendix C.

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

A rising head test was not conducted on GDI03D and GDI14D because falling head recovery of the well lasted more than 12 hours.

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Table 2.5
 Shallow-Well Slug Test Hydraulic Conductivity Results in feet/day

Well ID	Stratigraphic Unit	Falling Head	Rising Head	Geometric Mean*
GDI001	Qs _U /Qm	0.42	0.29	0.35
GDI003	Qs _U	1.46	1.69	1.57
GDI007	Fill/Qm	1.96	0.62	1.10
GDI010	Fill/Qs _U	1.13	1.40	1.26
GDI014	Qs _U	7.94	6.07	6.94
GDI015	Qs _U /Qm	0.91	1.07	0.99
GDI018	Fill	0.79	0.70	0.74
GDI019	Qs _U	1.37	1.70	1.53
671004	Qs _U	3.53	6.21	4.68
677002	Fill	0.019	0.023	0.021
687002	Qs _U	0.082	0.091	0.086

Note:

- * = Average of falling and rising head values.
- Qm = Quaternary marsh clay
- Qs_U = Upper Quaternary sand

Table 2.6
 Deep-Well Slug Test Hydraulic Conductivity Results in feet/day

Well ID	Stratigraphic Unit	Falling Head	Rising Head	Geometric Mean*
GDI01D	Qs _L	3.81	3.31	3.55
GDI03D	Qm	0.0012	-	0.0012
GDI07D	Qs _L	0.42	0.39	0.40
GDI10D	Qs _L	3.93	4.34	4.13
GDI14D	Qm	0.0029	-	0.0029
GDI15D	Qs _L	3.58	10.61	6.16
GDI18D	Qs _L /Qm	0.42	0.39	0.40
GDI19D	Qs _L	3.21	2.85	3.02

Note:

- * = Average of falling and rising head values.
- Qm = Quaternary marsh clay.
- Qs_L = Lower Quaternary sand

Hydraulic conductivities in Zone I shallow wells ranged from 0.021 to 6.94 ft/day. These values further reinforce the finding that the shallow sediments are highly heterogeneous both naturally and anthropogenically. The geometric mean for the slug-tested Zone I shallow wells is 0.76 ft/day.

Hydraulic conductivities in Zone I deep wells ranged between 0.0012 and 6.16 feet/day, with a geometric mean of 0.33 ft/day. This range reflects the interbedded nature of much of the Q_{sL} deposits as well as the prevalence of Q_m overlying the Ta.

The mean hydraulic conductivities from Tables 2.5 and 2.6 were plotted next to their respective wells on Figure 2.15 to show the areal distribution of hydraulic conductivity in the surficial aquifer.

2.3.7 Horizontal Groundwater Velocity

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

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

Where:

- V = horizontal groundwater velocity (ft/day)
- K_h = hydraulic conductivity (ft/day)
- i = horizontal hydraulic gradient (unitless)
- n_e = effective porosity (unitless)

An estimated average sand porosity of 35% was used as the effective porosity in the equation for both the Q_{sU} and Q_{sL} units. To provide a more conservative estimate of groundwater velocity,

the four highest hydraulic conductivity estimates from Q_{S_U} and Q_{S_L} slug tests were used to calculate a geometric mean for each unit. These mean K_h values were found to be 3.0 and 4.1 ft/day for the Q_{S_U} and Q_{S_L} units, respectively. Horizontal groundwater velocity was calculated along each of the groundwater flowpaths presented in Table 2.7.

Table 2.7
 Horizontal Groundwater Velocity Results in feet/day

Shallow Aquifer	Flowpath	K_h	i	v
Q_{S_U}	GDI009 to 1 ft contour adjacent to Cooper River	3.0	0.0168	0.144
	656001 to GDI012	3.0	0.0027	0.023
	GDH005 to 3 ft contour near GDH010	3.0	0.0046	0.039
	GDI004 to 1 ft contour adjacent to Shipyard Creek	3.0	0.0051	0.044
	009009 to 2 ft contour to west	3.0	0.0047	0.040
	009011 to 3 ft contour south of GDI018	3.0	0.0020	0.017
Q_{S_L}	00903D to 00912D	4.1	0.0125	0.146
	GDI09D to GDI10D	4.1	0.0049	0.057
	00908D to 00904D	4.1	0.0105	0.123
	00905D to GDI16D	4.1	0.0041	0.048

Notes:

- K_h = Hydraulic conductivity (ft/day)
- i = Horizontal hydraulic gradient
- v = Horizontal groundwater velocity (ft/day)

2.4 Climatology

Regional climate in the CNC area is described in Section 2.3 of the *Draft Zone A RFI Report*.

3.0 FIELD INVESTIGATION

The following section lists the field investigation objectives and describes the technical sampling methods, procedures, and protocols implemented during Zone I data collection. Fieldwork was conducted in accordance with the approved final RFI work plan and CSAP and the United States Environmental Protection Agency (USEPA) Region IV, *Standard Operating Procedures and Quality Assurance Manual* (ESDSOPQAM) (USEPA, 1991a). 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 I 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 excess risk
- Assess the need for corrective measures

3.2 Sampling Procedures, Protocols, and Analyses

The media sampled during the Zone I field investigation were soil, groundwater, sediment, dust (lead, aluminum oxide, and asbestos), and surface water. Sampling was generally conducted in accordance with the approved final RFI work plan. The media collected and the analyses varied between sites. The goal of the site-specific sampling and analyses was 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, dust, and groundwater samples included:

• Volatile organic compounds (VOCs)	USEPA Method 8260	1
• Semivolatile organic compounds (SVOCs)	USEPA Method 8270	2
• Pesticides/Polychlorinated Biphenyls (PCBs)	USEPA Method 8080	3
• Cyanide	USEPA Method 9010	4
• Metals/Mercury	USEPA Method 6010/7470	5
• Herbicides	USEPA Method 8150	6
• Organophosphorous (OP) pesticides	USEPA Method 8140	7
• Organotins	Per Triangle Laboratories	8
	Standard Operating Procedures (SOP)	9
• Total Dissolved Solids (TDS)	USEPA Method 160.1	10
• Chlorides	USEPA Method 325.1	11
• Sulfates	USEPA Method 375.1	12
• Total Petroleum Hydrocarbons (TPH)		13
Diesel Range Organics (DRO)	USEPA Method 8015	14
• TPH — Gasoline Range Organics (GRO)	USEPA Method 8015	15
• Lead/aluminum oxide wipe samples	National Institute for Occupational Safety and Health (NIOSH)	16
	Method 7300	17
• Asbestos wipe samples	NIOSH Method 7400	18

Approximately 10% of the samples collected for each medium at Zone I was 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 for additional parameters. In addition to analyses for VOCs, SVOCs, pesticides, OP pesticides, PCBs, metals, and cyanide constituents, Appendix IX samples included:

- Hexavalent chromium USEPA Method 7196
- Dioxins/Dibenzofurans USEPA Method 8290
- Herbicides USEPA Method 8150

To support corrective measures at CNC, selected soil samples in Zone I were analyzed for the following engineering parameters: leachability (Synthetic Precipitation Leaching Procedure [SPLP]), cation exchange capacity (CEC), total organic carbon (TOC), total moisture, total phosphorous, ammonia, nitrate-nitrite, sulfur, and chlorides. Additionally, thin-walled Shelby tube soil samples were collected for physical parameters, in accordance with 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 sample, location, and depth of sample. Shelby tube results were presented in Section 2.

Subsequent samples were analyzed for site-specific parameters based on the chemicals of potential concern (COPCs) identified at each site during initial sampling.

3.2.1 Sample Identification

All samples collected during the RFI 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, etc. The ninth and tenth characters represent sample-specific

identification such as depth to the nearest foot, depth interval, sampling event for water samples, etc.

The following codes were used to identify specific media for sample identification during the Zone I 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) surface water samples — W; (5) Direct Push Technology (DPT) soil samples — SP; (6) DPT groundwater samples — GP.

3.2.2 Soil Sampling

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

In accordance with Section 3 of the approved final RFI work plan, a systematic grid-based sampling approach was selected to more fully characterize background conditions, and supplement the biased sampling locations. Grid-based soil samples at Zone I consisted of 15 surface and six subsurface soil samples, as depicted in Figure 3.1. Collection of upper- and lower-interval samples was describes as described in Section 3.2.2.2 of this report. Sample analysis for metals, cyanide, pesticides/PCBs, SVOCs, and VOCs, was described in Section 3.2, above.

3.2.2.1 Soil Sample Locations

Soil samples were generally 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 2.12 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 0 to 1 foot bgs and from 3 to 5 feet bgs. The 0 to 1 foot bgs interval is referred to in this report as the first or upper-interval sample. At soil sample locations overlain by pavement, the upper interval was collected from the base of the pavement to 1 foot below the base of the pavement. The 3 to 5 feet 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 I, typically from 4 to 6 feet bgs.

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 overlying the soil sample at the upper interval was removed before augering to 1 foot bgs. The sod layer was generally less than 2 inches thick. A coring machine was used to gain access to soil covered by concrete and/or asphalt pavement.

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 I 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 I RFI. Analytical protocols specific to the Zone I RFI are described in Section 3.2 of this report.

3.2.3 Monitoring Well Installation and Development

Zone I monitoring wells were generally installed and sampled in accordance with the approved final RFI work plan. Following analysis and interpretation of initial groundwater sample analytical data, additional wells and/or subsequent sampling were required at some sites to determine the extent of groundwater contamination. Typically, these additional samples were justified due to relatively high concentrations of COPCs on the perimeter of the previous sample pattern. Section 10 figures present 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 I, 19 shallow/deep well pairs (GDI001/GDI01D through GDI019/GDI19D) were installed. Zone I grid-based groundwater samples were analyzed for metals, cyanide, pesticides/PCBs, SVOCs, VOCs, sulfates, chlorides, and TDS, as described in Section 3.2. Duplicate samples were analyzed for Appendix IX parameters. In addition, several shallow and deep grid groundwater samples were also analyzed for dioxin. In accordance with the approved final RFI work plan, data from grid wells near Zone I AOCs/SWMUs were incorporated into the appropriate site assessments. Figure 3.2 presents the Zone I grid-based groundwater sample locations.

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). All shallow and deep monitoring wells were constructed of an appropriate length of 2-inch inside diameter polyvinyl chloride (PVC) riser pipe attached to a 10-foot section of 0.010-inch slotted PVC well screen. The following subsections briefly describe Zone I site-specific methods. All identification numbers for monitoring wells installed during the Zone I 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 I grid-based monitoring wells, the first three characters are GDI. Appendix A includes the Zone I lithologic boring logs and monitoring well construction diagrams.

3.2.3.1 Shallow Monitoring Well Installation

Zone I shallow monitoring wells were installed to facilitate groundwater sampling in the upper water-bearing zone of the shallow aquifer. 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 3 to 6 feet bgs across Zone I, the shallow monitoring wells were set between 12 and 15 feet bgs. These monitoring well borings were advanced using the hollow-stem auger drilling method, in accordance with procedures set forth in Section 5 of the approved final CSAP.

3.2.3.2 Deep Monitoring Well Installation

Deep grid-based monitoring wells were installed at Zone I to facilitate groundwater sampling at the base of the shallow aquifer. Per Section 5 of the approved final CSAP, rotasonic and mud rotary drilling methods were used to advance the deep monitoring well borings. The deepest well installed was 75 feet bgs.

3.2.3.3 Monitoring Well Protector Construction

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

3.2.3.4 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 I 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 I RFI.

3.2.4.1 Groundwater Sampling Locations

Zone I monitoring wells were installed at 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 groundwater sample locations. Supplementary wells were installed to further define the extent of contaminants.

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 I RFI. At Zone I, peristaltic pumps were used in accordance with Section 6 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 I 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 I RFI. Analytical protocols specific to the Zone I RFI are described in Section 3.2 of this report.

3.2.5 DPT/Groundwater Sampling

Direct Push Technology (DPT) groundwater sampling was not specified in the final Zone I RFI Work Plan. Based on the review of data collected during the RFI and additional information that became available regarding historic base activities, DPT groundwater samples were collected at selected locations within Zone I. The purpose of these samples was to provide additional data, to delineate the extent of contamination, and/or to confirm or refute the presence of a possible contaminant plume.

3.2.5.1 DPT Screening Locations

Groundwater samples were collected from locations at AOC 678, AOC 680, AOC 681, and surrounding grid-based well GDI011. DPT sample locations are shown on Figure 1.3 in Section 1.

3.2.5.2 DPT Sample Collection

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

3.2.5.3 DPT Sample Preparation, Packaging, and Shipment

Guidelines in Section 11 of the final CSAP were followed for preparing, packaging, and shipping DPT samples collected in Zone I. These samples were submitted to the contracted laboratory.

3.2.5.4 DPT Sample Analysis

DPT samples were submitted to the contracted laboratory for VOC analysis at DQO Level III. Analytical protocols specific to the Zone I RFI are described in Section 3.2 of this report.

3.2.6 Sediment/Surface Water Sampling

Section 7 of the approved final CSAP describes the procedures used for sediment and surface water sample collection at Zone I.

3.2.6.1 Sediment/Surface Water Sample Locations

Sediment and surface water samples were collected from the locations proposed in the approved final RFI work plan. Sediment samples were collected at AOC 687/SWMU 16, AOC 688, and the Dredged Materials Area (DMA). The purpose was to determine the impact of contaminant transport via the surface water drainage pathways from these areas. Locations sampled included drainage ditches, downgradient surface water flow-paths from these sites, and dredge disposal areas. Thirteen sediment samples were collected during the field investigation for Zone I. Five surface water samples were collected from the DMA site (the only Zone I site where surface water samples were collected). Section 10 contains site-specific figures that identify the sediment sample locations.

3.2.6.2 Sediment/Surface Water Sample Collection

At Zone I, composite sediment samples were collected for laboratory analysis from 0 to 6 inches bgs using the scoop sampling method outlined in Section 7.2.3 of the approved final CSAP. Section 7.3 of the CSAP details procedures used to collect the surface water samples.

3.2.6.3 Sediment/Surface Water Sample Preparation, Packaging, and Shipment

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

3.2.6.4 Sediment/Surface Water Sample Analysis

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

3.2.7 Wipe Sampling

Wipe sampling for asbestos, lead dust, and aluminum oxide dust was conducted at AOC 681 in accordance with Section 9.1 of the approved final CSAP and Section 4.12.6 of the ESDSOPQAM (USEPA, 1991a). The following subsections briefly summarize those methods as applied at Zone I.

3.2.7.1 Wipe Sample Locations

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

3.2.7.2 Wipe Sample Collection

Lead and aluminum oxide wipe samples were collected by swabbing or wiping the sample location surface with No. 42 Whatman Filters that had been dampened with deionized water. Asbestos wipe samples were collected with prepared 37-millimeter (mm) mixed cellulose ester filters which had also been dampened with deionized water. The wipes were supplied by the Wisconsin Occupational Health Laboratory (WOHL) of Madison, Wisconsin, in 8-ounce, pre-cleaned glass jars. A clean set of gloves was used with each individual sample to prevent cross-contamination. The optimal wipe sample area was 100 square centimeters (cm²). However, due to the nature of the matrices, the optimal sample area was not always available. The sample area was approximated and documented in a field logbook. The filter was folded with the exposed sides

against each other, then folded again. The filter was then returned to the sample jar and a 1
corresponding number was recorded in the logbook. One of each type of filter was dampened with 2
deionized water, folded, and returned to the sample jar to serve as a media blank. 3

3.2.7.3 Wipe Sample Preparation, Packaging, and Shipment 4

The sample jar was labeled immediately in accordance with Section 11.4 of the approved final 5
CSAP. The jars were individually custody-sealed, encased in bubble wrap, and boxed for 6
shipment. A chain-of-custody form was prepared and placed in the box. The samples were 7
shipped overnight to WOHL. Air-bill information and sample labels were recorded in a master 8
sample log. 9

3.2.7.4 Wipe Sampling Analysis 10

The lead and aluminum oxide wipe samples were submitted to WOHL for elemental analysis. The 11
samples were analyzed by inductively coupled argon plasma, atomic emission spectroscopy using 12
NIOSH Method 7300. 13

The asbestos wipe samples were submitted to WOHL for bulk asbestos analysis. WOHL is 14
accredited by the National Voluntary Laboratories Accreditation Program for Bulk and 15
Transmission Electron Microscopy (TEM) Asbestos Analysis. The samples were analyzed by 16
polarized light microscopy with dispersion staining technique using NIOSH Method 7400. 17

3.2.8 Microvacuum Sampling 18

Microvacuum sampling to confirm the presence of asbestos fibers was conducted at AOC 680 in 19
accordance with the approved final work plan. Samples were collected in the hallway and the ship 20
fitters shop area of Building NS-26. Samples were analyzed for bulk asbestos by phase contrast 21
light microscopy. 22

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4.0 DATA VALIDATION

4.1 Introduction

Section 4.1 of the *Draft Zone A RFI Report* defines the DQOs used for the Zone I investigation. For Zone I, Level III analytical 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. Level IV data analyses were performed only for the first-round of data collected for Zone I.

Appendix D includes the complete analytical data set for Zone I.

4.2 Validation Summary

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

Field samples were collected at Zone I from February 1995 to December 1998, in accordance with the approved work plan. Samples were analyzed by CompuChem Laboratories, Southwest Laboratories of Oklahoma, Savannah Laboratories, and Laucks Testing Laboratory. Dioxins and dibenzofurans were analyzed by Southwest Laboratories of Oklahoma. Organotins were analyzed by Triangle Laboratories of North Carolina. In accordance with the final CSAP, sample analyses followed the guidance in *Test Methods for Evaluating Solid Waste*, SW-846 (USEPA, 1986a) and Title 40 CFR Part 264.

Third-party independent data validation of all analytical work performed under the CSAP was conducted by Validata Chemical Services and Heartland Environmental Services 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 I RFI. Appendix D includes the complete analytical data set for Zone I.

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 I RFI.

4.2.1.2 Gas Chromatography/Mass Spectrometer 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 I 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 I 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 I RFI.

4.2.1.5 Matrix Spike/Matrix Spike Duplicate

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Section 4.2.1.8 of the <i>Draft Zone A RFI Report</i> discusses field-derived blank analyses as they apply to the organic data evaluation for the Zone I RFI.	8 9
4.2.1.9 Internal Standard Performance	10
Section 4.2.1.9 of the <i>Draft Zone A RFI Report</i> discusses internal performance standards as they apply to the organic data evaluation for the Zone I RFI.	11 12
4.2.1.10 Diluted Samples	13
A special evaluation was performed for diluted samples to determine if method detection limits (MDLs) were low enough to be compared to reference concentrations (e.g., Maximum Contaminant Levels [MCLs], Risk-Based Concentrations [RBCs], etc.). Table 4.1 lists the diluted samples for Zone I.	14 15 16 17
4.2.2 Inorganic Evaluation Criteria	18
Section 4.2.2 of the <i>Draft Zone A RFI Report</i> discusses the inorganic evaluation criteria as they apply to the Zone I RFI. Appendix D includes the complete analytical data set for Zone I.	19 20

4.2.2.1 Holding Times

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

Table 4.1
 Diluted Samples

Sample ID	Sample Delivery Group	Parameter	Dilution Factor	Results ($\mu\text{g}/\text{kg}$)
671SB00101	00215	Pyrene	3	7,600
671SB00101	00215	Fluoranthene	3	11,000
671SB00101	00215	Anthracene	3	5,200
671SB00101	00215	Fluorene	3	3,300
671SB00101	00215	Phenanthrene	3	13,000
677SB00902	00569	Naphthalene	2	10,000
677SB00902	00569	Phenanthrene	2	10,000
677SB00902	00569	Fluorene	2	4,700
677SB00902	00569	1-Methylnaphthalene	2	3,000
677SB00902	00569	Acenaphthene	2	4,600
677SB00902	00569	Dibenzofuran	2	3,300
677SB00902	00569	Anthracene	2	1,700
677SB00902	00569	Fluoranthene	2	5,300
677SB00902	00569	Pyrene	2	3,600
677SB00902	00569	2-Methylnaphthalene	2	3,400
690SB00901	CHS28	Acetone	113	6,400 J
671SB00701	00589	4,4'-DDE	5.1	230 J

Note:
 $\mu\text{g}/\text{kg}$ = micrograms per kilogram

4.2.2.2 Instrument Calibration	1
Section 4.2.2.2 of the <i>Draft Zone A RFI Report</i> discusses instrument calibration as it applies to the Zone I RFI.	2 3
4.2.2.3 Blank Analysis	4
Section 4.2.2.3 of the <i>Draft Zone A RFI Report</i> discusses blank analysis as it applies to the Zone I RFI.	5 6
4.2.2.4 Inductively Coupled Argon Plasma Interference Check Samples	7
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 I RFI.	8 9
4.2.2.5 Laboratory Control Samples	10
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 I RFI.	11 12
4.2.2.6 Spike Sample Analysis	13
Section 4.2.2.6 of the <i>Draft Zone A RFI Report</i> discusses spike sample analyses as they apply to the Zone I RFI.	14 15
4.2.2.7 Laboratory Duplicates	16
Section 4.2.2.7 of the <i>Draft Zone A RFI Report</i> discusses laboratory duplicates as they apply to the Zone I RFI.	17 18
4.2.2.8 ICAP Serial Dilutions	19
Section 4.2.2.8 of the <i>Draft Zone A RFI Report</i> discusses ICAP serial dilutions as they apply to the Zone I RFI.	20 21

4.2.2.9 Atomic Absorption Duplicate Injections and Postdigestion Spike Recoveries

Section 4.2.2.9 of the *Draft Zone A RFI Report* discusses atomic absorption (AA) analysis, duplicate injections, and postdigestion spikes as they apply to the Zone I RFI.

4.3 Zone I Data Validation Reports

The complete Zone I data validation reports and a table of validation qualifiers are included in Appendix E. These reports are the outcome of the evaluations described above and are specific to the analytical data collected during the Zone I RFI. During data validation review of Zone I soil and groundwater analyses, the following per-site deficiencies and/or problems were noted in the VOC, SVOC, and metals methods. Although field blanks were site specific, trip, equipment, and distilled water blanks were not necessarily specific to the site.

4.3.1 Soil Blanks

SWMU 12 — Soil blanks numbered for SWMU 12 for the volatile method contained detectable:

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

SWMU 177— Soil blanks numbered for SWMU 177 for the volatile fraction contained detectable:

- Acetone in the method blank.
- Chloroform in the equipment and distilled water blanks.
- Carbon disulfide in the trip blank.

Blanks for the semivolatile fraction contained detectable:

- Phenol, diethylphthalate, and bis(2-Ethylhexyl)phthalate in the distilled water blank.
- Bis(2-Ethylhexyl)phthalate in the equipment blank.

Blanks for the metals fraction contained detectable:	1
• Aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, copper, iron, magnesium, manganese, potassium, sodium, thallium, tin, and zinc in the method blank.	2 3
• Barium, calcium, iron, magnesium, manganese, potassium, sodium, and zinc in the equipment blank.	4 5
• Beryllium, iron, sodium, and zinc in the distilled water blank.	6
AOC 671 — Soil blanks numbered for AOC 671 for the volatile fraction contained detectable chloroform in the distilled water and equipment blanks.	7 8
Blanks for the metals fraction contained detectable:	9
• Aluminum, barium, calcium, magnesium, manganese, potassium, sodium, and zinc in the distilled water and equipment blanks.	10 11
• Copper in the distilled water blank.	12
AOC 673 — Soil blanks numbered for AOC 673 for the volatile fraction contained detectable:	13
• Acetone in the method blank.	14
• Chloroform and methylene chloride in the distilled water and equipment blanks.	15
• Methylene chloride in the trip blank.	16
Blanks for the semivolatile fraction contained detectable di-n-butylphthalate in the distilled water and equipment blanks.	17 18
Blanks for the metals fraction contained detectable:	19
• Aluminum, barium, calcium, lead, potassium, sodium, and zinc in the distilled water and equipment blanks.	20 21
• Iron and manganese in the equipment blank.	22

AOC 678 — Soil blanks numbered for AOC 678 for the volatile fraction contained detectable:	1
• Carbon disulfide and methylene chloride in the equipment blank.	2
• Chloroform in the distilled water, equipment, and trip blanks.	3
Blanks for the metals fraction contained detectable:	4
• Aluminum, barium, calcium, copper, iron, lead, magnesium, manganese, potassium, sodium, vanadium, and zinc in the distilled water and equipment blanks.	5
• Antimony and cobalt in the equipment blank.	6
• Antimony and cobalt in the equipment blank.	7
AOC 679 — Soil blanks numbered for AOC 679 for the volatile fraction contained detectable:	8
• Methylene chloride in the method blank.	9
• Acetone, chloroform, and methylene chloride in the trip blank.	10
AOC 680 — Soil blanks numbered for AOC 680 for the volatile fraction contained detectable:	11
• Acetone and 2-butanone and carbon disulfide in the trip blank.	12
• Carbon disulfide in the equipment and distilled water blanks.	13
• Chloroform in the distilled water blank.	14
Blanks for the semivolatile fraction contained detectable bis(2-Ethylhexyl)phthalate in the equipment blank.	15
	16
Blanks for the metals fraction contained detectable:	17
• Beryllium, cadmium, lead, manganese, nickel, sodium, and zinc in the method blank.	18
• Cadmium, iron, manganese, nickel, potassium, sodium, and zinc in the distilled water blank.	19
• Antimony, barium, cadmium, magnesium, manganese, potassium, sodium, and zinc in the equipment blank.	20
	21

AOC 681 — Soil blanks for AOC 681 for the volatile fraction contained detectable:	1
• Methylene chloride in the trip and method blanks.	2
• Acetone in the method blank.	3
AOC 687 — Soil blanks numbered for AOC 687 for the volatile fraction contained detectable:	4
• Methylene chloride in the method and trip blanks.	5
• Chloroform and toluene in the trip blank	6
• Acetone in the method blank.	7
AOC 690 — Soil blanks for AOC 690 for the volatile fraction contained detectable:	8
• Acetone in the trip and method blanks.	9
• Chloroform in the distilled water and equipment blanks.	10
• Methylene chloride in the trip blank.	11
Blanks for the metals fraction contained detectable:	12
• Aluminum, barium, calcium, lead, manganese, potassium, sodium, and zinc in the distilled water and equipment blanks.	13 14
• Iron in the distilled water blank.	15
DMA — Soil blanks for the DMA for the volatile fraction contained detectable:	16
• Acetone and methylene chloride in the method and trip blanks.	17
• Carbon disulfide in the trip blank.	18
• Chloroform in the distilled water, equipment and trip blanks.	19
• Methylene chloride in the distilled water and equipment blanks.	20
Blanks for the semivolatile fraction contained detectable di-n-butylphthalate in the equipment blank.	21 22

Blanks for the metals fraction contained detectable:	1
• Aluminum, barium, calcium, copper, lead, magnesium, potassium, sodium, and zinc in the distilled water and equipment blanks.	2 3
• Iron and manganese in the equipment blank.	4
4.3.2 Groundwater Blanks	5
SWMU 12 — Groundwater blanks numbered for SWMU 12 (fourth-round groundwater samples) for the volatile fraction contained detectable methylene chloride and xylene in the trip blank.	6 7
Blanks for the metals fraction contained detectable antimony, cadmium, calcium, cyanide, iron, and silver in the method blank.	8 9
AOC 671 — Groundwater blanks numbered for AOC 671 (first-round groundwater samples) for the volatile fraction contained chloroform and methylene chloride in the field blank.	10 11
Blanks for the semivolatile fraction contained detectable:	12
• di-n-butylphthalate in the field and method blanks.	13
• N-nitrodimethylamine in the field blank.	14
Blanks for the metals fraction contained aluminum, antimony, barium, cadmium, calcium, chromium, iron, manganese, potassium, sodium, and zinc in the method blank.	15 16
Groundwater blanks numbered for AOC 671 (third-round groundwater samples) for the metals fraction contained detectable:	17 18
• Aluminum, barium, calcium, manganese, potassium, sodium, vanadium, and zinc in the distilled water, equipment, and field blanks.	19 20
• Iron, silver, and tin in the distilled water, field, and method blanks.	21

• Copper in the field blank.	1
• Vanadium in the method blank.	2
	3
AOC 675 – Groundwater blanks numbered for AOC 675 (first-round groundwater samples) for the volatile fraction contained detectable:	4
	5
• Methylene chloride in the trip blank.	6
• Trichlorotrifluoroethane was the method blank.	7
Groundwater blanks numbered for AOC 675 (second -round groundwater samples) for the volatile fraction contained detectable:	8
	9
• Acetone and methylene chloride in the trip and method blanks.	10
• Bromodichloromethane in the distilled water, equipment, field, and trip blanks.	11
• Carbon disulfide in the field and trip blanks.	12
Blanks for the semivolatile fraction contained detectable bis(2-Ethylhexyl)phthalate in the distilled water, equipment, and field blanks.	13
	14
Blanks for the metals fraction contained detectable:	15
• Aluminum, barium, calcium, manganese, and sodium in the method blank.	16
• Zinc in the equipment and field blanks.	17
• Lead in the distilled water and field blanks.	18
• Iron in the distilled water blank.	19
Groundwater blanks numbered for AOC 675 (fourth-round groundwater samples) for the volatile fraction contained detectable:	20
	21
• Chloroform in the distilled water, equipment, and field blanks.	22
• Methylene chloride in the trip and method blanks.	23

• Acetone in the method blank.	1
• Bromodichloromethane in the field blank.	2
Groundwater blanks numbered for AOC 676 (fourth-round groundwater samples) for the volatile fraction contained detectable:	3
	4
• Chloroform in the distilled water, equipment, and field blanks.	5
• Methylene chloride in the trip and method blanks.	6
• Acetone in the method blank.	7
• Bromedichloromethane in the field blank.	8
Blanks for the semivolatile fraction contained detectable bis(2-Ethylhexyl)phthalate in the distilled water, equipment, and field blanks.	9
	10
Groundwater Grid-Based Samples — Blanks numbered for the first-round of groundwater grid-based samples for the volatile fraction contained detectable:	11
	12
• Acetone and methylene chloride in the distilled water, equipment, field, trip, and method blanks.	13
	14
• Chloroform in the distilled water, equipment, field, and trip blanks.	15
• Xylene in the method blank.	16
Blanks for the semivolatile fraction contained detectable di-n-butylphthalate in the distilled water and method blank.	17
	18
Blanks for the metals fraction contained detectable aluminum, antimony, barium, calcium, chromium, copper, iron, lead, magnesium, manganese, potassium, sodium, and zinc in the distilled water, equipment, and field blanks.	19
	20
	21

Blanks numbered for the second-round of groundwater grid-based samples for the volatile fraction	1
contained detectable:	2
• Acetone and methylene chloride in the equipment, field, trip, and method blanks.	3
• Chloroform in the distilled water, equipment, field, and trip blanks.	4
• Carbon disulfide in the equipment and trip blanks.	5
• Xylene in the trip blank.	6
Blanks for the semivolatile fraction contained detectable:	7
• Bis(2-Ethylhexyl)phthalate in the distilled water, field, and method blanks.	8
• Diethylphthalate in the field, equipment, and method blanks.	9
• Dimethylphthalate in the method blank.	10
Blanks for the metals fraction contained detectable:	11
• Potassium and sodium in the equipment and method blanks	12
• Nickel in the field blank.	13
Blanks numbered for the third-round of groundwater grid-based samples for the volatile fraction	14
contained detectable:	15
• Bromodichloromethane and chloroform in the distilled water, equipment, field, and trip	16
blanks.	17
• Acetone in the equipment, trip, and method blanks.	18
• Carbon disulfide in the field and trip blanks.	19
• Methylene chloride in the trip and method blanks.	20
Blanks for the semivolatile fraction contained detectable bis (2-Ethylhexyl)phthalate in the distilled	21
water and method blanks.	22

Blanks for the metals fraction contained detectable:	1
• Aluminum, barium, calcium, manganese, potassium, sodium, and zinc in the distilled water, equipment, and field blanks.	2
	3
• Lead and vanadium in the distilled water, equipment, and field blanks.	4
• Antimony, barium, chromium, cobalt, iron, mercury, selenium, and vanadium in the method blank.	5
	6
Blanks numbered for the fourth round of grid-based groundwater samples for the volatile fraction contained detectable:	7
	8
• Acetone in the distilled water, equipment, field, and method blanks.	9
• Methylene chloride in the distilled water, field, trip, and method blanks.	10
• Chloroform in the distilled water, equipment, field, and trip blanks	11
• Carbon disulfide in the field blank.	12
• Bromodichloromethane in the trip blank.	13

5.0 DATA EVALUATION AND BACKGROUND COMPARISON

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

Types of chemicals detected at Zone I include VOCs, SVOCs, pesticides (including OP pesticides), PCBs, herbicides, organotins, dioxins, petroleum hydrocarbons, and inorganics. Detected concentrations were compared to corresponding RBCs listed in the USEPA Region III *Risk-Based Concentration Table* (April 15, 1998) to: (1) evaluate the significance of the detections; (2) determine the need for additional sampling to define the extent of contamination; and (3) develop investigative endpoints. Detected inorganic concentrations were also compared to corresponding background concentrations specific to Zone I. The comparisons pertain only to the protection of human health and do not address protection of ecological receptors. Risk to the ecosystem from the onsite contaminants is assessed in Section 8.

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

5.1 Organic Compound Analytical Results Evaluation

Concentrations of organic compound concentrations in Zone I soil and groundwater samples were compared to RBCs. Information was also compiled on each compound's frequency of detection and its mean 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-TCDD equivalency quotients (TEQs) and benzo(a)pyrene equivalents (BEQs), respectively, in accordance with recent USEPA guidance. Section 5.1 of the *Draft Zone A RFI Report* details the guidance and procedures followed during the Zone I RFI.

5.2 Inorganic Analytical Results Evaluation

Inorganic sample analytical results are often difficult to evaluate because inorganics are naturally occurring and ubiquitous in soil, and frequently present in groundwater. Further, CNC 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 inorganics in soil and groundwater at Zone I and the approach for comparing background data to site data.

Many naturally occurring elements, particularly the carcinogenic inorganic arsenic are typically detected at concentrations much higher than their corresponding risk-based screening levels. It is usually necessary to supplement site-specific sampling efforts with an attempt to determine the non-site-related concentrations of these chemicals. The problem is how to determine these background concentrations, and how much higher than background a specific site parameter must be before it is of concern. USEPA Region IV guidance on this subject recommends using twice the mean of the background sample concentrations for each inorganic as an upper limit, considering any site-related values higher than this limit to represent contamination. Although this method is appropriate with small data sets, it would be less appropriate to use with the relatively large grid-based background data sets developed for soil (15 soil borings) and groundwater (19 shallow-deep well pairs) at Zone I. The larger data sets allowed the use of more sophisticated statistical tests.

Where possible, EnSafe used a dual testing procedure to compare site-specific inorganic values to those of the grid-based background data sets. Parametric or nonparametric upper tolerance limits (UTLs) were calculated and used as reference concentrations in combination with Wilcoxon rank sum tests to compare surface soil and shallow groundwater. Due to the small size of the subsurface soil background data sets (six samples), twice the mean concentrations of subsurface soil constituents in grid samples served as their background concentration. Although background values were calculated for inorganics in deep groundwater, no deep monitoring wells were installed at Zone I AOCs or SWMUs. Background concentrations were calculated according to established procedures developed for CNC, in consultation with the project team technical subcommittee at their meeting on June 9, 1997, and in subsequent telephone conferences.

5.2.1 Grid-Based Background Data Sets

The background data set for Zone I surface soil consisted of 15 grid-based samples (GDISB00201; GDISB00501 to GDISB01801). The subsurface soil background data set consisted of six grid-based samples (GDISB01202 to GDISB01502; GDISB01702 to GDISB01802). The background data set for shallow groundwater was derived from four rounds of samples from each of 19 monitoring wells (GDI001 to GDI019) as was the data set for deep groundwater (GDI01D to GDI19D). Figures 3.1 and 3.2 in Section 3 depict the Zone I grid-based soil and groundwater sample locations, respectively.

Descriptive statistics were compiled for the original data values, including frequency distribution histograms and normal probability plots. Results were examined and, where appropriate (i.e., histogram positively skewed; normal probability plot concave upward; high skewness and kurtosis), data were transformed into natural logarithms (NL) or square roots of their original values to more closely approximate normal distributions. Descriptive statistics of the transformed data were compared to those of the originals to determine the best approximations of normal distributions. Four of the eight surface soil data sets that were analyzed parametrically required

transformation before analysis, as did all four of the shallow groundwater and the single deep 1
groundwater data sets that were analyzed parametrically. Data sets that could not be transformed 2
to approximate normal distributions were analyzed nonparametrically. As explained above, 3
background values for subsurface soil constituents consisted of twice their mean concentrations. 4

It has been suggested that lognormal data indicate the presence of contamination in the samples 5
at the high end of the range. However, "EPA's experience with environmental concentration data 6
... suggests that a lognormal distribution is generally more appropriate as a default statistical 7
model than the normal distribution, a conclusion shared by researchers at the United States 8
Geological Survey" (USEPA, 1992a). 9

Many of the background data sets examined were more nearly lognormal than normal. It is more 10
reasonable to assume that lognormal background distributions of chemical concentrations are the 11
norm for CNC than to assume the data sets document a background contaminated in comparable 12
fashion by numerous inorganics at different depths in both soil and groundwater. However, a few 13
potential outliers did appear at the high ends of some of the data sets, and it was important to 14
eliminate them to preserve the integrity and utility of the background data. Normally, outliers 15
should be removed from a data set only in unusual circumstances and with specific reasons for 16
each removal. In lognormal or square-root distributions, even apparently extreme values may fit 17
a straight line on a normal probability plot of transformed data. Statistical rules of thumb for 18
outlier removal generally are based on sample variance, and include methods such as the "rule of 19
the huge error" (Taylor, 1990), in which all values greater than four standard deviations above the 20
mean are discarded, as well as Rosner's test, Dixon's test, the Shapiro-Wilk test, and others 21
(Gibbons, 1994). 22

Because of concerns about inadvertently including contaminated samples in the background data 23
sets, outliers were eliminated more readily than many standard statistical guidelines would suggest. 24

After consultation with the project team, outliers were removed on a chemical-by-chemical basis, descriptive statistics were recalculated for each chemical's data set, and the resulting modified data sets were used for all further comparisons to background.

5.2.2 Nondetect Data

Following guidelines in various USEPA documents, one-half of the sample quantitation limit (SQL) was used to represent nondetect (ND) values of inorganics in the data sets. 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 data sets.

5.2.3 Developing Data Sets for Sites

For comparison to background, results of samples from the AOCs and SWMUs were assembled into data sets for each chemical of interest from surface and subsurface soils, and from shallow groundwater. Other than the grid-based deep monitoring wells, no deep groundwater wells were installed at AOCs or SWMUs in Zone I.

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, which involves a tolerance-interval test and the Wilcoxon rank sum test.

5.2.5 Tolerance Interval or Reference Concentration Test

Individual data values from a site can be compared to a high percentile (95th, 98th, 99th) of background values. Parametric comparisons can be made to a specified percentile of the background values, obtained from either a normal probability chart of original or transformed values. Similarly, standard methods of estimating quartiles (Gilbert, 1987) may be used. Nonparametric comparisons can also be made to a percentile of the background values themselves, rather than to an assumed distribution of this data.

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

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

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

Where:

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

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

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

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

$$X + k (s)$$

The tolerance factor, k , is obtained from tables with specified levels of α and P_0 , where $(1 - P_0)$ equals the proportion of the population contained within the tolerance intervals (the coverage). For a given set of α and P_0 , k depends on the sample size, n . For $n = 15$ (the background sample size for surface soil in Zone I), $k = 2.566$ when $\alpha = 0.05$ and $P_0 = 0.05$ (confidence = 95%, coverage = 95%). Based on these numbers, the UTL for original (untransformed) background concentration values of a given element is therefore:

$$\text{UTL} = \text{mean} + 2.566 (\text{standard deviation})$$

According to a USEPA statistical training course manual (USEPA, 1992b), "Tolerance intervals can be computed with as few as three data values; however, to have a passable estimate of the standard deviation, one should probably have at least 8 to 10 samples." Outliers were first identified and removed from the data sets, as explained in Section 5.2.1. A UTL, or background reference concentration, was then calculated for the revised data set of each chemical in surface soil and shallow and deep groundwater, to be used for background comparisons. Subsurface soil background data sets for most Zone I inorganics contain only six samples apiece. Background concentrations for these chemicals were computed as twice the mean of the six sample concentrations.

Where a significant proportion (> 50%) of the samples were ND, or where transformed values did not approximate a normal distribution, means and standard deviations could not be accurately computed, and it became necessary to employ nonparametric tolerance intervals. In these circumstances, the UTLs or reference concentrations were taken directly from the sample sets, rather than from calculations based on the presumed data distributions. In practice, this meant using the largest or second-largest observed background value as the standard of comparison, depending on the sample size (USEPA, 1992a). As with the parametric calculations, the method was applied after outliers were removed.

The following procedure was applied to the background data sets for soil:

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

The power of a tolerance-limit test varies according to several factors, such as: (1) the number of samples assumed to originate from the distribution having the larger mean; (2) the magnitude of the shift in the mean; and (3) the distribution of the background sample values. It also depends on the sample size at each site and the sample size of the background.

5.2.6 Wilcoxon Rank Sum Test

When values for the majority of a site's samples are higher than the mean background value, but none is dramatically higher, the site samples, as a group, must be shown to be significantly higher than the background samples, as a group, for contamination to be identified onsite.

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 data sets that are compared need not be drawn from normal or even symmetric distributions, and the test can accommodate a moderate number of nondetect values by treating them as ties (Gilbert, 1987). The Wilcoxon test was used where justified by the number of samples (at least four in each data set) and the percentage of detections (normally, at least 20 to 25 %). Section 5.2.6 of the *Zone A RFI Report* describes the Wilcoxon rank sum test and the justification for its further use.

5.2.7 Summary of Statistical Techniques Used

Techniques that allow the use of statistical inference were chosen wherever possible. Methods used are capable of detecting situations where: (a) individual site values are much higher than background, or (b) site values are generally higher than background. For situation (a), surface soil and groundwater background data values were transformed where appropriate to approximate normal distributions, then site values were compared to parametric UTLs consisting of mean plus *k* standard deviations of the background data values, where *k* depends on sample size. Where the percentage of background nondetects was high or an approximately normal distribution could not be achieved, nonparametric UTLs were used; above 90% nondetects in background, no reliable tolerance limits can be determined. For subsurface soil constituents, twice the mean concentrations of the background samples served as the background values.

To account for situation (b) above, the Wilcoxon rank sum test was applied to both soil and groundwater results, where appropriate, to compare each group of site values to its corresponding background group. Where the Wilcoxon test could not be run due to an insufficient number (less

than four) of site and/or background samples, only the tolerance-limit test or the “twice the mean” test was performed.

5.2.8 Combined Results of the Background Concentration and Wilcoxon Rank Sum Tests

Methods described in Section 5.2.5 identify individual site samples with concentrations significantly higher than background, while the method in Section 5.2.6 identifies entire sites. If the outcome of either test was 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). Where background comparisons could not be carried out for a chemical due to lack of detections in background samples, site concentrations were screened against risk-based concentrations only.

5.2.9 Conclusion

The overall approach documented here is conservative for the following reasons:

- The number of background samples for surface soil and groundwater at both depths exceeds the minimum recommended in various guidance documents (e.g., USEPA Risk Assessment Guidance [RAGS], 1989a), producing confidence in the ability to characterize background from site-specific concentrations.
- Following procedures described in Section 5.2.1, high values were removed from the background data sets whether they were true outliers in the conventional sense or not, thereby lowering the total background concentrations to which the site values were compared.
- The use of two complementary tests for soil sample results increased the likelihood that any contamination would be identified and addressed further. A positive result from either

test triggered a detailed HHRA whenever site concentrations exceeded corresponding USEPA RBC values.

- The use of twice the mean of background sample concentrations as background concentrations generally results in lower background values than justified by more sophisticated statistical tests.

The effect of these factors is to increase the rate of false-positive test results while minimizing the rate of false negatives, as explained in Section 5.2.4 of the *Zone A RFI Report*.

5.3 Screening Values

5.3.1 Background Values

Tables 5.1, 5.3, and 5.4 summarize the steps taken in calculating UTL or background concentrations for *Zone I* surface soil, shallow groundwater, and deep groundwater, respectively. UTLs were calculated for 16 inorganic chemicals in surface soil, 14 inorganics in shallow groundwater, and 13 inorganics in deep groundwater. Table 5.2 presents reference concentrations for 14 inorganics in subsurface soil, derived using USEPA’s “twice the mean” guideline. In all background calculations, ND values were treated as discussed in Section 5.2.2.

5.3.2 Other Screening Values

Tables 5.5 and 5.6 present all of the screening values used to evaluate nature and extent, fate and transport, and the HHRA for Zone I. Concentrations of chemicals detected in site samples were compared to residential soil and tap-water RBCs; soil-to-groundwater and soil-to-air screening levels (SSLs); MCLs; saltwater surface water chronic screening values; and background values for surface soil, subsurface soil, shallow groundwater, and deep groundwater (Section 5.3.1).

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**Table 5.1
 Charleston Zone I Surface Soil
 Characteristics of Background Data Sets**

Chemical	n	Mean (mg/kg)	Data Transformation	Type of UTL	UTL (mg/kg)	RBC (mg/kg)
Aluminum	15	11,600	None	Nonparametric	27,400	7,800
Antimony	15	ND	ND	ND	ND	3.1
Arsenic	14	5.96	Sqrt	Parametric	21.6	0.43
Barium	14	26.7	None	Parametric	54.2	550
Beryllium	15	0.41	None	Nonparametric	0.95	16
Cadmium	15	0.42	None	Nonparametric	0.61	7.8
Chromium	9	16.5	None	Parametric	34.5	39
Cobalt	15	2.90	None	Nonparametric	5.8	470
Copper	14	59.0	LN	Parametric	240	310
Cyanide	15	ND	ND	ND	ND	160
Lead	15	51.7	None	Nonparametric	203	400 d
Manganese	15	160	None	Nonparametric	419	160
Mercury	15	0.20	None	Nonparametric	0.47	2.3
Nickel	15	9.27	None	Parametric	23.9	160
Selenium	15	0.76	None	Parametric	1.49	39
Silver	15	—	(no valid UTL; NDs > 90%)	—	—	39
Thallium	15	ND	ND	ND	ND	0.55
Tin	15	1.74	None	Nonparametric	7.5	4,700
Vanadium	15	27.3	LN	Parametric	113	55
Zinc	15	53.1	Sqrt	Parametric	206	2,300

Notes:

- d = USEPA de facto residential soil level
- LN = natural logarithm
- mg/kg = milligrams per kilogram
- n = number of samples
- Sqrt = square root
- ND = nondetect
- RBC = risk-based concentration
- UTL = upper tolerance limit

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**Table 5.2
Charleston Zone I Subsurface Soil
Characteristics of Background Data Sets**

Chemical	Number of Detections	Mean (mg/kg)	Background Value (mg/kg)	Soil-to-Groundwater SSL (mg/kg)
Aluminum	6	9,470	18,900	560,000 c
Antimony	0	ND	ND	2.7
Arsenic	5	3.23	6.45	15
Barium	6	18.0	36.0	820
Beryllium	4	0.33	0.67	32
Cadmium	1	0.27	0.54	4
Chromium	6	25.7	51.3	19
Cobalt	3	1.74	3.48	990 c
Copper	6	5.75	11.5	5,600 c
Cyanide	0	ND	ND	20
Lead	6	6.15	12.3	400 d
Manganese	6	59.2	118	480 c
Mercury	0	ND	ND	1
Nickel	5	7.83	15.7	65
Selenium	5	0.89	1.77	2.6
Silver	0	ND	ND	17
Thallium	0	ND	ND	0.36
Tin	0	ND	ND	5,500 c
Vanadium	6	19.1	38.1	3,000
Zinc	6	18.1	36.2	6,200

Notes:

- c = calculated soil-to-groundwater SSL (see Table 6.2)
- d = USEPA de facto residential soil level
- mg/kg = milligrams per kilogram
- ND = nondetects
- SSL = soil screening level

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Table 5.3
 Charleston Zone I Shallow Groundwater
 Characteristics of Background Data Sets

Chemical	n	Mean ($\mu\text{g/L}$)	Data Transformation	Type of UTL	UTL ($\mu\text{g/L}$)	MCL ($\mu\text{g/L}$)
Aluminum	76	107	None	Nonparametric	1,440	NL
Antimony	76	—	(no valid UTL; NDs > 90%)	—	—	6
Arsenic	72	6.5	None	Nonparametric	23.0	50
Barium	72	41.4	Sqrt	Parametric	110	2,000
Beryllium	76	0.42	None	Nonparametric	1.1	4
Cadmium	76	—	(no valid UTL; NDs > 90%)	—	—	5
Chromium	76	2.2	None	Nonparametric	14.3	100
Cobalt	76	1.1	None	Nonparametric	2.2	NL
Copper	76	1.2	None	Nonparametric	4.4	1,300 *
Cyanide	76	4.8	None	Nonparametric	25.2	200
Lead	71	1.7	None	Nonparametric	4.4	15 *
Manganese	76	746	LN	Parametric	5,430	NL
Mercury	76	—	(no valid UTL; NDs > 90%)	—	—	2
Nickel	76	2.9	LN	Parametric	13.3	100
Selenium	76	ND	ND	ND	ND	50
Silver	76	—	(no valid UTL; NDs > 90%)	—	—	NL
Thallium	76	2.5	None	Nonparametric	6.6 #	2
Tin	76	—	(no valid UTL; NDs > 90%)	—	—	NL
Vanadium	76	3.1	LN	Parametric	14.0	NL
Zinc	76	7.1	None	Nonparametric	24.4	NL

Notes:

- | | | | |
|-----------------|--|-----|-----------------------------|
| n | = number of samples | MCL | = maximum contaminant level |
| LN | = natural logarithm | ND | = nondetect |
| Sqrt | = square root | NL | = not listed |
| $\mu\text{g/L}$ | = micrograms per liter | UTL | = upper tolerance limit |
| * | = treatment technique action level | | |
| # | = thallium UTL set at 2.0 $\mu\text{g/L}$ pending results of basewide study of thallium in groundwater | | |

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Table 5.4
 Charleston Zone I Deep Groundwater
 Characteristics of Background Data Sets

Chemical	n	Mean ($\mu\text{g/L}$)	Data Transformation	Type of UTL	UTL ($\mu\text{g/L}$)	MCL ($\mu\text{g/L}$)
Aluminum	76	24.7	None	Nonparametric	180	NL
Antimony	76	—	(no valid UTL; NDs > 90%)	—	—	6
Arsenic	76	3.1	None	Nonparametric	14.2	50
Barium	72	100	LN	Parametric	347	2000
Beryllium	76	0.50	None	Nonparametric	1.2	4
Cadmium	76	—	(no valid UTL; NDs > 90%)	—	—	5
Chromium	75	1.7	None	Nonparametric	6.7	100
Cobalt	76	1.0	None	Nonparametric	2.3	NL
Copper	75	—	(no valid UTL; NDs > 90%)	—	—	1,300 *
Cyanide	75	5.4	None	Nonparametric	27.2	200
Lead	74	—	(no valid UTL; NDs > 90%)	—	—	15 *
Manganese	75	104	None	Nonparametric	261	NL
Mercury	76	—	(no valid UTL; NDs > 90%)	—	—	2
Nickel	75	1.8	None	Nonparametric	6.8	100
Selenium	76	ND	ND	ND	ND	50
Silver	76	ND	ND	ND	ND	NL
Thallium	75	2.8	None	Nonparametric	7.1 #	2
Tin	76	31.9	None	Nonparametric	347	NL
Vanadium	76	2.6	None	Nonparametric	15.7	NL
Zinc	74	4.6	None	Nonparametric	22.1	NL

Notes:

- | | |
|--|---------------------------------|
| LN = natural logarithm | MCL = maximum contaminant level |
| n = number of samples | ND = nondetect |
| $\mu\text{g/L}$ = micrograms per liter | NL = not listed |
| * = treatment technique action level | UTL = upper tolerance limit |
| # = thallium UTL set at 2.0 $\mu\text{g/L}$ pending results of basewide study of thallium in groundwater | |

Table 5.5
Organic Screening Values Used for Nature and Extent, Fate and Transport, and Risk Assessments
Organic Chemicals Detected in Surface Soil, Subsurface Soil, Sediment, and Shallow Groundwater
Charleston Naval Complex
Charleston, South Carolina

Parameter	Residential	Soil to	Soil to	Tap Water	MCL	Saltwater	Soil	Water
	Soil RBC (THQ=0.1)	GW SSL	Air SSL	RBC (THQ=0.1)		Surf. Wtr. Chronic		
Volatile Organic Compounds								
Acetone	780000	8000	1.0E+08	370	NA	NA	µG/KG	µG/L
Acetonitrile (methyl cyanide)	47000	440 a	NA	22	NA	NA	µG/KG	µG/L
Benzene c	22000	15	800	0.36	5	109	µG/KG	µG/L
2-Butanone (MEK)	4700000	3900 a	NA	190	NA	NA	µG/KG	µG/L
Carbon disulfide	780000	16000	720000	100	NA	NA	µG/KG	µG/L
Chlorobenzene	160000	700	130000	3.5	NA	105	µG/KG	µG/L
Chloroethane c	220000	9 a	2600000	3.6	NA	NA	µG/KG	µG/L
Chloromethane c	49000	3.7 a	63	1.5	NA	NA	µG/KG	µG/L
1,1-Dichloroethane	780000	11000	1300000	80	NA	NA	µG/KG	µG/L
1,2-Dichloroethane (EDC) c	7000	10	400	0.12	5	1130	µG/KG	µG/L
1,1-Dichloroethene c	1100	30	70	0.044	7	2240	µG/KG	µG/L
1,2-Dichloroethene (total)	70000	200	1100000	5.5	NA	NA	µG/KG	µG/L
Ethylbenzene	780000	6500	400000	130	700	4.3	µG/KG	µG/L
Methylene chloride c	85000	10	13000	4.1	NA	2560	µG/KG	µG/L
4-Methyl-2-Pentanone (MIBK)	630000	6700 a	NA	290	NA	NA	µG/KG	µG/L
Propionitrile (ethyl cyanide)	47000 m	440 m	NA	22 m	NA	NA	µG/KG	µG/L
1,1,2,2-Tetrachloroethane c	3200	1.5	600	0.053	NA	90.2	µG/KG	µG/L
Tetrachloroethene (PCE) c	12000	30	11000	1.1	5	45	µG/KG	µG/L
Toluene	1600000	6000	650000	75	1000	37	µG/KG	µG/L
Trichloroethene (TCE) c	58000	30	5000	1.6	5	NA	µG/KG	µG/L
Trichlorofluoromethane (CFC-11)	2300000	10000 a	790000	130	NA	NA	µG/KG	µG/L
Trichlorotrifluoroethane (Freon 113)	230000000	NA	2400000	5900	NA	NA	µG/KG	µG/L
Xylene (total)	16000000	70000 a	410000	1200	10000	NA	µG/KG	µG/L
Semivolatile Organic Compounds								
Acenaphthene	470000	290000	NA	220	NA	9.7	µG/KG	µG/L
Acenaphthylene	310000 d	96000 a	NA	150 d	NA	NA	µG/KG	µG/L
Acetophenone	780000	0.12 a	NA	0.0042	NA	NA	µG/KG	µG/L
4-Aminobiphenyl	2.8 n	NA	NA	0.00029 n	NA	NA	µG/KG	µG/L
Anthracene	2300000	5900000	NA	1100	NA	NA	µG/KG	µG/L
Benzoic acid	31000000	200000	NA	15000	NA	NA	µG/KG	µG/L
Benzo(g,h,i)perylene	310000 d	1.2E+08 a	NA	150 d	NA	NA	µG/KG	µG/L
Benzo(a)pyrene Equivalents (BEQs) c	87	1600 a	NA	0.0092	0.2	NA	µG/KG	µG/L
Benzo(a)anthracene c	870	800	NA	0.092	NA	NA	µG/KG	µG/L
Benzo(a)pyrene c	87	4000	NA	0.0092	0.2	NA	µG/KG	µG/L
Benzo(b)fluoranthene c	870	2500	NA	0.092	NA	NA	µG/KG	µG/L
Benzo(k)fluoranthene c	8700	25000	NA	0.92	NA	NA	µG/KG	µG/L
Chrysene c	87000	80000	NA	9.2	NA	NA	µG/KG	µG/L
Dibenz(a,h)anthracene c	87	800	NA	0.0092	NA	NA	µG/KG	µG/L
Indeno(1,2,3-cd)pyrene c	870	7000	NA	0.092	NA	NA	µG/KG	µG/L
Benzyl alcohol	2300000	25000 a	NA	1100	NA	NA	µG/KG	µG/L
Butylbenzylphthalate	1600000	930000	930000	730	NA	29.4	µG/KG	µG/L

Table 5.5
Organic Screening Values Used for Nature and Extent, Fate and Transport, and Risk Assessments
Organic Chemicals Detected in Surface Soil, Subsurface Soil, Sediment, and Shallow Groundwater
Charleston Naval Complex
Charleston, South Carolina

Parameter	Residential	Soil to	Soil to	Tap Water	MCL	Saltwater	Soil	Water
	Soil RBC (THQ=0.1)	GW SSL	Air SSL	RBC (THQ=0.1)		Surf. Wtr. Chronic		
Chlorobenzilate c	2400	100 a	NA	0.25	NA	NA	µG/KG	µG/L
Dibenzofuran	31000	6800 a	120000	2.4	NA	NA	µG/KG	µG/L
Di-n-butylphthalate	780000	2300000	2300000	370	NA	3.4	µG/KG	µG/L
1,2-Dichlorobenzene	700000	8500	560000	6.4	600	19.7	µG/KG	µG/L
Diethylphthalate	6300000	230000	2000000	2900	NA	75.9	µG/KG	µG/L
2,4-Dimethylphenol	160000	4300	NA	73	NA	NA	µG/KG	µG/L
Di-n-octyl phthalate	160000	10000000	10000000	73	NA	NA	µG/KG	µG/L
bis(2-Ethylhexyl)phthalate (BEHP) c	46000	1800000	31000000	4.8	NA	NA	µG/KG	µG/L
Ethyl methacrylate	700000	1500 a	NA	55	NA	NA	µG/KG	µG/L
Fluoranthene	310000	2100000	NA	150	NA	1.6	µG/KG	µG/L
Fluorene	310000	280000	NA	150	NA	NA	µG/KG	µG/L
Isodrin	NA	NA	NA	NA	NA	NA	µG/KG	µG/L
Isophorone	670000	260	4600000	70	NA	129	µG/KG	µG/L
Methapyrilene	NA	NA	NA	NA	NA	NA	µG/KG	µG/L
1-Methylnaphthalene	310000 e	72000 a	NA	150 e	NA	NA	µG/KG	µG/L
2-Methylnaphthalene	310000	230000 a	NA	150	NA	23.5	µG/KG	µG/L
2-Methylphenol (o-cresol)	390000	7500	NA	180	NA	NA	µG/KG	µG/L
3-Methylphenol (m-cresol)	390000	6700 a	NA	180	NA	NA	µG/KG	µG/L
4-Methylphenol (p-cresol)	39000	670 a	NA	18	NA	NA	µG/KG	µG/L
Naphthalene	310000	42000	NA	150	NA	23.5	µG/KG	µG/L
3-Nitroaniline	23000 b	270 a	NA	11 b	NA	NA	µG/KG	µG/L
N-Nitrosodimethylamine c	13	0.0026 a	NA	0.0013	NA	NA	µG/KG	µG/L
N-Nitroso-di-n-propylamine c	91	0.023	NA	0.0096	NA	NA	µG/KG	µG/L
Pentachlorophenol c	5300	13	NA	0.56	1	7.9	µG/KG	µG/L
Phenanthrene	230000 f	660000 a	NA	110 f	NA	NA	µG/KG	µG/L
Phenol	4700000	50000	NA	2200	NA	58	µG/KG	µG/L
Pyrene	230000	2100000	NA	110	NA	NA	µG/KG	µG/L
1,2,3,4-Tetrachlorobenzene	2300 q	200 q	NA	0.18 q	NA	129 q	µG/KG	µG/L
1,2,4-Trichlorobenzene	78000	2500	3200000	19	70	4.5	µG/KG	µG/L
2,4,6-Trichlorophenol c	58000	80	200000	6.1	NA	NA	µG/KG	µG/L
Pesticides/PCBs								
Aldrin c	38	230	3000	0.0039	NA	0.13	µG/KG	µG/L
Aroclor-1260 c	320	1000	1000	0.033	0.5	0.03	µG/KG	µG/L
alpha-BHC (alpha-HCH) c	100	0.25	800	0.011	NA	1400	µG/KG	µG/L
beta-BHC (beta-HCH) c	350	1.3	1000000000	0.037	NA	NA	µG/KG	µG/L
delta-BHC (delta-HCH) c	350 g	1.8 a	NA	0.037 g	NA	NA	µG/KG	µG/L
gamma-BHC (Lindane) c	490	4.5	NA	0.052	0.2	0.016	µG/KG	µG/L
Chlordane c	1800	5000	20000	0.19	2	0.004	µG/KG	µG/L
alpha-Chlordane c	1800 h	5000 h	20000	0.19 h	NA	0.004 p	µG/KG	µG/L
gamma-Chlordane c	1800 h	5000 h	20000	0.19 h	NA	0.004 p	µG/KG	µG/L
4,4'-DDD c	2700	8000	NA	0.28	NA	0.025	µG/KG	µG/L
4,4'-DDE c	1900	27000	NA	0.2	NA	0.14	µG/KG	µG/L

Table 5.5
 Organic Screening Values Used for Nature and Extent, Fate and Transport, and Risk Assessments
 Organic Chemicals Detected in Surface Soil, Subsurface Soil, Sediment, and Shallow Groundwater
 Charleston Naval Complex
 Charleston, South Carolina

Parameter	Residential	Soil to	Soil to	Tap Water	MCL	Saltwater	Soil	Water
	Soil RBC (THQ=0.1)	GW SSL	Air SSL	RBC (THQ=0.1)		Surf. Wtr. Chronic		
4,4'-DDT c	1900	16000	100000000	0.2	NA	0.001	µG/KG	µG/L
Dieldrin c	40	2	1000	0.0042	NA	0.0019	µG/KG	µG/L
Endosulfan I	47000 i	9000 i	NA	22 i	NA	0.0087	µG/KG	µG/L
Endosulfan II	47000 i	9000 i	NA	22 i	NA	0.0087	µG/KG	µG/L
Endosulfan sulfate	47000 i	4600 a	NA	22 i	NA	NA	µG/KG	µG/L
Endrin	2300	500	NA	1.1	2	0.0023	µG/KG	µG/L
Endrin aldehyde	2300 j	340 a	NA	1.1 j	2 j	NA	µG/KG	µG/L
Heptachlor c	140	11000	100	0.0023	0.4	0.0036	µG/KG	µG/L
Heptachlor epoxide c	70	330	5000	0.0012	0.2	0.0036	µG/KG	µG/L
Methoxychlor	39000	80000	NA	18	40	0.03	µG/KG	µG/L
Organophosphate Pesticides								
Dimethoate	1600 b	15 a	NA	0.73 b	NA	NA	µG/KG	µG/L
Disulfoton	310	39 a	NA	0.024	NA	NA	µG/KG	µG/L
Famphur	47000 o	27000 o	110000 o	22 o	NA	0.178 o	µG/KG	µG/L
Methyl parathion	2000	150 a	28000	0.91	NA	NA	µG/KG	µG/L
Parathion	47000	27000 a	110000	22	NA	0.178	µG/KG	µG/L
Phorate	1.6 b	820 a	NA	0.73 b	NA	NA	µG/KG	µG/L
Herbicides								
2,4-D	78000	370 a	7000000	6.1	70	NA	µG/KG	µG/L
2,4,5-T	78000	990 a	NA	37	NA	NA	µG/KG	µG/L
2,4,5-TP (Silvex)	63000	5600 a	NA	29	50	NA	µG/KG	µG/L
Organotin								
Dibutyltin	2300 k	NA	NA	1.1 k	NA	NA	µG/KG	µG/L
Monobutyltin	2300 k	NA	NA	1.1 k	NA	NA	µG/KG	µG/L
Tetrabutyltin	2300 k	NA	NA	1.1 k	NA	NA	µG/KG	µG/L
Tributyltin	2300 k	NA	NA	1.1 k	NA	0.01	µG/KG	µG/L
TPH								
Petroleum hydrocarbons, TPH	NA	NA	NA	NA	NA	NA	µG/KG	µG/L
TPH-DRO								
Diesel	NA	NA	NA	NA	NA	NA	µG/KG	µG/L
Naphtha C6 - C12	NA	NA	NA	NA	NA	NA	µG/KG	µG/L
TPH-GRO								
Gasoline	NA	NA	NA	NA	NA	NA	µG/KG	µG/L
Dioxin Compounds								
2,3,7,8-TCDD equivalents (TEQs) c	4.3	1600 a	NA	0.45	30	10	NG/KG	PG/L
123478-HxCDD c	43	4100	NA	4.5	NA	NA	NG/KG	PG/L

Table 5.5
Organic Screening Values Used for Nature and Extent, Fate and Transport, and Risk Assessments
Organic Chemicals Detected in Surface Soil, Subsurface Soil, Sediment, and Shallow Groundwater
Charleston Naval Complex
Charleston, South Carolina

Parameter	Residential Soil RBC (THQ=0.1)	Soil to GW SSL	Soil to Air SSL	Tap Water RBC (THQ=0.1)	MCL	Saltwater Surf. Wtr. Chronic	Soil Units	Water Units
123678-HxCDD c	43	4100 r	NA	4.5	NA	NA	NG/KG	PG/L
123789-HxCDD c	43	4100 r	NA	4.5	NA	NA	NG/KG	PG/L
1234678-HpCDD c	430	108000 a	NA	45	NA	NA	NG/KG	PG/L
OCDD c	4300	1080000 a,s	NA	450	NA	NA	NG/KG	PG/L
2378-TCDF c	43	200 a	NA	4.5	NA	NA	NG/KG	PG/L
12378-PeCDF c	85	800 a	NA	8.9	NA	NA	NG/KG	PG/L
23478-PeCDF c	8.5	100 a	NA	0.89	NA	NA	NG/KG	PG/L
123478-HxCDF c	43	216000 a	NA	4.5	NA	NA	NG/KG	PG/L
123678-HxCDF c	43	216000 t	NA	4.5	NA	NA	NG/KG	PG/L
123789-HxCDF c	43	216000 t	NA	4.5	NA	NA	NG/KG	PG/L
234678-HxCDF c	43	216000 t	NA	4.5	NA	NA	NG/KG	PG/L
1234678-HpCDF c	430	54000 a	NA	45	NA	NA	NG/KG	PG/L
OCDF c	4300	540000 a,u	NA	450	NA	NA	NG/KG	PG/L

Notes:

Screening Concentrations:

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

Soil to GW - Generic SSLs based on DAF = 10, adapted from USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or calculated using values from Table 6.2

Soil to Air - From USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or USEPA Region III Risk-Based Concentration Table, June 1996

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

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

Choice of screening values for benzo(a)pyrene equivalents (BEQs) and 2,3,7,8-TCDD equivalents (TEQs) explained in Section 6.2

a - Calculated soil to groundwater SSL value (See Table 6.2)

b - RBCs from October 1997 RBC Table

c - Carcinogenic

d - Naphthalene used as surrogate

e - 2-Methylnaphthalene used as surrogate

f - Pyrene used as surrogate

g - beta-BHC used as surrogate

h - Chlordane used as surrogate

i - Endosulfan used as surrogate

j - Endrin used as surrogate

k - Tributyltin dioxide used as surrogate

m - Acetonitrile used as surrogate

n - Benzidine used as surrogate

o - Parathion used as surrogate

p - Chlordane used as surrogate

q - 1,2,4,5-Tetrachlorobenzene used as surrogate

r - 123478-HxCDD used as surrogate

s - 1234678-HpCDD used as surrogate

t - 123478-HxCDF used as surrogate

u - 1234678-HpCDF used as surrogate

GW - Groundwater

NA - Not applicable/not available

ND - Not detected

RBC - Risk-based concentration

SSL - Soil screening level

NG/KG - Nanograms per kilogram

UG/KG - Micrograms per kilogram

PG/L - Picograms per liter

µG/L - Micrograms per liter

Table 5.6
 Inorganic Screening Values Used for Nature and Extent, Fate and Transport, and Risk Assessments
 Inorganic Chemicals Detected in Surface Soil, Subsurface Soil, Sediment, and Shallow Groundwater
 Charleston Naval Complex
 Charleston, South Carolina

Parameter	Residential Soil RBC (THQ=0.1)	Surface Soil Backgroun Reference	Subsurface Soil Background Reference	Soil to GW SSL	Soil to Air SSL	Tap Water RBC (THQ=0.1)	Shallow GW Background Reference	Deep GW Background Reference	MCL	Saltwater Surf. Wtr Chronic	Soil Units	Water Units
Inorganic Chemicals												
Aluminum (Al)	7800	27400	18900	560000 a	NA	3700	1440	180	NL	NA	MG/KG	µG/L
Antimony (Sb)	3.1	ND	ND	2.7	NA	1.5	NA	NA	6	NA	MG/KG	µG/L
Arsenic (As) c	0.43	21.6	6.45	15	750	0.045	23	14.2	50	36	MG/KG	µG/L
Barium (Ba)	550	54.2	36	820	690000	260	110	347	2000	NA	MG/KG	µG/L
Beryllium (Be)	16	0.95	0.67	32	1300	7.3	1.1	1.2	4	NA	MG/KG	µG/L
Cadmium (Cd)	7.8	0.61	0.54	4	1800	1.8	NA	NA	5	9.3	MG/KG	µG/L
Chromium (Cr) (total)	39 f	34.5	51.3	19 f	270	18 f	14.3	6.7	100	50 f	MG/KG	µG/L
Chromium (Cr6) (hexavalent)	39	ND	ND	19	270	18	ND	ND	NL	50	MG/KG	µG/L
Cobalt (Co)	470	5.8	3.48	990 a	NA	220	2.2	2.3	NL	NA	MG/KG	µG/L
Copper (Cu)	310	240	11.5	5600 a	NA	150	4.4	NA	1300 e	2.9	MG/KG	µG/L
Cyanide	160	ND	ND	20	NA	73	25.2	27.2	200	1	MG/KG	µG/L
Lead (Pb)	400 d	203	12.3	400 d	400	15 e	4.4	NA	15 e	8.5	MG/KG	µG/L
Manganese (Mn)	160	419	118	480 a	NA	73	5430	261	NL	NA	MG/KG	µG/L
Mercury (Hg)	2.3 b	0.47	ND	1	10	1.1 b	NA	NA	2	0.025	MG/KG	µG/L
Nickel (Ni)	160	23.9	15.7	65	13000	73	13.3	6.8	100	8.3	MG/KG	µG/L
Selenium (Se)	39	1.49	1.77	2.6	NA	18	ND	ND	50	71	MG/KG	µG/L
Silver (Ag)	39	NA	ND	17	NA	18	NA	ND	NL	0.23	MG/KG	µG/L
Thallium (Tl)	0.55	ND	ND	0.36	NA	0.26	6.6#	7.1#	2	21.3	MG/KG	µG/L
Tin (Sn)	4700	7.5	ND	5500 a	NA	2200	NA	347	NL	NA	MG/KG	µG/L
Vanadium (V)	55	113	38.1	3000	NA	26	14	15.7	NL	NA	MG/KG	µG/L
Zinc (Zn)	2300	206	36.2	6200	NA	1100	24.4	22.1	NL	86	MG/KG	µG/L

Notes:

Screening Concentrations:

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

Soil to GW - Generic SSLs based on DAF = 10, adapted from USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or calculated using values from Table 6.2

Soil to Air - From USEPA Soil Screening Guidance: Technical Background Document, May 1996 (first preference), or USEPA Region III Risk-Based Concentration Table, June 1996

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

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

Background reference values as per June 1997 project team technical subcommittee meeting

a - Calculated soil to groundwater SSL value (See Table 6.2)

b - Mercury RBCs from October 1997 RBC Table

c - Carcinogenic

d - USEPA de facto residential soil level

- Assume background equals 2.0 ug/L pending results of basewide thallium study.

e - USEPA treatment technique action level

f - Assumes hexachrome

GW - Groundwater

NA - Not available/Not applicable

ND - Not detected

RBC - Risk-based concentration

SSL - Soil screening level

MG/KG - Milligrams per kilogram

µG/L - Micrograms per liter

6.0 FATE AND TRANSPORT

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

After evaluating Zone I for the above characteristics, four potential routes of constituent migration have been identified:

- Constituents leaching from soil to groundwater
- Constituents migrating from shallow groundwater into surface water bodies
- VOCs released from surface soil into air
- Surface soil erosion and runoff of constituents into adjacent sediment deposition zones

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 due to the concentration gradient. In very fine sediments with very low hydraulic conductivities, diffusive transport may be the dominant mode of migration.

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

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

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

6.1 Properties Affecting Fate and Transport

Numerous chemical and physical properties of constituents and their 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 ($T_{1/2}$), Henry's law constant (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.

Table 6.1
Constituent Characteristics Based On
Chemical and Physical Properties

Chemical Property	Critical Value	High (>)	Low (<)
Vapor pressure	10 ⁻³ mm Hg	volatile	nonvolatile
Density ^a	1 g/cm ³	sinks/falls	floats/rises
Solubility ^a	0 to 100 mg/L	leaches from soil, mobile in water, does not readily volatilize from water	sorbs to soil, immobile in water, volatilizes from water
Henry's law constant	5x10 ⁻⁶ to 5x10 ⁻³ 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 ^a (K _{oc})	10 to 10,000 L _{water} /kg _{oc}	tends to sorb to organic material in soil; immobile in the soil matrix	tends not to sorb to organic material in soil; mobile in the soil matrix
Molecular weight	400 g/mole	difficult to predict chemical's behavior with respect to the properties listed above.	exhibits predictable behavior with respect to the properties listed above.

Notes:

- ^a = Critical values were based on literature review and professional judgment.
- mm Hg = Millimeters of mercury
- atm-m³/mole = Atmosphere cubic meters per mole
- L_{water}/kg_{oc} = Liters of water per kilogram of organic carbon
- g/cm³ = Grams per cubic centimeter
- mg/L = Milligrams per liter
- g/mole = Grams per mole
- K_{oc} = Organic carbon/Water Partitioning Coefficient

For each constituent detected in Zone I soil and sediment samples, Table 6.2 lists chemical and physical properties needed to compute soil screening levels for protection of groundwater. Section 10 discusses AOC- or SWMU-specific fate and transport, migration pathways, and potential receptors.

Compounds with similar chemical and physical properties display similar fate and transport behavior, which facilitates grouping them 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 are TOC, normalized partitioning coefficient (K_d), CEC, redox conditions, pH, soil type, and retardation factor (R). These properties are briefly describe below.

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 the fraction of organic carbon content (f_{oc}) of the soil (e.g., grams of solid organic carbon per gram of dry soil).

Table 6.2
Soil to Groundwater and Soil-to-Air Soil Screening Levels
Chemicals Detected in Surface Soil, Subsurface Soil, and Sediment
Charleston Naval Complex
Charleston, South Carolina

Site-Specific Parameters:											
Fraction Organic Carbon (--):	0.002	Dimension- less Henry's Law Constant [HF] (--)	Organic Carbon Water Part. Coeff. [Koc] (L/kg)	Tap Water RBC (mg/L)	MCL/ MCLG (mg/L)	Acceptable Ground- water Conc. (mg/L)	Target Leachate Conc. (mg/L)	Calculated Zonewide Soil to GW SSL (mg/kg)	USEPA Generic Soil to GW SSL {DAF=20} (mg/kg)	Soil to Air SSL (mg/kg)	
Dilution Factor (--):	10										
Dry Soil Bulk Density (kg/L):	1.5										
Water-filled Soil Porosity (--):	0.3										
Air-filled Soil Porosity (--):	0.13										
Soil Porosity (--):	0.43										
Volatile Organic Compounds											
Acetone (2-Propanone)	1.59E-03	5.75E-01	3.7	NL	3.7	37	7.4	16	100000		
Acetonitrile	1.40E-03	4.70E-01	0.22	NL	0.22	2.2	0.44	NL	NDA		
Benzene	2.28E-01	5.89E+01	0.00036	0.005	0.005	0.05	0.0169	0.03	0.8		
2-Butanone (MEK)	2.30E-03	1.91E+00	1.9	NL	1.9	19	3.88	NL	NDA		
Carbon disulfide	1.24E+00	4.57E+01	1	NL	1	10	3.99	32	720		
Chlorobenzene	1.52E-01	2.19E+02	0.035	NL	0.035	0.35	0.228	1	130		
Chloromethane	3.60E-01	6.50E+00	0.0015	NL	0.0015	0.015	0.00366	NL	0.063		
1,1-Dichloroethene	1.07E+00	5.89E+01	4.4E-05	0.007	0.007	0.07	0.0287	0.06	0.07		
1,2-Dichloroethene (total)	NDA	NDA	0.055	NL	0.055	0.55	NA	NL	1200		
Methylene chloride	8.98E-02	1.17E+01	0.0041	NL	0.0041	0.041	0.0095	0.02	13		
Propionitrile	NDA	NDA	NL	NL	NA	NA	NA	NL	NDA		
Tetrachloroethene	7.54E-01	1.55E+02	0.0011	0.005	0.005	0.05	0.0288	0.06	11		
Toluene	2.72E-01	1.82E+02	0.75	1	1	10	5.9	12	650		
Trichloroethene	4.22E-01	1.66E+02	0.0016	0.005	0.005	0.05	0.0284	0.06	5		
Trichlorofluoromethane (CFC-11)	4.00E+00	1.20E+02	1.3	NL	1.3	13	10.2	NL	790		
Trichlorotrifluoroethane (Freon 113)	NDA	NDA	59	NL	59	590	NA	NL	2400		
Xylene (total)	2.48E-01	2.40E+02	12	10	10	100	70.1	NL	320		
Semivolatile Organic Compounds											
Acenaphthene	6.36E-03	7.08E+03	2.2	NL	2.2	22	316	570	NDA		
Acenaphthylene	4.50E-03	3.10E+03	1.5	NL	1.5	15	96	NL	NDA		
Acetophenone	4.50E-04	4.10E+01	4.2E-05	NL	4.2E-05	0.00042	0.00012	NL	NDA		
4-Aminobiphenyl	NDA	NDA	NL	NL	NA	NA	NA	NL	NDA		
Anthracene	2.67E-03	2.95E+04	11	NL	11	110	6512	12000	NDA		
Benzoic acid	6.31E-05	6.00E-01	150	NL	150	1500	302	400	NDA		
Benzo(g,h,i)perylene	5.70E-06	3.90E+06	1.5	NL	1.5	15	117003	NL	NDA		
Benzo(a)pyrene equivalents (BEQs)	6.03E-07	3.98E+05	9.2E-06	0.0002	0.0002	0.002	1.59	NL	NDA		
Benzo(a)anthracene	1.37E-04	3.98E+05	9.2E-05	NL	9.2E-05	0.00092	0.73	2	NDA		
Benzo(a)pyrene	4.63E-05	1.02E+06	9.2E-06	0.0002	0.0002	0.002	4.08	8	NDA		
Benzo(b)fluoranthene	4.55E-03	1.23E+06	9.2E-05	NL	9.2E-05	0.00092	2.26	5	NDA		
Benzo(k)fluoranthene	3.40E-05	1.23E+06	0.00092	NL	0.00092	0.0092	22.6	49	NDA		
Chrysene	3.88E-03	3.98E+05	0.0092	NL	0.0092	0.092	73	160	NDA		
Dibenzo(a,h)anthracene	6.03E-07	3.80E+06	9.2E-06	NL	9.2E-06	9.2E-05	0.70	2	NDA		
Indeno(1,2,3-cd)pyrene	6.56E-05	3.47E+06	9.2E-05	NL	9.2E-05	0.00092	6.4	14	NDA		
Butylbenzylphthalate	5.17E-05	5.75E+04	7.3	NL	7.3	73	8410	930	930		
Chlorobenzilate	3.70E-06	2.00E+04	0.00025	NL	0.00025	0.0025	0.101	NL	NDA		
Dibenzofuran	5.30E-04	1.40E+04	0.024	NL	0.024	0.24	6.8	NL	120		
Di-n-butylphthalate	3.85E-08	3.39E+04	3.7	NL	3.7	37	2516	2300	2300		
Diethylphthalate	1.85E-05	2.88E+02	29	NL	29	290	225	470	2000		
Di-n-octylphthalate	2.74E-03	8.32E+07	0.73	NL	0.73	7.3	1.21E+06	10000	10000		
bis(2-Ethylhexyl)phthalate (BEHP)	4.18E-06	1.51E+07	0.0048	0.006	0.006	0.06	1812	3600	31000		
Ethyl methacrylate	3.40E-02	3.70E+01	0.55	NL	0.55	5.5	1.5	NL	NDA		
Fluoranthene	6.60E-04	1.07E+05	1.5	NL	1.5	15	3213	4300	NDA		
Fluorene	2.61E-03	1.38E+04	1.5	NL	1.5	15	417	560	NDA		
Isodrin	NDA	NDA	NL	NL	NA	NA	NA	NL	NDA		
Isophorone	2.72E-04	4.68E+01	0.07	NL	0.070	0.700	0.206	0.5	0.25		
Methapyrilene	NDA	NDA	NL	NL	NA	NA	NA	NL	NDA		
1-Methylnaphthalene	1.60E-02	2.30E+03	1.5	NL	1.5	15	72	NL	NDA		
2-Methylnaphthalene	2.10E-02	7.50E+03	1.5	NL	1.5	15	228	NL	NDA		
2-Methylphenol (o-cresol)	4.92E-05	9.12E+01	1.8	NL	1.8	18	6.9	15	NDA		
3-Methylphenol (m-cresol)	3.50E-05	8.50E+01	1.8	NL	1.8	18	6.7	NL	NDA		
4-Methylphenol (p-cresol)	3.20E-05	8.50E+01	0.18	NL	0.18	1.8	0.67	NL	NDA		
Naphthalene	1.98E-02	2.00E+03	1.5	NL	1.5	15	63	84	NDA		
3-Nitroaniline	5.70E-06	2.20E+01	0.11	NL	0.11	1.1	0.268	NL	NDA		
N-Nitrosodimethylamine	4.90E-05	2.80E-01	1.3E-06	NL	1.3E-06	1.3E-05	2.6E-06	NL	NDA		

Table 6.2
Soil to Groundwater and Soil-to-Air Soil Screening Levels
Chemicals Detected in Surface Soil, Subsurface Soil, and Sediment
Charleston Naval Complex
Charleston, South Carolina

Site-Specific Parameters:	Dimensionless	Organic Carbon	Henry's Law Constant [H'] (-)	Tap Water RBC (mg/L)	MCL/ MCLG (mg/L)	Acceptable Ground-water Conc. (mg/L)	Target Leachate Conc. (mg/L)	Calculated Zonewide Soil to GW SSL (mg/kg)	USEPA Generic Soil to GW SSL {DAF=20} (mg/kg)	Soil to Air SSL (mg/kg)
N-Nitroso-di-n-propylamine	9.23E-05	2.40E+01	9.6E-06	NL	9.6E-06	9.6E-05	2.38E-05	5E-05	NDA	
Pentachlorophenol	1.00E-06	5.92E+02	0.00056	0.001	0.001	0.01	0.014	0.03	NDA	
Phenanthrene	9.40E-04	3.00E+04	1.1	NL	1.1	11	662	NL	NDA	
Pyrene	4.51E-04	1.05E+05	1.1	NL	1.1	11	2312	4200	NDA	
Pesticide/PCB Compounds										
Aldrin	6.97E-03	2.45E+06	4E-06	NL	4E-06	4E-05	0.196	0.5	3	
Aroclor 1260	NDA	3.09E+05	3.30E-05	0.0005	0.0005	0.005	3.091	1	1	
alpha-BHC (alpha-HCH)	4.35E-04	1.23E+03	1.1E-05	NL	1.1E-05	0.00011	0.00029	0.0005	0.8	
beta-BHC (beta-HCH)	3.05E-05	1.26E+03	3.7E-05	NL	3.7E-05	0.00037	0.00101	0.003	1000000	
delta-BHC (delta-HCH)	1.80E-05	2.30E+03	3.7E-05	NL	3.7E-05	0.00037	0.00178	NL	NDA	
gamma-BHC (Lindane)	5.74E-04	1.07E+03	5.2E-05	0.0002	0.0002	0.002	0.00468	0.009	NDA	
Chlordane	1.99E-03	1.20E+05	0.00019	0.002	0.002	0.02	4.80	10	20	
alpha-Chlordane	1.99E-03	1.20E+05	0.00019	0.002	0.002	0.02	4.80	10	20	
gamma-Chlordane	1.99E-03	1.20E+05	0.00019	0.002	0.002	0.02	4.80	10	20	
4,4'-DDD	1.64E-04	1.00E+06	0.00028	NL	0.00028	0.0028	5.6	16	NDA	
4,4'-DDE	8.61E-04	4.47E+06	0.0002	NL	0.0002	0.002	17.9	54	NDA	
4,4'-DDT	3.32E-04	2.63E+06	0.0002	NL	0.0002	0.002	10.5	32	1000000	
Dieldrin	6.19E-04	2.14E+04	4.2E-06	NL	4.2E-06	4.2E-05	0.00181	0.004	1	
Endosulfan I	4.59E-04	2.14E+03	0.22	NL	0.22	2.2	9.9	18	NDA	
Endosulfan II	4.59E-04	2.14E+03	0.22	NL	0.22	2.2	9.9	18	NDA	
Endosulfan sulfate	8.60E-02	9.50E+02	0.22	NL	0.22	2.2	4.6	NL	NDA	
Endrin	3.08E-04	1.23E+04	0.011	0.002	0.002	0.02	0.496	1	NDA	
Endrin aldehyde	NDA	8.50E+03	0.011	0.002	0.002	0.02	0.344	1	NDA	
Heptachlor	6.07E+01	1.41E+06	2.3E-06	0.0004	0.0004	0.004	11.3	23	0.1	
Heptachlor epoxide	3.90E-04	8.32E+04	1.2E-06	0.0002	0.0002	0.002	0.333	0.7	5	
Methoxychlor	6.48E-04	9.77E+04	0.18	0.04	0.04	0.4	78	160	NDA	
Organophosphate Pesticides										
Dimethoate	2.50E-09	4.80E+00	0.0073	NL	0.0073	0.073	0.015	NL	NDA	
Disulfoton	1.60E-04	8.00E+03	0.00024	NL	0.00024	0.0024	0.039	NL	NDA	
Famphur	NDA	NDA	NL	NL	NA	NA	NA	NL	NDA	
Methyl parathion	4.10E-06	7.00E+02	0.0091	NL	0.0091	0.091	0.146	NL	28	
Parathion	2.30E-05	6.00E+03	0.22	NL	0.22	2.2	26.8	NL	110	
Phorate	NDA	5.50E+03	0.0073	NL	0.0073	0.073	0.818	NL	NDA	
Herbicides										
2,4-D	4.10E-07	1.65E+02	0.061	0.07	0.07	0.7	0.371	NL	7000	
2,4,5-T	NDA	NDA	0.37	NL	NA	NA	NA	NL	NDA	
2,4,5-TP (Silvex)	3.20E-09	5.50E+03	0.29	0.05	0.05	0.5	5.60	NL	NDA	
Dioxin Compounds										
2,3,7,8-TCDD equivalents (TEQs)	3.2E-03	2.7E+06	4.5E-10	3E-08	3E-08	3E-07	0.0016	NL	NDA	
123478-HxCDD	3.2E-03	4.6E+07	4.5E-09	NL	4.5E-09	4.5E-08	0.0041	NL	NDA	
123678-HxCDD	3.2E-03	4.6E+07	4.5E-09	NL	4.5E-09	4.5E-08	0.0041	NL	NDA	
123789-HxCDD	3.2E-03	4.6E+07	4.5E-09	NL	4.5E-09	4.5E-08	0.0041	NL	NDA	
1234678-HpCDD	3.2E-03	1.2E+08	4.5E-08	NL	4.5E-08	4.5E-07	0.1080	NL	NDA	
OCDD	3.2E-03	1.2E+08	4.5E-07	NL	4.5E-07	4.5E-06	1.0800	NL	NDA	
2378-TCDF	3.2E-03	2.7E+06	4.5E-09	NL	4.5E-09	4.5E-08	0.0002	NL	NDA	
12378-PeCDF	3.2E-03	4.3E+06	8.9E-09	NL	8.9E-09	8.9E-08	0.0008	NL	NDA	
23478-PeCDF	3.2E-03	6.5E+06	8.9E-10	NL	8.9E-10	8.9E-09	0.0001	NL	NDA	
123478-HxCDF	3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.2160	NL	NDA	
123678-HxCDF	3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.2160	NL	NDA	
123789-HxCDF	3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.2160	NL	NDA	
234678-HxCDF	3.2E-03	2.4E+09	4.5E-09	NL	4.5E-09	4.5E-08	0.2160	NL	NDA	

Table 6.2
Soil to Groundwater and Soil-to-Air Soil Screening Levels
Chemicals Detected in Surface Soil, Subsurface Soil, and Sediment
Charleston Naval Complex
Charleston, South Carolina

Site-Specific Parameters:															
	Fraction Organic Carbon (-):	Dilution Factor (-):	Dry Soil Bulk Density (kg/L):	Water-filled Soil Porosity (-):	Air-filled Soil Porosity (-):	Soil Porosity (-):	Dimension-less Henry's Law Constant [H] (-)	Organic Carbon Water Partitioning Coeff. [Koc] (L/kg)	Tap Water RBC (mg/L)	MCL/MCLG (mg/L)	Acceptable Groundwater Concent. (mg/L)	Target Leachate Conc. (mg/L)	Calculated Zonewide Soil to GW SSL (mg/kg)	USEPA Generic Soil to GW SSL {DAF=20} (mg/kg)	Soil to Air SSL (mg/kg)
1234678-HpCDF	0.002	10	1.5	0.3	0.13	0.43	3.2E-03	6.0E+07	4.5E-08	NL	4.5E-08	4.5E-07	0.0540	NL	NDA
OCDF							3.2E-03	6.0E+07	4.5E-07	NL	4.5E-07	4.5E-06	0.5400	NL	NDA
Organotin															
Dibutyltin							NDA	NDA	0.011	NL	NA	NA	NA	NL	NDA
Monobutyltin							NDA	NDA	0.011	NL	NA	NA	NA	NL	NDA
Tetrabutyltin							NDA	NDA	0.011	NL	NA	NA	NA	NL	NDA
Tributyltin							NDA	NDA	0.011	NL	NA	NA	NA	NL	NDA
Inorganics															
<i>Kd (6.8 pH)</i>															
Aluminum							NA	1.50E+03	37	NL	37	370	5.55E+05	NL	NDA
Antimony							NA	4.50E+01	0.015	0.006	0.006	0.06	2.71	5	NDA
Arsenic							NA	2.90E+01	4.5E-05	0.05	0.05	0.5	14.6	29	750
Barium							NA	4.10E+01	2.6	2	2	20	824	1600	690000
Beryllium							NA	7.90E+02	0.073	0.004	0.004	0.04	31.6	63	1300
Cadmium							NA	7.50E+01	0.018	0.005	0.005	0.05	3.76	8	1800
Chromium (total)							NA	1.90E+01	0.18	0.1	0.1	1	19.2	38	270
Chromium (trivalent)							NA	1.80E+06	37	NL	37	370	6.66E+08	NL	NDA
Chromium (hexavalent)							NA	1.90E+01	0.18	0.1	0.1	1	19.2	38	270
Cobalt							NA	4.50E+01	2.2	NL	2.2	22	994	NL	NDA
Copper							NA	4.30E+02	1.5	1.3	1.3	13	5593	NL	NDA
Cyanide							NA	1.00E+01	0.73	0.2	0.2	2	20.4	40	NDA
Lead							NA	9.00E+02	0.015	NL	0.015	0.15	135	400	400
Manganese							NA	6.50E+01	0.73	NL	0.73	7.3	476	NL	NDA
Mercury							4.67E-01	5.20E+01	0.011	0.002	0.002	0.02	1.04	2	10
Nickel							NA	6.50E+01	0.73	0.1	0.1	1	65	130	13000
Selenium							NA	5.00E+00	0.18	0.05	0.05	0.5	2.60	5	NDA
Silver							NA	8.30E+00	0.18	NL	0.18	1.8	15.3	34	NDA
Thallium							NA	7.10E+01	0.0026	0.0005	0.0005	0.005	0.356	0.7	NDA
Tin							NA	2.50E+01	22	NL	22	220	5544	NL	NDA
Vanadium							NA	1.00E+03	0.26	NL	0.26	2.6	2601	6000	NDA
Zinc							NA	6.20E+01	11	NL	11	110	6842	12000	NDA

Notes:

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

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

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

Acceptable Groundwater Concentration - MCL/MCLG if available, otherwise tap water RBC

Target Leachate Concentration - Acceptable groundwater concentration multiplied by dilution factor

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

Soil to Air SSL - From USEPA Soil Screening Guidance: Technical Background Document, Appendix A, May 1996 (first preference), or USEPA Region III Risk-Based Concentration Table, June 1996

Choice of screening values for benzo(a)pyrene equivalents (BEQs) and 2,3,7,8-TCDD equivalents (TEQs) explained in Section 6.2

Kd - Normalized partitioning coefficient

kg/L - Kilograms per liter

NA - Not applicable

L/kg - Liters per kilogram

NDA - No data available

mg/kg - Milligrams per kilogram

NL - Not listed

mg/L - Milligrams per liter

Normalized Partitioning Coefficient

K_d is used to predict the capacity for a constituent to partition between soil and water. To estimate K_d , the constituent's K_{oc} is adjusted by the soil's TOC: $K_d = K_{oc} \times f_{oc}$. Soil/constituent combinations with higher K_d values have a higher potential for sorption.

Cation Exchange Capacity

CEC reflects the soil's capacity to adsorb ions, neutralizing ionic deficiencies on particle surfaces. Generally, trivalent ions are preferentially adsorbed to soil over divalent ions, and divalent ions are preferentially adsorbed over monovalent ions. Soils with high CEC values have the potential to adsorb inorganic ions and organic compounds with dipole moments. CEC varies directly with clay content, depending on the type of clay. The amount of cation exchange also depends on soil pH.

Redox Conditions

Redox is the process that includes oxidation (loss of electrons), and reduction (gain of electrons). This change in oxidation state generates products different from the reactants in solubility, toxicity, reactivity, and mobility. 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 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 retardation factor is a measure of the ability of an aquifer matrix to inhibit the movement of a chemical by preferentially binding contaminants with high organic carbon/water partitioning coefficients. Retardation factors are calculated as follows:

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

Where:

R = Retardation factor

K_d = Normalized partitioning coefficient (liters per kilogram [L/kg])

ρ_b = Soil dry bulk density (kilograms per liter [kg/L])

n = Soil total porosity

Table 6.3 summarizes the soil and aquifer parameters used to evaluate fate and transport for Zone I. The geometric mean CEC of nine surface soil samples (collected at eight AOCs/SWMUs) is 9.9 millequivalents per 100 grams (meq/100g), ranging from 4.5 to 26 meq/100g. Moderate CEC values and nonacidic soil conditions imply limited inorganic mobility by the processes of advection, diffusion, and dispersion. TOC values for the same nine soil samples analyzed for CEC (above) ranged from 3,232 to 45,268 milligrams per kilogram (mg/kg), with a geometric

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Table 6.3
 Soil and Aquifer Parameters Used to Evaluate Fate and Transport

Parameter	Number of Samples	Zone I Minimum Value	Zone I Maximum Value	Zone I Geometric Mean Value	Units
CEC	9	4.5	26	9.9	meq/100g
TOC ^a	9	3,232	45,268	11,600	mg/kg
pH ^b	19	6.7	9.2	7.5	Standard Units
Total Porosity ^c	4	0.32	0.41	0.37	decimal %
Dry Bulk Density ^c	4	1.51	1.75	1.63	kg/L
Hydraulic Conductivity ^d					
Shallow Wells	11	0.021	6.94	0.76	ft/d
Deep Wells	8	0.0012	6.16	0.33	ft/d

Notes:

- a = TOC soil results only; sediment results discussed in text
 - b = pH soil results only; sediment results discussed in text
 - c = Total porosity and dry bulk density values based on Zone H Shelby tube aquifer samples (see text)
 - d = Hydraulic conductivity values based on slug test results
- ft/d = feet per day

mean of 11,600 mg/kg. Reported TOC values for nine sediment samples collected at the DMA 1
 were somewhat lower (geomean = 10,100 mg/kg) than those for soil, while values for five 2
 sediment samples from three other sites were higher (geomean = 18,800 mg/kg). Soil TOC 3
 readings document a relatively high organic content that should inhibit movement of 4
 contaminants, particularly organic compounds with high K_{oc} values, due to extensive adsorption. 5
 The geometric mean pH of 19 Zone I soil samples (17 surface soil samples collected at six sites 6
 and two subsurface soil samples from AOC 687) is 7.5; the geometric mean of pH readings for 7
 six sediment samples collected at three sites is 7.2. Reported pH values for Zone I soil range from 8
 6.7 to 9.2, and from 6.2 to 10.1 for sediment. All pH readings were measured by the analytical 9
 laboratory as part of the prescreening process for pesticide analysis. Geotechnical results from 10
 the four Shelby tube samples collected from aquifer sands in adjoining Zone H served as 11
 surrogates to estimate sandy soil and aquifer properties in Zone I. The average total porosity of 12
 the shallow aquifer in Zone I is 37%, as determined through Shelby tube analysis of the four 13

Zone H samples, with a range of values from 32% to 41%. All four Zone H samples were collected from the 10 to 12 ft bgs soil interval. Dry bulk density of the same four aquifer samples ranges from 1.51 kg/L to 1.75 kg/L, with a geometric mean of 1.63 kg/L.

Although 20 Shelby tube samples were collected from Zone I well borings (Table 2.2 in Section 2), sandy soil or aquifer samples could not be recovered by this method.

As presented in Section 2.3.6, the geometric mean horizontal hydraulic conductivity (K_h) sediments in shallow wells, based on slug tests in 11 Zone I wells, ranges from 0.021 ft/day to 6.94 ft/day, with a geometric mean of 0.76 ft/day for the upper quaternary fill sediments. Measured in eight deep Zone I wells, the geometric mean horizontal hydraulic conductivity ranges from 0.0012 ft/day to 6.16 ft/day, with a geometric mean of 0.33 ft/day. Corresponding hydraulic conductivity values for adjoining Zone H are 1.05 ft/day for shallow wells and 0.89 ft/day for deep wells. Consistent with the heterogeneity of surficial deposits (Section 2.2.3.2) and the interbedded nature of deeper sediments, the spatial distribution of K_h values in Zone I exhibits no apparent pattern.

Table 6.4 lists the approximate travel time for advective groundwater flow from various Zone I sites to downgradient water bodies (Cooper River or Shipyard Creek), depending on direction of flow, local groundwater gradient, and local hydraulic conductivity. A river gauging station at the Army Depot in North Charleston at mile 10.5 of the Cooper River, upstream from Zone I, reported a mean river stage of 1.06 feet for the year 10/92 to 9/93. Downstream from Zone I 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 feet local elevation for water in the Cooper River and the lower portion of Shipyard Creek.

Table 6.4
 Travel Time Analysis
 Advective Transport Only

AOC/SWMU	Hydraulic Conductivity (ft/day) ^a	Horizontal Gradient (—)	Effective Porosity (—) ^b	Horizontal Velocity (ft/year)	Horizontal Distance (feet) ^c	Travel Time (years)
AOC 671	2.72	0.0137	0.20	68.0	175	2.6
AOCs 672-673	0.790	0.0123	0.20	17.7	200	11
AOCs 675-676	0.506	0.0100	0.20	9.23	170	18
AOC 677	0.267	0.0110	0.20	5.36	100	19
AOC 678-679	4.37	0.0200	0.20	160	110	0.7
AOC 680	1.94	0.0173	0.20	61.3	150	2.4
AOC 681	0.760	0.00711	0.20	9.86	450	46
AOC 685	1.26	0.0200	0.20	46.0	110	2.4
AOC 687, SWMU 16	0.311	0.0175	0.20	9.93	160	16
AOC 688	1.10	0.0167	0.20	33.5	150	4.5
SWMU 12	1.57	0.00625	0.20	17.9	480	27
SWMU 177	1.54	0.00400	0.20	11.2	200	18
RTC	1.54	0.00375	0.20	10.5	320	30

Notes:

- a = Based on slug test data from nearby and zonewide monitoring wells
- b = Estimated, based on textural classes of shallow aquifer samples (USEPA 1989)
- c = Based on the potentiometric path of groundwater flow

6.2 Fate and Transport Approach for Zone I

Each site-specific fate and transport discussion in Section 10 begins with a description of site characteristics that can affect constituent migration. As previously discussed, four potential routes of constituent migration have been identified for Zone I. Each AOC and SWMU has been evaluated for site conditions that promote these migration pathways. In some cases, it is logical to evaluate fate and transport for a combination of AOCs/SWMUs based on their proximity.

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 potential transfer mechanism based on empirical data available for each medium sampled. For example, if a constituent is found in soil as well as groundwater, it is reasonable to conclude that the soil constituent may be leaching to the groundwater. In support of such conclusions, Zone I fate and transport were evaluated using constituent-specific chemical and physical properties, assumed soil and aquifer properties, USEPA risk-based screening concentrations and maximum contaminant levels, and grid-based background concentrations (Tables 5.5 and 5.6 in Section 5, and Table 6.2).

The following sections describe the methods used to evaluate 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), nor for chlorides or sulfates, which are abundant in shallow coastal/estuarine environments. Section 10 contains discussions of site-specific fate and transport, migration pathways, and potential receptors.

6.2.1 Soil-to-Groundwater Cross-Media Transport

A phased screening approach was used to evaluate the potential for soil-to-groundwater migration of constituents, focusing attention on chemicals that have the greatest potential for impacting the surficial aquifer. Due to the nature and age of most 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, moderately permeable soil layer above the water table at Zone I. 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 with leachability-based generic SSLs as presented in the USEPA *Soil Screening Guidance: Technical Background Document* (1996a). SSLs were modified from those in the *Technical Background Document* or calculated independently, as described below, assuming a dilution attenuation factor (DAF) of 10.

Soil background values for inorganics in Zone I were determined after consultation with the project team technical subcommittee. At the request of SCDHEC, however, background values were not considered during initial comparisons of maximum soil concentrations with SSLs. The theoretical effect of this exclusion from the screening process was to identify all possible threats to groundwater, irrespective of their sources as naturally occurring or anthropogenic soil constituents. Since chromium is the only inorganic chemical in Zone I soil samples with background values greater than its SSL (conservatively assuming that all detected chromium is hexavalent), the practical effect of the exclusion was limited.

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

- Tap-water risk-based screening concentrations as presented in the USEPA Region III RBC table (April 15, 1998), assuming a target hazard quotient (THQ) of 1.0.
- Groundwater background values for Zone I inorganics, 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 with the potential to impact the surficial aquifer, identifying areas where relatively recent releases or immobile constituents may not yet have

impacted existing monitoring wells. A conservative screening approach was employed using generic SSLs to provide the most comprehensive list of constituents that could impact groundwater. It was assumed that if soil concentrations do not exceed conservative leachability-based screening levels, there is no significant threat to groundwater via leachate migration. Likewise, if current groundwater concentrations do not exceed risk-based tap-water screening values or background, it was concluded that current soil/groundwater equilibria sufficiently protect human health relative to potential groundwater ingestion exposure pathways.

The soil-to-groundwater migration pathway was assessed using generic SSLs that assume a DAF of 10, rather than site-specific SSLs. DAFs higher than 10 would be justified for Zone I 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). Section 6.3 compares assumptions underlying the fate and transport screening process with site-specific and zonewide conditions, including factors affecting dilution and attenuation of contaminants. A DAF of 10 was chosen rather than the value of 20 used in RFI reports for some other CNC zones because the relatively low hydraulic conductivities and gradients in Zone I produce less leachate dilution by groundwater, according to the equations in the *Soil Screening Guidance*. Higher DAF values would translate into higher, less conservative SSLs. As a screening tool, generic SSLs are used to compile a conservative, inclusive list of potential fate and transport concerns; detailed fate and transport assessments then evaluate the identified concerns to facilitate risk management decisions.

Table 6.2 contains physical site characteristics along with chemical and physical properties and regulatory standards for each constituent detected in Zone I soil and sediment samples, enabling calculation of SSLs for protection of groundwater. Where generic SSLs for organics were not listed in the *Technical Background Document* or the Region III RBC table, they were calculated using the chemical property values shown in Table 6.2. Values of HL, K_{oc} , and K_d not available

in the *Technical Background Document* or the USEPA *Soil Screening Guidance: User's Guide* 1
(1996b), were obtained from the Superfund Chemical Data Matrix (SCDM), (USEPA, 1997a), 2
which is the source of the values in the two *Soil Screening Guidance* documents. Values of K_d 3
for inorganics not available in the EPA documents were taken from the TERRA model (Baes, 4
C.S. III et al., September 1984), which is considered a standard reference source. Where 5
calculated SSLs in Table 6.2 differed from EPA's generic values, the EPA values prevailed. 6
Differences between the EPA generic listed values and calculated SSLs were generally due to 7
EPA's use of nonstandard target leachate concentrations as starting points for their calculations: 8
rather than starting with their own listed RBCs or MCLs, EPA often rounds them off to one 9
significant figure. EPA's starting-point values are listed in Attachment D, "Regulatory and 10
Human Health Benchmarks for SSL Development," of the *User's Guide*. 11

Because all AOC/SWMU shallow monitoring wells were drilled to depths of 13 ft bgs or less, 12
background values for inorganics in shallow groundwater were used as the screening alternative 13
to tap-water RBCs. The lithology of Zone I's surficial aquifer is complex, with discontinuous 14
sandy units and widespread aquitards of marsh clay. Vertical hydraulic gradients measured at 15
pairs of wells with different depths are almost all positive (Section 2.3.4), indicating general 16
downward movement of groundwater. Arsenic, manganese, and thallium are the only inorganics 17
with shallow groundwater background values higher than their corresponding tap-water RBCs. 18
Background concentrations of inorganics in deep groundwater are generally equivalent to or lower 19
than those of shallow groundwater (Table 5.6 in Section 5). 20

Because unique risk assessment procedures are mandated by USEPA for the seven primary PAHs 21
and the chlorinated dibenzodioxins/dibenzofurans, these two groups were also treated uniquely 22
in the fate and transport screening assessment. Although each cPAH has its own fate and transport 23
and toxicity characteristics and its own SSL, evaluating these compounds individually does not 24
allow for their combined carcinogenic effects as measured by BEQs. To estimate a conservative 25

soil screening level for BEQs, the lowest HL constant and organic carbon/water partitioning coefficient of the seven cPAH compounds were combined with benzo(a)pyrene's MCL, as documented in Table 6.2. The resulting calculated SSL of 1,600 micrograms per kilogram ($\mu\text{g}/\text{kg}$) (for $\text{DAF} = 10$) should be used as a "pre-screening" value. If total BEQs in a soil sample exceed 1,600 $\mu\text{g}/\text{kg}$, then the concentrations, distribution, and transport characteristics of the individual cPAHs should be examined to gauge the potential threat to groundwater. Using the lowest values of HL and K_{oc} to calculate the SSL ensures that a BEQ value based largely on (for example) benzo(a)anthracene, which is more mobile in soil than benzo(a)pyrene, will not result in underestimating the mobility and groundwater impact of the combined cPAHs. For comparison, the USEPA SSL for benzo(a)pyrene is 8,000 $\mu\text{g}/\text{kg}$.

Fate and transport screening for TEQs was approached in similar fashion. As with BEQs, the lowest K_{oc} value from the component congeners was used, along with HL and the MCL for 2,3,7,8-TCDD, to calculate a conservative SSL of 1,600 nanograms per kilogram (ng/kg). Although the HL value for 2,3,7,8-TCDD is the only dioxin HL value available in SCDM, HL has virtually no effect on the calculated SSL since K_{oc} values for dioxin congeners are so high. SSLs were also calculated for individual congeners, using data available in SCDM. For congeners without listed K_{oc} values, surrogate values from congeners with similar chemical structures were used to calculate SSLs. Some of the calculated SSLs for individual congeners are more conservative (lower) than the TEQ SSL. This is because they are based on multiples of 2,3,7,8-TCDD's RBC (0.45 picograms per liter [pg/L]) rather than its much higher MCL (30 pg/L), since there are no MCLs listed for congeners other than 2,3,7,8-TCDD. As with BEQs, the calculated SSL for TEQs should be used as a "pre-screening" value. If total TEQs in a soil sample exceed 1,600 ng/kg , then the concentrations, distribution, and transport characteristics of the individual congeners should be examined to gauge the potential threat to groundwater.

Detailed Assessment — Upon completion of the quantitative screening process, site constituent concentrations exceeding the screening values were examined to delineate the magnitude, number, and areal extent of soil impacts potentially affecting groundwater. Maximum constituent concentrations in surface soil were compared with those in subsurface samples to estimate the extent of downward migration. The number and spatial distribution of exceedances were noted, and relative concentrations in soil and groundwater were compared. If relevant, corresponding exceedances in nearby AOCs/SWMUs in Zones H and I were examined as possible contaminant sources or as indicators of lateral migration.

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 could cause localized shallow groundwater impact, 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 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

Groundwater in the upper part of the surficial aquifer moves generally northeast, east and southeast toward the Cooper River, and southwest toward Shipyard Creek (Figures 2.10 and 2.12 in Section 2); in the lower part of the aquifer, groundwater moves more consistently northeast toward the Cooper River and south toward Shipyard Creek, with possible localized movement radially outward from a small high area near the southern tip of the peninsula (Figures 2.11 and 2.13 in Section 2). The principal focus of this evaluation was determining whether constituents identified in groundwater have the potential to extend their impacts to different locations in the surficial aquifer or to surface water in the Cooper River or Shipyard Creek. Other than at five DMA sample locations (DMAW000101 through DMAW000501),

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

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

- Tap-water risk-based screening levels as presented in USEPA Region III RBC tables, (April 15, 1998), assuming a THQ of 1.0.
- Shallow groundwater background values for inorganics in Zone I, 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 groundwater analytical results for each AOC/SWMU (or group thereof) were also compared with USEPA saltwater surface water chronic screening values (also known as ambient water quality criteria [AWQC]) for hazardous waste sites, from *Supplemental Guidance to RAGS: Region IV Bulletins, Ecological Risk Assessment* (USEPA, 1995a). Since the only surface water samples collected during the Zone I RFI were the five DMA samples from inside the diked area, no background values for surface water inorganics were determined for use as alternatives to surface water screening standards applicable to the Cooper River and Shipyard Creek.

The quantitative assessment identifies chemicals detected in groundwater with the potential to disperse within the aquifer, increasing the areal extent of groundwater concentrations that exceed human health-based standards, or impacting surface water via groundwater migration and

discharge. If current groundwater chemical concentrations do not exceed tap-water risk-based screening levels and background concentrations, there is no significant threat of offsite groundwater contamination via migration. If reported chemical concentrations in groundwater do not exceed published AWQC, it is assumed that those chemicals present no risk to ecological receptors from groundwater discharge to surface water. This screening assessment purposely does not consider effects of dilution and attenuation on transport between the affected well(s) and the surface water discharge point, or the dilutional capacity of the receiving water body. Omitting these factors from the quantitative screening ensures that a conservative list of potential groundwater-to-surface water concerns is developed.

Detailed Assessment — Upon completion of the quantitative screening process, detailed assessments were performed to delineate the magnitude and areal extent of groundwater impacts that may adversely affect human or ecological receptors. Maximum constituent concentrations in shallow groundwater were compared with those in deep groundwater at nearby grid wells to estimate the extent of any downward migration. The number and spatial distribution of exceedances were noted. Where relevant, corresponding exceedances in nearby AOCs/SWMUs in Zones H and I were examined as possible sources or as indicators of lateral migration.

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

6.2.3 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 form contaminated sediments from 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 largely by surface soil erosion, with accumulation in depositional areas. Normally, site topography and ground cover are used to identify areas with erosional potential and the corresponding expected areas of deposition. Because erosional/depositional processes within Zone I are inhibited at many AOCs/SWMUs due to the presence of buildings, paved surfaces, and engineered drainage, evidence of constituent migration from surface soil-to-sediment is limited to sites with substantial unpaved and non-landscaped areas, generally found in the south half of the zone. Nevertheless, all sediment results were compared with data for proximate surface soil representing possible points of origin for sediment contaminants.

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

Evaluation of fate and transport for sediments in Zone I was limited to sediments as contaminant receptors. Fate and transport for constituents originating in Zone I wetland or fluvial sediments will be provided in the RFI report for Zone J. Potential impacts of contaminated sediments on ecological receptors are discussed in Section 8 of this report.

6.2.4 Soil-to-Air Cross-Media Transport

The soil-to-air migration pathway was evaluated by screening soil constituents to determine the potential for inhalation of volatilized organics or inorganic fugitive particulates in ambient air.

The screening process may be summarized as follows:

Quantitative — Maximum chemical concentrations detected in surface soil at each AOC/SWMU were compared with soil-to-air screening concentrations as presented in the USEPA *Soil Screening Guidance: Technical Background Document* (1996a) (primary source) or USEPA Region III RBC table, June 1996 (1996c) (secondary source). Concentrations of organic compounds were compared with generic values representing the volatile inhalation pathway; concentrations of inorganics were compared with values representing the fugitive dust pathway, except for mercury, whose concentrations were compared with the inhalation of volatiles pathway.

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

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

The outcome of the detailed assessments was used to determine the significance of soil impacts on air. In some instances, isolated areas of soil contamination above soil-to-air screening levels could cause localized ambient air impacts but not 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 and Shipyard Creek. The screening tables identify the constituents, while the detailed assessments evaluate their significance. The procedure depends heavily on EPA's soil screening methodology, and makes many simplifying assumptions that come directly from the 1996 *Soil Screening Guidance*. This section compares some of the assumptions of the screening procedure with actual conditions encountered at AOCs and SWMUs in Zone I in an attempt to demonstrate the conservative nature of the method. The screening assumptions are shown in italics, followed by commentary.

- The contaminant source is infinite (i.e., steady-state concentrations are maintained during the future exposure period).* At the majority of Zone I sites, the original sources of soil and/or groundwater contamination have been eliminated; there is no ongoing contamination. As constituent molecules migrate through the system or degrade, they are generally not replaced from the original sources.
- 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.* In reality, dissolved organic compounds and metallic ions originating in the upper soil horizons are not particularly mobile, due to sorption. Because of their origins in back-barrier lagoons and other low-energy environments (Section 2.2.3.2), many CNC soils and lithologic units exhibit clay content varying from moderate to very high. Typical aluminum and iron concentrations in surface and subsurface soil samples are high, indicating high clay content. The average clay proportion of Shelby tube samples from 20 Zone I wells, collected from the Qm unit at depths ranging from 13 to 22 feet (Table 2.2 in Section 2), was 39.8%. The geometric mean CEC of nine Zone I surface soil samples was 9.9 meq/100g (arithmetic mean = 11 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 moderate clay content and corresponding CEC values of Zone I soil and the high proportion of marsh clay in deeper sediments should result in varying but substantial attenuation of migrating site constituents, especially inorganics.

The geometric mean TOC of the same nine surface soil samples was 11,600 mg/kg ($f_{oc} = 0.0116$), while the arithmetic mean was 15,000 mg/kg ($f_{oc} = 0.015$). Measured TOC values ranged from 3,232 to 45,268 mg/kg. The default soil value of f_{oc} used by EPA to calculate generic SSLs is 0.002 (corresponding to TOC = 2,000 mg/kg), indicating that Zone I soils probably average several times more available organic carbon than soils assumed in the generic model's partitioning equation for migration to groundwater. Because organic carbon correlates positively with the soil's sorptive capacity, Zone I soils should provide a greater measure of protection to underlying groundwater than the soils in the generic model, especially for organic compounds. Results from four SPLP leach

samples analyzed for SVOCs (two at AOC 690 and one each at AOC 685 and SWMU 12) 1
tend to confirm this interpretation, because no SVOCs were detected in the samples. 2

EPA's generic SSLs are based on reference values of K_{oc} for ionizing organics and K_d for 3
inorganics. The listed reference values assume a soil pH of 6.8. For Zone I, the 4
geometric mean pH for 17 surface soil samples was considerably higher at 7.5; 16 of the 5
17 measured pH values exceeded 6.8. Two subsurface soil samples reported pH values 6
of 6.9 and 7.2. Values of K_d for most metals are higher with higher soil pHs and lower 7
with lower pHs. The effect of pH variations on the value of K_{oc} for ionizing organics is 8
reversed, but is weaker than for inorganics. 9

4. *The generic SSLs used in the screening tables are based on a DAF of 10. Since EPA's 10
methodology unrealistically assumes zero attenuation for migration of leachate through the 11
vadose zone and groundwater through the aquifer, the default DAF of 20 recommended 12
in the 1996 Soil Screening Guidance is actually a dilution factor only. Using equations 13
in the User's Guide, site-specific dilution factors ranging from 6.0 (at AOC 687-SWMU 14
16) to 138 (at AOC 678-679) were calculated for leachate and shallow groundwater at 15
Zone I sites. The calculations assume a rainfall infiltration rate of 0.3 inches per year at 16
sites such as AOC 678-679 that are mostly paved, and a rate of 0.6 inches per year at 17
grassy sites such as AOC 687-SWMU 12. In contrast, the ongoing United States 18
Geological Survey (USGS) groundwater modeling study assigns a preliminary uniform 19
infiltration rate of 0.3 inches per year to the "semi-industrial" areas of the base (Zones A, 20
H, and I). In the DAF equation, a higher infiltration rate is conservative because it 21
increases contaminant delivery via leachate to the aquifer, where it is diluted by 22
groundwater flowing past the site. Considering the high clay content (Table 2.2 in 23
Section 2), and the moderate CEC and high TOC (Table 6.3) of Zone I soil and aquifer 24*

- sediments – none of which are reflected in the DAF formula – a default DAF of 10 is suitably conservative for initial screening purposes.
5. *There is no contaminant attenuation as groundwater moves through the aquifer.* The CEC and TOC values of soil samples in the vadose zone and the lithology of Shelby tube samples in the saturated zone imply otherwise, as discussed above in item 3:
- Moderate amounts of clay present, especially locally
 - Geometric mean CEC of nine soil samples similar to those of some clay minerals
 - Geometric mean TOC of nine soil samples five times higher than EPA default values
6. *The mean contaminant concentration in the theoretical groundwater plume associated with each site is equal to (a) the concentration of leachate produced by the maximum detected soil concentration and diluted 10:1 by groundwater, or (b) maximum detected groundwater concentration.* This assumption should be compared with analytical results from soil and groundwater samples collected at each AOC/SWMU and groundwater samples collected downgradient from each site (where available). High constituent concentrations in Zone I 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 are discussed in the detailed assessment for each site.
7. *An appropriate human health screen for Zone I groundwater is EPA’s Region III tap-water RBCs (April 15, 1998) using a target hazard quotient of 1.0.* Although no water-supply wells are completed in the surficial aquifer at CNC or nearby, and high percentages of Zone I groundwater samples analyzed for chloride, iron, manganese, sulfate, or TDS reported concentrations exceeding USEPA’s Secondary MCLs, groundwater was evaluated as if it were a potential drinking water source. 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. The only exceptions to this approach were for the carcinogenic PAHs, which were evaluated in terms of BEQs, and the chlorinated dibenzodioxins/dibenzofurans, which were evaluated in terms of TEQs.

8. *An appropriate ecological screen for surface water in the Cooper River and Shipyard Creek is USEPA's saltwater surface water chronic screening values for hazardous waste sites (1995a).* Shipyard Creek and the portion of the Cooper River opposite CNC are both tidally influenced streams containing brackish water. The screening values in USEPA's publication include the "Criteria to Protect Aquatic Life" incorporated by reference into SCDHEC's Water Classifications and Standards (Regulation 61-68), plus additional values.

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7.0 HUMAN HEALTH RISK ASSESSMENT

7.1 Introduction

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

Chemical contamination at the site must be adequately characterized before an HHRA can be used to determine whether detected concentrations are potentially toxic and may cause increased cancer incidences. Characterizing the study area requires determining contaminant sources' amount, type, and location. 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 I 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. Analytical results from surface soils and groundwater were used to assess possible exposure to environmental contaminants.

Organization

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

- **Site characterization** — Evaluation of site geography, geology, hydrogeology, climate, and demographics, and past and current land use conditions.
- **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 exposure and toxicity assessment results to quantify the total cancer and noncancer risk to the hypothetical receptors. 1
2

- **Uncertainty** — Discussion and evaluation of the areas of recognized uncertainty in human health risk assessments in addition to medium- specific and exposure pathway-specific influences. 3
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- **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
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This general process was followed in preparing the HHRA for each Zone I AOC and SWMU or groups of sites at CNC. 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 I 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 I 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 I RFI.

7.3.3 Management of Site-Related Data

All environmental sampling data were evaluated for suitability of 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 addressed limitations of analytical results by including estimated concentrations for nondetected parameters. A nondetect indicates that the analyte was not detected above the sample quantitation limit (*U*-qualified results), as 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 detections 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 detection (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 data set.

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 data set. If two
nondetects were reported for any one location (a result of QA/QC samples), one-half the lesser
of the *U* values was compared to the lowest detection at the site (for organics, as above) or applied
directly (for inorganics) to estimate a concentration value to be used in the Zone I 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 data set 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 and 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, 1989a), (RAGS
Part A).
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987).
- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (USEPA, 1992c).

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 list or group 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 a hazard quotient (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 values 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 (RBC) Table* (USEPA, April 15, 1998). According to this guidance, USEPA recommends the use of 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, which is consistent with current USEPA Office of Solid Waste and Emergency Response directives considering protection of a hypothetical child resident (USEPA, 1994a). The screening value used for lead in groundwater was the USEPA Office of Water treatment technique action level (AL) of 15 µg/L (USEPA, 1996d).

A soil screening value of 1,000 nanograms per kilogram (ng/kg) [as 2,3,7,8-TCDD toxicity equivalent quotient (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 picograms per liter (pg/L).

In accordance with recent cPAH guidance (USEPA, 1993), benzo(a)pyrene equivalent quotients (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 risk based screening concentrations 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 I 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 represents a very conservative approach.

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 methodology is 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 I using results from the grid-based soil and groundwater background sampling. Surface soil, subsurface soil, shallow groundwater, and deep groundwater were all addressed separately to determine background concentrations. After the risk-based screening process, CPSS were retained for further consideration as COPCs in the HHRA on an AOC- or SWMU-specific basis under the following

conditions: (1) their maximum detected concentrations exceeded corresponding background concentrations, or (2) 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, health risk potentially 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," 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 data set). Ideally, population tests identify general elevations in chemical concentrations, absent definable hot spots. Statistical methods, UTL calculations, Wilcoxon rank sum test outputs, and background sample information are discussed in Section 5. In the RFI, 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 site specific HHRA. 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 RBCs are available for the generic group total petroleum hydrocarbons (TPH). As a result, TPH assessment was consistent with the CNC screening level of 100 mg/kg for soil.

7.3.5 Calculation of Risk and Hazard	1
Section 7.3.5 of the <i>Draft Zone A RFI Report</i> discusses the calculation of risk and hazard as it applies to the Zone I RFI HHRA.	2 3
7.3.6 Exposure Assessment	4
Section 7.3.6 of the <i>Draft Zone A RFI Report</i> discusses exposure assessment for the Zone I RFI HHRA.	5 6
7.3.7 Toxicity Assessment	7
Section 7.3.7 of the <i>Draft Zone A RFI Report</i> discusses the toxicity assessment procedures for the Zone I RFI HHRA.	8 9
7.3.8 Risk Characterization	10
Section 7.3.8 of the <i>Draft Zone A RFI Report</i> discusses the risk characterization procedures used for the Zone I RFI HHRA.	11 12
7.3.9 Risk Uncertainty	13
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.	14 15 16 17
General	18
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. In the exposure assessment, the use of high-end estimates of potential exposure concentrations, frequencies, durations, and rates leads to conservative	19 20 21 22

chronic daily intake (CDI) estimates. Toxicological values for chemicals derived from USEPA 1
databases and other sources are generally derived from animal studies. Uncertainty and modifying 2
factors are applied to the results of these animal studies to predict potential human responses, and 3
provide a margin of safety based upon confidence in the studies. Use of these safety margins 4
during all exposure and risk/hazard computations provides an extremely conservative means of 5
predicting potential human health effects. The margins of safety or "conservatisms" inherent in 6
each step of the human health risk assessment are addressed in the risk uncertainty discussions. 7
All uncertainties or potential variability cannot be eliminated from the risk assessment process. 8
However, recognizing the influences of these factors is fundamental to understanding and 9
subsequently using risk assessment results. 10

During the risk assessment process, assumptions are based on population studies and USEPA 11
guidance. This guidance divides the assumptions into two basic categories: (1) the upper bound 12
(90 to 95th percentile), and (2) the mean or 50th percentile central tendency (CT) exposure 13
assumptions. As discussed in the exposure assessment section, the reasonable maximum exposure 14
(RME) is based on the upper-bound assumptions, while CT exposure is based on mean 15
assumptions. Therefore, risks and hazards calculated using RME assumptions are generally over, 16
rather than underestimates. The following paragraphs discuss sources of uncertainty and 17
variability pertinent to each exposure pathway evaluated. 18

Quality of Data

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Data collected during the Zone I investigation are presented in Section 10 of this RFI, which 20
includes results from AOC and SWMU sites. The QA/QC of those data is addressed in Section 4. 21
The purpose of the data evaluation is to verify that the QC requirements of the data set have been 22
met and to characterize questionable data. 23

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, a risk based screening approach was used to select COPCs for further evaluation. Uncertainties associated with criteria used for identifying COPCs are discussed below.

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. More than 10 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 I 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 Background Concentrations

Because the HHRA estimates the excess cancer risk or health hazard posed by COPCs, individual sample data values for naturally occurring inorganic chemicals were compared to background concentrations in the Zone I 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 I, they are not specific to individual AOCs or SWMUs. The use of zone-specific background 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 I 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 I sites is not likely, based on historical use, the nature of surrounding areas, and potential use/reuse plans. If this area were to become residential in the future, 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 future site residents.

Groundwater is not currently used at any Zone I location as a source of potable or process water. A basewide potable water system provides drinking and process water to buildings throughout Zone I. 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 risk/hazard calculated for shallow groundwater exposure is highly conservative.

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 for the shallow aquifer, 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 outlines a statistical estimation of EPC. These calculated concentrations are 95% UCLs for the arithmetic 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. Although the statistic appears to be nonlinear, local linearity was assumed as a way to interpolate the statistic for each COPC addressed in the HHRAs.

Linear interpolation provides a good estimate of the *H*-statistic; however, both the UCL formula and *H* are natural log values. The effect of multiplying natural log numbers is not equivalent to multiplying untransformed values. When data are log transformed, adding two numbers is the

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

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

Frequency of Detection and Spatial Distribution

Because of the influence of the standard deviation on EPC, low frequency of detection can cause COPCs to be addressed inappropriately in the risk assessment. More specifically, COPCs detected only once or twice in all samples analyzed (having concentrations exceeding the RBCs and reference concentrations) would be expected to show relatively higher standard deviations as concentration variability or range widens. A higher standard deviation results in a high H -statistic, typically leading to a UCL greater than the maximum concentration detected onsite. If that is the case, use of the UCL or maximum concentration detected as the EPC (or possibly the inclusion of the COPC in question as 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) ratio 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 effects in humans. 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. Uncertainty factors ranging from 1 to 10,000 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 that is 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 I site HHRA.

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

Where CDDs and dibenzofurans 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 are not expected to 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 excluded from the HHRA based on their low potential for toxicity.

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 presented 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 distribution can affect the magnitude of exposure to 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, the risk and hazard projected for each receptor group, exposure medium, and exposure pathway are discussed separately.

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 I RFI.

8.0 ECOLOGICAL RISK ASSESSMENT

The ecological risk assessment (ERA) is a key component of the BRA. Its purpose is to develop a qualitative and/or quantitative ecological appraisal of the actual or potential effects on the ecosystem from CNC Zone I contamination. The assessment considers environmental media and exposure pathways that could result in unacceptable levels of exposure to flora and fauna now or in the foreseeable future. The approach to assessing risk components at Zone I was based on *Ecological Risk Assessment—Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997b), *Risk Assessment Guidance for Superfund, Volume II—Environmental Evaluation Manual* (USEPA, 1989b), and *Framework for Ecological Risk Assessment* (USEPA, 1992d).

Zone Rationale

Eight Ecological Study Areas (ESAs) were designated to help appropriately qualify geographic boundaries of CNC areas with contiguous habitats or similar ecosystem distributions (Figure 8.1). Within these ESAs, smaller Areas of Ecological Concern (AECs) were further specified to focus the investigation on potential AOC/SWMU contribution and consequent receptor exposure. This survey methodology, which is used in conjunction with the Zone I RFI Report, is also described in the Zone J RFI Work Plan (E/A&H 1995b).

Zone configurations for the basewide RFIs were based on AOC or SWMU locations, and therefore do not necessarily parallel ESA or AEC boundaries. Zone I, which contains portions of two ESAs (ESAs IV and V), is mostly within AEC V-3, the largest area of ecological concern at CNC. The northern part of Zone I is a fully developed coastline and was not considered relevant to this ERA based on the lack of habitat and receptors. It is designated on Figure 8.2 as a "Non-Ecological Area" and will not be discussed relative to ecological risk. If Zone I RFI data indicate potential contaminant migration to aquatic areas outside the Zone I perimeter, risks to

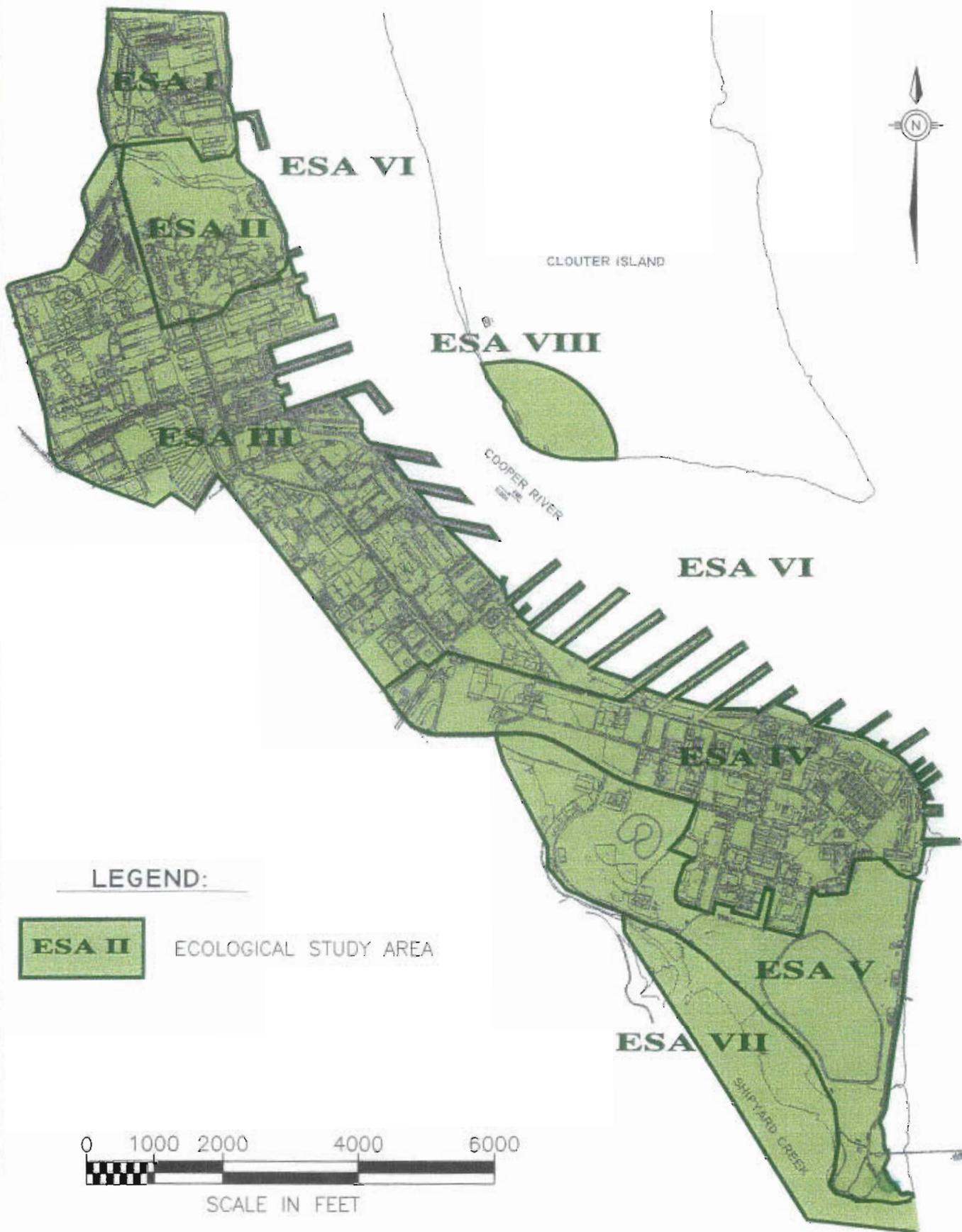
applicable ecological receptors will be evaluated during the Zone J investigation of the surrounding water bodies.

Three geographical areas will be addressed in this risk assessment, each with similar and contiguous habitats constituting portions of AEC V-3. For discussion purposes, these areas will be designated as Subzones I-1, I-2, and I-3 (also on Figure 8.2). Since the assessment addressed the entire ecological subzone, the total number of contaminant detections and concentrations reported in this section refers to samples collected throughout this larger subzone, not just those from a single AOC/SWMU. It should also be noted that some samples are used in more than one subzone assessment, and may not be specific to any one subzone. Specific endpoints and assessment techniques used for the ecological risk assessment of each subzone are presented in the following sections.

8.1 Problem Formulation

Environmental Setting

Subzone I-1 – This subzone includes an approximately 58-acre dredged material area (DMA) used by the Navy for deposition of permitted inland spoils. Although there are no AOCs/SWMUs in this subzone, two soil samples, seven sediment samples, and five surface water samples were collected to aid the overall area assessment. The DMA, currently inactive, last received dredge spoils in 1993 during maintenance dredging in Shipyard Creek. The DMA is surrounded by a dike approximately 15 feet above msl, and the northernmost portion (near Partridge Avenue) has been filled, creating an approximately 5-acre plateau which is significantly higher than the rest of the subzone. Frequent inundation of the DMA has limited the interior habitat to early successional vegetation throughout, characterized by low-shrub cover with several stands of young trees. Observed plant species include Southern red cedar (*Juniperus silicicola*), broom sedge (*Andropogon* spp.), coastal plain willow (*Salix caroliniana*), groundsel tree (*Baccharis halimifolia*), and tallow tree (*Sapium seiviferum*). Drainage within the DMA is directed by several



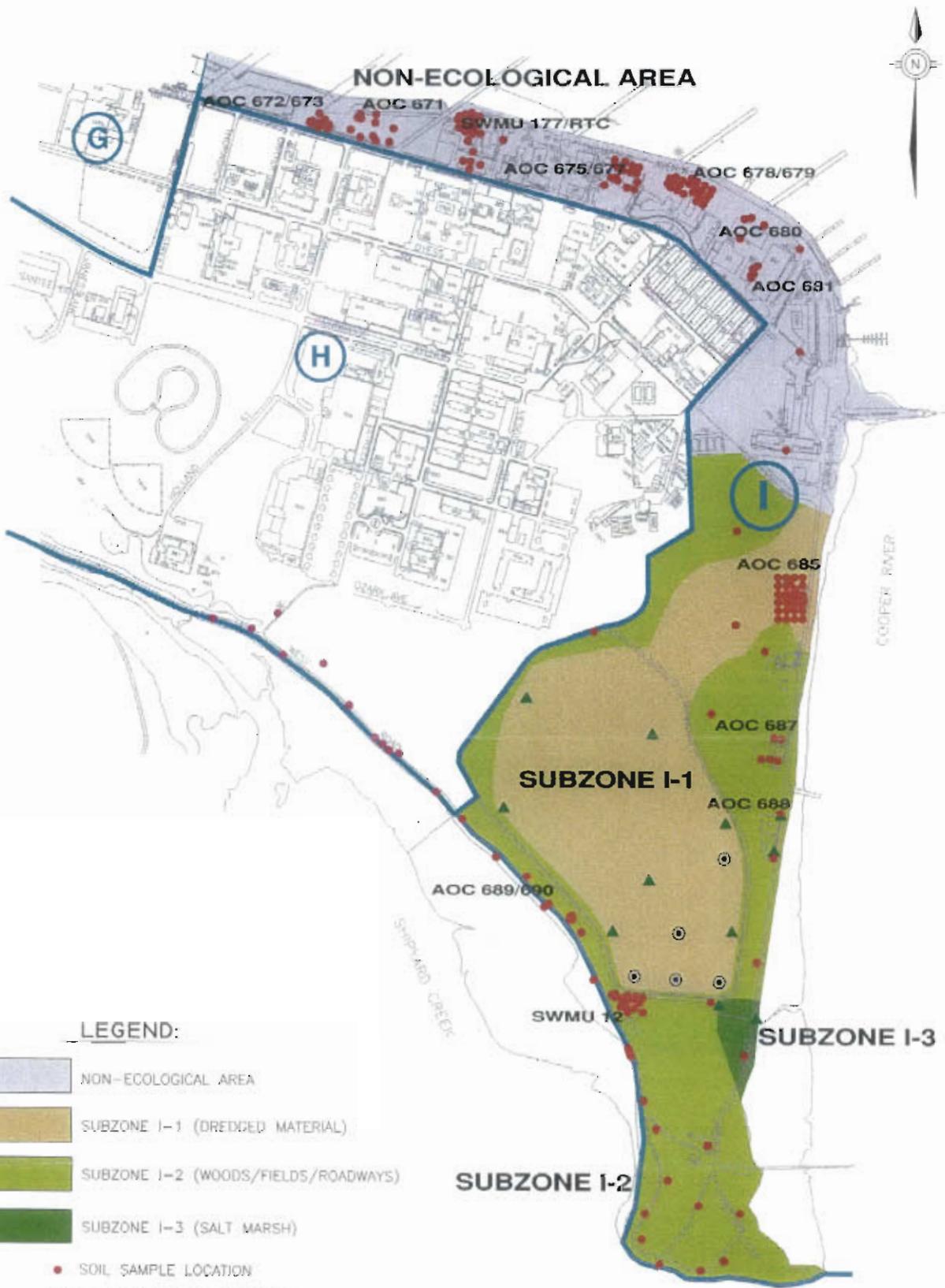
LEGEND:

ESA II ECOLOGICAL STUDY AREA



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FIGURE 8.1
ECOLOGICAL
STUDY AREAS
LOCATION MAP



LEGEND:

- NON-ECOLOGICAL AREA
- SUBZONE I-1 (DREDGED MATERIAL)
- SUBZONE I-2 (WOODS/FIELDS/ROADWAYS)
- SUBZONE I-3 (SALT MARSH)
- SOIL SAMPLE LOCATION
- SEDIMENT SAMPLE LOCATION
- SURFACE WATER SAMPLE LOCATION



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FIGURE 8.2
 ECOLOGICAL
 SUBZONES
 WITHIN ZONE I

long narrow channels transecting the site, which lead to two spillways along the western and southern dikes. Because the drainage channels and the low-lying areas around the spillways often retain water, hydrophytic vegetation (*Typha* spp.) has established itself in these predominantly wet areas. Habitats in Subzone I-1 provide suitable nesting and/or foraging areas for red-wing blackbirds (*Agelaius phoeniceus*), egrets and herons (Family Ardeidae), white ibis (*Eudocimus albus*), and other waterfowl. The drier upland areas to the northeast offer nesting and/or foraging habitat suitable for bird species such as killdeer (*Chadradrius vociferus*), red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), Eastern meadowlark (*Sturnella magna*), and Savannah sparrow (*Passerculus sandwichensis*). The predominant terrestrial faunal species associated with this upland habitat include white-tailed deer (*Odocoileus virginianus*), Eastern cottontail rabbit (*Sylvilagus floridanus*), gray fox (*Urocyon cinereoargenteus*), and raccoon (*Procyon lotor*), along with other small mammals, reptiles, and amphibians. A variety of shorebirds may also occasionally forage in the flooded portions of Subzone I-1.

Subzone I-2 - This subzone encompasses the approximately 66 acres of forested habitat surrounding the DMA and throughout the southernmost peninsula of Zone I. The open grass fields around the bunkers west of Juneau Avenue are also included. All six Zone I AOC/SWMU sites with potentially affected natural terrestrial habitats are inside Subzone I-2. Sixty-nine soil samples (upper interval) were collected from this subzone's terrestrial sites, and four sediment samples from the drainage ditch along the inland side of Juneau Avenue. Vegetation throughout the wooded portion of the subzone consists of mid- to lower-canopy trees typical of mid-succession areas, including Southern hackberry (*Celtis laevegata*), tallow (*Sapium sebiferum*), Eastern sycamore (*Platanus occidentalis*), Eastern red cedar, and red mulberry (*Morus rubra*). The dense understory found throughout most of the subzone consists of woody and herbaceous species such as honeysuckle (*Lonicera* spp.) and wax myrtle (*Myrica cerifera*). Observed fauna in Subzone I-2 is also typical of mid-succession habitats and includes passerine species such as cedar waxwing (*Bombyllica cedrorum*), loggerhead shrike (*Lanius ludovicianus*), sparrows, warblers, and

American robin (*Turdus migratorius*). Mammals that may live in Subzone I-2 include the Eastern gray squirrel (*Sciurus carolinensis*), Eastern cottontail rabbit, and small rodents. The subzone may also support populations of various native reptiles and amphibians.

Subzone I-3 – This subzone, a 3.5-acre salt marsh immediately south of the DMA, is a typical estuarine intertidal emergent wetland. Although there are no AOCs/SWMUs associated with this subzone, two sediment and two soil samples were collected inside or near its boundary as part of the DMA sampling plan and zonewide grid-based soil sampling. The hydrology of this *Spartina* spp. wetland is influenced by the drainage swale leading from a spillway in the southern portion of the DMA, which leads into the wetland, then flows beneath Juneau Avenue and into the Cooper River. With this unobstructed connection to the river, the wetland is regularly inundated during high tide. The wetland and intertidal zone’s mud flats and scrub-shrub vegetation provides foraging habitat for numerous avian species, including northern harriers (*Circus cyaneus*), black-crowned night herons (*Nycticorax nycticorax*), marsh wrens (*Cistothorus palustris*), egrets (*Egretta* spp.), white ibis (*Eudocimus albus*), and fiddler crabs (*Uca* spp.). Since the terrestrial habitat in this subzone is limited to a narrow riparian fringe, subzone terrestrial receptors will be addressed in the assessment of the surrounding wooded Subzone I-2.

Threatened and Endangered Species

Several species of concern may live in parts of Zone I. Table 8.1 provides a list of those species which have been either historically or recently identified on or near CNC, and risks to these species from contamination will be addressed as appropriate. Appendix F presents a list of species actually observed at CNC.

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

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

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

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

Notes:

- a = Wading bird colony has been a confirmed resident at the base, but was not present during field studies in April 1994.
- CR = Confirmed resident
- PR = Possible resident
- UR = Unlikely resident
- LM = Likely migrant or occasional visitor
- PM = Possible migrant or occasional visitor
- UM = Unlikely migrant or occasional visitor
- SC = Of concern, state
- SR = Status review
- E = Endangered

- T = Threatened
- SL = State listed
- RC = Of concern, regional
- NC = Of concern, national
- C2 = Candidate species for federal listing, Category 2
- T/SA = Threatened due to similarity of appearance
- USF&WS = U.S. Fish and Wildlife Service
- SCWMRD = South Carolina Wildlife and Marine Resources Department

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

8.2 Conceptual Model

Figure 8.3 presents a conceptual model of pathways from potential contaminant sources to ecological receptors in Zone I subzones. For this assessment, exposure routes directly related to soil pathways are evaluated for Subzones I-1 and I-2. Subzones I-1, I-2, and I-3 will be preliminarily characterized for sediment exposure routes to determine the need for subsequent assessment during the Zone J RFI of surrounding water bodies. A preliminary evaluation of contaminants detected in Zone I groundwater will also be conducted during the Zone J RFI to assess risks associated with potential migration and discharge to adjacent surface water bodies. Direct impacts to plants are not assessed but transfer mechanisms are considered in food chain transfer analyses. Specific contaminant toxic mechanisms to vegetation are also discussed.

8.3 Selection of Ecological Chemicals of Potential Concern

Section 10 of this report discusses previous activities at Zone I AOCs and SWMUs which may have impacted the surrounding ecosystem. COCs from these activities have been identified and quantified according to USEPA methods and protocols for analyses of soil, surface water, and sediment.

For an ERA, COCs are further evaluated and classified as Ecological Chemicals of Potential Concern (ECPCs) using ecological-based selection criteria. For example it is presumed, even considering root development in the lower strata, that most biological effects will be limited to the upper zone, and thus only the results from surficial soil (0 to 1 foot bgs) are addressed. Based on the transient or mobile nature of biological components within the subzones (i.e., a species home range), parameter concentrations detected at one location will be used in this ERA to assess the entire subzone. Risk will be estimated using the maximum concentration detected; for concentrations that pose significant risk, mean concentrations will be used for risk calculation.

Although Zone I groundwater has been monitored, the water table (approximately 5 to 15 feet bgs) is below the depth likely to be encountered by non-aquatic receptors, and thus assessing

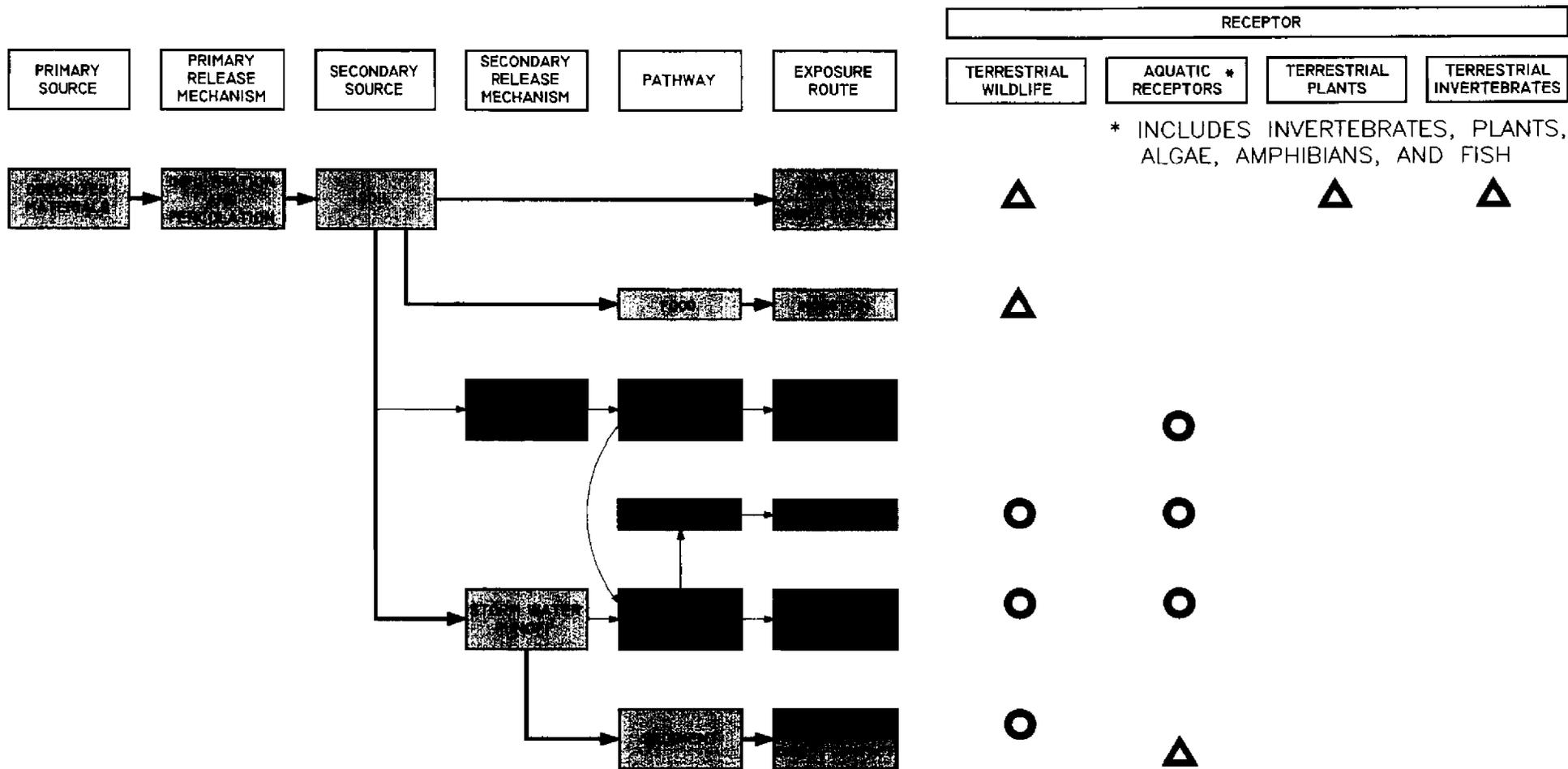
groundwater’s ecological impact immediately inside the zone perimeter is not warranted. Potential 1
impact from migration and discharge of contaminated groundwater to the surrounding water bodies 2
will be addressed in the Zone J RFI. 3

Inorganic parameters detected in subzone surface soil are identified as ECPCs if they exceed the 4
background UTL or lack a corresponding UTL. Any organic constituent detected in more than 5
5% of the subzone’s samples was considered an ECPC. Conversely, any inorganic or organic 6
constituent detected in less than 5% of the samples was not considered an ECPC. 7

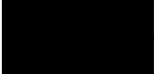
Surface water analytes were selected as ECPCs if the maximum concentration detected exceeded 8
the South Carolina or USEPA water quality criteria, exceeded the USEPA Region IV Screening 9
Value (USEPA 1995a), or if appropriate benchmarks were unavailable. 10

In sediment, analytes were selected as ECPCs if the maximum concentration detected exceeded 11
the USEPA Region IV Sediment Screening Value (SSV) (USEPA 1995a), exceeded the most 12
conservative effects level found in literature, or if appropriate benchmarks were unavailable. 13

14
Calcium, iron, magnesium, potassium, and sodium were not assessed as they are naturally 15
occurring nutrients. Tables 8.2 through 8.7 present ECPCs identified for Subzones I-1, I-2, and 16
I-3. 17



LEGEND

-  SELECTED SOURCE/RELEASE MECHANISM AND SELECTED PATHWAY
-  POSSIBLE SOURCE/RELEASE MECHANISM AND POSSIBLE PATHWAY
-  SELECTED RECEPTOR
-  POSSIBLE RECEPTOR - NOT ASSESSED DUE TO INSUFFICIENT INFORMATION



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FIGURE 8.3
CONTAMINANT PATHWAY MODEL
FOR
ECOLOGICAL RECEPTORS

Date: 02/23/99

DWG Name: 2909C044

Table 8.2a
Subzone I-1
Organic Constituents in Surface Soil

Compound Name	Number of Detections	Range of Concentrations ($\mu\text{g}/\text{kg}$)	ECPC
Volatile Organic Compounds (N = 2)			
Acetone	1	5.0	Yes
Toluene	1	2.0	Yes
Tetrachloroethene	1	1.0	Yes
Semivolatile Organic Compounds (N = 2)			
Benzo(b)fluoranthene	1	61	Yes
Benzo(k)fluoranthene	1	66	Yes
bis(2-Ethylhexyl)phthalate (BEHP)	1	150	Yes
Pesticides (N = 2)			
Beta BHC	1	2.6	Yes

Notes:

N = Number of samples
 $\mu\text{g}/\text{kg}$ = microgram per kilogram

Table 8.2b
Subzone I-1
Inorganic Constituents in Surface Soil

Inorganic Elements	Number of Samples	Number of Detections	Range of Concentrations (mg/kg)	Upper Tolerance Limit of Background ^a	ECPC
Aluminum	2	2	787 - 23,000	27,400	No
Antimony	2	1	0.32	Not Valid ^b	Yes
Arsenic	2	1	11.4	21.6	No
Barium	2	2	5.9 - 28.7	54.2	No
Beryllium	2	2	0.15 - 0.84	0.95	No
Cadmium	2	1	0.88	0.61	Yes
Chromium	2	2	4.1 - 52.5	34.5	Yes
Cobalt	2	2	0.42 - 5.3	5.8	No
Copper	2	1	23.4	240	No
Iron	2	2	1,750 - 216,000	NA	Yes
Lead	2	1	23.3	203	No

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Table 8.2b
 Subzone I-1
 Inorganic Constituents in Surface Soil

Inorganic Elements	Number of Samples	Number of Detections	Range of Concentrations (mg/kg)	Upper Tolerance Limit of Background ^a	ECPC
Manganese	2	2	25.3 - 318	419	No
Mercury	2	1	0.14	0.47	No
Nickel	2	2	0.58 - 17.7	23.9	No
Selenium	2	1	1.1	1.49	No
Tin	2	1	1.4	7.5	No
Vanadium	2	2	2.6 - 48.1	113	No
Zinc	2	1	77.5	206	No

Notes:

a = See Section 5 for Upper Tolerance determination.

b = Number of nondetections prevented determination of upper tolerance limit.

NA = Data not available

Table 8.3a
 Subzone I-2
 Organic Constituents in Surface Soil

Compound Name	Number of Detections	Range of Concentrations (µg/kg)	ECPC
Volatile Organic Compounds (N = 69)			
Acetone	18	5 - 96	Yes
2-Butanone	2	11 - 13	No
Ethylcyanide	1	660	No
Freon 113	2	4 - 15	No
Methylene Chloride	1	28	No
Toluene	25	1 - 27	Yes
Tetrachloroethene	1	1	No
Semivolatile Organic Compounds (N = 78)			
Benzoic acid	1	150	No
4-Aminobiphenyl	1	60	No
Anthracene	3	43 - 110	No
Benzo(a)anthracene	19	43 - 1,500	Yes

Table 8.3a
Subzone I-2
Organic Constituents in Surface Soil

Compound Name	Number of Detections	Range of Concentrations ($\mu\text{g}/\text{kg}$)	ECPC
Benzo(b)fluoranthene	25	42 - 2,400	Yes
Benzo(k)fluoranthene	26	39 - 2,600	Yes
Benzo(g,h,i)perylene	2	150 - 430	No
Benzo(a)pyrene	19	20 - 1,200	Yes
bis(2-Ethylhexyl)phthalate (BEHP)	24	44 - 2,400	Yes
Chrysene	24	40 - 1,600	Yes
Dibenzo(a,h)anthracene	1	130	No
Dibenzofuran	3	50 - 170	No
Di-n-butylphthalate	14	41 - 120	Yes
Fluoranthene	25	18 - 2,600	Yes
Indeno(1,2,3-cd)pyrene	2	81 - 410	No
1-Methylnaphthalene	8	47 - 760	Yes
2-Methylnaphthalene	6	39 - 690	Yes
3-Methylphenol	1	160	No
4-Methylphenol	1	160	No
Naphthalene	6	43 - 540	Yes
Pentachlorophenol	1	45	No
Phenanthrene	19	12 - 950	Yes
Pyrene	26	30 - 2,200	Yes
Pesticides (N = 69)			
Aldrin	4	1.7 - 2.7	Yes
beta-BHC	9	1.3 - 8	Yes
delta-BHC	2	2.3 - 2.4	No
Chlordane	3	2.2 - 54	No
4,4'-DDD	10	6.3 - 36	Yes
4,4'-DDE	16	5.2 - 220	Yes
4,4'-DDT	8	5.3 - 53	Yes
Endosulfan	11	1.9 - 35.7	Yes

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Table 8.3a
Subzone I-2
Organic Constituents in Surface Soil

Compound Name	Number of Detections	Range of Concentrations ($\mu\text{g}/\text{kg}$)	ECPC
Endrin	4	1.2 - 5.6	Yes
Endrin aldehyde	18	1.2 - 8.9	Yes
gamma-BHC (Lindane)	3	1.2 - 3.7	No
Heptachlor Epoxide	12	0.087 - 49	Yes
Methoxychloride	5	1.9 - 75	Yes
Polychlorinated Biphenyls (N = 69)			
Aroclor 1260	9	23 - 170	Yes
OP Pesticides (N = 6)			
Disulfoton	1	3.4	Yes
Dioxin (ng/kg) (N = 24)			
Total Tetradoxins	4	2.70 - 5.69	Yes

Notes:

N = Number of samples
 $\mu\text{g}/\text{kg}$ = micrograms per kilogram
 ng/kg = nanograms per kilogram

Table 8.3b
Subzone I-2
Inorganic Constituents in Surface Soil

Inorganic Elements	Number of Samples	Number of Detections	Range of Concentrations (mg/kg)	Upper Tolerance Limit of Background ^a	ECPC
Aluminum	69	66	787 - 48,400	27,400	Yes
Antimony	69	20	0.26 - 21.4	Not Valid ^b	Yes
Arsenic	69	62	0.46 - 28.7	21.6	Yes
Barium	69	63	5.4 - 203	54.2	Yes
Beryllium	69	44	0.15 - 1.4	0.95	Yes
Cadmium	69	29	0.07 - 1.4	0.61	Yes
Chromium	69	69	4.1 - 131	34.5	Yes
Chromium VI	5	1	0.628	NA	No
Cobalt	69	60	0.32 - 8.9	5.8	Yes

Table 8.3b
Subzone I-2
Inorganic Constituents in Surface Soil

Inorganic Elements	Number of Samples	Number of Detections	Range of Concentrations (mg/kg)	Upper Tolerance Limit of Background ^a	ECPC
Copper	69	63	0.72 - 483	24.0	Yes
Iron	69	66	308 - 36,700		Yes
Lead	69	64	1.8 - 949	203	Yes
Manganese	69	68	8.7 - 815	419	Yes
Mercury	69	25	0.12 - 0.39	0.47	Yes
Nickel	69	66	0.56 - 46.8	23.9	Yes
Selenium	69	58	0.48 - 2.2	1.49	Yes
Thallium	69	1	0.71	Not Valid ^b	No
Tin	69	23	0.96 - 42	7.5	Yes
Dibutyltin	40	1	6.6	NA	No
Tetrabutyltin	40	2	5.5 - 316.23	NA	No
Vanadium	69	63	2.6 - 83.8	113	No
Zinc	69	68	2.6 - 876	206	Yes

Notes:

a = See Section 5 for Upper Tolerance determination.

b = Number of nondetections prevented determination of upper tolerance limit.

NA = Data not available.

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Table 8.4
 Subzone I-1
 Surface Water Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level (EL)	HQ	ECPC
Inorganic ($\mu\text{g/L}$)							
Arsenic	5	1	26.3	-	36 ^a	0.73	No
Aluminum	5	5	364 - 21,000	8,834	1,500 ^c	14	Yes
Barium	5	5	25.8 - 58.6	45.4	NA	-	Yes
Cadmium	5	2	0.41 - 1.4	0.91	9.3 ^a	0.15	No
Chromium	5	5	4.1 - 34.1	16.4	103 ^b	0.33	No
Cobalt	5	4	1.5 - 4.7	2.5	NA	-	Yes
Copper	5	5	4.8 - 23.1	12.72	2.9 ^a	8	Yes
Iron	5	5	2,020 - 17,000	8,668.3	NA	-	Yes
Lead	5	5	4.3 - 60.7	17.17	8.5 ^a	7.1	Yes
Manganese	5	5	1,650 - 3,560	3140	NA	-	Yes
Nickel	5	5	2.9 - 12.8	7.32	8.3 ^a	1.54	Yes
Selenium	5	5	5.0 - 7.3	6.2	71	0.1	No
Vanadium	5	5	4.7 - 42.6	21.5	NA	-	Yes
Zinc	5	5	27.8 - 139	62.58	86 ^a	1.62	Yes

Table 8.4
Subzone I-1
Surface Water Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level (EL)	HQ	ECPC
Organics ($\mu\text{g/L}$)							
Volatile Organic Compounds							
Acetone	5	2	6.0 - 12.0	9	36 ^a	0.33	No
Semivolatile Compounds							
Phenol	5	2	17.0 - 22.0	19.5	58 ^b	0.38	No
Pesticides							
delta-BHC	5	2	0.03	-	NA	-	Yes
gamma-BHC	5	1	0.03	-	0.016 ^b	1.88	Yes

Notes:

- a = USEPA/SCDHEC ambient water quality criteria — chronic saltwater
- b = USEPA Region IV (1995-Draft) saltwater screening value
- c = Florida surface water quality criteria (closest state having criteria for constituent)
- HQ = Hazard Quotient — calculated using maximum concentration divided by EL
- NA = Not available
- $\mu\text{g/L}$ = micrograms per liter

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Table 8.5
 Subzone I-1
 Sediment Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level ^a (EL)	Number of Times EL Exceeded	HQ	ECPC
Inorganic (mg/kg)								
Aluminum	7	7	6,010 - 39,500	27,051	NA	-	-	Yes
Arsenic	7	7	3.0 - 16.7	12.4	7.24	6	2.3	Yes
Barium	7	7	12.7 - 45.5	34.0	NA	-	-	Yes
Beryllium	7	7	0.33 - 1.4	1.1	NA	-	-	Yes
Cadmium	7	1	0.2	-	1.0	0	0.2	No
Chromium	7	7	23.1 - 84.7	59.0	52.3	6	1.6	Yes
Cobalt	7	7	2.1 - 10.5	7.7	NA	-	-	Yes
Copper	7	7	6.3 - 54.1	31.2	18.7	5	2.9	Yes
Iron	7	7	5,970 - 33,500	25,871	NA	-	-	Yes
Lead	7	7	7.0 - 38.8	24.8	30.2	3	1.3	Yes
Manganese	7	7	66.5 - 610	452	NA	-	-	Yes
Nickel	7	7	7.5 - 22.3	15.5	15.9	4	1.4	Yes
Selenium	7	7	1.0 - 2.7	1.8	NA	-	-	Yes
Vanadium	7	7	14.3 - 73.5	51.7	NA	-	-	Yes
Zinc	7	7	25.2 - 136	88.65	124	0	1.1	Yes

Table 8.5
Subzone I-1
Sediment Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level ^a (EL)	Number of Times EL Exceeded	HQ	ECPC
Organic ($\mu\text{g}/\text{kg}$)								
Benzo(a)anthracene	7	3	89 - 130	109.7	330	0	0.4	No
Benzo(b)fluoranthene	7	3	110 - 160	140	NA	-	-	Yes
Benzo(k)fluoranthene	7	3	130 - 180	160	NA	-	-	Yes
Chrysene	7	3	110 - 130	117	330	0	0.39	No
Fluoranthene	7	5	94 - 250	170.8	330	0	0.76	No
Pyrene	7	5	120 - 340	200	330	1	1.0	Yes
tPAHs	7	5	214 - 1,170	490	1684	0	0.69	No
Organotins ($\mu\text{g}/\text{kg}$)								
Dibutyltin	1	1	8.7	-	NA	-	-	Yes
Monobutyltin	1	1	4.5	-	NA	-	-	Yes
Tetrabutyltin	7	2	49.8 - 87	68.4	NA	-	-	Yes
Tributyltin	7	5	15.0 - 29.2	20.78	NA	-	-	Yes

Notes:

- a = Effects levels represent USEPA Region IV (1995) Sediment Screening Values (SSVs).
- HQ = Hazard Quotient calculated using maximum concentration divided by EL.
- $\mu\text{g}/\text{kg}$ = micrograms per kilogram

Table 8.6
Subzone I-2
Sediment Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level* (EL)	Number of Times EL Exceeded	HQ	ECPC
Inorganic (mg/kg)								
Aluminum	4	4	5,240 - 16,300	9,000	NA	-	-	Yes
Antimony	4	4	0.3 - 1.1	0.585	12	0	0.09	No
Arsenic	4	4	2.9 - 12.2	6.45	7.24	1	1.69	Yes
Barium	4	4	13.3 - 35.4	20.53	NA	-	-	Yes
Beryllium	4	1	0.620	0.620	NA	-	-	Yes
Chromium	4	4	14.5 - 42.3	23.85	52.3	0	0.81	No
Cobalt	4	4	1.5 - 3.4	2.23	NA	-	-	Yes
Copper	4	4	8.3 - 54.9	26.93	18.7	2	2.94	Yes
Iron	4	4	4,260 - 14,300	8,117.5	NA	-	-	Yes
Lead	4	4	12.5 - 51.7	27.23	30.2	2	1.71	Yes
Manganese	4	4	103 - 238	170.0	NA	-	-	Yes
Nickel	4	4	5.4 - 16.6	10.13	15.9	1	1.04	Yes
Selenium	4	2	1.5 - 2.2	1.85	NA	-	-	Yes
Tin	4	4	1.7 - 3.5	2.38	NA	-	-	Yes
Zinc	4	4	68.1 - 536	280.78	124	3	4.32	Yes

Table 8.6
Subzone I-2
Sediment Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level ^a (EL)	Number of Times EL Exceeded	HQ	ECPC
Organic ($\mu\text{g}/\text{kg}$)								
2-Butanone	4	1	2.0	2.0	NA	-	-	Yes
Acenaphthylene	4	1	63	63	330	0	0.19	No
Anthracene	4	1	100	100	330	0	0.30	No
Benzo(a)anthracene	4	1	610	610	330	1	1.85	Yes
Benzo(a)pyrene	4	1	910	910	330	1	2.76	Yes
Benzo(b)fluoranthene	4	1	3,200	3,200	NA	-	-	Yes
Benzo(g,h,i)perylene	4	1	580	580	NA	-	-	Yes
Benzo(k)fluoranthene	4	1	3,600	3,600	NA	-	-	Yes
Bis(2-Ethylhexyl)phthalate	4	2	180 - 250	215	182	1	1.37	Yes
Chrysene	4	1	1,800	1,800	330	1	5.45	No
Dibenzo(a,h)anthracene	4	1	120.0	120	330	0	0.40	No
Dimethoate	4	1	36.0	36.0	NA	-	-	Yes
Fluoranthene	4	2	49 - 2,600	1,325.5	380	1	6.84	Yes
1-Methylnaphthalene	4	1	89	89	NA	-	-	Yes
Phenanthrene	4	1	250.0	250.0	330	0	0.76	No
Pyrene	4	2	38.0 - 1,800	919.0	330	1	5.45	Yes
2,4,5-T	4	1	7.8	7.8	NA	-	-	Yes
2,4,5-TP Silvex	4	1	120	120	NA	-	-	Yes
4,4'-DDD	4	3	0.820 - 21.0	7.61	3.3	1	10.5	Yes

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Table 8.6
 Subzone I-2
 Sediment Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level ^a (EL)	Number of Times EL Exceeded	HQ	ECPC
Organic (µg/kg)								
4,4'-DDE	4	4	3.3 - 160	52.8	3.3	4	80	Yes
4,4'-DDT	4	4	1.0 - 12.0	4.38	3.3	3	3.64	Yes
Aldrin	4	4	0.057 - 1.3	0.386	-	-	-	Yes
Aroclor 1260	4	1	98	98	-	-	-	Yes
beta-BHC	4	1	4.5	4.5	NA	-	-	Yes
delta-BHC	4	4	0.77 - 1.6	1.03	NA	-	-	Yes
gamma-BHC (Lindane)	4	3	0.26 - 2.0	0.970	3.3	0	0.61	No
Chlordane	4	1	5,300	5,300	1.7	1	3117	Yes
Dieldrin	4	4	0.68 - 3.4	1.93	330	1	1.03	Yes
Dinoseb	4	1	27.0	27.0	NA	-	-	Yes
Endosulfan	4	4	2.36 - 15.7	7.51	NA	-	-	Yes
Endrin	4	3	0.96 - 8.4	3.59	3.3	1	2.54	Yes
Endrin aldehyde	4	4	1.2 - 84	23.28	NA	-	-	Yes
Heptachlor	4	4	0.46 - 74.9	19.17	NA	-	-	Yes
Indeno(1,2,3-cd)pyrene	4	1	530.0	530.0	NA	-	-	Yes
Methoxychlor	4	3	2.0 - 11.0	5.67	NA	-	-	Yes
Parathion	4	1	9.6	9.6	NA	-	-	Yes

Table 8.6
Subzone I-2
Sediment Concentrations

Parameter	Number of Samples	Number of Detections	Range	Mean	Effects Level ^a (EL)	Number of Times EL Exceeded	HQ	ECPC
Dioxins (ng/kg)								
1,2,3,4,6,7,8-HpCDD	4	1	7.61	7.61	NA	-	-	Yes
OCDD	4	1	39.39	39.39	NA	-	-	Yes
OCDF	4	1	2.66	2.66	NA	-	-	Yes
Total Hepta-Dioxins	4	1	15.73	15.73	NA	-	-	Yes
Total Hexa-Dioxins	4	1	2.69	2.69	NA	-	-	Yes

Notes:

- a = Effects levels represent USEPA Region IV (1995) Sediment Screening Values.
- HQ = Hazard Quotient = maximum concentration/effects level.
- ECPC = Ecological Chemical of Potential Concern.
- mg/kg = milligrams per kilogram
- µg/kg = micrograms per kilogram
- ng/kg = nanograms per kilogram
- NA = Data not available

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Table 8.7
 Subzone I-3
 Sediment Concentrations

Parameter	Number of Samples	Number Detected	Range	Mean	Effects Level* (EL)	Number of Times EL Exceeded	HQ	ECPC
Inorganic (mg/kg)								
Aluminum	2	2	19,500 - 26,900	23,200	NA	-	-	Yes
Arsenic	2	2	10.6 - 15.4	13	7.24	2	2.1	Yes
Barium	2	2	25.2 - 37.2	31.2	NA	-	-	Yes
Beryllium	2	2	0.71 - 0.96	0.84	NA	-	-	Yes
Chromium	2	2	39.2 - 58.0	48.6	52.3	1	1.1	Yes
Cobalt	2	2	5.3 - 6.5	5.9	NA	-	-	Yes
Copper	2	2	21.9 - 29.5	25.7	18.7	2	1.6	Yes
Iron	2	2	17,100 - 26,900	22,000	NA	-	-	Yes
Lead	2	2	18.5 - 25.4	22	30.2	0	0.84	No
Manganese	2	2	542 - 559	550.5	NA	-	-	Yes
Nickel	2	2	11.8 - 16.4	14.1	15.9	1	1.0	Yes
Selenium	2	2	1.4 - 2.0	1.7	NA	-	-	Yes
Vanadium	2	2	24.4 - 50.4	42.4	NA	-	-	Yes
Zinc	2	2	67.5 - 93.4	80.5	124	0	0.75	No
Organic (µg/kg)								
Acetone	2	1	28.0	NA	-	-	-	Yes
2-Butanone	2	1	81.0	NA	-	-	-	Yes
Endrin aldehyde	2	1	67.0	NA	-	-	-	Yes

Table 8.7
Subzone I-3
Sediment Concentrations

Parameter	Number of Samples	Number Detected	Range	Mean	Effects Level ^a (EL)	Number of Times EL Exceeded	HQ	ECPC
Organic ($\mu\text{g}/\text{kg}$)								
4,4'-DDD	2	1	31.0	-	3.3	1	9.4	Yes
4,4'-DDE	2	1	34.0	-	3.3	1	10.3	Yes
Pyrene	2	1	79	-	330	0	0.2	No
tPAHs	2	1	79	-	1,684	0	0.05	No
TOC	2	2	11,100 - 13,000	12,050				
Organotins ($\mu\text{g}/\text{kg}$)								
Tributyltin	2	1	12.2	-	NA	-	-	Yes

Notes:

- a = Effects levels represent USEPA Region IV (1995) Sediment Screening Values (SSVs).
- HQ = Hazard Quotient = maximum concentration/effects level.
- NA = Data Not Available
- $\mu\text{g}/\text{kg}$ = micrograms per kilogram

8.4 Contaminant Fate and Transport

Surface soil across Zone I consists of fine- to medium-grained sand with silt and some clay. This soil type is typically low in organic material with high permeability and low pH. These factors most likely limit development of a microbial community and reduce the likelihood that sorbed organic contaminants will undergo microbial decomposition. The expected fate of these contaminants is to remain in the soil and undergo degradation and/or migrate downward.

Contaminants sorbed to surface soil could also conceivably be transported via air or surface water runoff, although these pathways are unlikely as major routes. Contaminants are not expected to spread far via surface runoff due to the substrate's highly permeable nature. Physical adsorption of contaminants to soil particles and available organic material also limits horizontal migration. Migration via air pathways could be significant only as it relates to dispersal of upper soil layer particles during high winds typical of coastal areas. Because sand particles are relatively large and heavy, extended migration through this route is not expected. Fate and transport issues are presented in Section 6.

8.5 Exposure Pathways and Assessment

8.5.1 Infaunal Invertebrates

The primary exposure pathway for infaunal invertebrates will be direct contact with surface soil. An assessment endpoint of a well-balanced soil infaunal community will be qualitatively measured by comparing literature data on toxic effects with actual soil concentrations.

8.5.2 Terrestrial Wildlife

For terrestrial wildlife species, exposure would include direct dermal contact, ingestion of soil particles, and food-chain transfer. Small mammals could contact contaminated soil if the area is used as a migratory corridor or if they burrow into it. The contact time, and thus exposure, will be limited when animals are crossing the area, but could be lengthy if burrows are established. Dermal contact by small reptiles and amphibians would be similar to that for mammals. For insect

populations, direct exposure to ground-dwelling species could provide a link for contaminant transfer to higher-level predators.

The assessment endpoint selected for terrestrial wildlife in Subzones I-1 and I-2 is the maintenance of well-balanced terrestrial wildlife populations and communities. As a measure of the assessment endpoint selected, results were used from laboratory toxicity studies in literature that relate the oral dose of a contaminant to adverse growth, reproduction, or survival responses. Selected measurement endpoint species include: red-tailed hawk (*Buteo jamaicensis*) and Eastern cottontail rabbit (*Sylvilagus floridanus*) in Subzone I-1, and American robin (*Turdus migratorius*), Eastern cottontail, and short-tailed shrew (*Blarina brevicauda*) in Subzone I-2. All of these species are likely to occur within the designated subzones in Zone I.

To assess biotransfer of contaminants along food chains the total potential dietary exposure (PDE) has been modeled for representative wildlife species within Subzones I-1 and I-2. PDEs are calculated based on predicted concentrations of the ECPC in food items that the species would consume, the amount of soil it would ingest, the relative amount of different food items in its diet, body weight, and food ingestion rate (Table 8.8). The concentrations of ECPCs in food items are estimated based on bioaccumulation factors (BAFs) reported in literature, which are a ratio of the ECPC concentration in dietary items to the concentration in soil. The BAFs reported for avian and mammalian species are reported ratios of ECPCs in the animals' tissue to ECPC concentrations in their diets.

The site foraging factor (SFF) considers the frequency of feeding in the site area by estimating its acreage relative to the receptors' feeding range, and by considering the fraction of the year the receptor would be exposed to site contaminants. To generate conservative SFF values, it was assumed that each species foraged within the designated subzone 100% of the year (exposure duration factor = 1.0).

Table 8.8
Wildlife Contaminant Exposure Model for Surface Soil

Food Contaminant Concentration (T_n) in mg/kg =	$BAF^1 \times \text{Soil Contaminant Concentration (mg/kg)}$
Soil Exposure (SE) in mg/kg =	$(\% \text{ diet soil}) \times \text{Soil Contaminant Concentration (mg/kg)}$
PDE (mg contaminant/kg BW/day) =	$\frac{[P_1 \times T_1 + P_2 \times T_2 + \dots P_n \times T_n + SE] \times IR_{\text{diet}} \times SFF}{BW}$

where:

- P_n = percent of diet composed of food item n
- T_n = Food Contaminant Concentration (mg/kg)
- IR_{diet} = food ingestion rate of receptor (kg of food per day)
- SFF = site foraging factor (cannot exceed 1)
- BW = receptor body weight (kg)
- BAF^1 = bioaccumulation factor from Table 8.10
- PDE = Potential Dietary Exposure

8.5.3 Vegetation

Woody and herbaceous vegetation in Subzones I-1, I-2, and I-3 could incorporate certain detected constituents (metals) through processes such as uptake/accumulation, translocation, adhesion, or biotransformation. Terrestrial herbivores could also ingest plant-borne constituents.

1
2
3
4

8.5.4 Aquatic Wildlife

The primary exposure pathway evaluated for aquatic wildlife species in Subzones I-1 and I-3 will be contact/interface with water and sediment. An assessment endpoint evaluating the aquatic community health has been selected, with a measurement endpoint that predicts chronic effects on aquatic community species.

8.6 Ecological Effects Assessment

Stressor Characteristics

Inorganics

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

There are relatively little data on the behavior of antimony. Over a broad range of soil oxidation reduction potentials (-0.5 to 0.5), most soil antimony is expected to be insoluble, if pH is less than 7.5, and thus have limited mobility.

Arsenic occurs naturally, and is constantly changing as it cycles through the environment. Many inorganic arsenicals are known teratogens and are more toxic than organic arsenicals (Eisler, 1988a). Soil biota appear to be capable of tolerating and metabolizing relatively high concentrations of arsenic (microbiota to 1,600 mg/kg) (Wang et al., 1984). Adverse effects on aquatic organisms, however, have been reported at concentrations of 19 to 48 µg/L in water. Arsenic in soil does not appear to magnify along the aquatic food chain.

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

Hexavalent chromium produces more adverse effects on biota than does the trivalent phase. In clayey sediments, trivalent chromium dominates and benthic invertebrate bioaccumulation is limited (Neff et al., 1978). The solubility and potential bioavailability of waste chromium added to soil through sewage sludge are modified by soil pH and organic complexing substances (James and Bartlett, 1983).

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

In soil, lead concentrates in organic-rich surface horizons (NRCC, 1973). Lead's estimated residence time in soil is about 20 years (Nriagu, 1978). In sediments, lead is primarily found in association with iron and manganese hydroxides and may also form associations with clay and organic matter. Under oxidizing conditions, lead tends to remain tightly bound to sediments, but is released into the water column under reducing conditions. Lead may accumulate to relatively high concentrations in aquatic biota.

Mercury is a known mutagen, teratogen and carcinogen. It adversely affects reproduction, growth, development, motor coordination, and metabolism. Mercury has a high potential for bioaccumulation and biomagnification, and is slow to deplete. Organomercury compounds

produce more adverse effects than inorganic mercury compounds. Inorganic mercury can be modified to organic mercury compounds through biological transformation processes.

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

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

Organics

Very little data are available to calculate the toxic effects or potential dietary uptake of VOCs by terrestrial organisms. Information is primarily available from human health effects studies on inhalation of specific compounds by laboratory animals. It is difficult to assess the impact from the limited occurrence and relatively low concentrations of volatile compounds observed in Zone I samples, but it is predicted that there will be little to no effect on terrestrial species. For example, acetone evaporates very quickly in the environment (vapor pressure 231 mm of mercury at 25°C) and is subject to biodegradation under both aerobic and anaerobic conditions. Tetrachloroethene also evaporates fairly rapidly due to its high vapor pressure (18.49 mm of mercury at 25°C) as does toluene (vapor pressure 28.4 mm of mercury at 25°C), which will biodegrade as well. K_{oc} values for toluene in sandy soils have been reported at 178, indicating high mobility and high potential for leaching to groundwater, away from potential receptors (*Handbook of Environmental Fate and Exposure Data*, Sage et al., 1990). Based on these factors, these VOCs are not expected to stress ecological receptors.

Polynuclear aromatic hydrocarbons (PAHs) vary by molecular weight. With increasing molecular weight, aqueous solubility decreases and the logarithm of octanol-water partition coefficient (log

K_{ow}) increases, suggesting increased solubility in fats, a decrease in resistance to oxidation and reduction, and a decrease in vapor pressure (Eisler, 1987a). Accordingly, PAHs of different molecular weight vary substantially in their behavior and distribution in the environment and in their biological effects. In water, PAHs either evaporate, disperse into the water column, become incorporated into sediment or undergo degradative processes such a photooxidation, chemical oxidation, and biological transformation by bacteria and animals (Neff, 1979).

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

Organochlorine pesticides have been used extensively in the United States since the 1940s. They appear to be ubiquitous in the environment, being found in surface water, sediment, and biological tissue. They are readily absorbed by warm-blooded species and degradatory products are frequently more toxic than the parent form. Food chain biomagnification is usually low, except in some marine mammals. In soil invertebrates, organochlorine pesticides can accumulate to levels higher than those in the surrounding soil, and residues may in turn be ingested by birds and other animals feeding on earthworms (Beyer and Gish, 1980). Most environmental effects studies have been directed at mammals and birds.

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

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

Dioxins are present as trace compounds in some commercial herbicides and chlorophenols (Eisler, 1986). The most toxic and most extensively studied dioxin is 2,3,7,8-TCDD. Laboratory studies with birds, mammals, aquatic organisms, and other species have demonstrated that exposure to 2,3,7,8-TCDD can result in acute and delayed mortality as well as mutagenic and reproductive effects. In soil, microbial decomposition of TCDD is slow (Ramel, 1978) and uptake by vegetation is considered negligible (Blair, 1973).

8.6.1 Infaunal Invertebrates

Potential adverse ecological effects on soil invertebrates from identified ECPCs are predicted based on available literature effects information. Because soil screening levels are unavailable for infaunal effects levels, studies are used for comparative qualitative assessments only.

8.6.2 Terrestrial Wildlife

Potential adverse effects associated with the identified ECPCs on bird and mammal species are based on food uptake potential. Available reference toxicity values (RTVs) were determined for each measurement endpoint species selected for Subzones I-1 and I-2. Subzone I-3 is a tidal salt marsh with no terrestrial habitat, and thus there is limited potential for foraging terrestrial wildlife (great blue herons, red-winged blackbirds) to be exposed to contaminants in Subzone I-3 sediment. Since the terrestrial wildlife which may conceivably forage in the Subzone I-3 marsh would likely forage in Subzone I-2, the risk estimates from the DMA could reasonably apply to terrestrial species which occur in Subzone I-3.

The RTV relates the dose of oral exposure to a specific ECPC with an adverse effect. The lethal RTV has been determined to be one-fifth of the lowest reported LD₅₀ (the dosage lethal to 50%

of the test population) value for the most closely related test species (Appendix G). One-fifth of an oral LD₅₀ value is considered to be protective of lethal effects for 99.9% of individuals in a test population (USEPA, 1986b). It is assumed that this is an acceptable level of risk to individuals in terrestrial wildlife populations across Zone I.

An RTV representing a threshold for non-lethal effects has also been compared with the calculated PDE. Sublethal effects are those that impair or prevent reproduction, growth, or survival and the sublethal RTV reflects the LOAEL established for the assessment endpoint chosen as the basis for establishing risk.

8.6.3 Vegetation

Toxicity to terrestrial plants from soil contaminants detected in the subzones will be qualitatively evaluated. Risk potentials will be discussed relative to literature studies and general information on phytotoxic mechanisms by selected ECPCs.

8.6.4 Aquatic Wildlife

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

8.7 Risk Characterization

8.7.1 Infaunal Invertebrates

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

Although some of the semivolatiles found in soil are considered carcinogenic to mammals, very few field studies exist on their toxicity to terrestrial infauna. Generally, PAHs break down in natural systems via photodegradation and microbial transformation. Neuhauser et al. (1986) found that specific phenol compounds (4-nitrophenol, 2,4,6-trichlorophenol, phenol) were somewhat toxic to earthworms, with PAHs being relatively less toxic than other semivolatile compounds studied. Artificial soil tests produced lethal concentration (LC_{50}) values for fluorene and phenol near 200 mg/kg and 400 mg/kg, respectively (Table 8.9). Callahan et al. (1994) found similar results in their study on the toxicity of 62 chemicals to several earthworm species. Fluorene is considered acutely toxic at certain concentrations but is not considered a carcinogen. It is important to note that field variability and soil chemical matrices can greatly influence toxicological effects of PAH compounds.

Most toxicological studies on terrestrial infaunal organisms have been directed at measuring pesticide effects. Earthworm toxicology and response information is the most prevalent. In a study by Beyer and Gish (1980), persistence of DDT, dieldrin, and heptachlor was observed in earthworms from field study plots. Investigators agree that earthworms can accumulate pesticides to concentrations found in residential soil. Callahan et al. (1991) showed very good soil-to-tissue correlation ($r^2 = 0.725$), with accumulation of DDT in single earthworms up to 22 mg/kg. Beyer and Gish (1980) found that earthworms accumulated DDT (DDTR) to 32 mg/kg. Barker (1958) associated poisoning (lethality) of robins with 60 mg/kg DDTR in earthworms, and Collett and

Table 8.9
 Chemical Effects Studies on Terrestrial Infaunal Invertebrates

Study	Organisms	Measured Parameter	Effects Level	Measured Response
Parmelee et al. (1993)	nematode/microarthropods	Copper	200 mg/kg	Significant decline in numbers
Neuhauser et al. (1986)	earthworm (<i>Eisenia foetida</i>)	Copper salts	643 mg/kg	LC ₅₀
		Zinc salts	662 mg/kg	LC ₅₀
		Nickel salts	757 mg/kg	LC ₅₀
		Cadmium salts	1,843 mg/kg	LC ₅₀
		Lead salts	6,000 mg/kg	LC ₅₀
		4-Nitrophenol	38 mg/kg	LC ₅₀
		Fluorene	173 mg/kg	LC ₅₀
		Phenol	401 mg/kg	LC ₅₀
Roberts & Dorough (1984)	earthworm (<i>Eisenia foetida</i>)	Cadmium chloride	10 - 100 µg/cm ²	LC ₅₀
		Copper sulfate	10 - 100 µg/cm ²	LC ₅₀
		Lead nitrate	10 - 100 µg/cm ²	LC ₅₀
Malecki et al. (1982)*	earthworm (<i>Eisenia foetida</i>)	Cadmium	250 mg/kg	Growth difference from control
		Nickel	440 mg/kg	Growth difference from control
		Copper	1,320 mg/kg	Growth difference from control
		Zinc	2,800 mg/kg	Growth difference from control
		Lead	21,600 mg/kg	Growth difference from control
Strait (1984)	mite (<i>Platynothrus peltifer</i>)	Copper	200 mg/kg	Population decrease
van Straalen et al. (1989)	mites	Cadmium	> 128 mg/kg	Mortality

Table 8.9
 Chemical Effects Studies on Terrestrial Infaunal Invertebrates

Study	Organisms	Measured Parameter	Effects Level	Measured Response
McKee (1992)	terrestrial epigeic ^b invertebrates	PCBs	120,000 mg/kg	No community structure effects
Callahan et al. (1991)	earthworms (<i>L. terrestris</i>)	DDT	400 µg/kg	No detectable concentration in tissue from soil concentrations
		DDD	700 µg/kg	
		DDE	200 µg/kg	
Menzie et al. (1992)	earthworm (<i>Eisenia foetida</i>)	DDT	1,000 [4,000] ^a µg/kg	Survival; no effect for LC ₅₀ test
		DDD	1,000 [12,000] ^a µg/kg	
		DDE	1,000 [2,000] ^a µg/kg	
Miller et al. (1985)	earthworm	Copper	644 mg/kg	EC ₅₀
		Zinc	628 mg/kg	EC ₅₀
	microtox (15 min.)	Copper	0.28 - 0.42 mg/kg	Photo reduction
		Zinc	1.6 mg/kg	Photo reduction
Paine et al. (1993)	crickets (<i>Acheta domesticus</i>)	PCBs	1,200 mg/kg	LC ₅₀
Reinecke & Nash (1984)	earthworms (<i>Allolobophora caliginosa</i> and <i>Lumbricus rubellus</i>)	Dioxin	< 5 mg/kg	No mortality
			> 10 mg/kg	Lethality
Ma (1984)	earthworm (<i>Lumbricus rubellus</i>)	Copper	100 - 150 mg/kg	Cocoon production decrease
			300 mg/kg	Mortality
Beyer et al. (1985a)	earthworm (<i>Eisenia foetida</i>)	Methyl Mercury	25 mg/kg 5 mg/kg	100% mortality 21% mortality
Abbasi and Soni (1983)	earthworm (<i>Octochaetus pattoni</i>)	Inorganic Mercury	0.79 mg/kg	50% mortality
			5 mg/kg	100% mortality

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Table 8.9
 Chemical Effects Studies on Terrestrial Infaunal Invertebrates

Study	Organisms	Measured Parameter	Effects Level	Measured Response
Rhett et al. (1988)	earthworm (<i>Eisenia foetida</i>)	PCBs	240 mg/kg	LC ₅₀
Nielson (1951)	earthworms	Copper	150 mg/kg 260 mg/kg	Population reduced by 1/2 Population eliminated
van Rhee (1967)	earthworms	Copper	85 mg/kg	Gradual decline of population
Ma (1982)	earthworm (<i>Lumbricus rubellus</i>)	Copper chloride	1,000 mg/kg	6-wk LC ₅₀

Notes:

- a = Growth effects levels are average of at least five of six compounds: metal acetate, metal carbonate, metal chloride, metal nitrate, metal oxide, metal sulfate.
- b = Aboveground species including *Carabidae*, *Entobeyidae*, *Formicidae*, *Gryllidae*, and *Staphylinidae*.
- c = Average soil concentration levels [maximum values].
- LC₅₀ = Concentration lethal to 50% of the test population
- EC₅₀ = Concentration that produced adverse effects to 50% of the test population

Harrison (1968) found that blackbirds and thrushes were affected at residues near 20 mg/kg. At concentrations observed in their study, Callahan et al. (1991) suggested that robins feeding at a rate of 10 to 12 earthworms in as many minutes (as observed by McDonald, 1983) could ingest enough contamination to pose a significant risk. This study also found that chlordane, as other pesticides, was taken up rapidly by earthworms. Total DDT concentrations greater than 1,000 mg/kg in soil, along with documented long half-life information (5.7 years for DDT), indicated a long-term significant risk to receptors (Callahan et al., 1991).

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

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

Most studies on metals toxicity to terrestrial receptors have been directed at infaunal ecosystems or avian biology. Information on relative metals toxicity to earthworms was provided by Roberts and Dorough (1984) where, along with 90 other chemicals, three metal salts (cadmium chloride, copper sulfate, and lead nitrate) were tested. The results showed that these heavy metal salts fell into the "very toxic" category, with LC_{50} values in the 10 to 100 micrograms per square centimeter ($\mu\text{g}/\text{cm}^2$) range. Although these concentrations (more specifically, application doses) may be relative to earthworms, it is improper to apply them to upper-level trophic species. Studies

indicate that some degradation products become increasingly more toxic to earthworms and less 1
toxic to upper-level vertebrates. Other studies on toxicities of metal salts to earthworms have been 2
conducted by Neuhauser et al. (1986) and Malecki et al. (1982). In the former study, metal nitrate 3
compounds were relatively toxic to earthworms in this order: copper > zinc > nickel > 4
cadmium > lead. Mean LC₅₀ values were 643, 662, 757, 1,843 and 6,000 mg/kg, respectively. 5
In the latter study, six chemical forms of each metal were chosen to cover a broad range of 6
solubility and to represent the forms likely to be found in soil. Overall, cadmium was most toxic, 7
followed by nickel, copper, zinc, and lead. It appears obvious from the results of these two 8
studies that the form of the metal in soil is a major consideration in judging effects of their 9
concentrations on soil biota. 10

Ma (1984) investigated sublethal effects of copper in soil on growth, cocoon production and litter 11
breakdown activity for *Lumbricus rubellus*. Cocoon and litter breakdown activity were 12
significantly reduced at 131 mg/kg copper and mortality was first observed at concentrations near 13
300 mg/kg. 14

Parmelee et al. (1993) found that total nematode/microarthropod (mostly mites) numbers declined 15
in soil with copper concentrations above 200 mg/kg; omnivore-predator nematodes and specific 16
microarthropod groups were significantly reduced at 100 mg/kg copper. 17

Subzone I-1

 18

Within Subzone I-1, no risk is predicted to infaunal communities from observed chemical 19
concentrations. Individual compounds (see Tables 8.2a and 8.2b) are not at effects levels observed 20
in studies for soil biota. Risks related to biotransfer of contaminants through infaunal species to 21
terrestrial vertebrate species will be addressed in subsequent sections. 22

Subzone I-2

Levels of some inorganic constituents found in Subzone I-2 are at concentrations that pose a potential risk to infaunal species. Maximum copper and zinc concentrations of 483 mg/kg and 876 mg/kg, respectively, are above effects levels reported in the literature causing reduced populations (Nielson, 1951 and Miller, 1985) and decreased cocoon production (Ma, 1984) in earthworms. Also soil concentrations for copper could conceivably present a potential risk to soil microarthropod populations (Parmelee et al., 1993).

There should be no acute effects on infauna from organics in soils at Subzone I-2. The observed maximum concentrations are several orders of magnitude below acute effects levels for soil infauna.

PAHs are not at individual compound concentrations that would indicate toxicity to infauna. Considering the maximum levels detected, the potential for additive effects from total semivolatile compounds is low. Based on literature studies, PCB and dioxin concentrations should present no toxic effects.

Subzone I-3

Although the presence of infaunal organisms is unlikely at this subzone due to its hydrology, no soil inorganic concentrations were at levels posing a risk to any infaunal species.

SVOC and pesticide occurrences at Subzone I-3 are limited. Concentrations detected, when compared with effects information, do not indicate a risk to any infaunal organisms.

8.7.2 Terrestrial Wildlife

Risks to the representative wildlife species from ingestion of surface soil and food are quantitatively evaluated using HQs, which are calculated for each ECPC by dividing the estimated dietary exposure concentration (PDE) by the toxicological benchmark (RTV). Hazard Indices (HI)

are determined for each representative wildlife species by summing the HQs for all ECPCs. When the estimated PDE is less than the RTV ($HQ < 1$), exposure to contaminants is assumed to fall below the range associated with adverse effects on growth, reproduction, and survival, and no risks to wildlife are assumed. When the HQ or HI is greater than one, the ecological significance is discussed and risk is assumed. When only the HIs are greater than one, the HQs composing the HI were evaluated.

For representative terrestrial wildlife species, PDEs were calculated using available bioaccumulation data (Table 8.10) for ECPCs presented in Tables 8.2a, 8.2b, 8.3a, and 8.3b. Exposure parameters and assumptions for representative species at Subzones I-1 and I-2 (Tables 8.11, 8.12) were used to calculate food contaminant concentrations. PDEs were not calculated for Subzone I-3 since it lacks terrestrial habitat, yet the terrestrial species which occur within the marsh at Subzone I-3 are also likely to be present at Subzone I-1. Using the model for prediction of contaminant exposure presented in Table 8.8, PDE values were obtained. HQs were determined for both lethal and sublethal ECPC effects at Subzones I-1 and I-2 and the results are presented in Tables 8.13 and 8.14, with HI values determined for each representative species. If the sublethal HI was below 1, indicating no risk, then a lethal HI was not calculated

Subzone I-1

All sublethal HI values were less than one for each of the representative wildlife species selected for soil contamination in Subzone I-1 (Table 8.13). There is no potential for adverse effects on wildlife from exposure to ECPCs in surface soil.

Subzone I-2

The sublethal HI values calculated for the robin ($HI = 1.82$) and the shrew ($HI = 5.22$) indicated potential effects from soil contamination in Subzone I-2 (Table 8.14a). With an HQ of 1.63, copper was the robin's major risk contributor and arsenic ($HQ = 5.07$) contributed most to the

Table 8.10
Bioaccumulation Data¹
Baseline Risk Assessment

Analyte	Log K _{ow}	Plant	Bioaccumulation Factor (unitless)		
			Terrestrial Invertebrate	Mammal	Bird
Semivolatiles					
Anthracene	4.4 [c]	NA	0.005 [d]	6.30E-04 [a]	1 [ab]
Benzo(a)anthracene	5.74 [c]	0.019 [e]	0.0125 [d]	1.38E-02 [a]	1 [ab]
Benzo(a)pyrene	6.07 [c]	0.012 [e]	0.0342 [d]	2.95E-02 [a]	1 [ab]
Benzo(b)fluoranthene	6.32 [c]	0.008 [e]	0.032 [d]	5.25E-02 [a]	1 [ab]
Benzo(g,h,i)perylene	7 [c]	0.003 [e]	0.024 [d]	2.50E-01 [a]	1 [ab]
Benzo(k)fluoranthene	6.45 [c]	0.007 [e]	0.025 [d]	7.08E-02 [a]	1 [ab]
Bis(2-ethylhexyl)phthalate (BEHP)	5.3 [f]	0.033 [e]	0.022 [aj]	5.00E-03 [a]	1 [ab]
Butylbenzylphthalate	4.78 [g]	0.049 [e]	0.022 [aj]	1.50E-03 [a]	1 [ab]
Chrysene	5.71 [c]	0.019 [e]	0.031 [d]	1.29E-02 [a]	1 [ab]
Dibenzo(a,h)anthracene	6.42 [c]	0.008 [e]	0.022 [aj]	6.61E-02 [a]	1 [ab]
Di-n-butylphthalate	4.8 [h]	NA	0.022 [aj]	1.60E-03 [a]	1 [ab]
Fluoranthene	5.25 [c]	0.036 [e]	0.007 [d]	4.50E-03 [a]	1 [ab]
Indeno(1,2,3-cd)pyrene	7.7 [c]	0.0014 [e]	0.042 [d]	1.26E+00 [a]	1 [ab]
Pentachlorophenol	5.0 [ap]	0.050 [e]	8.0 [ap]	2.53E-03 [a]	1 [ab]

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Table 8.10
 Bioaccumulation Data¹
 Baseline Risk Assessment

Analyte	Log K_{ow}	Plant	Bioaccumulation Factor (unitless)		
			Terrestrial Invertebrate	Mammal	Bird
Semivolatiles					
Phenanthrene	4.43 [c]	NA	0.012 [d]	6.70E-04 [a]	1 [ab]
Pyrene	5.09 [c]	0.044 [e]	0.018 [d]	3.10E-03 [a]	1 [ab]
Pesticides/PCBs/Dioxins					
Aroclor-1248	6 [c]	0.013 [e]	1.2 [f]	1.00E+00 [ak]	1 [ab]
Aroclor-1254	6.02 [c]	0.013 [e]	1.2 [f]	1.00E+00 [ak]	1 [ab]
Aroclor-1260	6 [c]	0.013 [e]	1.2 [f]	1.00E+00 [ak]	1 [ab]
alpha-Chlordane	2.78 [f]	0.027 [ac]	0.8 [j]	7.10E-01 [ak]	0.71 [ai]
gamma-Chlordane	3.32 [f]	0.027 [ac]	0.8 [j]	7.10E-01 [ak]	0.71 [ai]
4,4'-DDE	5.69 [f]	0.02 [e]	0.98 [v]	2.91E+00 [ak]	2.91 [l]
4,4'-DDT	4.48 [f]	0.027 [ac]	0.98 [v]	2.91E+00 [ak]	2.91 [f]
Chlordane	6.00 [ao]	0.013 [e]	0.027 [ac]	2.50E-02 [a]	0.7 [ab]
Dieldrin	4.95 [f]	0.049 [e]	1.2 [m]	7.10E-01 [ak]	0.71 [n]
Endrin	5.16 [ao]	0.040 [e]	0.027 [ac]	3.60E-03 [a]	1 [ab]
Heptachlor	5.44 [ao]	0.028 [e]	0.027 [ac]	6.90E-03 [a]	1 [ab]

Table 8.10
Bioaccumulation Data¹
Baseline Risk Assessment

Analyte	Log K _{ow}	Plant	Bioaccumulation Factor (unitless)		
			Terrestrial Invertebrate	Mammal	Bird
Pesticides/PCBs/Dioxins					
Heptachlor epoxide	5.40 [ao]	0.029 [e]	0.027 [ac]	6.30E-03 [a]	1 [ab]
2,3,7,8 TCDD	6.80 [am]	0.005 [e]	5.0 [b]	8.40E-01 [an]	1 [ab]
Inorganics					
Arsenic	NA	0.3 [p]	0.77 [ae]	3.60E-01 [ag]	0.45 [ah]
Barium	NA	0.56 [ag]	0.77 [ae]	3.40E-01 [af]	0.45 [ah]
Cadmium	NA	33 [q]	1.4 [k]	2.06E+00 [r]	0.38 [s]
Copper	NA	0.78 [t]	0.16 [i]	6.00E-01 [q]	0.45 [ah]
Lead	NA	0 [q]	0.22 [u]	5.40E-01 [w]	0.45 [ah]
Manganese	NA	0.56 [ag]	0.77 [ae]	3.40E-01 [ag]	0.45 [ah]
Mercury	NA	0.56 [ag]	0.34 [x]	1.00E-02 [aa]	2.33 [aa]
Selenium	NA	0.009 [y]	0.77 [ae]	3.40E-01 [af]	0.51 [z]
Zinc	NA	0.61 [t]	1.77 [i]	2.06E+00 [w]	0.45 [ah]

- Notes:**
- [a] = Calculated using the following equation (Travis and Arms, 1988), unless otherwise noted: $\log \text{BAF} = \log K_{ow} - 7.6$; result multiplied by average of ingestion rates for non-lactating and lactating test animals. There is an uncertainty involved in using this equation for PAHs, because this study did not use any PAHs in the regression analysis.
 - [b] = Reinecke and Nash (1984).
 - [c] = Geometric mean of values from USEPA (1986b).
 - [d] = Marquerie et al. (1987) as cited in Beyer (1990). Mean of values. Converted to wet weight assuming 90% body weight as water.

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Notes: (Continued)

- [e] = Calculated using the following equation in Travis and Arms (1988) for analytes with $\log K_{ow,s} > 5$: $\log(\text{Plant Uptake Factor}) = 1.588 - 0.578 \log K_{ow,s}$.
- [f] = From USEPA (1986b).
- [g] = Value from Verschueren (1983).
- [h] = Value from Howard (1990).
- [i] = BCF (bioconcentration factor) for earthworms from Diercxsens et al. (1985).
- [j] = Value from Gish (1970).
- [k] = Mean of values reported for soil invertebrates in Macfadyen (1980) converted from dry weight to wet weight.
- [l] = Whole body pheasant BAF for 4,4'-DDT derived from Kenaga (1973).
- [m] = Average of values reported for soil invertebrates in Edwards and Thompson (1973).
- [n] = Jeffries and Davis (1968).
- [o] = Value reported for endrin from Gish (1970).
- [p] = Average of BAF values reported from Wang et al. (1984), Sheppard et al. (1985) and Merry et al. (1986).
- [q] = Levine et al. (1989).
- [r] = Mean of values reported for *Sorex araneus* in Macfadyen (1980).
- [s] = Based on accumulation of cadmium in kidneys of European quail in Pimentel et al. (1984).
- [t] = Median of values reported from Levine et al. (1989).
- [u] = Geometric mean of BAF values (fresh st. worm/dry st. soil) for worms and woodlice (USEPA, 1985a). Fresh weight tissue concentrations calculated assuming 90% body water content.
- [v] = Beyer and Gish (1980) reported dry weight to wet weight ratio.
- [w] = Mean of values for *Microtus agrestis* and *Apodemus sylvaticus* in Macfadyen (1980).
- [x] = Value from USEPA (1985b) sludge document.
- [y] = Based on reported ratio of selenium in plant tissue and iron fly ash amended soil (Stoewsand et al., 1978).
- [z] = Based on average of reported ratio of selenium in diet to liver, kidney, and breast tissue of chickens (Ort and Latshaw, 1977).
- [aa] = USEPA, 1985b.
- [ab] = Assumption.
- [ac] = Assumed value based on average of BAFs calculated for other pesticides and PCBs.
- [ad] = Assumed value based on average of BAFs for Aroclor 1260, alpha-chlordane, 4,4'-DDE, dieldrin, and endrin ketone.
- [ae] = Assumed value based on average of BAFs reported for other metals.
- [af] = Assumed value based on average of reported BAFs for Cd, Cu, Pb and Hg.
- [ag] = Assumed value based on average of reported BAFs for As, Cu, Hg and Zn.
- [ah] = Assumed value based on average of reported BAF values for Cd and Se.
- [ai] = Assumed value based on reported BAF for dieldrin.
- [aj] = Assumed value based on average of BAFs for semivolatiles.
- [ak] = Value for mammal unavailable. Bioaccumulation assumed to be the same as values reported for birds.
- [am] = Polder et al. (1995).
- [an] = Rose et al. (1976).
- [ao] = Travis and Arms (1988).
- [ap] = vanGestel and Ma (1988).
- NA = Not available.
- 1 = Table adapted from BRA, NAS Cecil Field, Jacksonville, Florida.

Table 8.11
 Exposure Parameters and Assumptions for Representative Wildlife Species at Subzone I-1

Representative Wildlife Species	Trophic Status	Prey in Diet (%)					Incidental Soil Ingestion (%)	Home Range (acres)	ED	Site Foraging Frequency*	Ingestion Rate (kg-day)	Body Weight (kg)
		Invertebrates	Plants	Small Mammals	Herpetofauna	Small Birds						
Red-Tailed Hawk ^a	Predatory Bird	0	0	82	3	10	5	1073	1	5.39E-02	0.10	1.1
Eastern Cottontail ^b	Small Herbivorous Mammal	0	97	0	0	0	3	9.3	1	1.00E+00	0.08	1.2
SITE AREA:		57.8 acres										

Notes:

- a** = - Diet assumptions and ingestion rates based on data and mean values from Craighead & Craighead, 1956.
 - Body weight reflects interpolated values for adults from Craighead & Craighead, 1956; Steenhof, 1983; Springer & Osborne, 1983.
 - Home range reflects interpolated values from Andersen & Rongstad, 1989; Craighead & Craighead, 1956; and U.S. Department of the Interior, 1979.
- b** = - Diet assumptions based on data from Dusi, 1952; and Spencer & Chapman, 1986.
 - Food ingestion rate (FI) from formula: $FI(kg\text{-day}) = 0.0687 \times Wt^{0.822} (kg)$ (Nagy, 1987).
 - Body weight reflects interpolated values from Chapman & Morgan 1973; Pelton & Jenkins, 1970.
 - Home range reflects interpolated values from Althoff & Storm, 1989; and Dixon et al., 1981.
- ED** = Exposure Duration (percentage of year receptor is expected to be found at study area; expressed as a factor (i.e., 100% = 1)

*Calculated by multiplying site area (acres) by exposure duration (ED), divided by Home Range (HR); cannot exceed 1.0.

Table 8.12
 Exposure Parameters and Assumptions for Representative Wildlife Species at Subzone 1-2

Representative Wildlife Species	Trophic Status	Prey in Diet (%)					Incidental Soil Ingestion (%)	Home Range (acres)	ED	Site Foraging Frequency*	Ingestion Rate (kg-day)	Body Weight (kg)
		Invertebrates	Plants	Small Mammals	Herpetofauna	Small Birds						
Eastern Cottontail ^a	Small Herbivorous Mammal	0	97	0	0	0	3	9.3	1	1	0.08	1.2
American robin ^b	Small Carnivorous Bird	83	7	0	0	0	10	1.04	1	1	0.01	0.077
Short-tailed Shrew ^c	Small Carnivorous Mammal	78	12	0	0	0	10	0.96	1	1	0.0025	0.018
SITE AREA:		66.0 acres										

Notes:

- a = - Diet assumptions based on data from Dusi, 1952; and Spencer & Chapman, 1986
 - Food ingestion rate (FI) from formula: $FI(kg\text{-day}) = 0.0687 \times Wt^{0.822}$ (kg) (Nagy, 1987)
 - Body weight reflects interpolated values from Chapman & Morgan 1973; Pelton & Jenkins, 1970
 - Home range reflects interpolated values from Althoff & Storm, 1989; and Dixon et al., 1981
- b = - Diet assumptions based on data from Hamilton, 1943 and Wheelwright, 1986
 - Food ingestion rate (FI) from formula: $FI(kg\text{-day}) = 0.0582 Wt^{0.651}$ (kg) (Nagy, 1987)
 - Body weight from Clench & Leberman, 1978.
 - Home range reflects interpolated values from Howell, 1942; and Weatherhead & McRae, 1990
- c = - Diet assumption based on data from Whitaker & Ferraro, 1963
 - Food ingestion rate (FI) from formula: $FI(kg\text{-day}) = 0.0687 \times Wt^{0.822}$ (kg) (Nagy, 1987)
 - Body weight from Lomolino, 1984
 - Home range value from Buckner, 1966
- ED = Exposure Duration (percentage of year receptor is expected to be found at study area; expressed as a factor (i.e., 100% = 1)

*Calculated by multiplying site area (acres) by exposure duration (ED), divided by Home Range (HR); cannot exceed 1.0

Table 8.13
Hazard Quotients for Potential Sublethal Effects on Wildlife Species Associated with
ECPC Maximum Exposure Concentrations in Soil at Subzone I-I

Analyte	Max Conc (mg/kg)	Red-Tailed Hawk			Eastern Cottontail Rabbit		
		PDE	RTV	HQ	PDE	RTV	HQ
Benzo(b)fluoranthene	0.061	5.80E-05	NA	NC	1.54E-04	NA	NC
Benzo(k)fluoranthene	0.066	6.75E-05	NA	NC	1.62E-04	NA	NC
bis(2-Ethylhexyl)phthalate (BEHP)	0.150	1.14E-04	NA	NC	6.20E-04	35	1.77e-05
beta-BHC	0.003	NA	NA	NC	NA	NA	NC
Antimony	0.32	NA	NA	NC	NA	NA	NC
Tin	1.4	NA	NA	NC	NA	NA	NC
HI =				NC			1.77e-05

- Notes:**
- NA = Data not available
 - NC = Not able to calculate value
 - Max Conc = Maximum Concentration of Analyte
 - PDE = Potential Dietary Exposure (mg/kg/BW) calculated based on equation in Table 8.8
 - RTV = Reference Toxicity Value (mg/kg/BW/day) - the lowest reported LOAEL value from Appendix G for closest related species
 - HQ = Hazard Quotient - PDE divided by the RTV
 - HI = Hazard Index (HQ₁ + HQ₂ + ...HQ_n)

Table 8.14a
 Hazard Quotients for Potential Sublethal Effects on Wildlife Species Associated with
 ECPC Maximum Exposure Concentrations in Soil at Subzone I-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	RTV	HQ	PDE	RTV	HQ	PDE	RTV	HQ
Acetone	0.096	NA	NA	NC	NA	NA	NC	NA	NA	NC
Benzo(a)anthracene	1.5	2.18E-02	NA	NC	4.84E-03	NA	NC	2.33E-02	NA	NC
Benzo(b)fluoranthene	2.4	3.96E-02	NA	NC	6.04E-03	NA	NC	4.20E-02	NA	NC
Benzo(k)fluoranthene	2.6	4.09E-02	NA	NC	6.38E-03	NA	NC	4.35E-02	NA	NC
Benzo(a)pyrene	1.2	2.01E-02	NA	NC	3.33E-03	4.0E+01	8.33E-05	2.14E-02	4.0E+01	5.35E-04
bis(2-Ethylhexyl)phthalate (BEHP)	2.4	3.8E-02	NA	NC	9.92E-03	3.5E+01	2.83E-04	4.04E-02	5.0E+01	8.10E-04
Chrysene	1.60	2.60E-02	NA	NC	5.17E-03	NA	NC	2.81E-02	NA	NC
Di-n-butylphthalate	0.12	NA	NA	NC	NA	NA	NC	NA	NA	NC
Fluoranthene	2.6	3.70E-02	NA	NC	1.13E-02	4.0E+02	2.83E-05	3.96E-02	4.0E+02	9.90E-05
1-Methylnaphthalene	0.76	NA	NA	NC	NA	NA	NC	NA	NA	NC
2-Methylnaphthalene	0.69	NA	NA	NC	NA	NA	NC	NA	NA	NC
Naphthalene	0.540	NA	NA	NC	NA	NA	NC	NA	NA	NC
Phenanthrene	0.950	NA	NA	NC	NA	NA	NC	NA	NA	NC
Pyrene	2.2	3.37E-02	NA	NC	1.07E-02	NA	NC	3.65E-02	NA	NC
Toluene	0.027	NA	NA	NC	NA	NA	NC	NA	NA	NC
Aldrin	0.0027	NA	NA	NC	NA	NA	NC	NA	NA	NC
Beta-BHC	0.008	NA	NA	NC	NA	NA	NC	NA	NA	NC
4,4'-DDD	0.036	NA	NA	NC	NA	NA	NC	NA	NA	NC
4,4'-DDE	0.22	2.61E-02	NA	NC	7.25E-04	NA	NC	2.65E-02	NA	NC
4,4'-DDT	0.053	6.30E-03	NA	NC	1.99E-05	NA	NC	6.39E-04	8.1E+01	7.89E-05

Table 8.14a
Hazard Quotients for Potential Sublethal Effects on Wildlife Species Associated with
ECPC Maximum Exposure Concentrations in Soil at Subzone I-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	RTV	HQ	PDE	RTV	HQ	PDE	RTV	HQ
Endosulfan	0.036	NA	NA	NC	NA	NA	NC	NA	2.6E-01	NC
Endrin aldehyde	0.009	NA	NA	NC	NA	NA	NC	NA	NA	NC
Heptachlor epoxide	0.049	7.92E-04	NA	NC	1.9E-04	NA	NC	8.48E-04	NA	NC
Methoxychloride	0.075	NA	NA	NC	NA	NA	NC	NA	NA	NC
Aroclor 1260	0.17	2.42E-02	NA	NC	4.83E-04	6.5E+00	7.48e-05	2.45E-02	NA	NC
Total Tetradoxins	0.056	NA	NA	NC	NA	NA	NC	NA	NA	NC
Aluminum	48,400	NA	NA	NC	NA	NA	NC	NA	NA	NC
Antimony	21.4	NA	NA	NC	NA	NA	NC	NA	NA	NC
Arsenic	28.7	2.83E+00	NA	NC	6.14E-04	5.8E-01	1.06e-03	2.94E+00	5.8E-01	5.07
Barium	203	2.05E+01	NA	NC	7.76E+00	NA	NC	2.16E+01	NA	NC
Cadmium	1.4	6.49E-01	1.0E+01	6.49e-02	2.99E+00	2.2E+01	1.36e-01	1.0E+00	4.5E+02	2.20e-03
Chromium	131	NA	2.5E+01	NC	NA	NA	NC	NA	NA	NC
Cobalt	8.9	NA	NA	NC	NA	NA	NC	NA	NA	NC
Copper	483	1.80E+01	1.1E+01	1.64	2.53E+01	1.5E+02	1.69e-01	2.14E+01	1.5E+02	1.43e-01
Iron	36,700	NA	NA	NC	NA	NA	NC	NA	NA	NC
Lead	949	3.48E+01	NA	NC	1.9E+00	5.2E+02	3.65e-03	NA	3.0E+02	NC
Manganese	815	8.24E+01	NA	NC	3.11E+01	9.3E+02	3.30e-02	8.96E+01	NA	NC
Nickel	46.8	NA	NA	NC	NA	1.6E+02	NC	NA	NA	NC
Selenium	2.2	2.11E-01	1.8E+00	1.17e-01	5.68E-03	1.3E+02	4.37e-05	2.14E-01	1.3E+02	1.65e-03

Table 8.14a
 Hazard Quotients for Potential Sublethal Effects on Wildlife Species Associated with
 ECPC Maximum Exposure Concentrations in Soil at Subzone I-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	RTV	HQ	PDE	RTV	HQ	PDE	RTV	HQ
Thallium	0.71	NA	NA	NC	NA	NA	NC	NA	NA	NC
Tin	42	NA	NA	NC	NA	NA	NC	NA	NA	NC
Vanadium	83.8	NA	NA	NC	NA	NA	NC	NA	NA	NC
Zinc	876	1.83E+02	NA	NC	3.63E+01	1.6E+02	2.26e-01	1.89E+02	NA	NC
HI =				1.83			0.57			5.22

- Notes:**
- Max Conc = Maximum Concentration of Analyte
 - NA = Data not available
 - NC = Not able to calculate value
 - PDE = Potential Dietary Exposure (mg/kg/BW) calculated based on equation in Table 8.8
 - RTV = Reference Toxicity Value (mg/kg/BW/day) - the lowest reported LOAEL value from Appendix G for closest related species
 - HQ = Hazard Quotient - PDE divided by the RTV
 - HI = Hazard Index (HQ₁ + HQ₂ + ...HQ_n)

Table 8.14b
Hazard Quotients for Potential Lethal Effects on Wildlife Species Associated with
ECPC Maximum Exposure Concentrations in Soil at Subzone I-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	RTV	HQ	PDE	RTV	HQ	PDE	RTV	HQ
Acetone	0.096	NA	NA	NC	NA	NA	NC	NA	NA	NC
Benzo(a)anthracene	1.5	2.18E-02	NA	NC	4.84E-03	NA	NC	2.33E-02	NA	NC
Benzo(b)fluoranthene	2.4	3.96E-02	NA	NC	6.04E-03	NA	NC	4.20E-02	NA	NC
Benzo(k)fluoranthene	2.6	4.09E-02	NA	NC	6.38E-03	NA	NC	4.35E-02	NA	NC
Benzo(a)pyrene	1.2	2.01E-02	NA	NC	3.33E-03	1.0E+01	3.33e-04	2.14E-02	1.0E+01	2.14e-03
bis(2-Ethylhexyl)phthalate (BEHP)	2.4	3.80E-02	NA	NC	9.92E-03	6.8E+03	1.46e-06	4.04E-02	1.6E+02	2.53e-04
Chrysene	1.6	2.60E-02	NA	NC	5.17E-03	NA	NC	2.81E-02	NA	NC
Di-n-butylphthalate	0.12	NA	NA	NC	NA	NA	NC	NA	NA	NC
Fluoranthene	2.6	3.70E-02	NA	NC	1.13E-02	NA	NC	3.96E-02	NA	NC
1-Methylnaphthalene	0.76	NA	NA	NC	NA	NA	NC	NA	NA	NC
2-Methylnaphthalene	0.69	NA	NA	NC	NA	NA	NC	NA	NA	NC
Naphthalene	0.54	NA	NA	NC	NA	NA	NC	NA	NA	NC
Phenanthrene	0.95	NA	NA	NC	NA	1.4E+02	NC	NA	1.4E+02	NC
Pyrene	2.2	3.37E-02	NA	NC	1.07E-02	5.4E+02	1.98e-05	3.65E-02	1.6E+02	2.28e-04
Toluene	0.027	NA	NA	NC	NA	NA	NC	NA	NA	NC
Aldrin	0.003	NA	NA	NC	NA	NA	NC	NA	NA	NC
Beta-BHC	0.008	NA	NA	NC	NA	NA	NC	NA	NA	NC
4,4'-DDD	0.036	NA	NA	NC	NA	NA	NC	NA	NA	NC
4,4'-DDE	0.22	2.61E-02	NA	NC	7.25E-04	1.6E+02	4.53e-06	2.65E-02	1.4E+02	1.89e-04

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Table 8.14b
 Hazard Quotients for Potential Lethal Effects on Wildlife Species Associated with
 ECPC Maximum Exposure Concentrations in Soil at Subzone I-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	RTV	HQ	PDE	RTV	HQ	PDE	RTV	HQ
4,4'-DDT	0.053	6.30E-03	NA	NC	1.99E-04	5.0E+01	3.98e-06	6.39E-03	2.7E+01	2.37e-04
Endosulfan	0.036	NA	NA	NC	NA	NA	NC	NA	4.8E+00	NC
Endrin aldehyde	0.009	NA	NA	NC	NA	NA	NC	NA	NA	NC
Heptachlor epoxide	0.049	7.92E-04	NA	NC	1.9E-04	NA	NC	8.48E-04	NA	NC
Methoxychloride	0.075	NA	NA	NC	NA	NA	NC	NA	NA	NC
Aroclor 1260	0.17	2.42E-02	NA	NC	4.83E-04	1.0E+02	4.83e-06	2.45E-02	1.0E+02	2.45e-04
Total Tetradoxins	0.056	NA	NA	NC	NA	NA	NC	NA	NA	NC
Aluminum	48,400	NA	NA	NC	NA	1.00E+02	NC	NA	NA	NC
Antimony	21.4	NA	NA	NC	NA	NA	NC	NA	NA	NC
Arsenic	28.7	2.83E+00	NA	NC	6.14E-01	1.50E+02	4.09e-03	2.94E+00	2.90E+01	1.01e-01
Barium	203	2.05E+01	NA	NC	7.76E+00	NA	NC	2.16E+01	NA	NC
Cadmium	1.4	6.49E-01	NA	NC	2.99E+00	3.0E+01	9.97e-02	1.0E+00	1.8E+02	5.56e-03
Chromium	131	NA	NA	NC	NA	NA	NC	NA	NA	NC
Cobalt	8.9	NA	NA	NC	NA	NA	NC	NA	NA	NC
Copper	483	1.80E+01	NA	NC	2.53E+01	NA	NC	2.14E+01	NA	NC
Iron	36,700	NA	NA	NC	NA	2.40E+02	NC	NA	2.0E+02	NC
Lead	949	34.8	4900	7.10e-03	1.9E+00	NA	NC	NA	NA	NC
Manganese	815	8.24E+01	NA	NC	3.11E+01	8.0E+01	3.89e-01	8.96E+01	NA	NC

Table 8.14b
Hazard Quotients for Potential Lethal Effects on Wildlife Species Associated with
ECPC Maximum Exposure Concentrations in Soil at Subzone I-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	RTV	HQ	PDE	RTV	HQ	PDE	RTV	HQ
Nickel	46.8	NA	NA	NC	NA	1.3E+01	NC	NA	NA	NC
Selenium	2.2	2.11E-01	NA	NC	5.68E-03	1.30E+03	4.37e-06	2.14E-01	1.3E+03	1.65e-04
Thallium	0.71	NA	NA	NC	NA	NA	NC	NA	NA	NC
Tin	42	NA	NA	NC	NA	NA	NC	NA	NA	NC
Vanadium	83.8	NA	1.9E+01	NC	NA	NA	NC	NA	NA	NC
Zinc	876	1.83E+02	NA	NC	36.3	500	7.26e-02	1.89E+02	NA	NC
HI =				0.007			0.565			0.110

- Notes:**
- Max Conc = Maximum Concentration of Analyte
 - NA = Data not available
 - NC = Not able to calculate value
 - PDE = Potential Dietary Exposure (mg/kg/BW) calculated based on equation in Table 8.8
 - RTV = Reference Toxicity Value (mg/kg/BW/day) - 1/5 of the lowest reported LD₅₀ value from Appendix G for closest related species
 - HQ = Hazard Quotient - PDE divided by the RTV
 - HI = Hazard Index (HQ₁ + HQ₂ + ...Hq_n)

shrew's sublethal risk. When the less conservative lethal HIs for Subzone I-2 were calculated, no risk was predicted for these species (Table 8.14b). Based on the HQ and HI values produced, potential sublethal effects on lower-level vertebrates exists from exposure to ECPCs in surface soil. A maximum arsenic concentration (28.7 mg/kg) was responsible for an HQ value of 5.07, which was the most significant contributor to an overall HI value of 5.21 for sublethal effects on the short-tailed shrew.

The risk potential produced by the model contradicts some literature information on arsenic transfer to small mammals. Pascoe et al. (1994) found that the fraction of arsenic in soil that is bioavailable to small mammals was limited. Results of the model, however, agree with other studies which show that transfer of metal to small mammals via plant uptake from soil is feasible (Leita et al., 1991). Measurement of tissue concentrations or in situ bioaccumulation studies are needed to assess the actual potential for impacts to small mammals at Subzone I-2.

8.7.3 Vegetation

Limited information exists on toxic effects of soil contamination on plants in natural environments. Most literature containing effects information deals with herbicide or fungicide application programs. Beyer et al. (1985b) demonstrated that only a small portion of all metals measured in soil became incorporated in plant foliage. In their study, the origin for plant metal residues was suggested to have come primarily from aerial deposition. Table 8.15 presents phytotoxic effects levels for arsenic, lead, and zinc for several species. Effects levels vary depending on specific soil physicochemical conditions such as pH, organic content, and cation exchange capacity (CEC). Risk to Zone I vegetation from soil contaminants was determined by a comparison of chemical concentrations with effects data.

Table 8.15
 Phytotoxic Responses to ECPCs in Soils at Subzones I-1, I-2, I-3

Study	Organism	Measured Parameter	Effects Level	Measured Response
EPA (1987)	Red Maple (<i>Acer rubrum</i>)	Zinc	100 mg/kg	Lethal to seedlings
EPA (1987)	Red Oak (<i>Quercus rubra</i>)	Zinc	100 mg/kg	Lethal to seedlings
NRCC (1978)	Canadian crops	Arsenic	25-85 mg/kg	Depressed crop yield
	Rice (<i>Oryza sativum</i>)	Arsenic (disodium methylarsenate)	50 mg/kg	75% decreased yield
Sadiq (1985)	Corn plant	Lead	800 mg/kg	No elevated concentration in plants
Krishnayya and Bedi (1986)	Weeds (<i>Cassia</i> spp)	Lead	500 mg/kg	90% reduced pollen germination
Miller et al. (1985)	Radish (seed germination)	Copper	47 mg/kg	EC ₅₀
		Zinc	53 mg/kg	EC ₅₀
	Cucumber (seed germination)	Copper	55 mg/kg	EC ₅₀
		Zinc	61 mg/kg	EC ₅₀

Notes:

EC₅₀ = Concentration that produced adverse effects to 50% of the test population

NRCC = National Resource Council of Canada

Arsenic availability to plants is typically highest in coarse-textured soil with little CEC, and lowest in clay with organic material, and containing iron, calcium, and phosphate (NRCC, 1978). Cadmium appears to be taken up by plants in soil with abnormally high cadmium residues. For chromium, the Towill et al. (1978) study showed no phytotoxic effects on plants for elevated chromium concentrations.

Like other metals, the bioavailability of lead in soil to plants is enhanced by reduced soil pH, reduced organic matter, and reduced iron oxides and phosphorus content (NRCC, 1973). Studies have shown that there is no convincing evidence that terrestrial vegetation is important in food chain biomagnification of lead (Eisler, 1988b). Chang et al. (1983) observed that zinc uptake was

lower in coarse loamy soils than in fine loamy soils. The phytotoxic nature of copper to crop 1
production has been studied relative to application rates (Hirst et al., 1961). Little information 2
exists on mercury effects on higher plants (Eisler, 1987b). 3

Studies by USEPA (1980), Lee and Grant (1981), Wang and Meresz (1982), and Edwards (1983) 4
generally conclude five points for PAHs' effect on plants. First, plants can absorb PAHs from 5
soil through roots to other parts. Second, lower molecular weight compounds are absorbed more 6
readily than higher molecular weight compounds. Third, aboveground parts have higher residue 7
levels which are most likely attributable to airborne deposition. Fourth, PAH-induced phytotoxic 8
effects are rare. Fifth, higher plants can catabolize benzo(a)pyrene and possibly other PAH 9
compounds. These studies also concluded that plant uptake of PAHs is probably not a significant 10
pathway to terrestrial vertebrate species. 11

For PCBs, Klekowski (1982) suggested that there was no evidence of genetic damage to terrestrial 12
plants at a PCB-contaminated site in Massachusetts. For dioxins, Isensee and Jones (1971) 13
indicated that isomer uptake by terrestrial plants was less readily compared with aquatic plants, 14
and studies by Blair (1973) and Ramel (1978) considered vegetation's uptake of 2,3,7,8-TCDD 15
from soil to be negligible. 16

Subzone I-1 17

Although the zinc concentration in soil (77.5 mg/kg) was slightly above effects levels reported by 18
Miller et al. (1985), which showed negative effects on seed germination for radish and cucumbers, 19
it was below the background upper tolerance limit. If there is a potential for phytotoxic effects, 20
it appears to be widespread across CNC. Phytotoxic effect levels for organics were not available. 21

Subzone I-2

Based on detected maximum concentrations of copper (483 mg/kg), lead (949 mg/kg), zinc (876 mg/kg), and possibly manganese (815 mg/kg), and considering the nature of the soil, there is a potential risk to woody seedlings and young herbaceous species at Subzone I-2. Lacking plant benchmarks, the effects from organic concentrations could not be assessed.

Subzone I-3

This subzone is primarily marshland and lacks significant terrestrial habitats. The riparian margins will be assessed in Subzone I-2.

8.7.4 Aquatic Wildlife

Subzone I-1

Contaminants in surface water and sediment were measured to assess potential risks to aquatic species in the DMA (Subzone I-1). Only five analytes with published surface water quality effects levels exceeded those levels (Table 8.4). Aluminum appeared to be the most critical contaminant (HQ = 14), with lead, nickel, zinc, and gamma-BHC each having HQs above 1 but less than 10. Overall, based on the concentrations observed, only a moderate risk to aquatic receptors exists.

A low potential risk to aquatic receptors from Subzone I-1 sediment exists based on exceedances of USEPA Region IV Sediment Screening Values (see Table 8.5). HQ values greater than 1 but less than 3 for copper, arsenic, chromium, nickel, lead, zinc, and pyrene. As SSVs are derived from statistical interpretation of effects databases obtained from literature, actual risks to receptors in the Subzone I-1 water body may be lower than that implied by use of the SSVs in the screening assessment. Overall risk to aquatic receptors from sediment concentrations appears low. This information will be used and referenced during the subsequent Zone J RFI.

Subzone I-2

In Subzone I-2, the ditches associated with AOCs 687 and 688 were assessed by measuring sediment contaminant concentrations. No definitive connection was discovered between the ditch and proximal water bodies, but the assessment assumed that if concentrations were found they could impact aquatic life in those water bodies.

Several inorganics (zinc, copper, lead, arsenic, and nickel) had HQ sediment values greater than 1 but less than 5 (see Table 8.6). Several PAH compounds had HQs above 1, and two pesticides had an HQ above 10. A chlordane concentration of 5,300 $\mu\text{g}/\text{kg}$ at one location produced an extremely high HQ value of 3,117. It is impossible to determine if this concentration was accurate or an anomaly, but future studies related to the Zone J RFI may solve this question. Overall, the potential risk to local aquatic receptors from sediment concentrations in the ditch is low.

Subzone I-3

Assessment of potential risks to aquatic wildlife from marsh sediments at Subzone I-3 found HQ values for several constituents above 1 (arsenic, chromium, copper, nickel, and 4,4' DDD; see Table 8.7), but only one organic compound (4,4'- DDE) had an HQ value above 10. The effects level was exceeded at only one of the two stations sampled. Overall, risks to aquatic receptors in Subzone I-3 appear to be low. The findings of this screening assessment for Subzone I-3 will be incorporated into the Zone J RFI.

8.8 Uncertainty

Some general uncertainties are associated with the Zone I ERA:

- Degradation of chemicals has not been considered in the ECPC selection process.
- Specific effects on area biota are unknown.

- Acute and chronic effects data were unavailable for some ECPCs. 1
- Synergistic or antagonistic effects cannot be quantified. 2
- For some ECPCs, only assumptions relative to similar compounds or classes of elements can be made. 3
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- Use of related species for risk determination may over or underestimate risk to selected representative wildlife species. 5
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- Dermal or inhalation exposure pathways were not evaluated. 7
- Maximum exposure scenarios and concentrations may tend to overestimate risk potentials. 8
- On occasion, BAFs were assumed due to lack of information. 9
- Actual occurrence of selected wildlife species within the contaminated area is uncertain. 10
- Food ingestion rates in food chain analyses may be a source of uncertainty in determining exposure. 11
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- Sediment screening values are obtained from laboratory studies and may not reflect field-based exposure scenarios. 13
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8.9 Risk Summary 15

Risk for ecological receptors was evaluated for ECPCs in surface soil, surface water, and sediment at Zone I. Risk associated with exposure to ECPCs in surface soil was evaluated for terrestrial wildlife based on model predictions of the amount of contaminant exposure via diet and incidental soil ingestion. The risk evaluation is based on a comparison of predicted doses for representative wildlife species with doses representing thresholds for both lethal and sublethal effects (RTVs). Risk for soil invertebrates and plants was evaluated based on qualitative comparisons with literature effects levels for taxonomic groups similar to those potentially occurring at Zone I. Risks for aquatic organisms were evaluated by calculating HQs from benchmark values that are either promulgated or proposed by federal and state regulatory agencies. 21
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Infaunal Invertebrates – Within each Zone I subzone, risk to infaunal communities from organic ECPCs appears to be low or absent. For inorganic ECPCs in Subzone I-2 soils (copper and zinc), however, a relatively high risk to infaunal organisms is predicted.

Terrestrial Wildlife – No risk potential exists for terrestrial wildlife species exposed to soil ECPCs in Subzone I-1. The model predicts potential sublethal effects on passerine birds (American robin) and small mammals (short-tailed shrew) exposed to soil metal concentrations in Subzone I-2.

Vegetation – No risk from soil ECPCs is predicted for vegetation found in either Subzones I-1 or I-3. Copper, lead, and zinc concentrations detected in Subzone I-2 soils may pose a risk to early seedlings.

Aquatic Wildlife – No risks are predicted to aquatic wildlife from ECPCs in surface water in Subzone I-1 (DMA). Potential low-level risks to aquatic wildlife exist from sediment ECPCs in the DMA. Some HQ values were above 1 for both inorganic and organic ECPCs.

There is also a low potential risk from sediment ECPCs in the Subzone I-2 ditches, with several inorganic HQs above 1 but all less than 5. An elevated chlordane concentration in one sediment sample may warrant additional study of the ditches during the Zone J RFI.

Risk to aquatic receptors from sediment ECPCs in Subzone I-3 appears to be low. Only one organic (4,4'-DDE) had an HQ slightly above 10. All but four inorganic compounds had HQ values less than 1.

9.0 CORRECTIVE MEASURES

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

9.1 Introduction

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

To establish this procedure, zone-specific CMS Work Plans will outline the basic elements of the CMS Report. The subsequent CMS Report that is generated as part of the CMS process is briefly described below:

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

Each required element will be discussed in detail in the comprehensive and/or zone-specific CMS Work Plans in order to: 10
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- Identify minimum requirements for CMS reports in each area. 12
- Define the base pool of technologies that will be evaluated for each medium. 13
- Describe the remedial technology identification and screening processes. 14
- Describe the remedial alternative evaluation process. 15

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

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

*SWMUs and AOCs at CNC will be discussed in the CMS Work Plan on a zone-wide basis. 18
Activities, contaminants, and issues specific to each zone will be discussed. The CMS 19
Work Plan will identify: specific sites to be addressed in the CMS, any focused approach 20
(such as naming a primary technology in lieu of the full screening), subsequent remedial 21
goals, and CMS data needs. 22*

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

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

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

Tables similar to those in the CNC RFI Work Plans will be used in the CMS Report to present the pool of technologies initially evaluated in the CMS. These tables represent a range of technologies with different applications; each technology must be screened and evaluated before it is 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 Report will identify factors to be considered, including type of media, depth and areal extent of contamination, number and type of contaminants, remedial goals, future land use scenarios, and adjacent remedial activities.

Once technologies have been screened, they will be assembled into corrective action alternatives which will be evaluated according to criteria discussed below. 1
2

- A description of the general approach to investigating and evaluating potential corrective action measures. 3
4

Corrective measures alternatives will be evaluated according to four primary and five secondary criteria: 5
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Primary 7

1. *Protection of human health and the environment.* 8

2. *Attainment of media cleanup standards set by the implementing agency.* 9

3. *Control the source of releases so as to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health or the environment.* 10
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4. *Compliance with any applicable standards for management of wastes.* 13

Secondary 14

1. *Long-term reliability and effectiveness* 15

2. *Reduction in the toxicity, mobility, or volume of waste* 16

3. *Short-term effectiveness* 17

4. *Implementability* 18

5. *Cost* 19

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

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

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

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

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

Statement of basis/response to comments will be handled through SCDHEC and SOUTHDIV. The CLEAN contractor, EnSafe, will assist the SCDHEC and the Navy in preparing statement of basis/response to comments. Permit modifications will be managed through the Caretaker Site Office (CSO) as the permit holder. SOUTHDIV will assist the CSO manage the permit modification process. According to the RCRA permit issued May 4, 1990, Appendix C, Facility Submission Summary, a permit modification is required to prepare and conduct a Corrective Action Study/Plan.

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

Overall project management is the responsibility of SOUTHDIV for the CSO. Lines of authority, communication, and project schedules have been developed and agreed upon and are provided in the Comprehensive Project Management Plan dated August 30, 1994, and amendments. In general, SOUTHDIV is responsible for ensuring that conditions of the permit are satisfied with the ultimate responsibility held by the CSO. The budget for conducting a CMS is defined by SOUTHDIV with funds provided by the U.S. Congress. EnSafe will assign qualified personnel on an as-needed basis for project-specific CMS items. EnSafe will manage the CMS effort through its Charleston, South Carolina office.

- A description of the qualifications of personnel directing or performing the work.

EnSafe will use qualified registered South Carolina engineers and geologists where required.

9.2 Remedy Selection Approach

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

- Background concentrations, particularly of inorganic compounds
- Land use/risk assessment
- Basewide groundwater impacts
- Presumptive remedies

9.3 Proposed Remedy

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

9.4 Development of Target Media Cleanup Goals

Cleanup goals will be developed for each site at CNC where risk or hazard exceeds acceptable levels, or MCLs are exceeded as specified in the Part B permit. The *RCRA Corrective Action Plan* (USEPA, 1994b) outlines issues to be considered in developing cleanup goals for groundwater, soil, surface water, sediment, and air. These recommendations are outlined below. Sites requiring further evaluation will undergo a CMS. During the CMS, alternatives will be developed for future residential and/or future worker scenarios. Two sets of alternatives may be presented for each site; they may differ due to the media cleanup standards required under residential versus site worker scenarios.

9.4.1 Groundwater Cleanup Goals

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

- MCLs for any constituents for which an MCL has been promulgated under the Safe Drinking Water Act.
- Background concentration of the constituent in groundwater.

- An alternate standard (e.g., an alternative concentration limit for a regulated unit) to be approved by the implementing agency. 1
2

Additional factors to be considered while developing cleanup goals include classification and primary use of the contaminated groundwater unit, proposed future uses for groundwater, proximity to surface water, etc. 3
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9.4.2 Soil Cleanup Goals 6

The CMS will provide information to support the development of soil cleanup goals. The following information may be required: 7
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- The volume, physical, and chemical characteristics of the wastes in the unit. 9
- The effectiveness and reliability of containing, confining, and collecting systems and structures in preventing contaminant migration. 10
11
- The hydrologic characteristics of the unit and the surrounding area, including surrounding topography. 12
13
- Regional precipitation patterns. 14
- The existing quality of surface soil, including other sources of contamination and their cumulative impact on surface soil. 15
16
- The potential for contaminant migration and impact to underlying groundwater. 17
- Land use patterns in the region. 18

- The potential for health risks caused by human exposure to waste constituents. 1

- The potential for damage to wildlife, food chains, vegetation, and physical structures 2
caused by exposure to waste constituents. 3

Additional information which may be considered includes background soil concentrations and 4
regulatory guidance. 5

9.4.3 Surface Water and Sediment Cleanup Goals 6

The CMS will provide information to support the development of surface water and sediment 7
cleanup goals. The following information may be required: 8

- The volume and physical and chemical characteristics of wastes in the unit. 9

- The effectiveness and reliability of containing, confining, and collecting systems and 10
structures in preventing contaminant migration. 11

- The hydrologic characteristics of the unit and the surrounding area, including surrounding 12
topography. 13

- Regional precipitation patterns. 14

- The quantity, quality, and direction of groundwater flow. 15

- Proximity of the unit to surface water. 16

- Current and potential uses of nearby surface water and any established water quality standards. 1
2
- The existing quality of surface water, including other sources of contamination and their cumulative impacts. 3
4
- The potential for damage to wildlife, food chains, vegetation, and physical structures caused by exposure to waste constituents. 5
6
- Land use patterns in the region. 7
- The potential for health risks caused by human exposure to waste constituents. 8

Additional data which may be considered include the presence of endangered, threatened, or ecologically sensitive species, National Oceanic and Atmospheric Association sediment values, etc. 9
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9.4.4 Air Cleanup Goals 12

The CMS will provide information to support the development of air cleanup goals. The following information may be required: 13
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- The volume and physical and chemical characteristics of waste in the unit, including the potential for emission and dispersal of gases, aerosols, and particulates. 15
16
- The effectiveness and reliability of systems and structures to reduce or prevent emissions of hazardous constituents to the air. 17
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- The operating characteristics of the unit. 1

- The atmospheric, meteorological, and topographic characteristics of the unit and the surrounding areas. 2
3

- The existing air quality including other sources of contamination and their cumulative impact on that medium. 4
5

- The potential for health risks caused by human exposure to waste constituents. 6

- The potential for damage to wildlife, vegetation, and physical structures caused by exposure to waste constituents. 7
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Other factors which may be considered include National Ambient Air Quality Standards, state and local air quality regulations, etc. 9
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9.5 Identification, Screening, and Development of Corrective Measures Technologies 11

The initial step in assembling corrective measures alternatives is to identify, screen, and develop corrective measure technologies which apply to the site. Technologies are typically screened using waste- and site-specific characteristics. This section addresses the range of technologies that may be assessed for each site, the screening process, and screening criteria. 12
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9.5.1 Identification of Corrective Measures Technologies 16

Each site will be assessed using the cleanup standard methodology described in Section 9.2. An initial list of impacted media and contaminants of concern has been compiled in the RFI. The site-specific HHRA in Section 10, and the ecological risk assessments in Section 8 will identify soil, 17
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groundwater and sediment as the contaminated media. Major contaminants at each site have been grouped into one or more of the following categories:

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

Potential remedial technologies are described in Section 9.5.2. Table 9.1 lists non-treatment options for soil, groundwater/leachate, sediment, surface water, and air. These options include removal, containment, and disposal. Table 9.2 lists treatment options for each type of compound and medium. These tables supply general waste management options for various situations.

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

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

Table 9.1
Removal/Containment/Disposal Options

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

Notes:

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

**Table 9.2
 Treatment Technology Options**

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

**Table 9.2
 Treatment Technology Options**

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

Note:
 SVE = Soil Vapor Extraction

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

9.5.2 Description of Pre-screened Technologies

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

In-Situ Soil Treatment

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, an insufficient number of electron acceptors is the greatest variable limiting bioremediation. The most common electron acceptor is oxygen for aerobic biodegradation. For these sites, it is likely that bioremediation via natural attenuation is a good candidate for some of the compounds. Nonchlorinated VOCs and SVOCs are typically good candidates for this technology.

Solidification/Stabilization

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

Ex-Situ Soil Treatment

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

Soil Washing

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

Thermal Desorption

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

Thermal Destruction/Incineration

1

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

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Solidification/Stabilization

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

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In-Situ Groundwater Treatment

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Bioremediation

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

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Intrinsic Remediation

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

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Ex-Situ Groundwater Treatment

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

Chemical Precipitation

Because the solubility of many metals is a function of pH, chemical agents can be added to water to change its pH and render the metals insoluble. In other cases, a chemical can be added to chelate the metal and precipitate it out of the solution. Either way, the contaminants can then be removed by filtering.

Air Stripping

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

Chemical Oxidation/UV-Ozone

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

Activated Sludge

Wastewater treatment plants use an activated sludge process to treat wastes. Microorganisms convert organic wastes to inorganic wastes and/or bacterial cell mass, carbon dioxide, and water.

9.5.3 Screening Criteria

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

- Site characteristics
- Waste characteristics
- Technology limitations

Site Characteristics

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

Waste Characteristics

Waste characteristics define the nature of contamination. The primary waste characteristic to be considered is the general type of contamination — volatiles, semivolatiles, pesticides/herbicides,

PCBs, dioxins, and inorganic compounds. Also critical is the presence of halogenated compounds, 1
such as chlorinated benzenes or trichloroethylene. 2

Where multiple types of contamination are present (such as PCBs and dioxins, or pesticides and 3
volatiles), certain technologies may be eliminated from consideration due to their inability to 4
effectively treat the wastes. For example, soil vapor extraction (SVE) typically is not used on 5
pesticide sites, although it is very effective for most volatile compounds. If both contaminants 6
must be treated concurrently, SVE would be eliminated from further evaluation. Where 7
appropriate, contaminant concentrations will be considered to screen remedial technologies. 8

Technology Limitations 9

Technology limitations are used to assess the implementation feasibility of a particular technology. 10
These limitations may include technical restrictions on application, including the presence of a 11
shallow water table, depth to bedrock, etc. Additional limitations include minimum or maximum 12
process volumes, such as technologies that are cost-effective only when contaminated soil volume 13
exceeds 1,000 cubic yards. Other possible limitations include effectiveness in meeting treatment 14
goals and remedial time frame. Technologies meeting these screening criteria may differ from 15
residential to BRAC-specified use scenarios due to the differences in RGOs. 16

9.6 Identification of Corrective Measures Alternatives 17

Once specific remedial technologies are identified for the site, they will be assembled into specific 18
alternatives which may meet the corrective action objectives for all media. Each alternative may 19
consist of an individual technology or a combination of sequential technologies (treatment train). 20
Depending on site-specific situations, different alternatives may be considered for separate areas 21
of the facility. 22

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

9.7 Evaluation of Corrective Measures Alternatives

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

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

These standards are detailed in the following sections.

9.7.1 Protection of Human Health and the Environment

Corrective action remedies must be protective of human health and the environment. The degree of protection afforded by each alternative will be discussed in this section of the CMS Report. Remedies may include measures that are necessary for protectiveness, but are not directly related to media cleanup, source control, or waste management. For example, access controls and deed restrictions may prevent contact with contaminated media while intrinsic remediation or attenuation processes are monitored or augmented. This section of the report will discuss any short-term remedies that may be implemented to meet this standard.

9.7.2 Attainment of Media Cleanup Standards Set by the Implementing Agency

Each alternative will be evaluated on its ability to achieve the remedial objective(s) set by the implementing agency and the time frame needed to attain these standards. Media cleanup standards which may be derived from current state, federal, or other regulations or standards, will often play a large part in determining the extent of and technical approaches to the remedy. In some cases, the practical capabilities of remedial technologies (or other technical aspects of the remedy) may also influence establishment of the cleanup standards.

9.7.3 Control the Sources of Releases

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

Source control measures will be considered when it is necessary to stop further environmental degradation by controlling or eliminating further releases that may threaten human health or the

environment. In some cases, without source control measures, cleanup efforts may be ineffective or will at best become a perpetual remedial effort. In such cases, an effective source control program may be essential to ensure the long-term effectiveness and protectiveness of the corrective action program. Source control measures may include all protective remedies to control the source. Such remedies may include partial waste removal, capping, slurry walls, insitu treatment and/or stabilization, and consolidation.

9.7.4 Compliance with Any Applicable Standards for Management of Wastes

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

9.7.5 Other Factors

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

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

Long-Term Reliability and Effectiveness

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

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

Reduction of Toxicity, Mobility, or Volume of Wastes

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

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

Short-Term Effectiveness

The short-term effectiveness of each alternative will be assessed, according to its potential for fire, explosion, and exposure to hazardous substances; as well as threats associated with treatment,

excavation, transportation, and redisposal or containment of waste. This criterion is important in densely populated areas and where waste characteristics are such that risks to workers or the environment are high, and special protective measures are needed.

Implementability

Each alternative will be evaluated to assess potential impacts on the implementation time required. Information to consider for implementability includes:

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

Cost

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

9.8 Ranking the Corrective Measures Alternatives

Once corrective measures have been discussed for each site using applicable scenarios (residential and/or BRAC-specified future use), alternatives for will be ranked in order of desirability. The ranking system will apply a weighting factor selected by the project team to determine the importance of each corrective measure criterion. The weighting factors will be developed by the project team during the CMS. Table 9.3 shows the ranking system format.

The example presented in Table 9.3 considers a hypothetical site where soil is contaminated with relatively high (10 to 1,000 ppm) PAH concentrations. Three alternatives were developed: excavation and disposal in a permitted landfill, excavation and thermal treatment, and capping insitu. This example shows the format and nature of comparisons that will be made in the CMS.

Once the weighting factors are selected, the rankings are set by multiplying the criteria values by the weighting factor. The weighted criteria values are then summed. Alternatives are ranked in order, with the highest total being the most preferable choice, and the lowest being the least preferable.

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Table 9.3
 Comparison and Ranking of Alternatives

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

Table 9.3
Comparison and Ranking of Alternatives

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

Notes:

Criteria ranking values are based on the following scale
 4 = Criteria exceeded
 3 = Criteria met
 2 = Criteria may be met
 1 = Criteria not met

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

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