N61165.AR.003059
CNC CHARLESTON
5090.3a

FINAL COMPREHENSIVE BASELINE RISK ASSESSMENT RESOURCE CONSERVATION AND RECOVERY ACT FACILITY INVESTIGATION VOLUME 3 OF 5 CNC CHARLESTON SC
8/30/1994
ENSAFE/ ALLEN AND HOSHALL

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

FINAL COMPREHENSIVE BASELINE RISK ASSESSMENT
RCRA FACILITY INVESTIGATION

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/ALLEN & HOSHALL
5720 SUMMER TREES DRIVE, SUITE 8
MEMPHIS, TENNESSEE 38134
(901) 383-9115

August 30, 1994

Release of this document requires the prior notification of the Commanding Officer of the Naval Base Charleston, Charleston, South Carolina.

VOLUME III

Acronym List

AOC	Area of Concern
AWQC	Ambient Water Quality Criteria
BaP	Benzo(a)pyrene
BOD	Biologic oxygen demand
BRA	Baseline Risk Assessment
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chemicals of Concern
COD	Chemical Oxygen Demand
CFR	Code of Federal Regulations
CRDL	Contract Required Detection Limits
DBH	Diameter at Breast Height
DOE	Department of Energy
DWEL	Drinking Water Equivalent Level
E/A&H	EnSafe/Allen & Hoshall
ECAO	Environmental Criteria and Assessment Office
ERA	Environmental Risk Assessment
FAC	Facultative Neutral Species
FACW	Facultative Wetland Species
g/m^3	grams per cubic meter
GIS	Geographic Information System
GPS	Global Positioning System
HA	Health Advisories
HEA	Health and Environmental Assessment
HEAST	Health Effects Assessment Summary Table
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
$\mu g/g$	micrograms per gram
$mg/\mu g$	milligrams per microgram
mg/m^3	milligrams per cubic meter
mg/kg-day	milligrams per kilogram day
NAVBASE	Naval Base Charleston
NCP	National Oil and Hazardous Substances Contingency Plan
NFI	no further investigation
NPL	National Priorities List
OBL	obligate wetland species
OSWER	Office of Solid Waste and Emergency Response
PAH	Polycyclic Aromatic Hydrocarbons
PRC	Preliminary Risk Characterization
PRG	Preliminary Remedial Goals
PSA	Preliminary Site Assessment
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose

RFI	RCRA Facility Investigation
RGO	Remedial Goal Options
SARA	Superfund Reauthorization and Amendments Act
SCS	Soil Conservation Service
SCDHEC	South Carolina Department of Health and Environmental Control
SCWQC	South Carolina Water Quality Criteria
SF	Slope Factor
SMCL	Secondary Maximum Contaminant Levels
SQL	Sample Quantitation Limit
SVOC	Semivolatile Organic Compounds
SWMU	Solid Waste Management Unit
TEF	Toxic Equivalency Factor
TOC	Total Organic Carbon
UCL	Upper Confidence Limit
USDA	U.S. Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Compounds

Table of Contents

1.0 REFERENCE AREA DETERMINATIONS 1-1

2.0 HUMAN HEALTH RISK ASSESSMENT 2-1
- 2.1 Background Determination 2-1
- 2.2 Human Health Risk Assessment 2-1
  - 2.2.1 Contaminant Identification 2-3
  - 2.2.2 Exposure Assessment 2-5
- 2.3 Toxicity Assessment 2-23
- 2.4 Risk Characterization 2-25
- 2.5 Uncertainty Discussion 2-28
  - 2.5.1 Remedial Goal Options 2-30
- 2.6 Conclusions 2-30
- 2.7 Summary of the Human Health Risk Assessment Procedure 2-30

3.0 ECOLOGICAL RISK ASSESSMENT 3-1
- 3.1 Phase I — Preliminary Site Assessment 3-1
  - 3.1.1 Habitat Evaluation 3-2
  - 3.1.2 Biological Inventory 3-5
  - 3.1.3 Migration Routes 3-5
  - 3.1.4 Exposure Routes 3-5
  - 3.1.5 Phase I Conclusions 3-6
- 3.2 Phase II — Contaminant Assessment 3-6
  - 3.2.1 Preliminary Risk Characterization 3-7
- 3.3 Phase III — Problem Formulation/Conceptual Model 3-8
  - 3.3.1 Site Assessment 3-8
  - 3.3.2 Site Investigation 3-9
- 3.4 Risk Calculation 3-9

4.0 REFERENCES 4-1

List of Figures

Figure 1-1 Areas Filled and Approximate Dates of Filling Operatoin 1-5
Figure 2-1 Formulae for Calculating Soil CDI 2-13
Figure 2-2 Formulae for Calculating CDI for Air Pathway 2-17
Figure 2-3 Formulae for Calculating CDI for Groundwater 2-19
Figure 3-1 ERA 3-3

List of Tables

Table 2-1 Current/Potential Pathways of Human Exposure, on Naval Base Charleston, Charleston, South Carolina 2-9
Table 2-2 Assumptions for Ingestion and Dermal Contact Exposure to Soil Chemicals of Concern at Naval Base Charleston[a] 2-11

List of Appendices

Appendix A Wetland Delineation Procedures
Appendix B Sediment Mapping
Appendix C Toxicity Tests
Appendix D Community Indices
Appendix E Tissue Burdens
Appendix F Checklist For Ecological Risk Assessment/Sampling

1.0 GRID SYSTEM/BACKGROUND DISCUSSION

Rationale:

The Naval Base Charleston (NAVBASE) encompasses 2,986 acres, a significant portion of which has been developed for industrial, commercial, and/or residential uses. EnSafe/Allen & Hoshall (E/A&H) has been tasked with performing a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and confirmation sampling at numerous solid waste management units (SWMUs) and areas of concern (AOC) identified during the RCRA Facility Assessment (RFA) process. Of 142 identified SWMU, 73 have been designated as requiring no further investigation (NFI) at this time based on available information regarding their waste activities. A similar classification has also been assigned to 59 of 196 AOCs. The remaining 206 sites (69 SWMU and 137 AOC) will require some level of investigation to confirm whether hazardous substances are present in environmental media.

To this end, the NAVBASE complex has been subdivided into 12 zones. A RFI work plan outlining the proposed investigative work will be developed for each zone before starting initiation of field activities . After receiving analytical data from all zone investigations, E/A&H will prepare an RFI report which will include a human health and ecological assessment. As stated in 40 Code of Federal Regulations (CFR) Part 264 Subpart F, the purpose of the RFI is to facilitate decision-making for actions required to protect human health and the environment.

NAVBASE, like many other parts of the Charleston peninsula, has been built upon dredge spoils. Because of the varying age and depositional history of the layered deposits, it is expected that there will be no unique background level that will characterize the whole site, and that levels of many substances, particularly inorganics, will depend on the "sedimentology" of the site. Therefore, a variable grid system will be overlain on each zone to direct the collection of supplemental media samples, allowing for a more accurate assessment of contamination patterns onsite. In turn, this information will allow the risk assessor to draw more accurate conclusions regarding the risk and/or hazard posed to exposed individuals and/or biota.

Basis for Approach:

In order to evaluate the significance of analytical results obtained for samples collected in individual SWMU and/or AOC, it is necessary to differentiate between naturally occurring and/or non-site-related anthropogenic (resulting from man's activities) medium constituents, and xenobiotics present due to site impacts. This is typically accomplished during RFIs by determining background parameter concentrations. In most instances, the list of Chemicals Present in Site Samples (CPSS) is refined by comparing offsite (background) and onsite concentrations. Because most organic compounds are not naturally occurring, the generic assumption is made that concentrations above detection are present as a result of site impacts absent additional information to the contrary. However, exceptions exist where adequate background delineation will allow for more accurate assessment of the relationship of detected organics to site impacts.

Examples of potential non site-related anthropogenic sources which could result in the exclusion of organic compounds through appropriate background comparisons are:

- Semivolatile organic compounds (SVC) which are associated with by-products of incomplete fossil fuel combustion are common in urban/industrial areas. Consistently elevated concentrations of these parameters near roadways and railways or heavy traffic waterways may suggest their presence is not associated with past hazardous materials/waste operations. In addition, polycyclic aromatic hydrocarbons (PAH) are present in asphalt and other petroleum-derived surfacing materials. Sampling methods will exclude these materials but the data evaluation process will consider the location's proximity to such surfaces. In some instances, volatile organic analysis (VOA) also may be found in association with these materials.

- Numerous pesticides formerly were used for general pest control in many areas of the southeastern United States. Due to their persistence, residual concentrations of these compounds may be expected in environmental media at NAVBASE.

The nature of soil (and necessarily shallow groundwater) quality at the NAVBASE unquestionably has been affected by past sediment dredge and fill practices. Modern dredge and fill areas are shown in Figure 1-1 along with the approximate dates the operations took place. Because these processes were conducted more or less haphazardly, significant variability in composition is expected. A simple comparison with a point estimate of background will not fully represent the complex situation at NAVBASE. Systematic sampling and a more spatially oriented analysis (geostatistics) will be used to visually represent media constituent concentration patterns to better understand the risk/hazard associated with these parameters.

In regards to groundwater, determination of background will also be of utility when determining aquifer quality reference levels. The South Carolina Water Classifications and Standards, R.61-68, classifies all groundwater as GB, or as an underground source of drinking water. Available data suggests that water quality of the shallow aquifer may not meet the primary and secondary drinking standards promulgated under the Safe Drinking Water Act due to both anthropogenic and naturally occurring sources. Establishing Remedial Goal Objectives (RGO) for NAVBASE groundwater cleanup to GB levels will not be possible if the underlying aquifer will not support this level. Therefore, determining "background" or reference levels of groundwater quality will be an important measure in determining remediation level of effort.

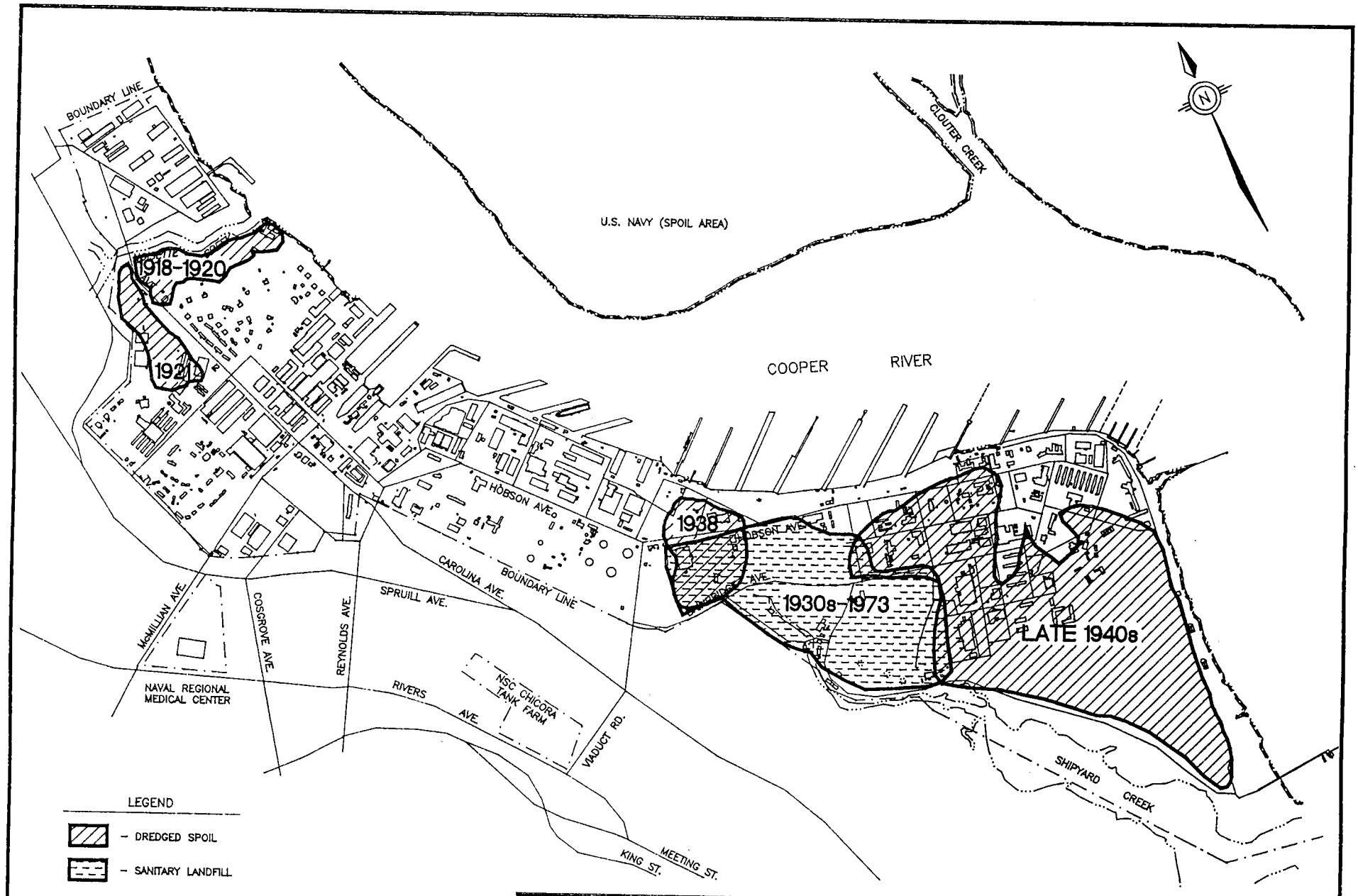
Grid System Components:

Systematic sampling on a regular grid has been shown to be more effective for local estimation of spatial variables than random sampling. However, to reduce redundancy with the biased sampling effort and to focus sampling near the investigational units not every grid node will be sampled. Nodes will be evaluated for use contingent upon their distance from biased sampling

points and other unbiased points selected in conjunction with SWMU or AOC specific investigations. A 200 foot grid spacing will be used, oriented north-south, with a random start. Each grid node will be evaluated as a possible soil sample or a groundwater well location. To determine soil sample locations, nodes that are within 150 feet of a biased sample location will not be used. Nodes that are between 151 and 300 feet from a biased sampling point will be sampled. Nodes that are 301 to 900 ft. from a biased sampling location will be used if they are more than 200 feet away from any other biased or grid based sampling point. Nodes that are more than 900 feet away from any biased sampling point will be used if they are more than 400 feet away from any other sampling point. For groundwater, the nodes evaluated for possible well locations will be those which have previously been chosen for soil sampling. Nodes that are more than 400 feet but less than 800 feet away from biased well locations will be chosen as supplemental well locations, under the condition that no supplemental well be within 400 feet of another grid based or biased well. Nodes that are greater than 800 feet away from biased well locations will be chosen as a well location if they are not within 600 feet of another grid based or biased well.

The algorithm will be implemented sequentially, with the nodes first evaluated at the shortest distance category from the biased sample locations. In order to provide a consistent selection of points independent of interpreter, grid nodes will be evaluated in a columnwise fashion from north to south, with columns evaluated from east to west. In the case where the algorithm produces two possible locations to sample, the node which produces the greatest number of sampling points will be chosen.

Sediment sampling will be focused on identified outfalls and other point/non-point sources. The basic sediment sampling plan detailed in zone-specific work plans will incorporate a progressive approach. It may be necessary, depending on the nature of the potential sediment contaminant source, to extend the grid sampling approach to this medium. This will be performed on an area-specific basis, taking into account the following general considerations. Identified



FINAL RFI BRA
NAVAL BASE CHARLESTON
CHARLESTON, S.C.

FIGURE 1-1
AREAS FILLED AND
APPROXIMATE DATES
OF FILLING OPERATIONS

DWG DATE: 08/08/94 | DWG NAME: 029FILCH

This page left blank intentionally.

outfalls/point discharges will serve as the origin for the grid-sampling effort and a unidirectional system will be imposed for shoreline discharges. If offshore end-of-pipe discharge impacts are to be addressed, substantial stream/river flow influences would be expected. Therefore, the grid pattern will be skewed downstream but also will encompass a finite distance upstream to account for or to assess potential tidal influences on contaminant dispersion.

Additional Background Condition Indicators:

It is likely that background conditions will not be definitively established by applying the systematic sampling program. As a result, it will be necessary to use other methods to determine the origins of environmental medium constituents found onsite. This information will be used to compare onsite data with those generated in offsite areas in no way influenced by past or current operations at NAVBASE. To this end, some or all of the following information sources may be used as part of the RFI data evaluation process:

- U.S. Department of Agriculture (USDA)/Soil Conservation Service (SCS) Soil Surveys for Charleston and Dorchester Counties.

- U.S. Geological Survey (USGS) technical papers related to coastal or distinct area which has a similar soil and geologic setting and composition.

- Agronomic/geologic studies prepared by other private and/or government entities pertaining to the site vicinity.

- General regional/state soil data compilations (Shacklette and Boerngen, Dragun and Chiasson, USC, Department of Agriculture).

- Upstream/downstream Cooper River sediment sample analytical results.

- Results of soil/sediment sampling conducted on offsite dredge piles/islands in the Cooper River; correlate aerial photograph information and depositional histories to ensure that materials from the same dredging/depositional periods are collected both on and offsite.

If necessary, the following algorithm will be applied to determine whether parameters detected in each environmental medium indicate site-related impacts. Although this process is proposed for application to all media and zones, modifications may be necessary to account for idiosyncrasies of affected areas. The sampling efforts described here will be conducted exclusively in areas off the NAVBASE property.

- Representative background samples will be collected for each zone and/or distinct area which has a similar depositional history.

- Background samples are to be collected for each medium sampled in the associated zone or depositional area.

- At least five to seven background samples from each medium and/or lithologic unit will be collected in order to have a sufficient data population to support standard statistical methods. These samples may have to be supplemented through additional sampling should the background medium composition be inadequately characterized.

- Background and onsite results will be qualitatively compared. If a particular parameter detected onsite is not detected in background samples, it will be classified as a chemical of potential concern (COPC).

- Inorganic parameters detected in background and onsite samples will be compared using the EPA Region IV rule that if the maximum detected concentration of an inorganic chemical onsite is greater than twice the average of the background sample

concentrations, then the chemical should be included as a COPC unless it is eliminated by other appropriate criteria (i.e. USEPA Region III RBC screening process).

- Organic compounds detected in background and onsite samples will be retained for further consideration. Although ubiquitous presence of a particular compound may suggest a non-site-related source, each detected organic parameter will be initially carried forward to the human health (risk) assessment.

Application of Biased/Unbiased Data Sets:

Principle purpose of the investigations to be conducted at NAVBASE is to establish what action (remedial or institutional) will be needed in order to protect human health and the environment under future land use scenarios. For this planning to be most effective, there exists a need to map not only concentrations of COPC for purposes of remedial action, but also the risk posed by such under various future use scenarios in order to facilitate land use decisions. Conventional methods of classical statistical analysis used in risk assessment are not well suited for spatial analysis, and it is anticipated that additional methods will be used for this phase of the investigation.

An effective approach to the problem of mapping a probability based decision process at a hazardous waste site is a methodology developed by A. Journel for USEPA Region IX at the Environmental Monitoring Lab in Las Vegas, using techniques known as non-parametric geostatistics. The full approach will not be detailed here, but interested readers may refer to Journel's chapter in *Principles of Environmental Sampling* (L.H. Keith, ed. American Chemical Society, Washington, DC, 45-72) for a more detailed discussion. Briefly, the process of interpolation of a spatially continuous variable to non-sampled locations is known as ordinary kriging. Like other statistical methods, this process can produce an estimate of the measure of uncertainty about the estimated value. However, the ability to make this inference comes with a cost: additional assumptions need to be made about the probability distribution function of the

process. When making such an assumption is undesirable, a class of statistical techniques has been developed known as non-parametric, or distribution free statistics. When dealing with spatial, or "regionalized" random variables, non-parametric geostatistics are used. The interpolation technique then used is known as *indicator kriging*. Lognormality or any other specific distributional form does not have to be assumed. This is necessary in the case of risk, as there is no simple relationship between risk and concentration. In a case study regarding a lead smelter, Journel used such methods to determine the spatial extent of contamination, as defined by exceedence of a certain threshold value. In addition, the probability of a Type I or Type II error was mapped, to help guide the decision for proceeding with additional sampling. It is anticipated that a similar process, extended to include exposure considerations, will be useful at NAVBASE.

Geostatistical techniques are now commonly used to help determine vertical and horizontal extent of contamination. Extension to risk posed by this contamination will be guided by EPA threshold values for various exposure scenarios, but knowledge of the exact nature of the relationship between risk and concentration will not be necessary by using non-parametric methods. The interpolated risk for various thresholds will be used to determine contour lines of equal risk for a particular chemical, or several chemicals simultaneously. The impact of different land use scenarios, using different default assumptions regarding exposure, can be presented in a visually integrated manner that should assist not only land use planning, but also with risk management decisions.

2.0 HUMAN HEALTH RISK ASSESSMENT

As part of the RFI at Naval Base Charleston (NAVBASE), baseline risk assessments (BRA) will be developed. The BRA's objective is to determine the potential for adverse effects, human health hazard and/or cancer risks, and/or the ecological impacts due to hazardous substances at the site as it currently exists (i.e., assuming no further action). Section 1 addresses the issue of background or reference concentrations and comparing of site data to reference concentrations and probabilistic methods to be used for risk/hazard projections. This section and Section 3 detail the procedures to be followed to develop the BRA at NAVBASE. Section 2 describes the Human Health Assessment approach, and Section 3 describes the Ecological Assessment approach.

2.1 Background Determination

The background or reference concentrations will be determined as specified in Section 1 of this document.

2.2 Human Health Risk Assessment

The human health assessment considers environmental media and exposure pathways that could result in unacceptable levels of exposure now or in the foreseeable future. The value of the BRA as a basis for making remedial decisions is contingent upon adequately characterizing site chemical contamination. Variables considered in characterizing the site and its associated risk are the amount, type, and location of contaminant sources; the pathways of exposure (media type and migration routes); and the type, sensitivities, exposure duration, and dynamics of the exposed populations (receptors). The RFI to be conducted by E/A&H will provide the site characterization data used in this assessment.

The RFI Guidance provides a loose framework within which a Health and Environmental Assessment (HEA) can be developed. This guidance may be supplemented, as stated in 40 CFR 264.91, "The Regional Administrator may include one or more of the programs

identified in paragraph (a) of this section in the facility permit as may be necessary to protect human health and the environment and will specify the circumstances under which each of the programs will be required." Since the RFI guidance for risk assessment closely mirrors that of Risk Assessment Guidance for Superfund (RAGS) in regards to the BRA, this assessment will be developed in accordance with the RFI guidance and as RAGS suggests. Specific guidance on conducting a BRA, including a full quantitative risk assessment for likely exposure pathways, is provided in the following USEPA documents:

- Risk Assessment Guidance for Superfund, Volume I — Human Health Evaluation Manual, Parts A & B, U.S. Environmental Protection Agency (USEPA)/OERR, EPA/540/1-89/002, December 1989 and EPA/540/R92/003, December 1991 (Interim). (RAGS, Parts A & B).

- Risk Assessment Guidance for Superfund, Volume I — Human Health Evaluation Manual, *Supplemental Guidance-Standard Default Exposure Factors-Interim Final*, USEPA/OERR, OSWER Directive: 9285.6-03, March 25, 1991.

- Risk Assessment Guidance for Superfund, Volume II — Environmental Evaluation Manual, Interim Final, USEPA/OERR, EPA/540/1-89/001, March 1989.

- Supplemental Region IV Risk Assessment Guidance (March 26, 1991).

- New Interim Region IV Guidance (February 11, 1992).

- Draft Supplemental Guidance to RAGS: Region IV Bulletin *Default Oral Absorption Values for Dermal Reference Dose Adjustment*, USEPA, March, 1994.

- Draft Supplemental Guidance to RAGS: Region IV Bulletin *Development of Health Based Preliminary Remediation Goals, Remedial Goal Options and Remediation Levels*, USEPA, March, 1994

- Draft Supplemental Guidance to RAGS: Region IV Bulletin *Exposure to VOCs during Domestic Water Use: Contributions from Ingestion, Showering and Other Uses*, USEPA, March, 1994

- Region III Technical Guidance Manual Risk Assessment *Selecting Exposure Routes and Chemicals of Concern by Risk-Based Screening,* USEPA, EPA/903/R-93-001, January, 1993.

The process of human health risk assessment can be roughly considered as a series of steps. First is contaminant identification using risk based screening methods. The second is exposure assessment, which includes analysis of any appropriate site specific data which departs from the default exposure scenario. Third is toxicity assessment, which incorporates any path-specific toxicological information into the exposure assessment. Fourth is risk characterization, which is the integrative step to summarize the investigation in terms of incremental risk or hazard opposed by the site. In parallel with these steps is uncertainty assessment, which documents the assumptions used in the various steps. This process is discussed along with background comparison discussions in detail in the sections below.

2.2.1 Contaminant Identification

The objective of contaminant identification is to screen the information that is available on hazardous substances present at the site and to identify COPC in order to focus subsequent efforts in the risk assessment process. COPC are selected in consideration of their intrinsic toxicological properties, their quantity, persistence, fate and transport characteristics, cross-media transfer potential (i.e., for soil to groundwater, soil to surface water, and groundwater

to surface water), and/or their presence in potentially critical exposure pathways (e.g., drinking water supply).

Before beginning to evaluate the potential risk/hazard a site poses, it is first necessary to thoroughly analyze the nature and extent of contamination. The first and most basic data analysis involves qualitative assessment. Simply stated, is the compound/parameter present? Two levels of data will be used in this assessment, 90 percent DQO Level 3 and 10 percent DQO Level 4. This assessment, the identification of CPSSs, will be narrowed to include detected compounds and, in some instances, potential degradation products.

At this point in the risk assessment process, risk-based screening of individual sites will be performed to reduce the number of parameters addressed in the formal assessment. Many parameters may be present that do not significantly affect the risk estimation and would only add bulk to the BRA. Reference values for inclusion in the COPC list will be garnered from the list of risk-based concentrations generated by USEPA Region III. These tables were developed using the conservative default assumptions for residential exposure, as discussed in the following section on Exposure Assessment, and the best available reference doses and carcinogenic potency slope factors, and represent relatively protective environmental concentrations. Chemicals whose maximum detected concentration exceeds the tabled value, representing 1E-6 excess cancer risk for carcinogens or a hazard quotient of 0.1 for non-carcinogens, will define the COPC list included in the risk assessment.

Specific contaminants not identified by screening may be included in the COPC list on the basis of historical data, toxicity, mobility, persistence, bioaccumulation, special exposure routes, special treatability problems or exceedance of ARARs. If no COPCs are identified after this step, it may be concluded that site conditions pose no threat to human health. If not empty, the list of COPCs may be further refined, taking into consideration background conditions, low frequency of detection or other statistical issues (e.g. possibility of an outlier), or contaminant

status as an essential nutrient. Parameters excluded from the risk assessment based on screening evaluation will be presented for each step in tabular format as an appendix.

2.2.2 Exposure Assessment

The objectives of an exposure assessment are to characterize the potentially exposed populations, identify actual or potential exposure pathways, and to determine (and quantify, if possible) the extent of exposure. For exposure to occur, four essential elements must exist: (1) a source and mechanism of chemical release to the environment, (2) an environmental transport medium (e.g., air, or groundwater-released chemical), (3) a point of potential contact (exposure point) with the contaminated medium defined in terms of a potential dose or availability, and (4) an exposure route (e.g., inhalation, ingestion) at the contact point. Exposure to each pathway will be quantified as Chronic Daily Intake (CDI), and presented in the Quantification of Exposure Section of the BRA. Exposure concentrations will be modified where appropriate to account for factors such as the fraction of time spent in a contaminated zone or source dissipation over time.

Calculation of CDI

The CDI is a calculated estimate of the intake of each COPC that is subsequently used to estimate risk. The usual method used in risk assessment is to obtain a point estimate of the greatest exposure any individual is likely to face. Therefore, it is typically calculated using the maximum concentration detected for each COPC. Also used as a reasonable upper bound, based on the empirical observation that contaminant concentrations often follow a log-normal distribution, is the upper limit of the 95% confidence interval, calculated following Region IV guidance with the following formula:

$$UCL = \exp\left(\bar{x} + 0.5\,s^2 + \frac{sH}{\sqrt{n-1}}\right)$$

Where n is the sample size, x is the mean of the logarithms of the concentration data, s is the sample standard deviation of the transformed data and H is the tabled value of the H statistic after Land, 1975. This formula assumes that the data represent an uncorrolated random sample, which is generally not the case in environmental problems, and therefore will not be used at NAVBASE. However, since risk management decisions will be highly influenced by land use planning at NAVBASE, a supplementary analysis incorporating the spatial position of each sample will be performed and presented for the benefit of these decision makers. This analysis will include calculation of the CDI for every sampled location, as well as for interpolated values found using ordinary kriging. If desired, the maximum value for each COPC can be extracted to perform a standard CDI calculation. Additional information regarding the location of these maximum values will be available if this maximum CDI is found to not truly represent conditions over the entire base.

The exposure assumptions used in calculating the CDI also reflect the concern of finding the upper bound for exposure, typically characterizing the individual with maximum exposure. These default assumptions may be modified in cases where site-specific exposure information is more representive. For example, if an exposed individual is known to ingest 5 pounds of fish (harvested onsite) per two-week period, this information can be used to more accurately qualify exposure for that exposure pathway accordingly, resulting in less uncertainty in the CDI and the subsequent risk estimate. Any modifications to exposure assumptions will be noted in this section of the BRA. A lifetime weighted average may be used (where deemed applicable) in some instances to address childhood exposure to carcinogens. The CDI will be presented in tabular format, representing each chemical and including Exposure Point Concentrations used in the calculation. A possible exception would be the PAHs, which are considered as a group based upon their Toxic Equivalency Factors (TEF). The TEFs are chemical-specific values used to relate the carcinogenic potential of various PAH to that of Benzo(a)pyrene (BaP). For each PAH the Exposure Point Concentration is multiplied by the TEF. The CDI is calculated using this value, which is then multiplied by the Slope Factor (SF) to determine the excess cancer risk.

The presentation of the adjusted CDI at this stage could lead to confusion regarding actual intake, and instead the unadjusted CDI will be presented. TEF adjustment will take place in the Risk Characterization section, where the modified exposure point concentration or modified CDI and corresponding excess cancer risk will be presented.

The CDI for current site workers will be calculated using the same values as for future residents, but excluding the lifetime weighted averages accounting for childhood exposure to carcinogens and including the current site worker assumptions. All assumptions and calculations used in the assessment will be presented in the Exposure Assessment section of the BRA. The commercial/industrial (current use) and residential (conservative for screening purposes) exposure pathways, assumptions, and calculations are presented in Tables 2-1 and 2-2 and Figures 2-1 through 2-3. Recreational, infrequent trespass, and other exposure scenarios may be proposed at a later time as site-specific conditions warrant.

Pathway Characterization

Table 2-1 represents preliminary pathway analysis using typical sources of contaminant exposure for human receptors. Table 2-2 indicates default values for use in the calculation of chronic daily intake.

Soil Pathway (Direct Ingestion and Dermal Contact)

This pathway addresses the potential for contaminant intake through direct ingestion of contaminated soil and dermal contact with said soil (and subsequent transdermal absorption). Figure 2-2 and Table 2-2 provide the risk/hazard formulae and exposure assumptions to be applied for soil at the subject sites. The risk/hazard formulae are standard for calculating residential exposure (through CDI) for residents. The standard 30-year, single-home habitation period has been divided into child stage (1 to 6 years) and adult stage (7 to 30 years) to account for differential exposures between life stages.

If inhalation of volatile or particulate-bound contaminants is not considered a major exposure pathway of concern, this exposure pathway will not be addressed. These calculation will not be included in the screening portion of the assessment. However, if determined to be a viable exposure pathway during the RFI process, the inhalation pathways will be included in the calculations and evaluated in the risk assessment. The decision on whether to include these pathways will be based on the potential for emanation from affected media.

If the future site resident exposure scenario calculations predict significant risk/hazard, additional evaluation relative to current site workers may be necessary using the assumptions provided in Table 2-2. For specific contaminants, the applicability or significance of the dermal pathway may be questionable and as such may be eliminated during refined assessment (USEPA, *Dermal Exposure Assessment: Principles and Applications*, Interim Report. EPA/600/8.91/011 B, January 1992).

Sediment Pathway (Direct Ingestion and Dermal Absorption of Contaminants)

The sediment exposure pathway will be evaluated on a site-specific basis using the same formulae and assumptions presented for soil. However, exposure to sediment at NAVBASE would likely be under a recreational, infrequent trespass, or worker scenario, and applicable assumptions would deviate significantly from those applicable for soil. Any changes in the assumptions and calculations will be presented in the BRA, and/or the corresponding figures will be referenced for applicable soil exposure pathway assumptions.

Air Pathway (Direct Inhalation of Gaseous or Particulate-Bound Contaminants)

As above, this exposure pathway will be addressed on a site-specific basis. Any formulae or assumptions used in the BRA for this exposure pathway will be presented. The applicability of the model shown below will be depend upon the type of cover (i.e., vegetative, asphalt, etc.) and depth of contamination. Typically, when significant surface soil contamination is identified in areas subject to significant wind erosion and areal transport, the commonly used and accepted

Table 2-1
Current/Potential Pathways of Human Exposure, on Naval Base Charleston, Charleston, South Carolina

Potentially Exposed Population	Medium and Exposure Route	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Current and Future Site/Area Residents	Air, Inhalation of gaseous contaminants	Yes (Qualified)	The air pathway may be a concern; this exposure scenario will be retained until the RFI is completed and data are available to substantiate or refute this position.
	Air, Inhalation of particulate-bound contaminants	Yes (Qualified)	The air pathway may be a concern; this exposure scenario will be retained until the RFI is completed and data are available to substantiate or refute this position.
	Groundwater, Inhalation of volatile contaminants	Yes (Qualified)	Inhalation of volatiles through groundwater use may be a concern; this exposure scenario will be retained until the RFI is completed and data are available to substantiate or refute this position.
	Groundwater, Ingestion and dermal contact with contaminants in medium from potable sources or general domestic use	Yes	No potable wells onsite. Deep wells onsite, potential (future use) of groundwater as industrial water supply. Possibility of communication between surface water and site groundwater systems; contaminant migration; potential (future use) screening scenario assumption as viable exposure pathway.
	Soil, Incidental ingestion of and dermal contact with (absorption) contaminants onsite	Yes	Potential for presence of contaminants in site soil exists.
	Sediment, Incidental ingestion and dermal contact (absorption) of contaminants while swimming	Yes	Although local surface water bodies are of limited use for swimming, the potential (future use) exists for exposure to sediments on rare occasions. Residential areas and streams.
	Surface water, Ingestion and dermal contact (absorption) of contaminants while swimming	Yes	Although local surface water bodies are of limited use for swimming, the potential (future use) exists for exposure to surface water on rare occasions.
	Surface water, Ingestion and dermal contact (absorption) of contaminants during potable or general domestic usage	Yes	Other sources of potable water are readily available. Surface water extends via Noisette Creek to offsite residential area.

Table 2-1
Current/Potential Pathways of Human Exposure, on Naval Base Charleston, Charleston, South Carolina

Potentially Exposed Population	Medium and Exposure Route	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Current and Future Site/Area Residents	Fish and shellfish, Ingestion of species obtained from surface water bodies surrounding the site	Yes (Qualified)	This exposure scenario will be retained until the RFI is completed and data are available to substantiate or refute this position.
	Wild game or domestic animals, Ingestion of species indigenous to the area which have contacted/ingested contaminated media onsite	No	No hunting or farming of animals are known to occur or would be expected to occur at NAVBASE.
	Fruits and vegetables, Ingestion of plant products grown in potentially contaminated media	No (Qualified)	Industrial area, this exposure scenario will be retained only in the case where the RFI is completed and data are available to substantiate this position such as personal gardens, gardening classes, etc., in residential areas at NAVBASE. At this time, there is no known pathway for this exposure route (i.e., no record of gardens, etc.).
Current and Future Site Workers	Air, Inhalation of gaseous contaminants	Yes (Qualified)	This exposure scenario will be retained until the RFI is completed and data are available to substantiate or refute this position.
	Air, Inhalation of particulate-bound contaminants	Yes (Qualified)	This exposure scenario will be retained until the RFI is completed and data are available to substantiate or refute this position.
	Groundwater, Ingestion and dermal contact with contaminants in medium from potable sources	No (Qualified)	Groundwater is not currently used as a source of potable or general purpose water onsite; another source of potable water is used onsite; retention of this pathway would be exceedingly conservative. If, during the RFI process, industrial use of groundwater is discovered, this pathway will be retained.
	Soil, Incidental ingestion and dermal contact (absorption) of soil contaminants onsite	Yes (Qualified)	Potential for waste presence in site soil exists due to the nature of operations; exposure potential for current site workers is reduced by safe work practices and personal hygiene requirements but risk calculations will be based on "worst-case" assumptions.

Table 2-1
Current/Potential Pathways of Human Exposure, on Naval Base Charleston, Charleston, South Carolina

Potentially Exposed Population	Medium and Exposure Route	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Current and Future Site Workers	Sediment, Incidental ingestion and dermal contact with contaminants while performing specific site activities	No	Current site workers have no occasions to swim in adjacent surface waters; short-term exposure during sampling processes is minimized through safe work practices; if this pathway is discovered during the RFI process, it will be addressed in the assessment.
	Surface water, Incidental ingestion and dermal contact with contaminants while performing specific site activities	No	Current site workers have no occasions to swim in adjacent surface waters; short-term exposure during sampling processes is minimized through safe work practices; if this pathway is discovered during the RFI process, it will be addressed in the assessment.
	Surface water, Ingestion and dermal contact with contaminants in surface water used as potable source or general purposes	Yes (Qualified)	Surface water is not currently used as a potable source by site workers; limited dermal contact during maintenance operations is possible under current conditions.

Table 2-2
Assumptions for Ingestion and Dermal Contact Exposure to Soil Chemicals of Concern at Naval Base Charleston[a]

Parameter	Future Child Resident	Future Adult Resident	Current Adult Workers
ORAL			
Daily soil ingestion level	200 mg	100 mg	50 mg
Fraction of time onsite in contaminated areas	100%[b]	100%[b]	100%[b]
Portion of ingested contaminant absorbed	100%	100%	100%
Days per year onsite	350 days	350 days	250 days
Years onsite	6 years	24 years	25 years
Body weight	15 kg	70 kg	70 kg
Averaging time:			
Carcinogen	70 years	70 years	70 years
Non-carcinogen	6 years	24 years	25 years

Table 2-2
Assumptions for Ingestion and Dermal Contact Exposure to Soil Chemicals of Concern at Naval Base Charleston[a]

Parameter	Future Child Resident	Future Adult Resident	Current Adult Workers
DERMAL			
Skin area contaminated[d]	4,272 cm^2	1,980 cm^2	1,980 cm^2
Soil adherence to skin	1 mg/cm^2	1 mg/cm^2	1 mg/cm^2
Portion of contaminant absorbed	0.01 (Organics) [c] 0.001 (Metals)	0.01 (Organics) [c] 0.001 (Metals)	0.01 (Organics) [c] 0.001 (Metals)
Days per year onsite	350 days	350 days	250 days
Years onsite	6 years	24 years	25 years
Body weight	15 kg	70 kg	70 kg
Averaging time: Carcinogen Non-carcinogen	 70 years 6 years	 70 years 24 years	 70 years 25 years

Notes:

[a] — References values from USEPA, RAGS, 12/89, OSWER Directive #9285.6-03, and USEPA, Region IV New Interim Guidance March 1994) unless otherwise footnoted.

[b] — Uniform contaminant distribution over the entire site area is assumed. No fraction of time factor was utilized in these calculations, uniform exposure to the entire site at average contaminant concentrations (conservative); only analytical hits used to compute contaminant averages.

[c] — 1.0% (Organics) or 0.1% (Metals) dermal transfer assumed; includes consideration of soil matrix effect.

[d] — Skin surface area (i.e., worker and adult resident — forearms and hands; child — arms, hands, legs and feet) provided in 3/17/94 phone conversation with Mr. Glenn Adams, USEPA Region IV Risk Assessor.

Figure 2-1
Formulae for Calculating Soil CDI

SOIL INGESTION PATHWAY
Ingestion Factor (IF) mg/kg

Residential Scenario:

$$IF_{soil/age1-6} = \frac{IR_{soil/age1-6} \times EF_{res} \times ED_{age1-6}}{BW_{age1-6}}$$

$$IF_{soil/age7-31} = \frac{IR_{soil/age7-31} \times EF_{res} \times ED_{age7-31}}{BW_{age7-31}}$$

Current and Future Site Worker Scenario:

$$IF_{soil/worker} = \frac{IR_{soil/worker} \times EF_{worker} \times ED_{worker}}{BW_{worker}}$$

Variable	Description	Default Value
BW_{age1-6}	average body weight from ages 1-6 (kg)	15 kg
$BW_{age7-31}$	average body weight from ages 7-31 (kg)	70 kg
BW_{worker}	worker body weight (kg)	70 kg
ED_{age1-6}	exposure duration during ages 1-6 (yr)	6 years
$ED_{age7-31}$	exposure duration during ages 7-31 (yr)	24 years
ED_{worker}	worker exposure duration (yr)	25 years
EF_{res}	residential exposure frequency (days/year)	350 days/year
EF_{worker}	worker exposure frequency (days/year)	250 days/year
$IR_{soil/age7-31}$	ingestion rate of soil age 7-31 (mg/day)	100 mg/day
$IR_{soil/age1-6}$	ingestion rate of soil age 1 -6 (mg/day)	200 mg/day
$IR_{soil/worker}$	worker soil ingestion rate (mg/day)	50 mg/day

Note: Absorbed doses for ingestion exposure are assumed to be the equivalent of administered doses (100 percent oral ingestion). Therefore, no conversion factor is incorporated into the associated formulae.

Figure 2-1 (cont)
Formulae for Calculating Soil CDI

DERMAL CONTACT PATHWAY
Contact Factor (CF) mg/kg

Residential Scenario:

$$CF_{age7-31} = \frac{SA_{age7-31} \times AF \times EY \times EF_{res} \times ED_{age7-31}}{BW_{age7-31}}$$

$$CF_{age1-6} = \frac{SA_{age1-6} \times AF \times EY \times EF_{res} \times ED_{age1-6}}{BW_{age1-6}}$$

Current and Future Site Worker Scenario:

$$CF_{worker} = \frac{SA_{worker} \times AF \times EY \times EF_{worker} \times ED_{worker}}{BW_{worker}}$$

Variable	Description	Default Value
AF	soil to skin adherence factor (mg/cm^2)	1 mg/cm^2
BW_{age1-6}	average body weight from ages 1-6 (kg)	15 kg
$BW_{age7-31}$	average body weight from ages 7-31 (kg)	70 kg
BW_{worker}	worker body weight (kg)	70 kg
ED_{ae7-31}	exposure duration during age 7-31 (yr)	24 yr
ED_{age1-6}	exposure duration during age 1-6 (yr)	6 yr
ED_{worker}	worker exposure duration (yr)	25 yr
EF_{res}	residential exposure frequency (days/year)	350 days/year
EF_{worker}	worker exposure frequency (days/year)	250 days/year
EY	events/day	1 event/day
SA_{age1-6}	skin surface area available for contact (cm^2/event)	4272 cm^2/event
$SA_{age7-31}$	skin surface area available for contact (cm^2/event)	1980 cm^2/event
SA_{worker}	skin surface area available for contact (cm^2/event)	1980 cm^2/event

Notes: Skin surface area (i.e., worker and adult resident — forearms and hands; child — arms, hands, legs and feet) provided in 3/17/94 phone conversation with Mr. Glenn Adams, USEPA Region IV Risk Assessor. Absorption factor assumes 1 percent of contaminants present in adsorbed soil will be absorbed by the exposed individual via the dermal contact pathway.

Figure 2-1 (cont)
Formulae for Calculating Soil CDI

Non-Carcinogens - Child - Residential Scenario:

$$CDI_{NC-C} = \frac{C_S \times 10^{-6}\ kg/mg}{AT_{NC-C}} \times \begin{cases} IF_{age1-6} & \textit{Ingestion - child} \\ CF_{worker} \times ABF & \textit{Dermal Contact - child} \end{cases}$$

Non-Carcinogens - Adult - Residential Scenario:

$$CDI_{NC-A} = \frac{C_S \times 10^{-6}\ kg/mg}{AT_{NC-A}} \times \begin{cases} IF_{age7-31} & \textit{Ingestion - adult} \\ CF_{age7-31} \times ABF & \textit{Dermal Contact - adult} \end{cases}$$

Non-Carcinogens — Current and Future Worker Scenario:

$$CDI_{NC-W} = \frac{C_S \times 10^{-6}\ kg/mg}{AT_{NC-W}} \times \begin{cases} IF_{worker} & \textit{Ingestion - worker} \\ CF_{worker} \times ABF & \textit{Dermal Contact - worker} \end{cases}$$

Carcinogens:

$$CDI_C = \frac{C_S \times 10^{-6}\ kg/mg}{AT_C} \times \begin{cases} (IF_{age1-6} + IF_{age7-31}) & \textit{Ingestion - age adjusted} \\ (CF_{age1-6} + CF_{age7-31}) \times ABF & \textit{Dermal Contact - age adjusted} \\ IF_{worker} & \textit{Ingestion - worker} \\ CF_{worker} \times ABF & \textit{Dermal Contact - worker} \end{cases}$$

Variable	Description	Default Values
ABF	Absorption factor (unitless)	0.01 (Organics) 0.001 (Metals)
AT_C	Averaging time (carcinogen)	25,550 days
AT_{NC-A}	Averaging time - adult (non-carcinogen residential)	10,950 days
AT_{NC-C}	Averaging time - child (non-carcinogen residential)	2,190 days
AT_{NC-W}	Averaging time - worker (non-carcinogen)	6,250 days
C_s	Chemical concentration in soil	Chemical-specific

Notes: Reference: USEPA, RAGS, Volume I, Part A, 12/89, pp. 6-40 and 6-41 and USEPA, RAGS, Volume I, Part B, pp. 23-25; USEPA Region IV Interim Risk Assessment Guidelines, February 11, 1992.

Absorption factor assumes 1 percent of contaminants present in adsorbed soil will be absorbed by the exposed individual via the dermal contact pathway.

This page left blank intentionally.

Figure 2-2
Formulae for Calculating CDI for Air Pathway

Dust Loading and Resuspension

$$Ca = Cs \times Di \times Cf$$

Variable	Description
Ca	chemical concentration in air milligrams per cubic meter (mg/m^3)
Cs	chemical concentration in soil micrograms per gram ($\mu g/g$)
Di	dust loading factor, soil in air grams per cubic meter (g/m^3)
Cf	conversion factor (0.001 milligrams per microgram [$mg/\mu g$])

Note: Default dust loading factors, for use when site-specific data are not available, based upon the nature of the onsite activity, are as follows:

Construction Work:	6 x 10-4 g/m^3
Construction Traffic:	4 x 10-4 g/m^3
Agriculture:	2 x 10-4 g/m^3
Other Activities:	1 x 10-4 g/m^3

CDI - Air Pathway

$$CDI = \frac{Ca \times INH \times ET \times EF \times ED}{BW \times AT}$$

Variable	Description	Default Value
$BW_{age1\text{-}6}$	average body weight from ages 1-6 (kg)	15 kg
$BW_{age7\text{-}31}$	average body weight from ages 7-31 (kg)	70 kg
BW_{worker}	worker body weight (kg)	70 kg
$ED_{ae7\text{-}31}$	exposure duration during age 7-31 (yr)	24 yr
$ED_{age1\text{-}6}$	exposure duration during age 1-6 (yr)	6 yr
ED_{worker}	worker exposure duration (yr)	25 yr
EF_{res}	residential exposure frequency (days/year)	350 days/year
EF_{worker}	worker exposure frequency (days/year)	250 days/year
$INH_{age1\text{-}6}$	inhalation rate — age 1-6 (m^3/day)	20 m^3/day
$INH_{age7\text{-}31}$	inhalation rate — age 7-31 (m^3/day)	20 m^3/day
INH_{worker}	inhalation rate — worker (m^3/day)	20 m^3/day

This page left blank intentionally.

Figure 2-3
Formulae for Calculating CDI for Groundwater

WATER INGESTION PATHWAY
Ingestion Factor (IF) mg/kg

Residential Scenario:

$$IF_{water/age1-6} = \frac{IR_{water/age1-6} \times EF_{res} \times ED_{age1-6}}{BW_{age1-6}}$$

$$IF_{water/age7-31} = \frac{IR_{water/age7-31} \times EF_{res} \times ED_{age7-31}}{BW_{age7-31}}$$

Current and Future Site Worker Scenario:

$$IF_{water/worker} = \frac{IR_{water/worker} \times EF_{worker} \times ED_{worker}}{BW_{worker}}$$

Variable	Description	Default Value
BW_{age1-6}	average body weight from ages 1-6 (kg)	15 kg
$BW_{age7-31}$	average body weight from ages 7-31 (kg)	70 kg
BW_{worker}	Worker body weight (kg)	70 kg
ED_{age1-6}	exposure duration during ages 1-6 (yr)	6 years
$ED_{age7-31}$	exposure duration during ages 7-31 (yr)	24 years
ED_{worker}	worker exposure duration (yr)	25 yr
EF_{res}	residential exposure frequency (days/year)	350 days/year
EF_{worker}	worker exposure frequency (days/year)	250 days/year
$IR_{water/worker}$	water intake rate — worker (L/day)	2 L/day
$IR_{water/age1-6}$	water intake rate — age 1-6 (L/day)	1 L/day
$IR_{water/age7-31}$	water intake rate — age 7-31 (L/day)	2 L/day

Note: Volatiles may be excluded from the calculation of CDI and resulting risk/hazard depending on the frequency of detection and concentration of volatile compounds at individual sites.

Figure 2-3 (cont)
Formulae for Calculating CDI for Groundwater

INHALATION PATHWAY
Inhalation Factor (INF) L/kg

Residential Scenario:

$$INF_{age7-31} = \frac{INH_{age7-31} \times K \times EF_{res} \times ED_{age7-31}}{BW_{age7-31}}$$

$$INF_{age1-6} = \frac{INH_{age1-6} \times K \times EF_{res} \times ED_{age1-6}}{BW_{age1-6}}$$

Current and Future Site Worker Scenario

$$INF_{worker} = \frac{INH_{worker} \times K \times EF_{worker} \times ED_{worker}}{BW_{worker}}$$

Variable	Description	Default Value
BW_{age1-6}	average body weight from ages 1-6 (kg)	15 kg
$BW_{age7-31}$	average body weight from ages 7-31 (kg)	70 kg
BW_{worker}	worker body weight (kg)	70 kg
ED_{ae7-31}	exposure duration during age 7-31 (yr)	24 yr
ED_{age1-6}	exposure duration during age 1-6 (yr)	6 yr
ED_{worker}	worker exposure duration (yr)	25 yr
EF_{res}	residential exposure frequency (days/year)	350 days/year
EF_{worker}	worker exposure frequency (days/year)	250 days/year
INH_{age1-6}	inhalation rate — age 1-6 (m^3/day)	20 m^3/day
$INH_{age7-31}$	inhalation rate — age 7-31 (m^3/day)	20 m^3/day
INH_{worker}	inhalation rate — worker (m^3/day)	20 m^3/day
K	Volatilization factor (L/m^3)	0.5 L/m^3

Note: Volatiles may be excluded from the calculation of CDI and resulting risk/hazard depending on the frequency of detection and concentration of volatile compounds at individual sites

Figure 2-3 (cont)
Formulae for Calculating CDI for Groundwater

Non-Carcinogens - Child - Residential Scenario:

$$CDI_{NC-C} = \frac{[C_W]}{AT_{NC-C}} \times \begin{cases} IF_{age1-6} & Ingestion - child \\ INF_{age1-6} & Inhalation - child \end{cases}$$

Non-Carcinogens - Adult - Residential Scenario:

$$CDI_{NC-A} = \frac{[C_W]}{AT_{NC-A}} \times \begin{cases} IF_{age7-31} & Ingestion - adult \\ INF_{age7-31} & Inhalation - adult \end{cases}$$

Non-Carcinogens - Current and Future Worker Scenario:

$$CDI_{NC-W} = \frac{[C_W]}{AT_{NC-W}} \times \begin{cases} IF_{worker} & Ingestion - worker \\ INF_{worker} & Inhalation - worker \end{cases}$$

Carcinogens:

$$CDI_C = \frac{[C_W]}{AT_C} \times \begin{cases} (IF_{age1-6} + IF_{age7-31}) & Ingestion - age\ adjusted \\ (INF_{age1-6} + INF_{age7-31}) & Inhalation - age\ adjusted \\ IF_{worker} & Ingestion - worker \\ INF_{worker} & Inhalation - worker \end{cases}$$

Variable	Description	Default Value
AT_C	Averaging time (carcinogen)	25,550 days
AT_{NC-A}	Averaging time (non-carcinogen adult)	10,950 days
AT_{NC-W}	Averaging time (non-carcinogen worker)	6,250 days
AT_{NC-C}	Averaging time (non-carcinogen child)	2,190 days
C_W	Chemical concentration in groundwater	Chemical-specific

Notes: Reference: USEPA, RAGS, Volume I, Part A, 12/89, pp. 6-40 and 6-41 and USEPA, RAGS, Volume I, Part B, pp. 23-25; USEPA Region IV Interim Risk Assessment Guidelines, February 11, 1992.

For all non-volatile groundwater chemicals, the inhalation portions of the carcinogenic and non-carcinogenic risk formulae will be excised.

This page left blank intentionally.

model below will be applied. This model addresses the release of contaminants in the form of airborne dust or particulates when contaminated soil is disturbed by onsite activities. The dust loading equation and resuspension model that follow were developed by the U.S. Department of Energy (DOE).

Groundwater Pathway (Direct Ingestion)

Groundwater ingestion is not a likely pathway at NAVBASE because groundwater is not used or considered to be a potable water source. As discussed in Section 1, one objective of the investigation into background conditions will be identification of water quality of the surficial aquifer. If groundwater is found to be unable to support Class GB use, than the groundwater pathway will not be used. However, if discovered as a viable pathway during the RFI process, it will be included in the calculations and evaluated in the risk assessment.

Surface Water Pathway (Direct Ingestion)

The human exposure pathway for surface water will use the same equations used to compute CDI and risk/hazard for the groundwater pathway. These formulae are presented in Figure 2-2. The following discussions outline those assumptions, which may be altered for the site-specific assessment of surface water. Recreational ingestion of potentially contaminated biota or other assumptions may be applied to surface water bodies.

2.3 Toxicity Assessment

The objective of the toxicity assessment is to further determine the potential hazard posed by the COPC for which exposure pathways have been identified. The USEPA has developed toxicological databases that provide information regarding common environmental media contaminants identified at hazardous waste sites. The primary information source (database) used for this purpose is the Integrated Risk Information System (IRIS). In the event that toxicological information for a particular contaminant is not available in IRIS, USEPA's Health Effects Assessment Summary Tables (HEAST) will be reviewed as a secondary reference. The

IRIS database files for each contaminant will be made available for review. The Fiscal Year 1993 HEAST will be used to derive toxicological data for these BRA. In the absence of IRIS or HEAST entries on a particular chemical, the risk assessor will pursue other avenues to evaluate the health effects or ecological significance of contaminant concentrations. USEPA's Environmental Criteria and Assessment Office (ECAO) in Cincinnati, Ohio, retains information on myriad chemical compounds and may be used to supplement primary reference information. Compounds which do not poses a toxicity value can sometimes use a reference value for a structurally related compound as a surragate. A general overview of information available in IRIS and HEAST is provided below, along with a discussion of applicability.

USEPA has established a classification system for rating the potential carcinogenicity of environmental contaminants based on the weight of scientific evidence. The cancer classes are described below. Cancer weight-of-evidence class "B2" indicates a possible human carcinogen, and this classification was based on positive laboratory animal data (for carcinogenicity) in the absence of human data. Weight-of-evidence class "A" (human carcinogens) means that human toxicological data indicate a proven correlation between exposure and the onset of cancer (in varying forms). The "B1" classification indicates that some human exposure studies have implicated the compound as a carcinogen. Weight-of-evidence class "C" identifies possible human carcinogens, and class "D" indicates that a compound is not classifiable with respect to its carcinogenic potential. The USEPA has established SF_o for carcinogenic compounds. The SF_o is defined as a "plausible upper-bound estimate of the probability of a response (cancer) per unit intake of a chemical over a lifetime." In addition to potential carcinogenic effects, most substances also can produce other toxic responses at doses greater than experimentally derived threshold levels. The USEPA has derived Reference Dose (RfD) values for these substances. A chronic RfD is defined as "an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime." These toxicological values are used in risk formulae to assess the upper bound level

of cancer risk and non-cancer hazard associated with exposure to a given concentration of contamination. Toxicological information for COPCs (i.e., RfD, toxic effects, Applicable or Relevant and Appropriate Requirements [ARARs], etc.) will be presented in tabular format in this section. Descriptions of most prominent toxicological effects/target organs and other pertinent information for each COPC will be presented in narrative form.

For some compounds, no toxicological information may be readily available. In such instances, ARAR will be reviewed to provide a point of reference. Drinking water Maximum Contaminant Levels (MCL) and Secondary MCLs (SMCL) have been established for a number of contaminants. The MCL are enforceable standards applicable to water supply systems and are generally based on filtered water quality. SMCL typically are based on aesthetic and/or engineering constraints and are not enforceable. The available MCL (USEPA, Office of Water, MCL Table, December 1993) for compounds detected in site groundwater will be included in the groundwater risk characterization tables (if applicable). USEPA also has established guidance levels for some contaminants in the form of Drinking Water Equivalent Levels (DWEL) and Health Advisories (HA). These values were developed as recommended concentrations below which exposure would not be predicted to have deleterious effects on human receptors. For groundwater and surface water contaminants identified onsite, a comparison of concentrations to MCL, SMCL, HA, or DWEL values may be used to evaluate the magnitude (or significance of detected concentrations).

2.4 Risk Characterization

The objective of risk characterization section is to estimate the overall potential adverse effect by using the exposure information and dose-response data for each exposure scenario. Risk is estimated by comparing incremental excess cancer risk and hazard index to threshold values agreed on by the SCDHEC, USEPA, and the Navy. The risk characterization provides numerical estimates of risk and a framework to help judge the significance of the risk and to assess and convey the related uncertainties. This information will be presented in tabular format

for each COPC and each reasonable exposure pathway and also discussed. For example, if significant risk is posed by a groundwater-bearing zone in which there are no wells, and the present conditions (such as high salinity) would make a well in this zone unpalatable or not useful without pre-treating the water, this water-bearing zone would be excluded from this section and discussed in the uncertainty section above. Also, the incremental excess cancer risk/hazard and hazard index will be presented for each applicable medium.

The statistically determined exposure point concentrations are evaluated relative to internal dose and toxicological responses. Data for each reasonable route of exposure are compared with generally accepted safe levels (i.e. RBCs). Contaminant-specific standards that are ARAR are used when available to determine acceptable concentrations. When ARAR are not available nor sufficiently protective for specific compounds or exposure media, health-based levels are determined by using USEPA RfD for non-carcinogens and USEPA SF for carcinogens. In some cases, ARAR may not apply. For example, the South Carolina Water Classifications and Standards, R.61-68, classifies all groundwater as GB, or as an underground source of drinking water. Available data suggests that water quality of the shallow aquifer may not meet the primary and secondary drinking standards promulgated under the Safe Drinking Water Act due to both anthropogenic and naturally occurring sources. Comparison of observed or medoleled concentrations to ingestion-based ARARs or risk/hazard-based concentrations for potable groundwater may not be appropriate for NAVBASE groundwater if the underlying aquifer will not support this level (GB). Therefore, determining "background" or reference levels of groundwater quality will be an important measure in this process. The general exposure pathways, and thus risk/hazard, are presented as default values; however, as circumstances dictate, the default conditions can be changed or additional conditions can be addressed to account for site-specific conditions.

Oral RfD and SF are used in quantifying risk for the dermal exposure pathway. Only a portion of most compounds are absorbed through the oral ingestion pathway, and the lower efficiency

of absorption in the gastro-intestinal (GI) tract is included in the oral RfDs and SFs. This lower efficiency must be adjusted to account for the higher dermal-to-bloodstream migration efficiency of contaminants that pass the skin barrier. For example, the absorption through the GI tract could have a significant effect on the risk estimate of an individual exposed to 10 milligrams (mg) of compound X. The absorption efficiency into the bloodstream from the GI tract for X could be 50 percent. Therefore, 5 mg would actually enter the bloodstream via absorption through the GI tract via the ingestion pathway. If the oral RfD is 8 mg, no risk would be expected because the absorbed dose or intake does not exceed the threshold dose. However, if 10 mg were dermally absorbed, the RfD is exceeded and risk could be posed by the dermal exposure pathway. For this reason, the oral RfD and SF must be adjusted in order to estimate the risk/hazard of the dermally absorbed dose. The formulae below show the risk/hazard calculation, including the dermal administered to absorbed dose adjustment factor for soil:

Ingestion:

$$Excess\ Cancer\ Risk = CDI_{oral} \times SFo$$

$$Hazard\ Quotient = \frac{CDI_{oral}}{RfD_o}$$

Dermal Absorption:

$$Excess\ Cancer\ Risk = \frac{SFo \times CDI_{derm}}{Adj}$$

$$Hazard\ Quotient = \frac{CDI_{derm}}{RfD_o \times Adj}$$

As shown above, the potential risk posed by a carcinogen is computed by multiplying the CDI in mg/kg-day by the SF in $(mg/kg\text{-}day)^{-1}$. The HQ, a measure of the potential for toxicological effects other than carcinogenicity, is computed by dividing the CDI by the RfD. The USEPA has set standard limits (or points of departure) for carcinogens and non-carcinogens to evaluate whether significant risk is posed by a contaminant (or combination of contaminants). For carcinogens, the typical point-of-departure range is 10^{-4} to 10^{-6}. These points of departure correlate with one in 10,000 and one in 1,000,000 excess cancer resulting from exposure to environmental contaminants. For non-carcinogens, other toxic effects are generally considered possible if the HQ exceeds unity (1). Although both cancer risk and non-cancer hazard are generally additive (within each group) only if the target organ is common to multiple contaminants, a most conservative estimate of each may be obtained by summing the individual risks or hazards regardless of target organ. This BRA will first take the universal summation approach as suggested in RAGS. However, as discussed above, it may be appropriate to use the summation approach only for each toxicant that exhibits the same effect by the same mechanism of action. The presence of competitive inhibition (or inhibition of toxicity via an indirect mechanism) and synergistic effects will not be addressed as no means of accurately predicting these effects has been universally accepted by the regulatory or scientific community.

2.5 Uncertainty Discussion

The objective of the uncertainty discussion is to evaluate uncertainties inherent in the risk assessment process. Uncertainty is a factor in each step of the exposure and toxicity assessments presented in the preceding sections. Uncertainties associated with the initial stages of the risk assessment process become magnified when they are associated with other uncertainties. For example, the use of the UCL as the exposure point concentration is a method of reducing uncertainty. However, a safety factor based on the standard deviation and number of samples is included in the UCL. During the risk characterization process, the risk is added to determine the incremental excess cancer risk for each exposure pathway. Risk was calculated based on the UCL, and the safety factor of the incremental risk is the sum of all the individual safety

factors. This multiplicative or exponential conservatism is inherent in the risk assessment process, and is also evident in the uncertainty factor and modifying factor applied to RfDs. It is not possible to eliminate all uncertainties; however, recognizing the uncertainties is fundamental to understanding and using risk assessment results.

This section will discuss the uncertainty of site-specific and medium-specific factors introduced in the risk assessment, in addition to other variables influencing the uncertainty of the calculated incremental excess cancer risks and hazard indices. Two liters of water per day are not likely to be consumed from one source. Other sources, such as work, malls, school, etc., typically will account for a significant fraction of water consumed from offsite sources. Another factor adding conservatism to a risk assessment is the assumption that the UCL is ubiquitous to the site and assumes preferential exposure to heavily contaminated areas. Another assumption included in this method is the ubiquitous exposure to all COPC identified onsite, regardless of detection frequency. The fraction of time/area onsite may be refined with sufficient demographic/behavior pattern documentation.

Currently, the exposure scenario is industrial with no anticipated move toward residential. Therefore, projections regarding residents are highly conservative; the exposure frequency is defined as the probability of focused exposure. In combination with the exposure duration of 30 years (which is three time greater than the actual 50th percentile residency duration), the estimation of risk based on these values is extremely conservative. As previously discussed, the fraction of time onsite and percent area affected may be included in the exposure duration and frequency for a more accurate estimate of risk/hazard.

A parallel assessment using mean concentrations of COPC conducted for comparison to the calculated risk posed by maximum point concentrations. In addition, the risk posed by reference concentrations ubiquitous to the site will be presented in the same format. This method assumes the site is the sole exposure point for contaminated media. Anthropogenic and natural

contamination are not addressed. Using the reference concentration risk, parallel reference risk/hazard assessments to evaluate whether sites possess risk/hazard in excess of that presented by ubiquitous substances and other sources outside the AOC.

2.5.1 Remedial Goal Options

Remedial Goal Options (RGO) will be presented in table format, containing media cleanup levels for each chemical of concern (COC) in each land use scenario evaluated in the baseline risk assessment. COCs are chemicals which contribute to a pathway that exceeds a 10^{-4} risk (or whatever risk level is chosen as the remediation "trigger" by the risk manager) or a HQ of 1 or greater or exceeds a state or federal chemical-specific ARAR. The table will include the 10-4, 10-5 and 10-6 risk levels for each chemical, media and scenario and the HQ 0.1, 1, and 10 levels as well as any chemical-specific ARAR values (state and federal). Calculations of the respective concentrations at each level will use site-specific average daily dose information within each pathway, and any other site-specific information that is applicable. Remediation Levels (RLs) will be derived from the RGOs by the risk manager, and thereafter will be considered required levels to be achieved by remedial action.

2.6 Conclusions

The objective of the conclusions section is to summarize the findings of the human health risk assessment considering current and future use exposure and uncertainty. This information will be summarily discussed and previously presented tables will be referenced.

2.7 Summary of the Human Health Risk Assessment Procedure

In summary, the BRA will first identify the list of COPC through data validation, risk-based screening, outside inclusion criteria, and comparison to reference concentrations. CDI calculations and assumptions will be presented before the calculation of the CDI for each COPC and relevant exposure pathways. After identifying the list of COPC and addressing exposure conditions, relevant toxicological information will be presented for each COPC, which includes

SF and RfD, sources, and other information used in characterizing risk. The risk will then be characterized (quantified) using the CDI and toxicological information. The general exposure pathways and resulting risk/hazard are presented as default, but should circumstances dictate, can be changed to account for site-specific conditions. Risk characterization results will be summarized in tabular format, and all relevant assumptions discussed in this section of the BRA. RGOs will be developed and presented including the percent contribution to overall risk. Uncertainty inherent in the risk assessment process as well as site-specific sources of uncertainty will be presented and discussed in the final section, with risk posed by the reference concentrations and that posed by the mean concentrations included in an appendix for comparison purposes. At this point, conclusions will be drawn as to the current and future risk to human receptors at the sites addressed in the BRA. An appendix will be included presenting the screening information used to identify the COPC addressed in the assessment.

This page left blank intentionally.

3.0 ECOLOGICAL RISK ASSESSMENT

As previously discussed, the RCRA Permit requires an Environmental Risk Assessment (ERA) to determine if cause-effects relationships exist between onsite contaminant concentrations and observed impacts to biological components. The ERA will be directed at NAVBASE as a whole but conducted on an individual SWMU/AOC basis. This method will focus efforts on site-specific contaminants along with relative biological receptors. Developing the ERA will follow USEPA guidance documents *Risk Assessment Guidance for Superfund (EPA/540/1-89/002)* and *Framework for Ecological Risk Assessment (EPA/630/R-92/001)*. The following sections provide a basic approach to meeting the objectives of determining ecological risk associated with contamination at NAVBASE.

Risk assessment at each applicable management unit will be approached in phases. The goal of each phase is to yield specific information about the site through source, pathway, and receptor identification. The first phase concentrates on reviewing the site primarily through qualitative information and concludes with developing a sampling strategy for the subsequent Phase II portion of the investigation. Phase II involves a contamination assessment of the site, with problem formulation and model development occurring in Phase III. Information from all phases, as appropriate, will be incorporated into a risk calculation. A flowchart describing the entire ERA process is provided in Figure 3-1.

3.1 Phase I — Preliminary Site Assessment

A Preliminary Site Assessment (PSA) will be conducted to determine baseline information to be used later to characterize risk associated with contamination at NAVBASE. Essential elements of the PSA will include reviewing analytical data obtained during the RFA process, along with collecting pertinent information for baseline assessment of impacts to the biological resources within the site area. Migration routes will be determined from topographic and site physical information. Exposure routes along with habitat types and sensitive resource areas, will be determined and a cursory review of potential biological receptors will be produced. The PSA

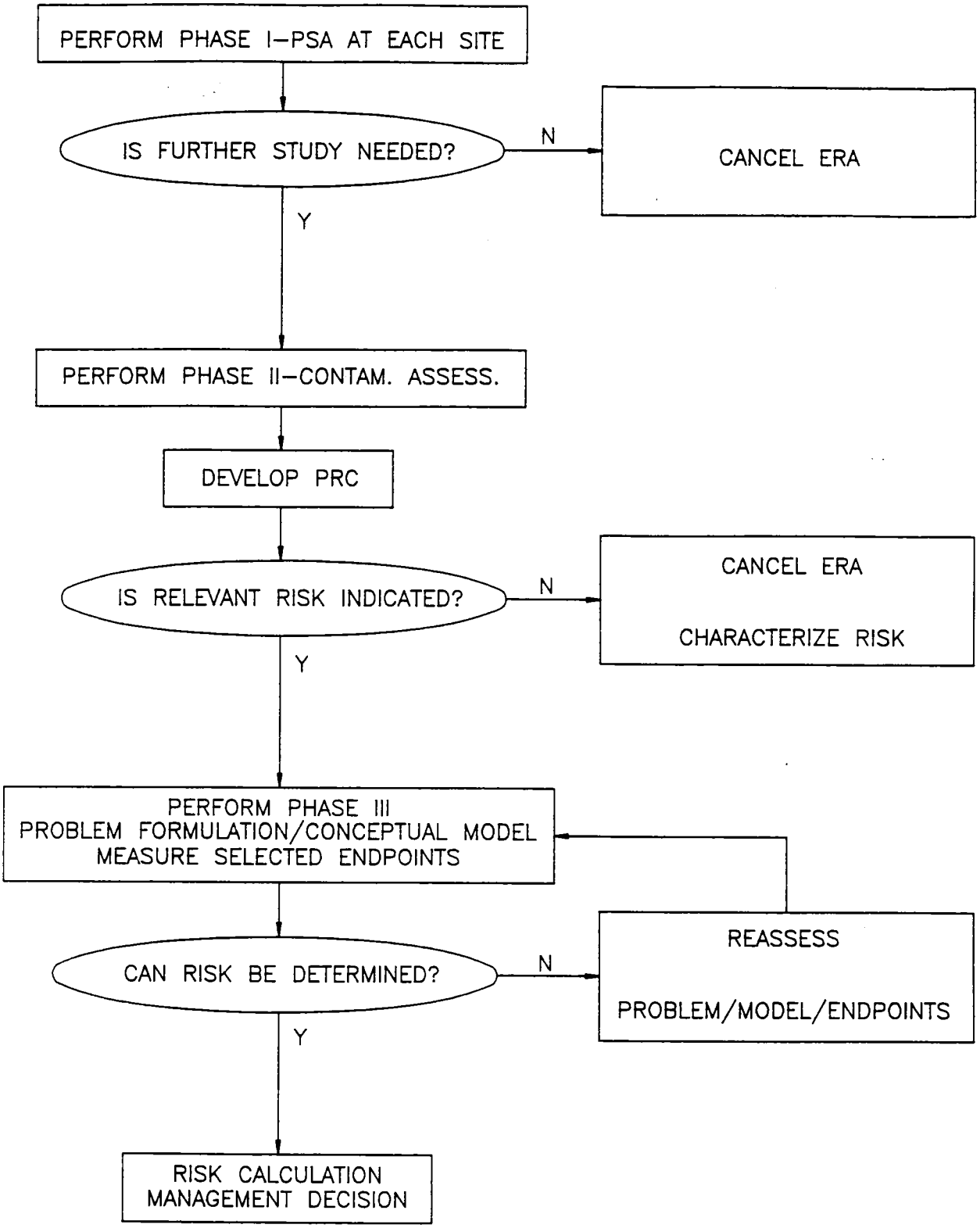
is a process to obtain information that will be critical to later stages of the ERA. Portions of the PSA may be conducted successional or concurrently.

3.1.1 Habitat Evaluation

To evaluate habitat types that may be involved in the ERA, a habitat evaluation will be conducted. This evaluation will involve field determinations for wetlands presence (see Appendix A), critical and unique habitats, and any other special habitat that might be indicated. Prior review of state and federal documents (i.e., National Wetlands Inventory Maps, National Forest List, South Carolina State Parks List, South Carolina Critical Habitats, etc.) will be used to enhance the field effort.

Site visits will be conducted for identified areas to assess current conditions. The site visit will be performed by a qualified specialist experienced in assessment procedures and familiar with the Charleston area's flora and fauna. The specialist will include areas of discipline such as wildlife biology, terrestrial ecology, and aquatic biology. The specialist will identify common plant communities and sensitive resources along with assessing the probability of threatened or endangered species within the area. A subjective assessment of the effects of contamination will be based on observation of anomalous features such as stressed or absent vegetation, unusual odors, and colors or stains. During the survey, checklists for all appropriate habitats will be completed (see Appendix A).

An essential part of the habitat survey will be identifying probable reference areas. These reference areas will be as geographically close to the site as possible, with habitat, topography, geology, and hydrology closely matching site characteristics. Reference areas chosen will have little to no apparent impacts from site source contamination, based on survey and historical information. Reference areas selected may be used for multiple investigated sites.



NAVAL
BASE
CHARLESTON

FIGURE 3–1
ENVIRONMENTAL RISK
ASSESSMENT (ERA)
FLOWCHART

DWG DATE: 04/29/94 | DWG NAME: 29ERA

3.1.2 Biological Inventory

To obtain basic information on the suspected biological receptors within the site area, biological data will be obtained from relevant sources. Regional state and federal agency information such as Natural Areas Inventories, Threatened and Endangered Species, and any other applicable studies within NAVBASE will be reviewed. Also, state agency personnel will be interviewed for current status of suspected biological receptors. From this information, a list of potential biological receptors at NAVBASE or in the vicinity will be produced.

Because there are no standard methods (many methods are available; however, no single method is currently recognized as the "industry standard) for conducting habitat and biological surveys, the specialist will use general survey methods outlined in USEPA's *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (EPA/600/3-89/013)*.

3.1.3 Migration Routes

To best determine if ecological components may be at risk, migration routes from identified sources need to be assessed. This will involve reviewing topographic features for each contaminated site along with identifying of physical conduits such as channels, drains, or streams. In some instances, groundwater may constitute the primary migration pathway for contaminant exposure to natural resources remote from a site. Much of this information can be obtained through review of documents USGS Topographic Maps, site visits, and the hydrogeologic portion of the RFI. A field checklist (see Appendix F) will be used to document information obtained during the site visit.

3.1.4 Exposure Routes

Based on information derived during the habitat and biological surveys and migration routes determination, exposure route scenarios can be developed that will indicate possible contamination pathways to suspected biological receptors. These scenarios will be working

hypotheses that provide a starting point for developing the subsequent problem formulation phase.

3.1.5 Phase I Conclusions

Upon completion of Phase I, a summary risk determination will be made that will incorporate all of the information gathered so far. This risk prediction will be a subjective analysis designed as a "go-stop" mechanism for the subsequent Phase II.

A technical memorandum will be produced to document the summary risk determination. The memorandum will be provided to federal and state trustees to ensure all parties are aware of the risk determination status.

3.2 Phase II — Contaminant Assessment

Baseline information on contaminant concentrations and distribution will be determined through systematic sampling in areas where biological receptors exist or are indicated. As appropriate, sampling media may include soil, sediment, or surface water. In soil, surface (0 to 1 foot) concentrations will be used for risk evaluations. Physical soil parameters (pH, porosity, grain size, organic content, etc.) that may alter contaminant bioavailability will be measured along with the chemical analyses. Sampling location densities will be determined based on location-specific information and data needs.

In aqueous environments, surface water and sediment samples may be collected in areas of suspected high contamination. Source location, along with a suspected risk to biological receptors in the area, will be used to weigh the need for sampling these media. Where applicable, a sediment mapping sub-phase will be used to select the most appropriate sampling locales (see Appendix B). Sampling methods will follow protocols suggested in USEPA's *Sampling Protocols for Collecting Surface Waters, Bed Sediment, Bivalves and Fish for Priority Pollution Analysis* (VERSAR, Inc., 1981) and USEPA's *Ecological Assessment of Hazardous*

Waste Site: A Field and Laboratory Reference Document (EPA/600/3-89/013). As with soil, physicochemical information on water and sediment will be obtained for use in bioavailability predictions. These parameters may include: temperature, salinity, alkalinity, dissolved oxygen, pH, conductivity, nutrients, total suspended solids, total dissolved solids, biologic oxygen demand (BOD), and chemical oxygen demand (COD) for water; and pH, total organic carbon (TOC), cation exchange capacity, grain size, and density for sediments. Background concentrations will be obtained from a reference location or literature.

After baseline information has been collected on contaminants, a study on the general characteristics of the stressor will be completed. This study will provide specific information on intensity, chemical alteration, duration, and secondary effects of the stressor chemical. Site-specific information on soil and water chemistry will aid in assessing the potential effects of the stressor.

3.2.1 Preliminary Risk Characterization

After completing the Phases I and II, a Preliminary Risk Characterization (PRC) will be formulated. This PRC will assimilate data obtained during the Phase I-PSA and Phase II-Contaminant Assessment in order to predict effects to critical biological receptors, based on a contaminant worst-case scenario. These predictions-of-effects will be based on comparison of observed contaminant values to regulatory ARAR (USEPA AWQC, South Carolina WQC, USEPA Region IV Sediment and Surface Water Screening Values, etc.), in addition to referenced effects concentrations of the toxicological characteristics for suspected contaminants. Receptor specific physiological traits and media-transport mechanisms that may alter toxic effects also may be used to formulate effects scenarios. At NAVBASE, since effects to receptors already may have occurred, a more in-depth analysis of historical biological data may be required for prediction verification. For instance, sediment-borne contaminants may have, over time, already altered fishery resources in the Cooper River. Recreational catch statistics may aid in verifying this prediction.

After completing the PRC, a decision will be made as to whether future ecological work is needed. This will be a critical point in the ERA process and therefore the PSA and PRC components are considered extremely important elements.

3.3 Phase III — Problem Formulation/Conceptual Model

The Problem Formulation stage is the most critical element of the ERA process. In this stage, data collected during the PSA and PRC will be analyzed to determine if assessment endpoints can be identified. Assessment endpoints at NAVBASE will be chosen based on the PRC. These could include changes to local fish populations, ecosystem alterations, or other ecological effects. Hypotheses will be critically reviewed to determine if studies or data produced can support risk-management decisions.

In conjunction with problem formulation, a conceptual model will be developed. This model will select measurement endpoints that can be used to quantitatively express the effects of the contaminant hazard. These measurement endpoints will include ecological characteristics that are related directly to the assessment endpoint chosen. Toxicity tests (see Appendix C), measurements of in-situ community indices (see Appendix D), or tissue burden studies (Appendix E), may be selected as measurement endpoints. The model will include the methods (sampling plan) needed to collect the information necessary for testing the model, in addition to addressing uncertainty issues. At this stage, again, a decision will be made on whether assessment endpoints are attainable to whether the ERA process should continue. Appropriate agency consultation, during this problem development and modeling phase, will ensure that selected objectives are applicable and relevant.

3.3.1 Site Assessment

After formulating a reasonable conceptual model, a site assessment will be conducted to determine the practicality of testing the hypothesis. Data collected on contaminant distributions and biological receptor availability will be used to propose sampling methods. The overall

feasibility of obtaining the necessary model components will be the goal of the site assessment. A decision will be made as to the model's applicability based on field observations.

3.3.2 Site Investigation

The site investigation will involve all remaining field sampling, in-situ monitoring, and measurable endpoint data collection. All work will follow the conceptual model design in order to test the formulated hypothesis.

3.4 Risk Calculation

After completing the site investigation, all data will be interpreted to determine the cumulative risk to biological receptors based on contamination found. Both quantitative and qualitative information derived during the site investigation will be used to determine a weight-of-evidence conclusion.

This page left blank intentionally.

4.0 REFERENCES

National Council on Radiation Protection and Measurements (NCRP). 1984. *Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment*. NCRP Report No. 76.

U.S. Department of Energy (DOE). 1989. *A Manual for Implementing Residual Radioactive Material Guidelines*. Argonne National Laboratory, ANL/ ES-160, DOE/CH/8901.

U.S. Department of Energy (DOE). 1983. *Pathway Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites*. DOE ORO-832, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

United States Environmental Protection Agency. 1991. Risk Assessment Guidance for Superfund, Volume I — Human Health Evaluation Manual, *Supplemental Guidance-Standard Default Exposure Factors-Interim Final, USEPA/OERR, OSWER Directive: 9285.6-03*. March 25, 1991.

USEPA. 1991. Risk Assessment Guidance for Superfund, Volume II — Environmental Evaluation Manual, Interim Final, USEPA/OERR, EPA/540/1-89/001. March 1989.

USEPA. 1991. Supplemental Region IV Risk Assessment Guidance. March 26, 1991.

This page left blank intentionally.

APPENDIX A
WETLAND DELINEATION PROCEDURES

In defining a wetland and its boundaries, three criteria must be met: hydrophytic vegetation, hydric soil, and wetland hydrology. The following abbreviated method, adapted from the *Corps of Engineers Wetland Delineation Manual* (1987) will be followed by all field biologists at NAVBASE. Adequately characterizing the wetlands to develop an accurate sampling approach for Phase I will be emphasized over performing a jurisdictional delineation.

Hydrophytic Vegetation

Hydrophytic vegetation is defined as total visible plant life growing in water, soil, or on a periodically inundated substrate at a duration which exerts a controlling influence on all plant species present. During wetland delineation, the percentage of plant species dominating the community, or the percent dominance, will be emphasized over individual species. This is because plants commonly associated with wetlands could be scattered about an upland area. Similarly, species *not* associated with wetlands could be scattered about wetland areas.

Hydrophytic vegetation will be assumed in areas where fifty percent or more of the dominant species have the wetland indicator status of obligate wetland species (OBL), facultative wetland species (FACW), or facultative neutral species (FAC). Plants will be identified through taxonomic references or by qualified biologists familiar with local vegetation. Once the species have been determined, their wetland indicator status can be determined by consulting the *National List of Plant Species that Occur in Wetlands: 1988 National Summary* (U.S. Department of the Interior, 1988).

Determining percent dominance involves analyzing four strata: trees, saplings and shrubs, herbs and woody vines. For the tree strata, each species occurring within a thirty foot radius of a selected observation point is noted. A tree is defined as any non-climbing, woody plant with a diameter at breast height (DBH) of at least 3 inches, regardless of its height. The percent dominance of a species is determined by comparing the approximate crown area of each species versus the total crown area of all species. If the tree species making up at least fifty percent or greater of the crown area are OBL, FACW, or FAC, then the tree strata will be considered hydrophytic.

For the sapling/shrub strata, each sapling or shrub within ten feet of the same selected observation point will be identified. A sapling/shrub is any woody plant at least 3.2 feet high with a stem diameter less than 3 inches, except for woody vines. Species will be ranked in descending order of dominance based on number and heights of all individual species found in the sample plot. If the species making at least fifty percent of the total height classes are OBL, FACW, or FAC, then the sapling/shrub strata is considered hydrophytic.

Herbs are plants less than 3.2 feet high with a DBH less than 3 inches, exclusive of woody vines. When evaluating the herb strata, make a 1.64 foot radius plot from the same observation point. Estimate the percent cover for each of the herbaceous or woody seedling species having foliage within the study area. If the species making up at least fifty percent of the crown area are OBL, FACW, or FAC, then the herb strata is considered hydrophytic.

For the woody vine strata, all woody vines within 10 feet of the same observation point will be identified by counting the number of stems of each woody vine at ground level: If the species

making up at least fifty percent of the total number of stems are either OBL, FACW, or FAC, then the woody vine strata is considered hydrophytic.

All four strata, if present, must be hydrophytic for the area to be classified as having hydrophytic vegetation. Note the same species might be considered in different strata. For example, a mature oak tree may be considered in the tree strata, an oak sapling may be considered in the sapling/shrub strata, and an oak seedling may be considered in the herb strata.

The above procedure is only one of many to determine relative dominance of plant species. This procedure may not be necessary in strata where one plant clearly dominates or when no plants or a limited number of plants in a particular strata are present. Professional judgement should be used when determining how to modify this procedure when calculating relative dominance.

Hydric Soil

Hydric soil is saturated, flooded, or ponded long enough during the growing season to yield anaerobic conditions in the upper portion favoring the growth of hydrophytic vegetation. Often, county soil maps will show predominant soil types in the area of study, including hydric soil.

Hydric soil is typically poorly drained and shows evidence the water table was or is within eighteen inches of the surface at least one week during the growing season. However, hydric soil may be drained and not support hydrophytic vegetation. Therefore, not all areas having hydric soil will qualify as wetlands. The soil be classified as a wetland soil only when it supports or would normally support hydrophytic vegetation and the area has indicators of wetland hydrology.

There are many indicators used to determine the presence of hydric soil such as physical and chemical characteristics, soil staining and soil colors. Soil color, which is strongly influenced by the frequency and duration of soil saturation leading to reducing soil conditions, is often the best indicator of hydric soil. Typically, gleyed soil (gray) or soil that has a matrix chroma (an index of soil color) of 2 or less is considered to be hydric soil. A Munsell soil color chart will be used to determine matrix chroma of suspected hydric soils. The *Corps of Engineers Wetlands Delineation Manual* will be used to determine unique conditions pertaining to a particular site and exceptions to those and other rules.

Much of the soil at NAVBASE is sandy. In areas containing predominantly sandy soil, there are separate criteria for determining hydric soil. In most of these sandy conditions, soil color may not be the best indicator. However, other indicators can be used including high organic matter content in the surface, streaking of subsurface layers, and layers of hardened organic matter within twelve inches of the surface.

Wetland Hydrology

Wetland hydrology encompasses all hydrologic characteristics of areas periodically inundated or saturated to the surface at some time of the growing season. Hydrology is the most important characteristic in defining a wetland. The presence of water for at least seven days during the growing season typically creates the anaerobic conditions giving wetlands their unique characteristics.

Generally, the well drained sandy soil of the Charleston area has wetland hydrology when the water table is less than twelve inches from the surface for at least a week during the growing season. If wetland hydrology is not present at the time of the investigation, various field indicators can be used to determine whether wetland hydrology existed at one time during the growing season. Common indicators are watermarks on nearby trees and other vegetation, lines of debris deposited during a high water event, sediment deposits, or drainage patterns within a wetland. It is also advisable to speak with people familiar with the area or consult topographic or flood plain maps to determine how often the area may be inundated.

Atypical Situations

When human activities have hindered the identification of wetlands, specific guidelines to determine their boundaries are listed in the *Corps of Engineers Wetlands Delineation Manual.* The first goal should be to establish exactly what the disturbance was and what affect it had on the area, followed by review of aerial photographs and other sources to determine what the area looked like in the past. It may be necessary to find an undisturbed reference area nearby to aid in this determination. Once an idea of past conditions has been determined, it may be possible to delineate wetland boundaries based on indicators existing before the alteration.

Delineation Conclusions

The abbreviated procedure described above does not have to be followed when delineating the entire boundary of a wetland. General trends in areas analyzed can be applied to all areas of the wetland. However, areas appearing different or suspect should be analyzed using the method outlined in this section. Common trends used in delineating wetland areas includes noting general breaks in topography or patterns in vegetation diversity. After determining the areas meeting all three criteria for being a wetland, boundaries should be mapped as accurately as possible. The size and characteristics of each wetland will guide the sampling strategy for subsequent portions of the ecological assessment. All wetlands related to a particular site should be delineated and included in the ecological assessment.

APPENDIX B
SEDIMENT MAPPING

To adequately characterize the sediment in wetlands and aqueous environments, a procedure must be followed for establishing transects and sample locations. The overall goal is to develop an accurate sediment map to guide the contaminant assessment sampling. If there are important outfalls or other locations deserving special consideration, emphasis should be placed on characterizing these areas more precisely.

Sediment shallower than wading depth within the wetlands and Cooper River will be collected using a stainless steel hand auger. Deeper locations will be sampled using a Ponar dredge. It is not likely every sample location along the transect will be samples. Because the entire goal of this part of the investigation is to map sediment distribution, it is not considered cost effective to analyze a sediment sample with no significant change from the previous sample. Analysis will be performed for grain size and total organic carbon. Professional judgement should be used on a site-specific basis when determining the sampling locations giving the best overall picture of the sediment distribution; however specific sampling locations will be presented and/or discussed in the zone specific workplans.

At every location along the transect, depth will be noted using a depth rod. Because of the tidal fluctuation of the water bodies, depth will be measured relative to a reference location easily read at all times. Afterwards, a map will be developed showing the approximate distribution of depth, sediment size and total organic carbon throughout the body of water. This information will be useful in determining hot spot areas to sample and the possible location of sampling zones.

Wetlands Gridding Procedures

A sampling grid will be used to determine the sample locations for mapping wetland sediments. Before sampling, each delineated wetland will be studied to determine the proper grid size and orientation that will yield an accurate representation of the sediment. Based on these findings, a baseline transect will be established to best orient the grid across the wetland. Its location will be marked with stakes and flagging. The origins of grid transects along the baseline will then be staked at the determined interval. At a consistent angle and distance, sample points will be established along each transect to form a grid of the entire wetland. All sample locations will be staked and identified. These stakes will also be used to establish sampling zones, if needed. Samples may be taken at locations other than at the nodes of the transects if it is determined the area may be important to map. It is not known how many samples will be taken per wetland. This number will vary depending on site conditions such as the size and diversity of the wetland.

Open Water Gridding Procedures

Sediment samples will be collected along previously determined transects. The transects will be located systematically to provide enough detail to accurately determine sediment distribution at the site. Transects will be sampled at consistent distances from the shore. Some of the transect locations will be biased at outfalls or other locations of obvious surface contamination. All transects will be aligned using the Global Positioning System (GPS).

APPENDIX C
TOXICITY TESTS

Bioassays will be used to establish a correlative cause-effect link between observations of community alterations and contaminant concentrations. Toxicity tests measure the effect of contaminated media on the survival, growth, and/or reproduction of aquatic and terrestrial organisms. These tests provide an integrated index of the bioavailable toxic contaminants at the sites.

Selected test organisms are chosen based on their wide acceptance in laboratory analysis and the wealth of information available about their behavior. Organisms will be selected for toxicity testing based on their representation of different trophic levels, ease of study, and the available information about their behavior patterns. Table C-1 shows organisms that may be used based on the media of concern. All organisms will be lab-cultured and will be directly exposed to the water, sediment, and soil during the tests.

Table C-1
Organisms Chosen for Toxicity Tests

Type of Media	Organism Chosen	Common Name
Marine Sediment	*Ampelisca abdita* *Mysidopsis bahia*	Marine Amphipod Mysid Shrimp
Marine Surface Water	*Menindia berrylina* *Mysidopsis bahia*	Silverside Minnow Mysid Shrimp
Fresh Water Sediment	*Hyalella azteca* *Chironomus tentans*	Freshwater Amphipod Chironomid Midge
Fresh Water Surface Water	*Ceriodaphnia dubia* *Pimephales promelas*	Water Flea Fathead Minnow
Soil	*Eisenia foetida* *Latuca sativa*	Sludge Worm Lettuce Plant

The use of either sediment, soil, or surface water in each toxicity test depends on the type of contaminants suspected in the area sampled and the amount of available surface water.

APPENDIX D
COMMUNITY INDICES

When necessary, community studies will be performed on benthic organisms at each site and a corresponding reference area. Benthic macroinvertebrates often serve as the primary food source for higher trophic level species. Based on their ecological significant and due to their abundance, and relatively stationary lifestyle, the organisms serve as continuous monitors of the ecological health of an area. In offshore areas and submerged wetlands, samples will be taken using a Ponar dredge. Samples will be collected from the upper six inches of the sediment. All species will be identified to the lowest taxonomic level. Community indices such as diversity, richness and evenness will be determined and compared to reference areas.

APPENDIX E
TISSUE BURDENS

Measurement of the bioaccumulation of contaminants by aquatic organisms is an important tool in establishing causality for ecological effects and in assessing the health of a community. The application of "biomarkers" in ecological assessments has been addressed in EPA's *Risk Assessment Guidance for Superfund, Vol. 2, Environmental Evaluation Manual* and EPA's *Ecological Assessment of Hazardous Waste Sites.* The most important element to this determination is the selection of the target species for analysis. Selection of the target species will be based on: (1) literature review of the contaminants of concern, (2) results of water chemistry from Phase II, and (3) results of the initial biological samples. Selection of the target species will be contingent on approval of EPA, SCWMRD and SCDHEC. Target species could include commercial shellfish such as blue crab or brown shrimp, important sport fish such as spotted seatrout, black drum, Atlantic croaker or flounder, or ecologically important fish such as catfish, Gulf killifish, anchovy, or star drum. Preferred target species would include non-mobile animals such as oyster or clams.

Target species will be selected for collection based on distribution, migratory patterns, capturability, abundance, and trophic level. Sampling periods will be limited, as much as possible, to reduce seasonal variability. Sample preparation will include rinsing of the sampling gear and of tissue removal utensils with acetone and hexane. Tissue samples will be wrapped in foil (which has also been rinsed with acetone and hexane), placed in polypropylene bags (to retain moisture) and frozen immediately in dry ice. The following will be incorporated in the plan:

- Minimum of five fish or invertebrates per composite sample;
- Minimum of 300 grams of tissue per sample;
- Samples of as many of the three trophic groups as feasible with limit on field time;

Protocol for tissue preparation, holding, and shipment will adhere to EPA guidance document *Sampling Protocols for Collecting Surface Water, Bed Sediment, Bivalves, and Fish for Priority Pollutant Analysis*, VERSAR, Inc. 1981)

To assess baseline toxicity tissue levels for the Cooper River, additional tissue samples will be collected from reference areas. These locations will be selected based upon known point sources and any historical tissue concentration data, as available.

APPENDIX F
CHECKLIST FOR ECOLOGICAL RISK ASSESSMENT/SAMPLING

EnSafe

CHECKLIST FOR ECOLOGICAL RISK ASSESSMENT/SAMPLING

I. SITE DESCRIPTION

Date _____

1. Site Name: _____

   Location: _____

   _____

   County: _____ City _____ State: _____

2. Latitude: _____ Longitude: _____

3. What is the approximate area of the site? _____

   _____

   _____

4. Is this the first site visit? ☐ Yes ☐ No If no, attach trip report of previous site visit(s) if available.

   Date(s) of previous site visit(s): _____

5. Please attach USGS topographic map(s) of the site to the checklist, if available.

6. Are aerial or other site photographs available? ☐ Yes ☐ No If yes, please attach any available photo(s) to the site map at the conclusion of this section.

   _____

   _____

   _____

7. The land use on the site is:

_____% Urban

_____% Rural

_____% Residential

_____% Industrial(☐ light ☐ heavy)

_____% Agricultural

(Crops: _____)

_____% Recreational

(Describe; note if it is a park, etc.)

_____

_____

_____% Undisturbed

_____% Other

The area surrounding the site is:
_____ mile radius

_____% Urban

_____% Rural

_____% Residential

_____% Industrial (☐ light ☐ heavy)

_____% Agricultural

(Crops: _____)

_____% Recreational

(Describe; note if it is a park, etc.)

_____

_____

_____% Undisturbed

_____% Other

8. Has any movement of soil taken place at the site? ☐ Yes ☐ No If yes, please identify the most likely cause of this disturbance:

_____ Agricultural Use _____ Heavy Equipment _____ Mining

_____ Natural Events _____ Erosion _____ Other

Please describe:

_____

_____

_____

_____

_____

_____

_____

9. Do any potentially sensitive environmental areas exist adjacent to or in proximity to the site, e.g., Federal and State parks, National and State monuments, wetlands, prairie potholes, etc.? *Remember, flood plains and wetlands are not always obvious; do not answer "no" without confirming information.*

_____

_____

9a. Please provide the source(s) of information used to identify these sensitive areas, and indicate their general location on the site map.

_____

_____

10. What type of facility is located at the site?

☐ chemical ☐ manufacturing ☐ mining ☐ waste disposal

☐ other (specify) _____

11. What are the suspected contaminants of concern at the site? If known, what are the maximum concentration levels?

_____

_____

12. Check any potential routes of off-site migration of contaminants observed at the site:

☐ swales ☐ depressions ☐ drainage ditches

☐ runoff ☐ windblown particulates ☐ vehicular traffic

☐ other (specify) _____

13. If known, what is the approximate depth to the water table? _____

14. Is the direction of surface runoff apparent from site observation? ☐ Yes ☐ No If yes, to which of the following does the surface runoff discharge? Indicate all that apply.

☐ surface water ☐ groundwater ☐ sewer ☐ collection impoundment

15. Is there a navigable waterbody or tributary to a navigable waterbody? ☐ Yes ☐ No

16. Is there a waterbody anywhere on or in the vicinity of the site? If yes, also complete Section III: Aquatic Habitat Checklist - Non-Flowing Systems and/or Section IV: Aquatic Habitat Checklist - Flowing Systems.

☐ Yes (approx. distance _____) ☐ No

17. Is there evidence of flooding? ☐ Yes ☐ No *Wetlands and flood plains are not always obvious; do not answer "no" without confirming information.* If yes, complete Section V: Wetland Habitat Checklist.

18. If a field guide was used to aid any of the identifications, please provide a reference. Also, estimate the time spent identifying fauna. [Use the back of this page if additional space for text is needed.]

_____

_____

_____

_____

_____

19. Are any threatened and/or endangered species (plant or animal) known to inhabit the area of the site? ☐ Yes ☐ No *If yes, it is required to verify this information with the U.S. Fish and Wildlife Service.* If species' identity is known please list them below.

_____

_____

_____

_____

_____

_____

20. Weather conditions at the time this checklist was prepared.

DATE: _____

_____ Temperature (°C/°F) _____ Normal daily high temperature

_____ Wind (Direction/Speed) _____ Precipitation (rain, snow)

_____ Cloud cover

IA. SUMMARY OF OBSERVATIONS AND SITE SETTING

Completed by _____

Additional Preparers _____

DATE: _____

II. TERRESTRIAL HABITAT CHECKLIST

IIA. WOODED

1. Are there any wooded areas at the site? ☐ Yes ☐ No If no, go to Section B: Shrub/Scrub.

2. What percentage or area of the site is wooded? (___% ___ acres). Indicate the wooded area on the site map attached to a copy of this checklist. Please identify what information was used to determine the wooded area of the site.

   _____

   _____

3. What is the dominant type of vegetation in the wooded area? (Circle one: Evergreen Deciduous Mixed) Provide a photograph, if available.

   Dominant plant, if known: _____

4. What is the predominant size of the trees at the site? Use diameter at breast height.

   ☐ 0-6 in. ☐ 6-12 in. ☐ > 12 in.

5. Specify type of understory present, if known. Provide a photograph, if available.

   _____

   _____

   _____

IIB. SHRUB/SCRUB

1. Is shrub/scrub vegetation present at the site? ☐ Yes ☐ No If no, go to Section C: Open Field.

2. What percentage of the site is covered by scrub/shrub vegetation? (___% ___ acres). Indicate the areas of shrub/scrub on the site map. Please identify what information was used to determine this area.

   _____

   _____

3. What is the dominant type of scrub/shrub vegetation, if known? Provide a photograph if available.

   _____

4. What is the approximate average height of the scrub/shrub vegetation?

☐ 0-2 ft. ☐ 2-5 ft. ☐ > 5 ft.

5. Based on site observations, how dense is the scrub/shrub vegetation?

☐ dense ☐ patchy ☐ sparse

IIC. OPEN FIELD

1. Are there open (bare, barren) field areas present at the site? ☐ Yes ☐ No If yes, please indicate the type below:

☐ prairie/plains ☐ savannah ☐ old field ☐ other (specify) _____

2. What percentage of the site is open field? (___ % ___ acres). Indicate the open fields on the site map.

3. What is/are the dominant plant(s)? Provide a photograph, if available.

_____

_____

4. What is the approximate average height of the dominant plant? _____

5. Describe the vegetation cover: ☐ dense ☐ sparse ☐ patchy

IID. MISCELLANEOUS

1. Are other types of terrestrial habitats present at the site other than woods, scrub/shrub, and open field? ☐ Yes ☐ No If yes, identify and describe them below.

_____

_____

2. Describe the terrestrial miscellaneous habitat(s) and identify these area(s) on the site map.

_____

_____

_____

_____

3. What observations, if any, were made at the site regarding the presence and/or absence of insects, fish, birds, mammals, etc.?

4. Review the questions in Section I to determine if any additional habitat checklists should be completed for this site.

III. AQUATIC HABITAT CHECKLIST - NON-FLOWING SYSTEMS

Note: Aquatic systems are often associated with wetland habitats. Please refer to Section V, Wetland Habitat Checklist.

1. What type of open-water, non-flowing system is present at the site?

   ☐ Natural (pond, lake)
   ☐ Man-made (lagoon, reservoir, canal, impoundment)

2. If known, what is the name(s) of the waterbody(ies) on or adjacent to the site?

   _____

3. If a waterbody is present, what are the known uses of it (e.g.: recreation, navigation, etc.)?

4. What is the approximate size of the waterbody(s)? _____ acre(s)

5. Is any aquatic vegetation present? ☐ Yes ☐ No If yes, please identify the type of vegetation present (if known).

   ☐ emergent ☐ submergent ☐ floating

6. If known, what is the depth of the water? _____

7. What is the general composition of the substrate? Check all that apply.

   ☐ Bedrock ☐ Sand (coarse) ☐ Muck (fine/black)

   ☐ Boulder (>10 in.) ☐ Silt (fine) ☐ Debris

   ☐ Cobble (2.5-10 in.) ☐ Marl (shells) ☐ Detritus

   ☐ Gravel (0.1-2.5 in.) ☐ Clay (slick) ☐ Concrete

   ☐ Other (specify) _____

8. What is the source of water in the waterbody?

   ☐ River/stream/creek ☐ Groundwater ☐ Industrial discharge

   ☐ Surface runoff ☐ Other (specify) _____

9. Is there a discharge from the site to the waterbody? ☐ Yes ☐ No If yes, please describe this discharge and its path.

_____

_____

10. Is there a discharge from the waterbody? ☐ Yes ☐ No If yes, and the information is available, identify from the list below the environment into which the waterbody discharges.

☐ River/stream/creek	☐ on-site	☐ off-site	Distance _____
☐ Groundwater	☐ on-site	☐ off-site	
☐ Wetland	☐ on-site	☐ off-site	Distance _____
☐ Impoundment	☐ on-site	☐ off-site	

11. Identify any field measurements and observations of water quality that were made. For those parameters for which data were collected provide the measurement and the units of measure below:

_____ Area

_____ Depth (average)

_____ Temperature (depth of the water at which the reading was taken _____)

_____ pH

_____ Dissolved oxygen

_____ Salinity

_____ Turbidity (clear, slightly turbid, turbid, opaque) (Secchi disk depth _____)

_____ Other (specify)

12. Describe observed color and area of coloration.

_____

_____

13. Mark the open-water, non-flowing system on the site map which will be attached to this checklist.

_____

_____

14. What observations, if any, were made at the waterbody regarding the presence and/or absence of benthic macroinvertebrates, fish, birds, mammals, etc.?

_____

_____

_____

_____

IV. AQUATIC HABITAT CHECKLIST - FLOWING SYSTEMS

Note: Aquatic systems are often associated with wetland habitats. Please refer to Section V, Wetland Habitat Checklist.

1. What type(s) of flowing water system(s) is (are) present at the site?

☐ River ☐ Stream ☐ Creek
☐ Dry wash ☐ Arroyo ☐ Brook
☐ Man-Made (ditch, etc.) ☐ Intermittent Stream ☐ Channeling
☐ Other (specify) _____

2. If known, what is the name of the waterbody? _____

3. For natural systems, are there any indicators of physical alteration (e.g., channeling, debris, etc.)? ☐ Yes ☐ No If yes, please describe indicators that were observed.

_____

_____

_____

4. What is the general composition of the substrate? Check all that apply.

☐ Bedrock ☐ Sand (coarse) ☐ Muck (fine/black)

☐ Boulder (>10 in.) ☐ Silt (fine) ☐ Debris

☐ Cobble (2.5-10 in.) ☐ Marl (shells) ☐ Detritus

☐ Gravel (0.1-2.5 in.) ☐ Clay (slick) ☐ Concrete

☐ Other (specify) _____

5. What is the condition of the bank (e.g., height, slope, extent of vegetative cover)?

_____

_____

6. Is the system influenced by tides? ☐ Yes ☐ No What information was used to make this determination?

_____

_____

7. Is the flow intermittent? ☐ Yes ☐ No If yes, please note the information that was used in making this determination.

_____

_____

_____

8. Is there a discharge from the site to the water body? ☐ Yes ☐ No If yes, please describe the discharge and its path.

_____

_____

_____

9. Is there a discharge from the waterbody? ☐ Yes ☐ No If yes, and the information is available, please identify what the waterbody discharges to and whether the discharge is on site or off site.

_____

_____

_____

10. Identify any field measurements and observations of water quality that were made. For those parameters for which data were collected provide the measurement and the units of measure in the appropriate space below:

_____ Width (ft.)

_____ Depth (ft.)

_____ Velocity (specify units: _____)

_____ Temperature (depth of the water at which the reading was taken _____)

_____ pH

_____ Dissolved oxygen

_____ Salinity

_____ Turbidity (clear, slightly turbid, turbid, opaque) (Secchi disk depth _____)

_____ Other (specify)

11. Describe observed color and area of coloration.

_____

_____

_____

_____

_____

12. Is any aquatic vegetation present? ☐ Yes ☐ No If yes, please identify the type of vegetation present if known.

☐ emergent ☐ submergent ☐ floating

13. Mark the flowing water system on the attached site map.

14. What observations were made at the waterbody regarding the presence and/or absence of benthic macroinvertebrates, fish, birds, mammals, etc.?

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

V. WETLAND HABITAT CHECKLIST

1. Based on observations and/or available information, are designated or known wetlands definitely present at the site? ☐ Yes ☐ No

   Please note the sources of observations and information used (e.g., USGS Topographic Maps, National Wetland Inventory, Federal or State Agency, etc.) to make this determination.

   _____

   _____

   _____

2. Based on the location of the site (e.g., along a waterbody, in a floodplain, etc.) and site conditions (e.g., standing water; dark, wet soils; mud cracks; debris line; water marks), are wetland habitats suspected? ☐ Yes ☐ No If yes, proceed with the remainder of the wetland habitat identification checklist.

3. What type(s) of vegetation are present in the wetland?

   ☐ Submergent ☐ Emergent
   ☐ Scrub/Shrub ☐ Wooded

   ☐ Other (specify) _____

4. Provide a general description of the vegetation present in and around the wetland (height, color, etc.). Provide a photograph of the known or suspected wetlands, if available.

   _____

   _____

   _____

5. Is standing water present? ☐ Yes ☐ No If yes, is this water: ☐ Fresh ☐ Brackish
   What is the approximate area of the water (sq.ft.)? _____
   Please complete questions 4, 11, 12 in Checklist III - Aquatic Habitat - Non-Flowing Systems.

   _____

   _____

   _____

6. Is there evidence of flooding at the site? What observations were noted?

☐ Buttressing ☐ Water marks ☐ Mud cracks ☐ Debris line

☐ Other (describe below) _____

_____

_____

7. If known, what is the source of the water in the wetland?

☐ Stream/River/Creek/Lake/Pond ☐ Groundwater

☐ Flooding ☐ Surface Runoff

8. Is there a discharge from the site to a known or suspected wetland? ☐ Yes ☐ No If yes, please describe.

_____

_____

_____

_____

9. Is there a discharge from the wetland? ☐ Yes ☐ No If yes, to what waterbody is discharge released?

☐ Surface stream/River ☐ Groundwater ☐ Lake/Pond ☐ Marine

10. If a soil sample was collected, describe the appearance of the soil in the wetland area. Circle or write in the best response.

Color (blue/gray, brown, black, mettled) _____

Water content (dry, wet, saturated/unsaturated) _____

11. Mark the observed wetland area(s) on the attached site map.

_____

_____

_____

_____

EXPLANATION OF TERMS USED IN THIS CHECKLIST

Arroyo	Dry gulch, brook, or creek. A deep gully cut by an intermittent brook or stream.
Benthic	Pertaining to the bottom of a waterbody.
Detritus	Loose fragments or particles formed by the disintegration of rocks.
Marl	A mixture of clays, carbonates of calcium and magnesium and remnants of shells.
Riparian	Of, or on the bank of a natural course of water.
Secchi (disk)	Basic measure of turbidity, visibility or transparency of water.
Submergent Vegetation	Hidden, obscure vegetation which is inundated with water.
Swales	Low traces of land which are often moist or marshy.

[General format for checklists was taken from information provided at 1993 SETAC Short Course: Ecological Impact, Rick Assessments, and Cleanup Decisions at Hazardous Waste Site; presented by M.D. Sprenger and D.W. Charters, USEPA.]