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April 6, 2001

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Submittal of Final Baseline Risk Assessment Work Plans for TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio; Contract Number DACA62-00-D-0002; IT Project Numbers 807112 and 807111

Dear Mrs. Ingram:

As requested and in accordance with the requirements of Delivery Orders 0004 and 0003 of Contract Number DACA62-00-D-0002, IT Corporation is pleased to submit the final Baseline Risk Assessment Work Plans (including the Baseline Human Health Risk Assessment Work Plan and Baseline Ecological Risk Assessment Work Plan) for TNT Areas A and C at the former Plum Brook Ordnance Works (PBOW) in Sandusky, Ohio. The work plans have been revised in response to technical review comments received from USACE and OEPA. Responses to the technical review comments are included as an appendix to each work plan.

Enclosed are seventeen copies of the final work plan. Should you have any questions or require additional information regarding this submittal, please do not hesitate to call.

Sincerely,

Mikael L. Spangberg
Project Manager

Enclosures

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DISCIPLINE SIGN-OFF REVIEW

Client Name: U.S. Army Engineer District, Nashville; CELRN-EC-R-M

Project Description: RI / FS / DD, TNT Area A / C, Former Plum Brook Ordnance Works, Sandusky, OH

Contract Number: DACA62-00-D-0002

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☒ SAP, SSAP, CDAP, or QAPP	Baseline Ecological Risk Assessment Work Plan, TNT Areas A and C, Apr. 2001	
☐ SHP or SSHP		**Document Status**
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Baseline Human Health Risk Assessment
Work Plan
TNT Areas A and C
Plum Brook Ordnance Works
Sandusky, Ohio

Prepared for:

Plum Brook Ordnance Works
Sandusky, Ohio

Prepared by:

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April 2001

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Acronym List

ABS	dermal absorption factor
AF	adherence factor
ARAR	applicable or relevant and appropriate requirement
AT	averaging time
atm	atmospheres
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
BSC	background screening criterion
BW	body weight
CDI	chronic daily intake
cm	centimeter
cm^2	square centimeter
COC	chemical of concern
COPC	chemical of potential concern
CSEM	conceptual site exposure model
days/week	days per week
days/year	days per year
DNT	dinitrotoluene
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
ECAO	Environmental Criteria and Assessment Office
ED	exposure duration
EF	exposure frequency
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
ET	exposure time
EU	exposure unit
FI	fraction
g	gram
g/kg-day	grams per kilogram of body weight per day
g/m^3	grams per cubic meter
GAF	gastrointestinal absorption factor
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
hours/day	hours per day

HQ	hazard quotient
IR	ingestion rate
IRIS	Integrated Risk Information System
IT	IT Corporation
kg	kilogram
kg/day	kilograms per day
L/day	liters per day
L/kg	liters per kilogram
L/L	liters per liter
µg/mg	micrograms per milligram
m	meter
m^3	cubic meters
m^3/day	cubic meters per day
m^3/hour	cubic meters per hour
m/m	meters per meter
m/year	meters per year
MDC	maximum detected concentration
mg/cm^2	milligrams per square centimeter
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mg/mg	milligrams per milligram
NASA	National Aeronautics and Space Administration
NCEA	National Center for Environmental Assessment
OEPA	Ohio Environmental Protection Agency
PAH	polynuclear aromatic hydrocarbon
PBOW	Plum Brook Ordnance Works
PC	permeability coefficient
PCB	polychlorinated biphenyl
PCDD	polycholorinated dibenzo-p-dioxins
PCDF	polycholorinated dibenzofurans
PRG	preliminary remediation goal
QC	quality control
RA	risk assessment

Acronym List (Continued)

RAWP	risk assessment work plan
RBRC	risk-based remediation criteria
RBSC	risk-based screening concentration
RfC	reference concentration
RfD	reference dose
RME	reasonable maximum exposure
SA	surface area
SF	slope factor
SSL	soil screening level
STC	source-term concentration
SVOC	semivolatile organic compound
TNT	trinitrotoluene
UCL	upper confidence limit
URF	unit risk factor
USACE	U.S. Army Corps of Engineers
UTL	upper tolerance limit
VOC	volatile organic compound
WWII	World War II

1.0 Introduction

Chemical contamination related to former U.S. Department of Defense (DOD) activities has been documented at the former Plum Brook Ordnance Works (PBOW) located near Sandusky, Ohio (U.S. Army Corps of Engineers [USACE], 2000a,b). PBOW operated from 1941 to 1945 as a manufacturing plant for 2,4,6-trinitrotoluene (TNT), dinitrotoluenes (DNT), and pentolite. Some of the areas used by the DOD were decontaminated in the 1950s and 1960s; other areas have been decommissioned but not decontaminated. The site is currently owned by the National Aeronautics and Space Administration (NASA) and is operated as the Plum Brook Station of the Lewis Research Center, which is headquartered in Cleveland, Ohio. In 1978 NASA declared approximately 2,152 acres of land as excess (IT Corporation [IT], 1997). The Perkins Township Board of Education acquired 46 acres of the excess for use as a bus transportation center. The Ohio National Guard has an agreement with the U.S. Army's General Services Administration to use 604 acres of the facility. The areas surrounding PBOW are predominantly agricultural and residential. The facility is currently surrounded by a chain-link fence, and the perimeter is regularly patrolled. Access by authorized personnel is limited to established checkpoints. Public access is restricted except during the annual deer hunting season.

Two deep, or bedrock, groundwater aquifer systems are utilized for drinking water in the area, a carbonate aquifer to the west and a shale aquifer to the east (USACE, 2000a,b). PBOW is located within the transition of the two systems. Upwards of 170 private drinking water wells permitted by the Erie County Health Department are located within 4 miles of PBOW. Permits are not required for agricultural wells. The Erie County Health Department does not permit using surface water as private drinking water. Lake Erie and Sandusky Bay are used for recreational swimming, fishing, and boating. A shallow groundwater system within the unconsolidated material atop the bedrock exists under much of the site. The shallow groundwater system is not used for drinking water, but it is sufficiently near the surface that exposure of a construction worker while excavating a ditch or trench is possible.

However, all risk evaluation of groundwater is deferred to the site-wide groundwater delivery order.

In this risk assessment work plan (RAWP), the term "facility" refers to the entire former PBOW property, and the term "site" refers to an area within PBOW under investigation, in this case, TNT Area A or TNT Area C. Current site use of the PBOW facility is classified as industrial for

the purpose of identifying plausible human receptors and exposure pathways for evaluation in the risk assessment (RA). USACE (2000a,b) describes potential future uses of all or portions of the facility as:

- Continued industrial use (NASA activities and programs)
- Recreational use of portions of the site by hunters and fishermen
- Portions of the site may be sold to state or local government or private individuals (no land-use restrictions were mentioned)
- Parts of the facility may be used for residential or agricultural purposes
- Parts of the facility may be used for training by the National Guard
- Construction activities may be performed during development of any of the sites.

In summary, future site use of TNT Areas A and C is considered to be industrial or residential for the purposes of developing receptor and exposure scenarios. It is assumed that groundwater may be developed as a source of potable water. Earlier investigations summarized by USACE (2000a,b) indicate that soil at TNT Areas A and C is heavily contaminated with nitroaromatic compounds, particularly in the areas of the former process houses.

The purpose of this RAWP is to describe the protocol for evaluating risk to human health at TNT Areas A and C. This RAWP is intended to serve as the template for the RA report. An RA is a stand-alone document, chapter or section; i.e., all the equations and values necessary for quality control (QC) and replication of computations must be contained within the report itself.

The RAWP is based on U.S. Environmental Protection Agency (EPA), USACE, and Ohio Environmental Protection Agency (OEPA) guidance, including, but not limited to, the following:

- Ohio Environmental Protection Agency (OEPA), 1993, ***Closure Plan Review Guidance for RCRA Facilities***, Interim Final, OEPA Division of Hazardous Waste Management, September 1.
- U.S. Environmental Protection Agency (EPA), 1989a, ***Risk Assessment Guidance for Superfund***, Volume I, Human Health Evaluation Manual (Part A), Interim Final, Office of Emergency and Remedial Response, Washington, DC, EPA/540/1-89/002.
- U.S. Environmental Protection Agency (EPA), 1991, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance,***

Standard Default Exposure Factors, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.6-03.

- U.S. Environmental Protection Agency (EPA), 1992a, ***Supplemental Guidance to RAGS: Calculating the Concentration Term***, Office of Solid Waste and Emergency Response, Washington, DC, Publication 9285.7-081.

- U.S. Environmental Protection Agency (EPA), 1992b, ***Dermal Exposure Assessment: Principles and Applications***, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

- U.S. Environmental Protection Agency (EPA), 1992c, "Guidance on Risk Characterization for Risk Managers and Risk Assessors," Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant Administrators, Regional Administrators, February 26, 1992.

- U.S. Army Corps of Engineers (USACE), 1995, ***Risk Assessment Handbook, Volume I: Human Health Evaluation***, Engineer Manual EM 200-1-4.

It should be noted that the writing of this RAWP coincides with the second draft of RAs performed for the Red Water Ponds Areas and TNT Area B. Therefore, this RAWP captures the "lessons learned" from the previous efforts, which should reduce the extent of revision necessary following regulatory review. However, it should be noted that the protocol presented herein may differ slightly from that used in the previous RAs, as a result on ongoing communication with OEPA, the primary regulatory authority for PBOW. The differences represent refinements or upgrades, particularly regarding levels of documentation, that were not available for the earlier RAs. Their inclusion at this point in time does not imply that the earlier RAs are deficient or that substantially different conclusions would be drawn if they were redone using the present protocol.

Ideally, this RAWP captures and solidifies all details of the protocol for RAs at TNT Areas A and C. However, RA knowledge is dynamic, and improvements and refinements occur frequently. Therefore, both USACE and OEPA reserve the right to initiate discussion regarding future changes to the protocol. The need for change is a matter of professional judgement, depending in part on the effect of the proposed change on the projected outcome or conclusions of the RA and the cost of changing the protocol.

The remainder of this document is organized as follows. Section 2.0, Data Evaluation, describes the selection of chemicals of potential concern (COPC) for each medium of interest, and

estimation of source-term concentrations (STC) for each COPC in each medium. (Please note: to increase clarity, the acronym COPC will be used for the singular, and COPCs will be used for the plural.) COPCs are chemicals that are identified as site-related (Section 2.1.5), potentially capable of contributing significantly to risk (Section 2.1.6), and are carried forward to quantitative evaluation in the RA. The STC is a conservative estimate of the average concentration of a COPC, statistically calculated (Section 2.2) from the analytical results of all samples for a particular environmental medium, such as surface soil. It is the concentration to which receptors are exposed during direct contact with the medium, such as dermal contact with surface soil. The STC is also used as the input concentration for transport models that estimate concentrations in indirect media. For example, the STC in soil is input into the dust loading equation (Equation 3.1, Section 3.2.1) to estimate the concentration of a COPC in dust-laden air.

Section 3.0, Exposure Assessment, describes the exposure scenarios and the rationale by which plausible receptors are selected, the pathways by which they may be exposed, the exposure-point concentrations (EPC) of COPCs, and the estimated dose or contact rates for each of the COPCs. The EPC is the concentration of chemical in an environmental medium to which receptors are exposed. Since it is calculated as a conservative estimate of average, it is identical to the STC when used for direct exposure pathways, such as dermal contact with surface soil. It is calculated with transport models for indirect exposure. In the example in the previous paragraph, the output from the dust loading equation is the EPC in air of a COPC identified in soil. It is assumed to reflect a conservative estimate of average because it is based on the STC, which is a conservative estimate of average.

Section 4.0, Toxicity Evaluation, describes the adverse health effects associated with each of the COPCs, and the dose-response evaluation, i.e., the relationship between dose or contact rate and the magnitude of the adverse effect.

Section 5.0, Risk Characterization, combines the output of the exposure analysis and the toxicity analysis to quantify cancer risk and noncancer hazard to each receptor, identifies chemicals of concern (COC), identifies applicable or relevant and appropriate requirements (ARAR) for the COCs and develops risk-based remediation criteria (RBRC) for the COCs. (Please note: to increase clarity, the acronym COC will be used for the singular, and COCs will be used for the plural.) COCs are the chemicals that contribute significantly to unacceptable risk or hazard estimates. ARARs are standards, criteria, guidelines or recommended concentrations from relevant federal and state environmental laws. They may or may not be entirely or partially risk

based. RBRCs are concentrations which, if left in place, will not result in unacceptable risk estimates for the receptor scenario on which they are based.

Section 6.0, Uncertainty Analysis, describes the uncertainty associated with the components of the RA. Section 7.0, Summary and Conclusions, briefly summarizes the RA protocol and results and interprets the results, in light of the uncertainty about their estimation, to draw realistic conclusions regarding risk to human health. Section 8.0, References, presents the references used in the preparation of this document.

2.0 Data Evaluation

2.1 Identification of Chemicals of Potential Concern

COPCs are chemicals that are identified as site-related, potentially capable of contributing significantly to risk, and are carried forward to quantitative evaluation in the RA. The following subsections describe their identification. Prior to initiation of an RA, a list of chemicals present in site samples will be compiled. This initial list includes all chemicals detected in any site medium. COPCs are selected from this list as follows.

2.1.1 Sorting the Analytical Data

Prior to initiation of an RA, a list of chemicals present in site samples will be compiled. This initial list includes all chemicals detected in any site medium. The data for each chemical will be sorted by medium. Surface soil and subsurface soil are considered separate media. Surface and subsurface soil data are combined to assess exposures under the construction worker and residential site-use scenarios, which involve excavation and mixing of surface and subsurface soil. Combined surface and subsurface soil data are termed "total soil" in the RA. The combination is formed by selecting as COPCs for total soil each COPC identified in either surface or subsurface soil. The higher STC estimated for the chemical in surface or subsurface soil will be selected as the STC for total soil. This approach to total soil accounts for the likelihood that surface and subsurface soil would not be perfectly blended for receptor exposure, but that exposure to either may predominate, at least for a period of time or at different locations within the exposure unit (EU).

Soil samples are taken from a sampling interval defined by the upper and lower depths of that interval. For example, a sample may be taken from 0.25 to 1.25 feet below ground surface (ft bgs), in which case 0.25 ft bgs is the upper end of the sampling interval and 1.25 ft bgs is the lower end. Ideally, surface soil should be defined as samples taken from 0 to 1 ft bgs, and subsurface soil should be defined as samples taken from 1 to 10 ft bgs for direct exposure pathways. A preview of the data, however, reveals that some samples were taken from depth intervals that crossed the 1 ft ideal lower end of the interval for surface soil. For example, some samples were taken from 0.5 to 1.5 ft bgs or 1 to 2 ft bgs. Also, there were fewer surface soil samples than subsurface soil samples. At TNT Area A, only one soil sample fell within the ideal 0 to 1 ft bgs interval. Therefore, to deal logically and consistently with sampling depth intervals that crossed 1 ft bgs and to increase the size of the surface soil data sets, surface soil is redefined as samples whose lower end of the sampling interval is less than or equal to 2 ft bgs. Subsurface

soil is redefined as samples whose lower end of the sampling interval is greater than 2 ft bgs but not greater than 10 ft bgs, regardless of the upper end of the sampling interval. For example, a soil sample at TNT Area C taken from 1.3 to 2.3 ft bgs is classified as a subsurface soil sample. The 10 ft bgs limit for subsurface soil reflects the maximum practical depth for direct exposure; i.e., it is unlikely that future development or construction activity would require excavation beyond 10 ft bgs.

TNT Areas A and C are approximately 113 and 119 acres in size, respectively (USACE, 2000a, b). USACE noted that the size of these areas may require special care to ensure that "hot spots," areas of unusually high contaminant concentrations, are adequately identified and evaluated. It is reasonable to expect that a groundskeeper or hunter may be exposed randomly and uniformly across the entire site as a result of his normal duties or activities. Therefore, it is appropriate to include all the surface soil data from across the entire site in the data set for these receptors. A hot spot analysis is not relevant for these receptors, because the high concentrations are appropriately averaged with lower concentrations in development of the STC. A construction worker, on the other hand, may be exposed to a much smaller area during excavation, building or installation of underground utilities. Likewise, a resident is unlikely to be exposed randomly and uniformly across the entire site, because a homestead may consist of as little as one-quarter acre. It is possible, when a reasonable exposure area for a given receptor is less than the entire area from which samples are taken, for the larger clean or lightly contaminated areas to obscure the risk associated with continuous exposure to small, heavily contaminated areas. This situation may give rise to the need for a hot spot, or EU, analysis.

The need for an EU analysis, as well as the number of EUs to analyze, is largely a matter of judgement. If the STCs approximate the maximum detected concentrations (MDC), *and* the risk estimates are clearly within acceptable limits, there is probably no need for an EU spot analysis. However, if either of these conditions is not met, an EU analysis is probably required. This would consist of separating the analytical data spatially into a number of reasonably sized EUs (e.g., perhaps quarter-acre units for residential exposure), and developing STCs and risk estimates for each. An EU is an area over which a receptor would be uniformly and randomly exposed. The EU approach ensures that areas of unusually high risk are not overlooked. The additional information provided by EU analysis may permit limiting remediation to a small number of circumscribed areas, thereby reducing cost and increasing efficiency without sacrificing protectiveness.

2.1.2 Evaluating Data Quality

The quality of the analytical data will be evaluated to select data for inclusion in the RA. Data quality is expressed by the assignment of qualifier codes during the analytical laboratory QC process or during third-party data evaluation. Some of the more common qualifiers and their meanings are (EPA 1989a):

U - Chemical was analyzed for but not detected; the associated value is the sample quantitation limit.

J - Value is estimated, probably below the contract-required quantitation limit.

N - The analysis indicates an analyte for which there is presumptive evidence to make a tentative identification.

NJ - The analysis indicates a "tentatively identified analyte" and the reported value represents its approximate concentration.

R - QC indicates that the data are unusable (chemical may or may not be present).

B - Inorganic chemicals: the concentration is less than the contract-required detection limit but greater than the instrument detection limit. Organic chemicals: the concentration in the sample is not sufficiently higher than concentration in the blank, using the five-times, ten-times (5x, 10x) rule: A chemical is considered a nondetect unless its concentration exceeds five times the blank concentration. For common laboratory contaminants (acetone, 2-butanone [methyl ethyl ketone], methylene chloride, toluene, and the phthalate esters), the sample concentration must exceed ten times the blank concentration to be considered a detection.

"J", "N" and "NJ" qualified data, and "B" qualified inorganic chemical data are used in the RA; "R" data and "B" qualified organic chemical data are not. The handling of "U" qualified data (nondetects) in the RA is described below. The use of data with other less common qualifiers is evaluated on a case-by-case basis. Generally, data for which the identity of the chemical is unclear are not used in the RA. If confidence is reasonably high that the chemical is present, but the actual concentration is somewhat in question, the data generally are used in the RA.

Occasionally, chemicals may be analyzed under two different analytical programs. For example, polynuclear aromatic hydrocarbons (PAH) are often included in EPA Method 8270B for semivolatile organic compounds (SVOC) as well as Method 8310, which is specific for PAHs. 2,4-DNT and 2,6-DNT are often included in Method 8330 for explosives and Method 8270B for SVOCs. Only the results from one analytical method for each chemical will be used in the RA.

The method chosen for each chemical will be the one that provides the greater sensitivity as reflected in lower reporting limits.

2.1.3 Frequency of Detection

As stated above, if confidence is high that a given chemical is present, the data generally are used in the RA. For most chemicals, their identification at concentrations above levels in blanks (considering the 5x, 10x rule; see above) is presumptive evidence of their presence. However, chemicals that are reported infrequently, e.g., in less than 5 percent of the samples, may be artifacts in the data that do not reflect the presence of the chemical in question. Generally, chemicals that are reported only at low concentrations in less than 5 percent of the samples from a given medium are dropped from further consideration, unless their presence is expected based on historical information about the site. Chemicals detected infrequently at high concentrations may identify the existence of "hot spots" and are retained in the evaluation.

2.1.4 Identifying Site-Related Chemicals

Identifying site-related chemicals is a matter of professional judgement that must be exercised for each chemical individually. Most organic chemicals are included in the list of site-related chemicals because most organic chemicals of interest are not naturally occurring. However, there are theoretically possible exceptions, including pesticides and herbicides present in soil in agricultural areas in which these chemicals are or were used in crop production. PAHs in soil, a class of organic compounds which form from natural or anthropogenic combustion of organic matter, including fossil fuels, and are generally ubiquitous in the environment, may be another exception. Plum Brook Station under NASA operation routinely performs controlled burning in various areas of the former PBOW facility. This burning may release PAHs to the atmosphere that travel downwind and deposit on soil at other areas such as TNT Areas A and C. In addition, any class of organic compound may be considered to be anthropogenic background if site concentrations are comparable to upgradient concentrations. For example, if concentrations of 2,4-DNT in the water in a creek meandering across TNT Area A are comparable to upgradient concentrations, it is probably appropriate to conclude that 2,4-DNT is not a site-related chemical. Although the chemical is clearly related to former PBOW activities and its presence in other media such as soil or groundwater may reflect activities that took place at that particular site, its presence in the creek probably does not. Since the 2,4-DNT in the creek does not reflect activities at TNT Area A, it is inappropriate to select the compound as a site-related chemical for TNT Area A and to develop RBRCs for it, because remediation at TNT Area A will not address the source of the contamination. Site-specific background data sufficient to develop background

screening criteria (BSC) (see below) are required to declare any organic chemical to be present at background levels, i.e., to be selected as a background chemical rather than as a site-related chemical. As a practical matter, background data sufficient for developing BSC are available only for inorganic chemicals. Therefore, no organic chemicals, including pesticides, herbicides or PAHs, will be judged to be present at background levels and deselected from the list of site-related chemicals. In other words, all organic chemicals will be subject to risk-based screening for selection as COPCs. Organic chemicals judged to be present at background levels will be discussed in the uncertainty section.

Resolving the site-related issue for metals is more difficult, because metals are naturally present in most environmental media. Historical data regarding site activities, processes, disposal practices, and inadvertent releases can provide much useful information, particularly to confirm the selection of a metal as a site-related chemical. Eliminating a metal from the site-related chemical list, however, requires confidence in the adequacy of the historical data. Frequently the historical data are incomplete; therefore, statistical techniques are often used as tools to aid the exercise of professional judgement. The statistical techniques generally involve comparing the site data with background data. This is frequently done in two steps.

The first step is considered a screening step, in which the MDC of site data is compared with its BSC. The upper tolerance limit (UTL) of the background data set (see below) is generally adopted as the BSC. It is a theoretical upper bound on background concentration. A chemical whose MDC is less than or equal to its BSC is designated a background chemical and is not subjected to risk-based screening or included in the quantitative risk assessment. A chemical whose MDC exceeds the UTL may be designated a site-related chemical and subjected to risk-based screening, or a more rigorous statistical analysis may be performed. The more rigorous statistical analysis consists of comparing the site and background data sets to determine if both are drawn from the same population. The Wilcoxon Rank Sum test is used for this purpose.

Development of a UTL depends on the nature of the background data set, which is tested for normality or lognormality. The Shapiro-Wilk test (EPA, 1992d) is used to test the nature of the distribution using the software package STATISTICA™. If the background data set fits neither a normal nor a lognormal distribution, it is considered to be nonparametric. The UTL is the concentration, that, with a probability of 0.95 (or a confidence of 95 percent), will capture (or cover) 95 percent of background samples if a sufficiently large number of samples were taken. The UTL for a normal distribution is calculated as follows (EPA, 1989b):

$$UTL = \bar{x} + Ks \qquad \text{Eq. 2.1}$$

where:

UTL	=	upper tolerance limit of background concentration (calculated)
$\bar{x}$	=	arithmetic mean
K	=	tolerance factor (Appendix B, EPA, 1989b)
s	=	standard deviation.

The same equation is used to estimate the UTL for lognormal background data sets, but the data are log-transformed before the arithmetic mean and standard deviation are calculated.

There is considerable uncertainty about the development of a UTL because of limitations of sample size and the presence (usually) of a great deal of variation. It is not uncommon for UTL values derived as described above to exceed the MDC of background. In these cases, as well as for nonparametric distributions, the MDC, rather than the UTL, is adopted as the BSC.

2.1.5 Risk-Based Screening

Risk-based screening for human health is introduced to focus the assessment on the chemicals that may contribute significantly to overall risk, and to remove from quantification those chemicals whose contribution is clearly insignificant. In this screen, the MDC is compared with the appropriate risk-based screening concentration (RBSC). If the MDC is less than or equal to the RBSC, the chemical in this medium is not considered further because it is very unlikely that it would contribute significant risk. If the MDC exceeds the RBSC, the chemical is considered to be a COPC and is evaluated in the risk assessment.

RBSCs for soil are EPA (2000) Region IX preliminary remediation goals (PRG) adjusted downward to reflect a cancer risk of 1E-7 or a hazard index (HI) of 0.1. A cancer risk of 1E-7 is chosen to be consistent with OEPA's policy to quantify the risk of any chemical that may contribute to a total cancer risk estimate above 1E-6, which is considered to be a point of departure. An HI of 0.1 is chosen to provide additional protection for simultaneous exposure to multiple chemicals. Soil contaminant concentrations are compared with "residential soil" RBSCs. The mechanisms by which receptors are exposed to sediment are similar to those for soil, but exposure to sediment is likely to be far less intensive. Therefore, the soil RBSCs are adjusted upward by an order of magnitude for application to sediment and are considered to reflect a cancer risk of 1E-7 and an HI of 0.1 because exposure to sediment is far less intensive than exposure to soil. Similarly, exposure to surface water is likely to be far less intensive than

exposure to tap water. Therefore, the tap water RBSCs are adjusted upward by an order of magnitude for application to surface water, and are considered to reflect a cancer risk of 1E-7 and an HI of 0.1 because exosure to surface water is far less intensive than exposure to tap water.

Certain receptors (indoor worker, resident) may be exposed to volatile organic compounds (VOC) in indoor air that volatilize from subsurface soil and penetrate the foundation or slab on which the building is constructed. Airborne concentrations, estimated as described in Section 3.0, are compared with ambient air RBSCs. Ambient air RBSCs are EPA (2000) Region IX ambient air PRGs adjusted to reflect a cancer risk of 1E-7 and a HI of 0.1.

The risk-based screening described above assumes that the RBSCs reflect a sufficiently conservative evaluation of the relevant exposure pathways. The soil RBSCs, however, may not be sufficiently conservative to screen sediment in water bodies from which fish are harvested for human consumption, because they do not address the relevant indirect pathway, which is bioaccumulation by fish. Similarly, the tap water RBSCs may not be sufficiently conservative to screen surface water from which fish are taken. Therefore, mercury and those organic chemicals known to bioaccumulate in aquatic food chains; i.e., organochlorine pesticides, polychlorinated biphenyls (PCB), and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDD/PCDF), will be selected as COPCs in sediment and surface water in surface water bodies from which fish are taken, even if their MDCs are below their RBSCs.

2.1.6 Evaluating Essential Nutrients

Evaluating essential nutrients is a special form of risk-based screening applied to certain ubiquitous elements that are generally considered to be required human nutrients. Essential nutrients such as calcium, iron, magnesium, potassium, and sodium are usually eliminated as COPCs because they are generally considered innocuous in environmental media. Other essential nutrients including chloride, iodine, and phosphorus may be eliminated as COPCs, provided that their presence in a particular medium is shown to be unlikely to cause adverse effects on human health. An exposure analysis will be performed whereby a daily dose of chemical from ingestion of the medium in question is calculated. The dose will be compared with levels known or expected to be safe or toxic, and/or with recommended daily allowances, depending on the availability of data.

2.2 Developing Source-Term Concentrations

The STC is a conservative estimate of the average concentration of a COPC, statistically calculated from the analytical results of all samples for a particular environmental medium within an exposure unit.

2.2.1 Soil, Surface Water, Sediment

Because of the uncertainty associated with characterizing contamination in environmental media, both the mean and the upper confidence limit (UCL) on the mean are usually estimated for each COPC in each medium of interest. The upper 95 percent confidence limit on the mean is generally referred to as the UCL. In general, unusually high values are included in the calculation of the UCL because high values seldom appear as statistical outliers in environmental data. Inclusion of outliers increases the overall conservatism of the risk estimate.

Data sets consisting of 5 or more data points are tested for normality and lognormality with the Shapiro-Wilk test as described above. Statistical analysis is performed only on those chemicals identified as background or site-related COPCs. The UCL is calculated for a normal distribution as follows (EPA, 1992a):

$$UCL = \bar{x} + t_{1-\alpha,n-1}\left(\frac{s}{\sqrt{n}}\right) \qquad \text{Eq. 2.2}$$

where:

UCL	=	upper 95th confidence limit on the arithmetic mean concentration (calculated)
$\bar{x}$	=	sample arithmetic mean
t_1	=	critical value for Student's *t*-test
α	=	0.05 (95 percent confidence limit for a one-tailed test)
n	=	number of samples in the data set
s	=	sample standard deviation.

The UCL will be calculated for a lognormal distribution as follows (Gilbert, 1987):

$$UCL = e^{\left(\bar{y} + 0.5 \cdot s_y^2 + \left[H_{0.95} \cdot \frac{s_y}{(n-1)^{0.5}}\right]\right)} \qquad \text{Eq. 2.3}$$

where:

UCL	=	upper 95th confidence limit on the arithmetic mean concentration (calculated)
$\bar{y}$	=	$\sum y/n$ = sample arithmetic mean of the log-transformed data, y = ln x
s_y	=	sample standard deviation of the log-transformed data

n	=	number of samples in the data set
$H_{0.95}$	=	value for computing the one-sided upper 95 percent confidence limit on a lognormal mean from standard statistical tables.

If the data distribution is nonparametric, the data point selected as the nonparametric UCL will be estimated as the 95 percent UCL rank order on the arithmetic mean of the data set. It will be estimated by ranking the data observations from smallest to largest. The arithmetic mean will be converted to a percentile by interpolation. The rank order of the data point selected as the UCL will be estimated from the following equation (Gilbert, 1987):

$$u = p(n + 1) + Z_{1-\alpha}\sqrt{np(1 - p)} \qquad \text{Eq. 2.4}$$

where:

u	=	rank order of value selected as UCL, calculated
p	=	percentile corresponding to the arithmetic mean
n	=	number of samples in the data set
α	=	confidence limit (95 percent)
$Z_{1-\alpha}$	=	normal deviate variable.

Analytical data from field duplicates are averaged with originals to yield one result for use in the statistical manipulations.

Generally, the detection limit is the lowest concentration of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method. Analytical results are presented as nondetects ("U" qualifier) whenever chemical concentrations in samples do not exceed the detection limits for the analytical procedures for those samples. To apply the statistical procedures described above, a concentration value must be assigned to nondetects. Generally, nondetects are assumed to be present at one-half the detection limit (EPA, 1989a). However, judgement is used in those cases where the detection limit is unusually high. For example, elevated detection limits that exceed the MDC due to matrix interference or sample dilution may be eliminated from the data set and not used in the estimation of the STC.

The UCL or MDC, whichever is smaller, is selected as the STC, and is understood to represent a conservative estimate of average for use in the RA or in various transport models used to estimate EPCs. If the data set consists of fewer than 5 data points, the MDC is selected as the

STC. The impact of eliminated data points on the adequacy of the data sets and the risk estimates will be discussed in the uncertainty section.

2.2.2 Groundwater

All risk evaluation of groundwater, including the protocol for the evaluation, is deferred to the site-wide groundwater delivery order, which is pending.

2.3 The Data Summary Table

A table will be prepared for each medium with the following information:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of detection limits
- Statistical distribution
- Arithmetic mean
- 95 percent UCL
- BSC
- Appropriate RBSC
- Selection as COPC
- STC.

Footnotes in the tables will provide justification for selection or rejection of the chemical as a COPC.

3.0 Exposure Assessment

Exposure is the contact of a receptor with a chemical or physical agent. An exposure assessment estimates the type and magnitude of potential exposure of a receptor to COPCs found at or migrating from a site (EPA, 1989a). An exposure assessment includes the following steps:

- Characterize the physical setting.
- Identify the contaminant sources, release mechanisms and migration pathways.
- Identify the potentially exposed receptors.
- Identify the potential exposure pathways.
- Estimate exposure concentrations.
- Estimate chemical intakes or contact rates.

3.1 Conceptual Site Exposure Model

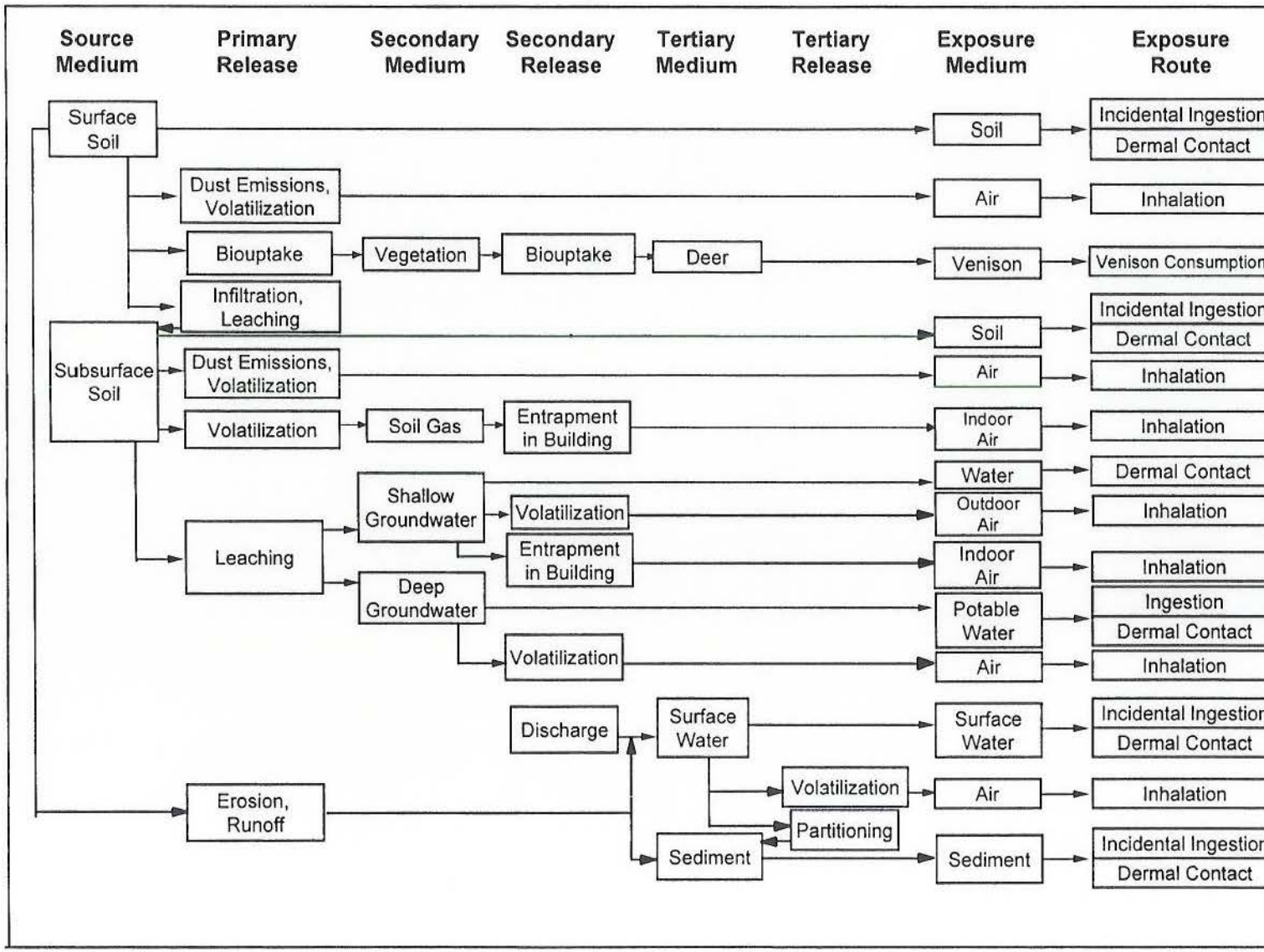
The conceptual site exposure model (CSEM) provides the basis for identifying and evaluating the potential risks to human health in the RA. The CSEM (Figure 3-1) includes the receptors appropriate to all plausible site-use scenarios and the potential exposure pathways. Graphically presenting all possible pathways by which a potential receptor may be exposed, including all sources, release and transport pathways, and exposure routes, facilitates consistent and comprehensive evaluation of risk to human health and helps ensure that potential pathways are not overlooked. The elements of a CSEM include:

- Source
- Source media (i.e., initially contaminated environmental media)
- Contaminant release mechanisms
- Contaminant transport pathways
- Intermediate or transport media
- Exposure media
- Receptors
- Routes of exposure.

Contaminant release mechanisms and transport pathways are not relevant for direct receptor contact with a contaminated source medium.

The receptors and pathways in Figure 3-1 reflect plausible scenarios developed from information regarding site background and history, topography, climate and demographics as presented by USACE, (2000a,b) and the site-wide groundwater investigation (IT, 1997). Asterisks identify exposure pathways that are complete and addressed in the RA. Justification for exclusion of other pathways is provided in the footnotes or the descriptions of the receptors in Section 3.1.3.

Figure 3-1
Human Health Conceptual Site Exposure Model
TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio



Exposure Route	Receptor Scenarios: Groundskeeper (Current)	Construction Worker (Current)	Groundskeeper (Future)	Construction Worker (Future	On-site Resident (Future)	Indoor Worker (Future)	Hunter (Current and Future)
Incidental Ingestion	*	*	*	*	*	*	*
Dermal Contact	*	*	*	*	*	2	*
Inhalation	*	*	*	*	*	2	2
Venison Consumption	1	1	1	1	1	1	*
Incidental Ingestion	1	*	1	*	*	1	1
Dermal Contact	1	*	1	*	*	1	1
Inhalation	1	*	1	*	*	1	1
Inhalation	1	1	1	1	*	*	1
Dermal Contact	1	*	1	*	1	1	1
Inhalation	2	*	2	*	2	1	2
Inhalation	1	1	1	1	*	*	1
Ingestion	1	1	*	*	*	*	1
Dermal Contact	1	1	*	*	*	2	1
Inhalation	1	1	2	2	*	2	1
Incidental Ingestion	3	2	3	2	2	1	1
Dermal Contact	3	*	3	*	*	1	1
Inhalation	2	2	2	2	2	1	1
Incidental Ingestion	3	*	3	*	*	1	1
Dermal Contact	3	*	3	*	*	1	1

* = Complete exposure route quantified in the risk assessment
1 = There is no plausible pathway for exposure to this medium.
2 = Although theoretically complete, this pathway is not quantified as explained in text.
3 = Contact with this medium, although plausible, is not part of this receptor's normal or expected activities; therefore contact would be sporadic and is not quantified.

KN/PBOW/TNT/area_c/fig 3-1.ppt/4/6/01 9:59 AM

Groundwater is potentially a medium of concern at TNT Areas A and C. However, all risk evaluation of groundwater is deferred to the site-wide groundwater delivery order, which is pending. Therefore, groundwater is not included in the CSEM. It is likely, however, that the CSEM will require revision during the groundwater evaluation.

3.1.1 Physical Setting

The description of the physical setting may be brief and may reference an earlier chapter or document where details are found. Sufficient detail, however, must be provided in the RA to validate the selection of contaminated source, transport and exposure media and to support the current and future site-use and receptor scenarios selected for evaluation. Relevant information is provided below.

3.1.1.1 TNT Area A

TNT Area A consists of approximately 113 acres located in the east central portion of PBOW (USACE, 2000a). This area was used during World War II (WWII) as a manufacturing site for TNT and DNT. After WWII, the site was maintained in an "as is" condition until the mid-1950s. Decommissioning and decontamination, begun in 1955, included removing soil around building catch basins, excavating and burning wooden and ceramic flume lines, and flushing and dismantling steam, flume, and drain lines. Burning was conducted in separate burning grounds rather than on TNT Area A proper. However, it is unclear where the various lines were flushed, or where or how flush water was disposed. The site, along with much of the rest of PBOW, was transferred to NASA in 1963. Additional decontamination was performed in 1966 in five stages:

- Ground inspection and removal of obvious contamination
- Digging up the ground at regular intervals and removing visible contamination
- Burning old buildings and rough grading the area
- Decontamination of sump basins and removal of concrete
- Further decontamination of previously decontaminated equipment for sale to outside buyers.

The decontamination was termed "substantial" (USACE, 2000a); overall, more than 16,000 pounds of TNT were removed.

TNT Area A is partially wooded (less than 25 percent) and consists predominantly of large, open areas of prairie grasslands. The Engineering Building is located in the central portion of TNT Area A and is occupied currently by NASA employees. The site is slightly hilly, generally increasing in elevation from the southeast to northwest.

3.1.1.2 TNT Area C

TNT Area C consists of approximately 119 acres located on the western side of PBOW between Campbell Street and Ransom Road (USACE, 2000b). This area was used during WWII as a manufacturing site for TNT and DNT. Virtually everything stated above regarding the decontamination of TNT Area A can be restated for TNT Area C, except that decontamination of TNT Area C was not as thorough as decontamination of TNT Area A.

The site is heavily wooded, with small areas of open grasslands. It is gently hilly. The area is not currently used by NASA.

Both sites are crossed by small streams. The streams are too small to support sport fishing; however, both sites provide habitat for deer and other wildlife.

3.1.2 Contaminant Sources, Release Mechanisms, and Migration Pathways

Contaminant sources, release mechanisms and migration pathways are summarized in Figure 3-1. Briefly, TNT is made by nitrating toluene in a three-step process that uses nitric and sulfuric acids (Dames and Moore, 1997). The processing lines consist of individual buildings connected by pipelines that carry the reactive materials and the reactions to completion. Contamination involved the inadvertent release of TNT, its precursors, contaminants and residues, and acids or sellite (sodium sulfite made from soda ash and sulfur) from the process lines or drying or packaging areas. Releases occurred to the surface soil and, from leaking or damaged underground pipelines, to subsurface soil. Runoff and erosion may have spread contamination over the surrounding surface soil and may have carried contaminants to nearby streams. Infiltration and leaching may have carried contaminants into the subsurface soil or groundwater. As noted above, the groundwater evaluation is deferred to a future site-wide groundwater delivery order.

3.1.3 Receptors and Exposure Pathways

Receptors, selected to represent the upper bound on exposure from all plausibly exposed groups of people at TNT Areas A and C, and the pathways by which they may be exposed to chemicals

are summarized in Figure 3-1 and Table 3-1. The exposure variable values used in the contaminant intake models are compiled in Table 3-2.

Most RAs are based on a reasonable maximum exposure (RME) assumption. The intent of the RME assumption is to estimate the highest exposure level that could reasonably be expected to occur, but not necessarily the worst possible case (EPA, 1989a, 1991). It is interpreted as reflecting the 90 to 95th percentile on exposure. In keeping with EPA (1991) guidance, variables chosen for a baseline RME scenario for ingestion rate (IR), exposure frequency (EF) and exposure duration (ED) are generally upper bounds. Other variables, e.g., body weight (BW) and exposed skin surface area (SA), are generally central or average values. In the case of contact rates consisting of multiple components, e.g., dermal contact with soil or water, which consists of a dermal absorption factor (ABS) and soil-to-skin adherence factor (AF) for soil, and permeability coefficient (PC) and exposure time (ET) for water, only one variable, ABS or PC, needs to be an upper bound. The conservatism built into the individual variables ensures that the entire estimate for contact rate is sufficiently conservative.

The averaging time (AT) for noncancer evaluation is computed as the product of ED (years) times 365 days per year (days/year), to estimate an average daily dose over the entire exposure period (EPA, 1989a). For cancer evaluation, AT is computed as the product of 70 years, the assumed human lifetime, times 365 days/year, to estimate an average daily dose prorated over a lifetime, regardless of the frequency or duration of exposure. This methodology assumes that the risk from short-term exposure to a high dose of a given carcinogen is equivalent to long-term exposure to a correspondingly lower dose, provided that the total lifetime doses are equivalent. This approach is generally consistent with the EPA (1986) policy of carcinogen evaluation, although it introduces considerable uncertainty into the cancer RA.

A fractional term (FI) is introduced into the chemical intake equations to account for scenarios in which exposure to a potentially contaminated medium associated with the site is less than total daily exposure to that medium. For example, if the site of interest is small, so that a groundskeeper may spend only one-half of his working time at the site, an FI of 0.5 is applied to the soil ingestion and dermal intake equations. An FI is used also if a receptor's exposure is split between two comparable media. For example, if a construction worker is exposed to both soil and sediment, FIs are introduced that apportion his exposure between the two media. The default value of FI is 1.

Table 3-1

Receptor/Exposure Scenarios
TNT Areas A and C
Plum Brook Ordnance Works, Sandusky, Ohio

Source Medium	Model	Exposure Medium	Exposure Pathway
Groundskeeper			
Surface soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on activity	Ambient air	Inhalation
Total soil	Not quantified[a]		
Surface water	Not quantified[b]		
Sediment	Not quantified[b]		
Indoor Worker			
Surface soil	None	Soil	Incidental ingestion Dermal contact[c]
Subsurface soil	Volatilization from soil	Indoor air	Inhalation
Total soil	Not quantified[a]		
Surface water	Not quantified[a]		
Sediment	Not quantified[a]		
Construction Worker			
Total soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on activity	Ambient air	Inhalation
Surface water	None	Surface water	Incidental ingestion[c] Dermal contact
	Volatilization from water	Ambient air	Inhalation[c]
Sediment	None	Sediment	Incidental ingestion Dermal contact

Table 3-1

Receptor/Exposure Scenarios
TNT Areas A and C
Plum Brook Ordnance Works, Sandusky, Ohio

Source Medium	Model	Exposure Medium	Exposure Pathway
On-Site Resident			
Total soil	None	Soil	Incidental ingestion Dermal contact
	Volatilization from soil	Ambient air	Inhalation
	Dust emissions based on wind erosion	Ambient air	Inhalation
Subsurface soil	Volatilization from soil	Indoor air	Inhalation
Surface water	None	Surface water	Incidental Ingestion[c] Dermal contact
	Volatilization from water	Ambient air	Inhalation[c]
Sediment	None	Sediment	Incidental ingestion Dermal contact
Hunter			
Surface soil	None	Soil	Incidental ingestion Dermal contact
	Dust, volatilization	Ambient air	Inhalation[c]
	Biouptake	Venison	Venison consumption

a There is no plausible pathway for exposure to this medium.

b Although contact with this medium is possible, exposure would be sporadic, rather than continuous or predictable. Such exposures do not lend themselves to evaluation under the chronic toxicity paradigm used in a baseline risk assessment.

c Although theoretically complete, this pathway is not quantified as explained in text.

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
General Variables Used in All Intake Models					
Body weight (BW), kg	70[a]	70[a]	Child: 15[b] Adult: 70[a]	70[a]	Child: 15[b] Adult: 70[a]
Averaging time, noncancer (AT), days[d]	9125	183	Child: 2190 Adult: 8760	9125	Child: 2190 Adult: 10950
Averaging time, cancer (AT), days[e]	25550	25550	25550	25550	25550
Inhalation of VOCs and Resuspended Dust from Surface Soil, Total Soil or Subsurface Soil					
Fraction exposed to contaminated medium (FI_a), unitless	1[c]	1[c]	1[c]	NA	NA
Inhalation rate (IR_a), m^3/day	20[a]	20[a]	Child: 10[b] Adult: 20[a]	NA	NA
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	NA	NA
Exposure duration (ED), years	25[a]	0.5[b]	Child: 6[b] Adult: 24[b]	NA	NA

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Inhalation of VOCs in Indoor Air from Subsurface Soil					
Fraction exposed to contaminated medium (FI_a), unitless	NA	NA	1[c]	1[c]	NA
Inhalation rate (IR_a), m^3/day	NA	NA	Child: 6.8[c] Adult: 13.7[c]	20[a]	NA
Exposure frequency (EF), days/year	NA	NA	350[a]	250[a]	NA
Exposure duration (ED), years	NA	NA	Child: 6[b] Adult: 24[b]	25[a]	NA
Incidental Ingestion of Soil					
Fraction exposed to contaminated medium (FI_{so}), unitless	1[c]	1[c]	0.9[c]	1[c]	1[c]
Soil incidental ingestion rate (IR_{so}), mg/day	100[a]	290[c]	Child: 200[b] Adult: 100[a]	50[a]	Child: NA Adult: 100[a]
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	250[a]	14[c]
Exposure duration (ED), years	25[a]	0.5[c]	Child: 6[b] Adult: 24[b]	25[a]	30[a]

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Incidental Ingestion of Sediment					
Fraction exposed to contaminated medium (FI_{sd}), unitless	NA	1[c]	0.1[c]	NA	NA
Sediment incidental ingestion rate (IR_{sd}), mg/day	NA	290[c]	Child: 200[b] Adult: 100[a]	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	350[a]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA
Dermal Contact with Soil					
Fraction exposed to contaminated medium (FI_{so}), unitless	1[c]	1[c]	0.9[c]	NA	1[c]
Body surface area exposed to soil (SA_{so}), cm^2	11,300[f]	11,300[f]	Child: 1750[g] Adult: 4550[g]	NA	Child: NA Adult: 4550[g]
Soil-to-skin adherence factor (AF_{so}), mg/cm^2	0.009[f]	0.08[f]	0.2[g]	NA	0.2[g]
Dermal absorption factor (ABS), unitless	csv	csv	csv	NA	csv
Exposure frequency (EF), days/year	250[a]	250[a]	350[a]	NA	14[c]
Exposure duration (ED), years	25[a]	0.5[c]	Child: 6[b] Adult: 24[b]	NA	30[a]

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Dermal Contact with Sediment					
Fraction exposed to contaminated medium (FI_{sd}), unitless	NA	1[c]	0.1[c]	NA	NA
Body surface area exposed to sediment (SA_{sd}), cm^2	NA	3100[f]	Child: 1750[g] Adult: 4550[g]	NA	NA
Sediment-to-skin adherence factor (AF_{sd}), mg/cm^2	NA	0.24[f]	0.2[g]	NA	NA
Dermal absorption factor (ABS), unitless	NA	csv	csv	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	350[a]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA
Dermal Contact with Surface Water					
Body surface area exposed to surface water (SA_{sw}), cm^2	NA	3100[f]	Child: 2100[g] Adult: 5450[g]	NA	NA
Permeability coefficient (PC), cm/hour	NA	csv	csv	NA	NA
Exposure time (ET_{sw}), hour/day	NA	4[c]	3[c]	NA	NA
Exposure frequency (EF), days/year	NA	250[a]	52[c]	NA	NA
Exposure duration (ED), years	NA	0.5[c]	Child: 6[b] Adult: 24[b]	NA	NA

Table 3-2

Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors TNT Areas A and C, Plum Brook Ordnance Works, Sandusky, Ohio

Pathway Variable	Grounds-keeper	Construction Worker	On-Site Resident	Indoor Worker	Hunter
Venison Consumption					
Venison ingestion rate (IR_v), kg/day	NA	NA	NA	NA	Child: 0.005[c] Adult: 0.013[c]
Exposure frequency (EF), days/year	NA	NA	NA	NA	350[a]
Exposure duration (ED), years	NA	NA	NA	NA	Child: 6[b] Adult: 30[a]

[a] U.S. Environmental Protection Agency (EPA), 1991, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors*, Interim Final, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.603.

[b] U.S. Environmental Protection Agency (EPA), 1999, *EPA Region 9: Preliminary Remediation Goals (PRGs) 1999*, 3 December, on-line.

[c] Assumed; see text.

[d] Calculated as the product of ED (years) x 365 days/year.

[e] Calculated as the product of 70 years (assumed human lifetime) x 365 days/year.

[f] U.S. Environmental Protection Agency (EPA), 1997b, *Exposure Factors Handbook*, Final, National Center for Environmental Assessment, Washington, DC, EPA/600/P-95/002Fa, August.

[g] EPA, 1992b, *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

NA = not applicable to this receptor; csv = chemical-specific value.

Exposure to groundwater is plausible for several of the receptor scenarios detailed below. However, the groundwater evaluation is deferred to a future site-wide groundwater delivery order. Plausible pathways for exposure to groundwater will be developed at that time.

3.1.3.1 Groundskeeper

The groundskeeper scenario is designed to evaluate the upper-bound for site worker exposure to surface soil in the current and future site-use scenario. Direct exposure pathways include incidental ingestion and dermal contact. Inhalation of dust, raised by operating lawn mowers or other equipment, is also evaluated because relatively high dust concentrations may be produced within the groundskeeper's breathing zone, with little opportunity for dilution by the large volume of ambient air.

IT Corporation experience has been that VOC-contaminated surface soil that has been in place for extended periods is not a significant source of airborne VOCs, because infiltration and dissipation over time reduce residues at the surface (i.e., first few centimeters from which volatilization would occur. However, as noted above, the data set for surface soil may include samples taken from up to 1 foot bgs, where dissipation has not reduced VOC concentrations. In other words, the surface soil data set might indicate the presence of VOCs, although volatilization to the air is unlikely to be significant. Therefore, a surface-soil-to-air volatilization model will not be used in addition to the activity-based dust emissions model to estimate airborne concentrations of VOCs. Instead, the airborne concentrations estimated by the dust emissions model will be assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the dust emissions model treats the VOCs as if they were located at the surface. It is assumed that VOC emissions from subsurface soil (i.e., at depths greater than 1 foot bgs) would be attenuated by the overlying soil so that concentrations in ambient air would not be toxicologically significant.

It is assumed that any contact with surface water or sediment in the streams associated with TNT Areas A and C would be infrequent and sporadic, since such contact would not be a part of the groundskeeper's regular duties or activities. Therefore, exposure to these media is not quantified.

The groundskeeper is assumed to be a 70-kilogram (kg) adult who works 8 hours per day (hours/day), approximately 5 days per week (days/week) year-round on site for a total of 250 days/year for 25 years (EPA, 1991). The respiratory rate for the groundskeeper is assumed to be

20 cubic meters (m^3) per 8-hour workday (2.5 m^3/hour), and the soil incidental ingestion rate is assumed to be 100 milligrams per day (mg/day), comparable to that for an agricultural worker.

Recent studies evaluating soil adherence that consider the nature of the activity performed and the different body regions were reviewed by EPA (1997a). Measurements of soil adherence to hands, arms, legs, feet, and face for 29 groundskeepers revealed AFs ranging from 8E-4 milligrams per square centimeter (mg/cm^2) (legs) to 1.5E-1 mg/cm^2 (hands). The AF averaged across these body regions (i.e., adjusted to reflect the different SAs of the different body regions) for males and females is 9E-3 mg/cm^2, which is used in this evaluation. The total SA of the body regions evaluated for groundskeepers include approximately 11,300 square centimeters (cm^2) (EPA, 1997a).

3.1.3.2 Indoor Worker

This receptor scenario is created to evaluate exposure to indoor airborne VOCs entrapped in a building. VOCs released from subsurface soil may enter a building through joints or cracks in the foundation or slab. The indoor worker is also potentially exposed to surface soil via incidental ingestion. Dermal exposure to surface soil and inhalation of airborne dust and VOCs from surface soil, although plausible, are expected to be less significant than incidental ingestion, because this receptor spends his work time indoors. Therefore, dermal contact and inhalation of dust and airborne VOCs from surface soil are not quantified separately from ingestion exposure. Exposure to VOCs in ambient (outdoor) air from volatilization from subsurface soil is not quantified for the reasons given for the groundskeeper.

The indoor worker is assumed to be a 70-kg adult who works 8 hours/day, approximately 5 days/week year-round on the site for a total of 250 days/year for 25 years (EPA, 1991). His soil incidental ingestion rate is assumed to be 50 mg/day, and his inhalation rate is assumed to be 20 m^3/8-hour workday.

3.1.3.3 Construction Worker

The construction worker scenario is created to evaluate short-term exposure to surface and subsurface soil (total soil) in either the current or future land-use scenario. Construction projects are expected to be infrequent. It is assumed that the construction worker participates in only one construction project on the site. Relevant exposure pathways include incidental ingestion and dermal contact, inhalation of dust raised by operating construction equipment, and inhalation of airborne VOCs released from subsurface soil during excavation and grading.

The construction worker may also be exposed to surface water and sediment during projects such as installation of underground utilities or rerouting stream flow. Dermal contact is the most significant pathway for exposure to surface water. Incidental ingestion of surface water is also possible, but is not expected to be nearly as significant as dermal contact. Inhalation of VOCs from surface water is also possible, but the large volume of outdoor air and natural air currents are expected to dilute airborne concentrations, so that this pathway is expected to be less significant than dermal contact, which is quantified. For these reasons, incidental ingestion and inhalation of VOCs from surface water are not quantified separately from dermal contact. Dermal contact and incidental ingestion may be important pathways for exposure to sediment, and both are evaluated.

The construction worker is assumed to be a 70-kg adult who works 8 hours/day, approximately 5 days/week year-round on site for a total of 250 days/year (EPA, 1991). Construction projects are assumed to last 6 months. The respiratory rate for the construction worker is assumed to be 20 m^3/8-hour workday (2.5 m^3/hour). Excavation and soil grading activities, which result in intensive soil contact, are assumed to last for 3 months; for the remaining 3 months, construction activities are assumed to result in less intensive soil contact. Soil ingestion rates of 480 mg/day (EPA, 1993) and 100 mg/day, similar for the agricultural worker (EPA, 1991), are assumed for the intensive and less intensive soil contact periods, respectively, resulting in a time-weighted average rounded to 290 mg/day.

As noted above, the construction worker may be exposed to surface water and sediment during the 6-month construction period. Dermal exposure to surface water and sediment is assumed to occur on 4 hours/day, or one-half the normal work day. The incidental ingestion rate for sediment is assumed to be 290 mg/day, the same as assumed for soil. It is assumed that the arms, forearms and hands, an SA of approximately 3,100 cm^2 (EPA, 1997a), are exposed to surface water and sediment. An AF for sediment of 0.24 mg/cm^2 (EPA, 1997a) is estimated for the hands and arms, using the same method as described for the groundskeeper is exposure to soil, using data for construction workers, utility workers, and equipment operators.

An AF for soil for the construction worker of 8E-2 mg/cm^2 is estimated using the same method as previously described for the groundskeeper, combining EPA (1997a) data for construction workers, utility workers, and equipment operators to capture the full range of activities likely to be performed by this receptor. The body regions evaluated for construction workers include approximately 11,300 cm^2.

The construction worker scenario described above provides for several different kinds of construction projects, such as upland excavation and building projects (exposure primarily to soil), and stream re-routing (exposure primarily to surface water and sediment). It is unlikely, however, that a single construction worker would participate in all these activities during a given project. Therefore, the evaluation described above is probably overly conservative and may represent some double counting. For example, it is unlikely that the construction worker would be dermally exposed simultaneously to soil, sediment and surface water. Similarly, the air in his breathing zone is not likely to contain the reasonable maximum concentrations of COPCs estimated from soil and surface water simultaneously. Dermal and inhalation exposure, however, are not expected to be risk drivers in the construction worker scenario. Therefore, the potential for double-counting is not expected to contribute significantly to total risk estimates summed across chemicals, pathways and media. Should construction worker risk estimates exceed acceptable limits, alternative RAs will be performed using refined exposure assumptions based on the physical characteristics of the site. For example, an upland excavation and building project may be assumed for one or more areas of the site, and a stream re-routing project may be assumed for another. This approach will more precisely reflect plausible exposure scenarios, reduce the likelihood of double counting, and more accurately identify risk-driving media and chemicals.

3.1.3.4 On-Site Resident

The on-site resident scenario is created to evaluate the upper bound for long term exposure to site soil, surface water, and sediment under the future land-use scenario. The resident is assumed to be exposed to total soil, because residential development would involve excavation and grading, which would mix surface and subsurface soil. Relevant pathways for total soil exposure include incidental ingestion, dermal contact, and inhalation of dust and VOCs. Evaluation of VOCs from total soil is addressed during evaluation of airborne dust as described for the groundskeeper. For evaluating inhalation of airborne dust, it is assumed that 80 percent of the soil surface is covered with pavement or vegetation. Inhalation of VOCs released from subsurface soil and entrapped in indoor air is also evaluated.

The resident could have access to the streams and creeks associated with TNT Areas A and C and could be exposed to surface water and sediment. It is assumed that the resident would visit the streams for 8 hours/day, 2 days/week during the warmer half of the year. The resident is assumed to wade for 3 hours/day on 52 days/year. Plausible exposure pathways include dermal contact with surface water, and incidental ingestion and dermal contact with sediment.

Incidental ingestion of surface water in a wading scenario is considered to be less significant than dermal contact and is not quantified separately from dermal contact. Inhalation of VOC emissions from surface water is also possible, but the large volume of outdoor air and natural air currents are expected to dilute airborne concentrations, so that this pathway is expected to be less significant than dermal contact, which is quantified. For these reasons, inhalation of VOC emissions from surface water is not quantified separately from dermal contact.

The on-site residential scenario is evaluated using both an adult and child. Cancer risk is estimated as the sum of the risks calculated for the adult and the child. Only the child is used for the noncancer evaluation. This approach captures the greater conservatism of the larger incidental soil and sediment ingestion rates and inhalation rate for the child when expressed on a BW basis.

The adult resident is assumed to be a 70-kg person with an incidental soil ingestion rate of 100 mg/day and an inhalation rate of 20 cubic meters/day (m^3/day) (0.83 m^3/hour) (EPA, 1991). Approximately 25 percent of his body SA, or 4,500 cm^2, is available for exposure to soil or sediment (EPA, 1992b). Approximately 30 percent of his total body SA, 5,450 cm^2, is available for exposure to surface water. It is assumed that dermal uptake of organic chemicals does not reach steady state. The adult resident is assumed to be exposed 350 days/year for 24 years (EPA, 2000). Mechanisms of exposure to soil and sediment are likely to be similar; therefore, the incidental soil ingestion rate of 100 mg/day is also applied to sediment.

The child resident is assumed to be a 1- through 6-year-old child with an average BW of 15 kg, a soil ingestion rate of 200 mg/day and an inhalation rate of 10 m^3/day (EPA, 2000). Approximately 25 percent of his body SA, or 1,750 cm^2, is available for exposure to soil or sediment (EPA, 1992b). Approximately 30 percent of his total body SA, 2,100 cm^2, is available for exposure to surface water. The child resident is exposed for 350 days/year for 6 years (EPA, 1991, 2000). Mechanisms of exposure to soil and sediment are likely to be similar; therefore, the incidental soil ingestion rate of 200 mg/day is also applied to sediment.

An average soil and sediment AF of 0.2 mg/cm^2 is adopted for the on-site resident (EPA, 1992b).

EPA (1989a) permits the development of a fraction to reflect the proportion of total daily exposure that a receptor obtains from potentially contaminated medium. In this scenario, the FI is used to apportion the resident's time of exposure between site soil and sediment. It is assumed

that the resident spends 16 hours/day awake and potentially exposed to soil or sediment. As previously noted, 350 days/year are available for contact with soil; 52 of those days are also available for contact with sediment. It is assumed that contact with soil and sediment does not occur simultaneously; i.e., on those days when the resident spends time at the streams, 8 hours would be spent in contact with soil and 8 hours would be spent in contact with sediment. The fraction of exposure to soil, therefore, is 16 hours/16 hours = 1 on the 298 days without time spent at the streams, and 8 hours/16 hours = 0.5 on the 52 days with some time spent at the streams. A weighted fraction of 0.93 (rounded to 0.9) is estimated for exposure to soil over the entire 350 days/year EF. A weighted fraction of 0.07 (rounded to 0.1) is estimated for exposure to sediment over the entire 350 days/year EF.

Inhalation of VOCs released from subsurface soil and entrapped in indoor air is evaluated by assuming that the resident spends 16.4 hours/day indoors (EPA, 1997a). The inhalation rate of the adult resident, 20 m^3/day, is multiplied by 16.4 hours/24 hours per day to estimate a daily indoor inhalation rate of 13.7 m^3/day. An indoor inhalation rate of 6.8 m^3/day is estimated in the same manner for the child resident.

3.1.3.5 Hunter

This scenario is created to evaluate the potential for contaminants in soil to affect food-chain pathways. Both TNT Areas A and C provide habitat for deer and other wildlife, and deer hunting is permitted on the PBOW facility (USACE, 2000a,b). Therefore, a hunter who consumes his game is a plausible scenario requiring evaluation. Many kinds of game animals may be hunted and consumed (e.g., squirrel, pheasant and other upland birds, turkey, deer); however, the deer is the species most likely to contribute meaningfully to the diet. Therefore, this evaluation is limited to a deer hunter. Potential exposure pathways include incidental soil ingestion, dermal contact with soil, and ingestion of venison from deer that browse plants growing on contaminated surface soil, all of which are evaluated quantitatively. Inhalation of airborne dust from wind currents is a potentially complete exposure pathway; however, vegetation reduces dust emissions to insignificant levels (EPA, 1996), and it is assumed that the deer hunter would spend virtually all of his time on vegetated rather than bare soil. Therefore, it is assumed that inhalation exposure would contribute much less than incidental ingestion, and the inhalation exposure pathway is not quantified separately from ingestion.

Inhalation exposure to airborne VOCs from subsurface soil and surface water is not evaluated for the reasons previously explained for other receptors.

The deer hunter is assumed to be a 70-kg adult nearby resident (exposure duration of 30 years) (EPA, 1991) who harvests deer and consumes venison. It is assumed that he spends his entire 2-week vacation hunting on PBOW; i.e., his EF for incidental soil ingestion and dermal contact is 14 days/year. His incidental soil ingestion rate is assumed to be 100 mg/day (EPA, 1991). It is assumed that approximately 25 percent of his body SA, or 4,550 cm^2, is available for exposure to soil (EPA, 1992b). A soil AF of 0.2 mg/cm^2 is assumed.

Data were not located regarding the rate of venison ingestion; therefore, a hypothetical scenario is adapted from the assumptions applied to a similar site in West Virginia (IT, 2000). A highly conservative but plausible scenario consists of a hunter who kills a deer each year. It is assumed that the hunter eats 10 pounds (4.5 kg) of venison per year (Sharp, 1995). This consumption rate corresponds to 0.013 kilograms/day (kg/day) (0.186 grams per kilogram of body weight per day [g/kg-day]) of venison for each of the 350 days per year (EPA, 1991) that the hunter spends at home.

It is likely that the successful hunter would share his venison with the rest of the family, which may include small children. Small children, however, would be unlikely to accompany the hunter afield. Therefore, the direct exposure pathways evaluated for the hunter (incidental ingestion and dermal contact with soil) will not be evaluated for the small child.

Data regarding the rate of venison ingestion by small children were not located. However, if it is assumed that venison may replace beef in the diet, the differences in beef consumption between adults and children can be used to estimate a venison ingestion rate for children. EPA (1997a) provides per capita beef intake data for <1- to 5-year-old children ranging from 0.941 to 1.46 g/kg-day (time-weighted average of 1.296 g/kg-day). EPA (1997a) provides per capita beef intake data for 12- to 70+-year-old adults ranging from 0.568 to 0.83 g/kg-day (time-weighted average of 0.727 g/kg-day). From these data it can be estimated that the rate of beef consumption of small children, expressed on a BW basis, is approximately 1.8 times that of an adult. Therefore, a venison ingestion rate of 0.335 g/kg-day is estimated for a young child from the venison ingestion rate of 0.186 g/kg-day for the adult. Assuming that the child is 0 to 6 years old with an average BW of 15 kg (EPA, 2000), the child 's venison ingestion rate may be expressed as 0.005 kg/day.

3.1.3.6 Other Receptors Not Considered

Another plausible receptor group is delivery personnel. These receptors, however, would be less intensively exposed to soil than the groundskeeper; therefore, their exposures are not evaluated. TNT Areas A or C could become part of the area used for National Guard training activities. National Guard trainees, however, may be less exposed to any of the potentially contaminated media than the receptors identified above. Since they may not represent upper bound for non-residential exposure, these receptors are not evaluated. Parts of PBOW are used for fishing and hunting. The streams on TNT Areas A and C, however, are too small to support fish and are not used for fishing. Therefore, fish ingestion as an indirect pathway for exposure to surface water and sediment is not evaluated.

Another potential receptor is an off-site resident. It is assumed, however, that the higher concentrations of contaminants occur on site; therefore, the on-site resident would be the more heavily exposed, and the off-site resident is not evaluated.

3.2 Quantification of Exposure-Point Concentrations

The EPC is defined as the concentration of COPC in an environmental medium to which a receptor is exposed. It is computed as a conservative estimate of average and is used to calculate COPC intake rates (Section 3.3). EPCs of COPCs in soil, surface water, and sediment to which receptors are directly exposed are mathematically equivalent to the STCs, which were also computed as conservative estimates of average (Section 2.2). EPCs are calculated for indirect exposure media (e.g., air) by using STCs for the concentration terms in the equations that follow. The EPCs thus calculated for the indirect exposure media are considered to be conservative estimates of average.

3.2.1 Exposure-Point Concentrations in Air

3.2.1.1 COPC Concentrations from Dust

Inhalation exposure to particulate (dust) emissions from soils for the groundskeeper and construction worker evaluations arises from activities that raise dust. Therefore, the most appropriate approach to estimating chemical concentrations in ambient air is the use an activity-based dust loading equation (U.S. Department of Energy [DOE], 1989):

$$C_a = (D)(C_{so})(CF_1) \qquad \text{Eq. 3.1}$$

where:

C_a = contaminant concentration in air (milligrams per cubic meter [mg/m^3], calculated)
D = dust loading factor (g of soil/m^3 of air)
C_{so} = contaminant concentration in soil (mg/kg)
CF_1 = conversion factor (1E-3 kg/g).

Plausible values for D include 2E-4 grams per cubic meter (g/m^3) for agricultural activity (DOE, 1989), 6E-4 g/m^3 for construction work (DOE, 1983), and 1E-4 g/m^3 for other activity (National Council on Radiation Protection and Measurements [NCRPM], 1984). The value for D of 1E-4 g/m^3 for other activity is used for the groundskeeper. It is assumed that construction activities requiring intimate contact with soil, for which D = 6E-4 g/m3, is appropriate, may last for one-half of a construction period. The remaining one-half of the time is more realistically characterized by D = 1E-4 g/m^3. Therefore, a time-weighted average dust loading factor for construction work of 3.5E-4 g/m^3 is estimated for the construction worker.

Airborne concentrations of VOCs estimated by the dust loading model will be assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the dust loading model treats the VOCs as if they were located at the ground surface.

The resident is more likely to be exposed to dust arising from wind erosion than from dust-raising activities on the site. EPA (1996) derived a model for estimating a dust particulate emission factor based on an "unlimited reservoir" model and the assumption that the source area is square:

$$PEF = Q/C \cdot \frac{3600}{0.036 \cdot (1 - V) \cdot (U_m/U_t)^3 \cdot F(x)} \qquad \text{Eq. 3.2}$$

where:

PEF = particulate emission factor (m^3/kg, calculated)
Q/C = inverse of the mean concentration at center of square source (43.08 g/m^2-second per kg/m^3, site-specific value from Table 3 in EPA [1996] [Zone 7, Cleveland, 30-acre site])
3600 = seconds/hour
V = fraction of surface covered with vegetation (0.8, unitless, assumed)
U_m = mean annual wind speed (default, 4.69 m/second)

U_t = equivalent threshold value of wind speed at 7 m (default, 11.32 m/second)
$F(x)$ = function dependent on U_m/U_t (default, 0.194).

The concentration of COPC in air is calculated as follows:

$$C_a = \frac{C_{so}}{PEF} \qquad \text{Eq. 3.3}$$

where:

C_a = contaminant concentration in air (mg/m^3, calculated)
C_{so} = contaminant concentration in soil (mg/kg)
PEF = particulate emission factor (m^3/kg).

Airborne concentrations of VOCs estimated by the wind erosion model will be assumed to sufficiently estimate levels of VOCs that may arise from volatilization, because the wind erosion model treats the VOCs as if they were located at the ground surface.

3.2.1.2 COPC Concentrations in Indoor Air

An EPA (1997b) modification of the Johnson and Ettinger model is used to estimate airborne concentrations of VOCs in indoor air from subsurface soil for the indoor worker and resident.

Estimating indoor airborne concentrations from subsurface soil can be considered to consist of three separate steps:

- Estimating VOC concentration in soil gas at source of contamination (C_{source})
- Estimating an attenuation coefficient that captures the decline in VOC concentration between soil gas at the source and indoor air (α)
- Combining C_{source} and α to estimate VOC concentration in indoor air in the building ($C_{building}$).

An "infinite source" assumption is selected to maintain consistency with the EPA (1996) methodology for PEF, and to impart a conservative bias to the evaluation. It is assumed that both the source of VOC contamination in subsurface soil and the foundation of the building are located above the groundwater saturation zone. It is also assumed that VOC contamination in soil does not exist in a nonaqueous phase. Because of the strongly conservative bias imparted by the infinite source assumption, average values are selected for model variables, when possible, if

site-specific data are not available. Default values are taken preferentially from EPA (1996) to maintain consistency with the other models described in Section 3.2.1, then from EPA (1997b).

The first step in estimating indoor air concentrations is to relate the concentration of VOC in soil gas at the source of contamination to the concentration of VOC in soil, as follows:

$$C_{source} = \frac{(H')(C_{so})(\rho_b)(CF_2)}{\theta_w + (K_d)(\rho_b) + (H')(\theta_a)} \qquad \text{Eq. 3.4}$$

where:

C_{source}	=	VOC concentration in soil gas at source of contamination (g/cm^3, calculated)
H'	=	dimensionless Henry's law constant (chemical-specific, may be estimated as H · 41 [EPA, 1996])
H	=	Henry's law constant (atmosphere-m^3/mole, chemical-specific)
C_{so}	=	contaminant concentration in soil (mg/kg)
ρ_b	=	dry soil bulk density (1.5 g/cm^3, default [EPA, 1996], or site-specific)
CF_2	=	conversion factor (10^{-6} kg/mg)
θ_w	=	water-filled soil porosity (0.15 L_{water}/L_{soil}, default [EPA, 1996], or site-specific)
K_d	=	soil-water partition coefficient (cm^3/g, chemical-specific, may be estimated as $K_{oc} \cdot f_{oc}$)
K_{oc}	=	soil organic carbon-water partition coefficient (cm^3/g, chemical-specific)
f_{oc}	=	organic carbon content of soil (0.006 g/g, default [EPA, 1996], or site-specific)
θ_a	=	air-filled soil porosity (0.28 unitless, default [EPA, 1996], or site-specific estimated as n-θ_w)
n	=	total soil porosity (0.43 unitless, default [EPA, 1996], or site-specific estimated as 1-[ρ_b/ρ_s]).

The next step in calculating indoor air concentrations is the estimation of an attenuation coefficient that reflects the phenomena that reduce concentration in air between the source and the interior of the building. Because of the many phenomena involved, it is helpful to break this step into several smaller segments.

Diffusion is probably the most important phenomenon involved in the transport of VOC vapors from source to building. The EPA (1997b) modification of the Johnson and Ettinger model provides for multiple layers; i.e., different soil types, each of which would have its own physical properties that affect diffusion, between the contaminant source and the foundation of the building. For the purposes of this evaluation, it is simplistically assumed that only one soil type – the predominant soil type in the area – intervenes between source and building foundation.

The equation for effective diffusivity through the soil between the source and the building foundation is given as:

$$D^{eff} = D_a(\theta_a^{3.33} / n^2) + (D_w / H')(\theta_w^{3.33} / n^2) \qquad \text{Eq. 3.5}$$

where:

- D^{eff} = effective diffusion coefficient across soil (cm^2/second, calculated)
- D_a = diffusivity in air (cm^2/second, chemical specific)
- θ_a = air-filled soil porosity (0.28 unitless, default [EPA, 1996], or site-specific estimated as $n-\theta_w$)
- n = total soil porosity (0.43 unitless, default [EPA, 1996], or site-specific estimated as $1-[\rho_b/\rho_s]$)
- D_w = diffusivity in water (cm^2/second, chemical specific)
- H' = dimensionless Henry's law constant (chemical-specific, may be estimated as H · 41 [EPA, 1996])
- H = Henry's law constant (atmosphere-m^3/mole, chemical-specific)
- θ_w = water-filled soil porosity (0.15 L_{water}/L_{soil}, default [EPA, 1996], or site-specific).

The equation for the attenuation coefficient is given as:

$$\alpha = \frac{\left(\left(\frac{D^{eff} A_B}{Q_{building} L_T}\right) x \exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right)\right)}{\left(\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) + \left(\frac{D^{eff} A_B}{Q_{building} L_T}\right) + \left(\frac{D^{eff} A_B}{Q_{soil} L_T}\right)\left(\exp\left(\frac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) - 1\right)\right)} \qquad \text{Eq. 3.6}$$

where:

- α = attenuation coefficient (unitless, calculated)
- D^{eff} = effective diffusion coefficient across soil (cm^2/second)
- A_B = area of enclosed space below grade (1.51E+6 cm^2, see below)
- $Q_{building}$ = building ventilation rate (4.61E+4 cm^3/second, see below)
- L_T = distance from source to building (site-specific)
- Q_{soil} = flow rate of soil gas into enclosed space (cm^2/second, see below)
- L_{crack} = foundation or slab thickness (15 cm, default [EPA, 1997b])
- D^{crack} = effective diffusion coefficient through cracks (cm^2/second, assumed to be equivalent to D^{eff} [EPA, 1997b])
- A_{crack} = area of total cracks (492 cm^2, see below).

The Engineering Building is located in the central portion of TNT Area A. This building could serve as the source of the building characteristics required for Equation 3.6. However, it is generally very difficult to measure most of the required building characteristics. Furthermore,

there is no assurance that the characteristics of the Engineering Building would reflect the characteristics of future buildings. Therefore, the building characteristics are obtained from other sources. EPA (1997a) reviewed several studies of the volumes of houses and recommends 369 cubic meters as a central estimate of the volume of a house. Assuming the house has 8 foot (2.44 meters) ceilings and exists on one level, an area of 151.3 square meters, equivalent to 1.51E+6 cm^2, can be estimated as an upper bound on the area below grade.

An average building ventilation rate of 3,984 m^3/day was estimated for a home (EPA, 1997a), which is equivalent to 4.61E+4 cm^3/second.

EPA (1997b) assumes that the only crack available for the entry of soil gas is a 0.1-centimeter-wide gap at the interface of the floor and foundation. As noted above, it is assumed that the area of the basement floor is 151.3 square meters. Assuming that the house is square, the length of one side would be 12.3 meters, and the total length of the wall would be 49.2 meters (4,920 centimeters). Therefore, the area of the crack would be 492 cm^2.

The equation for the flow rate of soil gas into enclosed space is:

$$Q_{soil} = \frac{2\,\pi\,\Delta P\,k_v\,X_{crack}}{\mu\,\ln(2\,Z_{crack}\,/\,r_{crack})} \qquad \text{Eq. 3.7}$$

where:

Q_{soil} = flow rate of soil gas into enclosed space (cm^2/second, calculated)
ΔP = pressure differential between soil surface and enclosed space (20 g/cm-second^2)
k_v = soil vapor permeability (cm^2, see below)
X_{crack} = floor-wall seam perimeter (4,920 cm, see above)
μ = viscosity of air (1.83E+5 g/cm-second [EPA, 1992e])
Z_{crack} = crack depth below grade (108 cm, see below)
r_{crack} = equivalent crack radius (0.1 cm, see below).

Data were not located from which to estimate the crack depth below grade. Presumably, however, houses or other buildings may be built on slabs or on full foundations. EPA (1997b) provides default depths of 15 centimeters for buildings on slabs and 200 centimeters for buildings on foundations. The average, 108 centimeters, is chosen for this evaluation.

Equation 3.7 assumes that vapor transport occurs solely by pressure-driven air flow to an idealized cylinder buried some distance (Z_{crack}) below grade. The length of the cylinder is assumed to be equal to X_{crack}. Therefore, the equivalent crack radius can be estimated as follows:

$$r_{crack} = \eta\left(\frac{A_B}{X_{crack}}\right) \qquad \text{Eq. 3.8}$$

where:

r_{crack} = equivalent crack radius (cm, calculated)
η = A_{crack}/A_B
A_{crack} = area of total cracks (492 cm^2, see above)
A_B = area of enclosed space below grade (1.51E+6 cm^2, see above)
X_{crack} = floor-wall seam perimeter (4920 cm, see above).

From the foregoing, a value of 0.1 cm is estimated for r_{crack}.

Soil vapor permeability is a very sensitive parameter associated with convective transport of vapors within the zone of influence of a building (EPA, 1997b). It can be estimated as the product of soil intrinsic permeability and the relative air permeability at the estimated water-filled soil porosity (θ_w). Soil intrinsic permeability is estimated as follows:

$$k_i = \frac{K_s \mu_w}{\rho_w g} \qquad \text{Eq. 3.9}$$

where:

k_i = soil intrinsic permeability (cm^2, calculated)
K_s = soil saturation hydraulic conductivity (cm/second, see below)
μ_w = dynamic viscosity of water (0.01307 g/cm-second [EPA, 1997b])
ρ_w = density of water (0.999 g/cm^2, [EPA, 1997b])
g = acceleration due to gravity (980.665 cm/$second^2$ [EPA, 1997b]).

Soil saturation hydraulic conductivity is related to soil texture. Site-specific data will be used in conjunction with Table 4 of EPA (1997b) to estimate an approximate value for K_s.

Relative air permeability is estimated as follows:

$$k_{rg} = \left(1 - S_{te}\right)^{0.5}\left(1 - S_{te}^{1/M}\right)^{2M} \qquad \text{Eq. 3.10}$$

where:

k_{rg} = relative air permeability (positive unitless value, calculated)
S_{te} = effective total fluid saturation (unitless, see below)
M = van Genuchten shape parameter (unitless, see below).

Site-specific data regarding the nature of the soil will be used in conjunction with Table 2 of EPA (1997b) to estimate an appropriate van Genuchten shape parameter.

S_{te} is calculated as follows:

$$S_{te} = \frac{\theta_w - \theta_r}{n - \theta_r} \qquad \text{Eq. 3.11}$$

where:

S_{te} = effective total fluid saturation (unitless, calculated)
θ_w = water-filled soil porosity (0.15 L_{water}/L_{soil}, default [EPA, 1996], or site-specific)
θ_r = soil water content (cm^3/cm^3, taken from Table 2 of EPA [1997b])
n = total soil porosity (0.43 unitless, default [EPA, 1996], or site-specific estimated as $1-[\rho_b/\rho_s]$).

Soil vapor permeability is estimated as follows:

$$k_v = (k_i)(k_{rg}) \qquad \text{Eq. 3.12}$$

where:

k_v = soil vapor permeability (cm^2, calculated)
k_i = soil intrinsic permeability (cm^2)
k_{rg} = relative air permeability (unitless).

The foregoing permit calculation of the attenuation coefficient, which, in turn permits calculation of the concentration of VOC in indoor air in the building, as follows:

$$C_{building} = \alpha\ CF_3\ C_{source} \qquad \text{Eq. 3.13}$$

where:

$C_{building}$ = VOC concentration in indoor air in the building (mg/m^3, calculated)
α = attenuation coefficient (unitless)
CF_3 = conversion factor (1E+9 $mg\text{-}cm^3/g\text{-}m^3$)
C_{source} = VOC concentration in soil gas at source of contamination (g/cm^3).

3.2.1.3 VOC Concentrations from Subsurface Soil in Ambient Air

The construction worker may be exposed to VOCs released from subsurface soil by volatilization. Exposure-point concentrations of VOCs in ambient air due to volatilization are

estimated with a chemical-specific soil volatilization factor calculated from the following equations and defaults provided by EPA (1996):

$$VF_s = Q/C \cdot CF_4 \cdot \left(\frac{[3.14 \cdot D_A \cdot T\ ]^{1/2}}{2 \cdot \rho_b \cdot D_A} \right) \qquad \text{Eq. 3.14}$$

and

$$D_A = \frac{(\theta_a^{10/3} \cdot D_i \cdot H' + \theta_w^{10/3} \cdot D_W)/n^2}{\rho_b \cdot K_d + \theta_w + \theta_a \cdot H'} \qquad \text{Eq. 3.15}$$

where:

- VF_s = chemical-from-soil volatilization factor (m^3/kg, calculated)
- Q/C = inverse of the mean concentration at center of square source (43.08 g/m^2-second per kg/m^3, site-specific value from Table 3 of EPA [1996] [Zone 5, Cleveland, 30-acre site])
- CF_4 = conversion factor (1E-4 m^2/cm^2)
- D_A = apparent diffusivity (cm^2/second, calculated)
- T = exposure interval (seconds, receptor-specific, estimated as ED · 3.15E7 seconds/year)
- ED = exposure duration (years, receptor-specific)
- ρ_b = dry soil bulk density (1.5 g/cm^3, default, or site-specific)
- θ_a = air-filled soil porosity (0.28 unitless, default, or site-specific estimated as n-θ_w)
- n = total soil porosity (0.43 unitless, default, or site-specific estimated as 1-[ρ_b/ρ_s])
- ρ_s = true soil or particle density (2.65 g/cm^3, default, or site-specific)
- θ_w = water-filled soil porosity (0.15 L_{water}/L_{soil}, default, or site-specific)
- D_i = diffusivity in air (cm^2/second, chemical specific)
- H' = dimensionless Henry's law constant (chemical-specific, may be estimated as H · 41)
- H = Henry's law constant (atmosphere-m^3/mole, chemical-specific)
- D_W = diffusivity in water (cm^2/second, chemical-specific)
- K_d = soil-water partition coefficient (cm^3/g, chemical-specific, may be estimated as $K_{oc} \cdot f_{oc}$)
- K_{oc} = soil organic carbon-water partition coefficient (cm^3/g, chemical-specific)
- f_{oc} = organic carbon content of soil (6E-3 g/g, default, or site-specific).

The concentration of COPC in ambient air is estimated as follows:

$$C_a = \frac{C_{so}}{VF_s} \qquad \text{Eq. 3.16}$$

where:

C_a = contaminant concentration in air (mg/m^3, calculated)
C_{so} = contaminant concentration in soil (mg/kg)
Vf_s = chemical-from-soil volatilization factor (m^3/kg, chemical-specific, calculated).

3.2.2 Exposure-Point Concentrations of COPCs in Venison

The hunter is assumed to harvest and consume game, and share it with his family, including small children. The game is assumed to be venison, because deer is the species hunted most widely and most likely to provide a regular contribution to the diet. Data do not exist to reliably estimate contaminant concentrations in venison, but the following simplifying assumptions permit estimates sufficient for an RA.

- Deer are small ruminants and as such are not unlike cattle; thus, it is reasonable to assume they may have similar physiological processes that could yield similar biotransfer factors. Unlike beef, however, deer meat does not undergo marbling with fat, and deer fat is quite unpalatable and is likely to be trimmed rather than consumed. Therefore, the biotransfer factors for edible venison are derived by adjusting biotransfer factors for beef to account for differences in the fat content of table-ready beef (cooked choice retail cuts trimmed to 0 inches of fat: average 14.4 percent fat) and venison (cooked boneless muscle meats: average 2.9 percent fat) (Nutrient Database, 1997).

- Deer are expected to browse a much larger area than that encompassed in either of the TNT Areas A or C; therefore the fraction of total browse consumed from the contaminated site is expected to be small.

- Indirect food-chain pathways may be significant for metals and for those SVOCs that persist in the environment and have the tendency to bioaccumulate. VOCs are generally mobile in the environment and labile in biological systems and do not tend to bioaccumulate.

To reflect the assumptions previously noted, venison biotransfer factors are estimated by multiplying beef biotransfer factors by 2.9/14.4 (or 0.20), and by a fraction, FI_e. FI_e reflects the areal portion of the site compared to a deer's home range area. These assumptions are captured in the following equation:

$$B_v = 0.20\ (FI_e)\ (B_b) \qquad \text{Eq. 3.17}$$

where:

B_v	=	biotransfer factor for venison (unitless, calculated)
0.20	=	factor to reflect differences in fat content between beef and venison (0.20, unitless, see above)
FI_e	=	areal portion of site compared to a deer's home range (1, unitless, see below)
B_b	=	biotransfer factor for beef.

Values for B_b for metals will be provided in the toxicity profiles appended to the RA. Toxicity profiles will be prepared for each of the COPCs evaluated in the RA. The toxicity profiles briefly describe the uses of the chemical, its physical properties, behavior in environmental media, biotransfer capability, and toxicity values.

The TNT Area A and C sites are fairly large (greater than 100 acres). Although a deer may naturally roam several hundred acres, the sites are very suitable habitat and it is plausible that either site could provide sufficient browse to support several deer. Therefore, FI_e is conservatively set equal to 1.

Deer are assumed to be exposed to contaminants by ingesting browse growing on contaminated soil. It is estimated that deer consume approximately 1.74 kg of browse per day (Sample, et al., 1996), which is approximately 50 percent dry matter (DM), or 0.87 kg browse DM per day (Mautz, et al., 1976). The contaminant concentration in browse is estimated from the following equation, which was originally developed for estimating the contaminant concentration in forage to which cattle may be exposed (EPA, 1994):

$$C_p = (CF_7)(C_{so}(B_p) \qquad \text{Eq. 3.18}$$

where:

C_p	=	concentration of contaminant in (plant) forage DM (mg/kg, calculated)
CF_7	=	conversion factor to adjust for soil containing 20 percent moisture (1.25 unitless).
C_{so}	=	concentration of contaminant in soil (mg/kg)
B_p	=	soil-to-forage biotransfer factor (mg of chemical per kg of dry plant/mg of chemical per kg of dry soil).

Values for B_p will be taken from the toxicity profiles appended to the RA. B_p values for the vegetative parts of plants, rather than the reproductive parts of plants, will be selected, when possible, because deer browse year-round, and the vegetative parts are more available for the greater part of the year.

The concentration of COPC in venison can be estimated from the following equation (adapted from EPA, 1994):

$$C_v = (Q_p)\ (C_p)\ (B_v) \qquad \text{Eq. 3.19}$$

where:

C_v = contaminant concentration in venison (mg/kg, calculated)
Q_p = browse ingestion rate (0.87 kg DM/day)
C_p = contaminant concentration in browse DM (mg/kg) .
B_v = biotransfer factor for venison (days/kg).

3.3 Quantification of Chemical Intake

This section describes the models used to quantify doses or intakes of the COPCs by the exposure pathways identified above. Models were taken or modified from EPA (1989a) unless otherwise indicated.

3.3.1 Inhalation of COPCs in Air

The following equation is used to estimate the inhaled dose of COPC in air (groundskeeper, construction worker, on-site resident: inhalation of dust and VOCs in ambient air from surface or total soil; construction worker: inhalation of VOCs in ambient air from subsurface soil; indoor worker and on-site resident: inhalation of VOCs in indoor air from subsurface soil:

$$I_a = \frac{(C_a)(FI_a)(IR_a)(ET_a)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 3.20}$$

where:

I_a = inhaled dose of COPC (mg/kg-day, calculated)
C_a = concentration of COPC in air (mg/m^3)
FI_a = fraction of exposure attributed to site media (unitless)
IR_a = inhalation rate (m^3/hour)
ET_a = exposure time (hours/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days).

3.3.2 Incidental Ingestion of COPCs in Soil

The ingested dose of COPC in soil (groundskeeper, construction worker, on-site resident, indoor worker, hunter) is estimated from the equation:

$$I_{so} = \frac{(C_{so})(FI_{so})(IR_{so})(EF)(ED)(CF_2)}{(BW)(AT)} \qquad \text{Eq. 3.21}$$

where:

I_{so} = ingested dose of COPC in soil (mg/kg-day, calculated)
C_{so} = concentration of COPC in soil (mg/kg)
FI_{so} = fraction of exposure attributed to site soil or sediment (unitless)
IR_{so} = ingestion rate of soil or sediment (mg/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
CF_2 = conversion factor (1E-6 kg/mg)
BW = body weight (kg)
AT = averaging time (days).

3.3.3 Incidental Ingestion of COPCs in Sediment

The ingested dose of COPC in sediment (construction worker, on-site resident) is estimated from the equation:

$$I_{sd} = \frac{(C_{sd})(FI_{sd})(IR_{sd})(EF)(ED)(CF_2)}{(BW)(AT)} \qquad \text{Eq. 3.22}$$

where:

I_{sd} = ingested dose of COPC in sediment (mg/kg-day, calculated)

C_{sd} = concentration of COPC in sediment (mg/kg)
FI_{sd} = fraction of exposure attributed to site sediment (unitless)
IR_{sd} = ingestion rate of sediment (mg/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
CF_2 = conversion factor (1E-6 kg/mg)
BW = body weight (kg)
AT = averaging time (days).

3.3.4 Dermal Contact with COPCs in Soil, Sediment, or Water

Unlike the methodologies for estimating inhaled or ingested doses of COPC, which quantify the dose presented to the barrier membrane (the pulmonary or gastrointestinal mucosa, respectively), dermal dose is estimated as the dose that crosses the skin and is systemically absorbed. For this reason, dermal toxicity values are also based on absorbed dose. The absorbed dose of COPC is estimated from the equation (EPA, 1992b):

$$DAD = \frac{(DA)(SA)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 3.23}$$

where:

DAD = average dermally absorbed dose of COPC (mg/kg-day, calculated)
DA = dose absorbed per unit body surface area per day (mg/cm^2-day)
SA = SA_{so} for soil, SA_{sd} for sediment, SA_{sw} for surface water, = surface area of the skin exposed (cm^2)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days).

DA is calculated differently for dermal uptake from soil or sediment and from water. Dermal uptake of constituents from soil (groundskeeper, construction worker, on-site resident, hunter) or sediment (construction worker, on-site resident) assumes that absorption is a function of the fraction of a dermally applied dose that is absorbed. It is calculated from the equation (EPA, 1992b):

$$DA = (C)(FI)(CF_2)(AF)(ABS) \qquad \text{Eq. 3.24}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C = C_{so} for soil, C_{sd} for sediment, = concentration of COPC in medium (mg/kg)
FI = FI_{so} for soil, FI_{sd} for sediment, = fraction of exposure attributed to site medium (unitless)
CF_2 = conversion factor (1E-6 kg/mg)
AF = AF_{so} for soil, AF_{sd} for sediment, = soil- or sediment-to-skin adherence factor (mg/cm^2-day)
ABS = absorption fraction (unitless, chemical-specific).

ABS values will be provided in the toxicity profiles for each COPC that will be appended to the RA.

Quantification of dermal uptake of constituents from surface water (construction worker, on-site resident) depends on a permeability coefficient (PC), which describes the rate of movement of a constituent from water across the dermal barrier to the systemic circulation (EPA, 1992b). The equation for dermal uptake of chemicals from water is the same as the equation for dermal uptake of chemicals from soil (Eq. 3.23). DA is calculated differently for inorganic and organic chemicals in water. For inorganic chemicals, DA is calculated from the following equation:

$$DA = (C)(PC)(ET)(CF_6) \qquad \text{Eq. 3.25}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C = C_{sw} for surface water = concentration of COPC in water (mg/L)
PC = permeability coefficient (cm/hour)
ET = ET_{sw} for surface water = time of exposure (hours/day)
CF_6 = conversion factor (1E-3 L/cm^3).

PC for organic chemicals varies by several orders of magnitude and is highly dependent on lipophilicity, expressed as a function of the octanol/water partition coefficient (EPA, 1992b).. Because the stratum corneum (the outer skin layer) is rich in lipid content, it may act as a sink, initially reducing the transport of chemical to the systemic circulation. With continued exposure and the attainment of steady state conditions, the rate of dermal uptake increases. Therefore, different equations are used to estimate DA, depending on whether the exposure time is less than or greater than the estimated time to reach steady state. Dermal exposure to water for the

receptors evaluated herein would be short-term or intermittent. Therefore, it is assumed that steady state is not reached, which is the usual case for relatively short exposure times. Under these conditions, DA is calculated from the following equation (EPA, 1992b):

$$DA = 2(C)(FI)(PC)(CF_6)\sqrt{\left(\frac{6\tau(ET)}{\pi}\right)} \qquad \text{Eq. 3.26}$$

where:

DA = dose absorbed per unit body surface area per day (mg/cm^2-day, calculated)
C = C_{sw} for surface water = concentration of COPC in water (mg/L)
FI = FI_{sw} for surface water, = fraction of exposure attributed to site medium (unitless)
PC = permeability coefficient (cm/hour)
CF_6 = conversion factor (1E-3 L/cm^3)
τ = time for concentration of contaminant in stratum corneum to reach steady state (hours)
ET = ET_{sw} for surface water = time of exposure (hours/day).

Assuming one exposure event/day allows expressing ET as hours/day, which preserves the dimensional integrity of the equation.

PC values will be provided in the toxicity profiles for each COPC that will be appended to the RA.

3.3.5 Consumption of Venison

Consumption of venison by the hunter or his child is evaluated by the following equation:

$$I_v = \frac{(C_v)(IR_v)(EF)(ED)}{(BW)(AT)} \qquad \text{Eq. 3.27}$$

where:

I_v = ingested dose of COPC in venison (mg/kg-day, calculated)
C_v = concentration of COPC in venison (mg/kg)
IR_v = venison ingestion rate (kg/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (days).

4.0 Toxicity Evaluation

Toxicity is defined as the ability of a chemical to induce adverse effects in biological systems. The purpose of the toxicity assessment is two-fold:

- To identify the cancer and noncancer effects that may arise from exposure of humans to the COPCs (hazard assessment)
- To provide an estimate of the quantitative relationship between the magnitude and duration of exposure and the probability or severity of adverse effects (dose-response assessment).

The latter is accomplished by the derivation of cancer and noncancer toxicity values, as described below.

4.1 Cancer Evaluation

A few chemicals are known to be, and many more are suspected to be, human carcinogens. The evaluation of the potential carcinogenicity of a chemical includes both a qualitative and a quantitative aspect (EPA, 1986). The qualitative aspect is a weight-of-evidence evaluation of the likelihood that a chemical might induce cancer in humans. The EPA (1986) recognizes six weight-of-evidence group classifications for carcinogenicity:

- Group A - Human Carcinogen: human data are sufficient to identify the chemical as a human carcinogen.
- Group B1 - Probable Human Carcinogen: human data indicate that a causal association is credible, but alternative explanations cannot be dismissed.
- Group B2 - Probable Human Carcinogen: human data are insufficient to support a causal association, but testing data in animals support a causal association.
- Group C - Possible Human Carcinogen: human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation.
- Group D - Not Classifiable as to Human Carcinogenicity: human and animal data are lacking or inadequate.
- Group E - Evidence of Non-Carcinogenicity to Humans: human data are negative or lacking, and adequate animal data indicate no association with cancer.

The toxicity value for carcinogenicity, called a cancer slope factor, is an estimate of potency. Potency estimates are developed only for chemicals in Groups A, B1, B2 and C, and only if the data are sufficient. The potency estimates are statistically derived from the dose-response curve from the best human or animal study or studies of the chemical. Although human data are often considered to be more reliable than animal data because there is no need to extrapolate the results obtained in one species to another, most human studies have one or more of the following limitations:

- The duration of exposure is usually considerably less than lifetime.
- The concentration or dose of chemical to which the humans were exposed can be approximated only crudely, usually from historical data.
- Concurrent exposure to other chemicals frequently confounds interpretation.
- Data regarding other factors (tobacco, alcohol, illicit or medicinal drug use, nutritional factors and dietary habits, heredity) are usually insufficient to eliminate confounding or to quantify its effect on the results.
- Most epidemiologic studies are occupational investigations of workers, which may not accurately reflect the range of sensitivities of the general population.
- Most epidemiologic studies lack the statistical power (i.e., sample size) to detect a low but chemical-related increased incidence of tumors.

Most potency estimates are derived from animal data, which present different limitations:

- It is necessary to extrapolate from results in animals to predict results in humans; this is usually done by estimating an equivalent human dose from the animal dose.
- The range of sensitivities arising from genotypic and phenotypic diversity in the human population is not reflected in the animal models ordinarily used in cancer studies.
- Usually very high doses of chemical are used, which may alter normal biology, creating a physiologically artificial state and introducing substantial uncertainty regarding the extrapolation to the low-dose range expected with environmental exposure.
- Individual studies vary in quality (e.g., duration of exposure, group size, scope of evaluation, adequacy of control groups, appropriateness of dose range, absence of concurrent disease, sufficient long-term survival to detect tumors with long induction or latency periods).

The slope factor is usually expressed as "extra risk" per unit dose; that is, the additional risk above background in a population corrected for background incidence. It is calculated by the expression:

$$SF = (p_{(d)} - p_{(0)}) / (1 - p_{(0)})$$

Eq. 4.1

where:

SF	=	cancer slope factor (risk per mg/kg-day, calculated)
$p_{(d)}$	=	the probability of cancer associated with dose = 1 mg/kg-day
$p_{(0)}$	=	the background probability of developing cancer at dose = 0 mg/kg-day.

The SF is expressed as risk per milligrams per kilogram of body weight per day (mg/kg-day). In order to be appropriately conservative, the SF is usually the 95 percent upper bound on the slope of the dose-response curve extrapolated from high (experimental) doses to the low-dose range expected in environmental exposure scenarios. EPA (1986) assumes that there are no thresholds for carcinogenic expression; therefore, any exposure represents some quantifiable risk.

The oral SF is usually derived directly from the experimental dose data, because oral dose is usually expressed as mg/kg-day. When the test chemical was administered in the diet or drinking water, oral dose first must be estimated from data for the concentration of the test chemical in the food or water, food or water intake data, and body weight data.

The EPA (2001) Integrated Risk Information System (IRIS) expresses inhalation cancer potency as a unit risk factor based on concentration, or risk per microgram (μg) of chemical/m^3 of ambient air. Because cancer risk characterization requires a potency expressed as risk per mg/kg-day, the unit risk factor must be converted to the mathematical equivalent of an inhalation cancer slope factor, or risk per unit dose. Since the inhalation unit risk is based on continuous lifetime exposure of an adult human (assumed to inhale 20 cubic meters of air/day and to weigh 70 kg), the mathematical conversion consists of multiplying the unit risk (per μg/m^3) by 70 kg and by 1,000 micrograms per milligram (μg/mg), and dividing the result by 20 m^3/day.

4.2 Evaluation of Noncancer Effects

Many chemicals, whether or not associated with carcinogenicity, are associated with noncarcinogenic effects. The evaluation of noncancer effects (EPA, 1989c) involves:

- Qualitative identification of the adverse effect(s) associated with the chemical; these may differ depending on the duration (e.g., acute or chronic) or route (e.g., oral or inhalation) of exposure

- Identification of the critical effect for each duration of exposure (i.e., the first adverse effect that occurs as dose is increased)

- Estimation of the threshold dose for the critical effect for each duration of exposure

- Development of an uncertainty factor; i.e., quantification of the uncertainty associated with interspecies extrapolation, intraspecies variation in sensitivity, severity of the critical effect, slope of the dose-response curve, and deficiencies in the data base, in regard to developing a reference dose (RfD) for human exposure

- Identification of the target organ for the critical effect for each route of exposure.

These information points are used to derive an exposure route- and duration-specific toxicity value called a reference dose (RfD), expressed as mg/kg-day, which is considered to be the dose for humans, with uncertainty of an order of magnitude or greater, at which adverse effects are not expected to occur. Mathematically, it is estimated as the ratio of the threshold dose to the uncertainty factor.

EPA (2001) and the Health Effects Assessment Summary Tables (HEAST) (EPA, 1997c) express the inhalation noncancer reference value as a reference concentration (RfC) in units of mg/m^3. Because noncancer risk characterization requires a reference value expressed as mg/kg-day, the RfC must be converted to an inhalation RfD. Since the inhalation RfC is based on continuous exposure of an adult human (assumed to inhale 20 m^3 of air/day and to weigh 70 kg) the mathematical conversion consists of multiplying the RfC (mg/m^3) by 20 m^3/day and dividing the result by 70 kg.

4.3 Target Organ Toxicity

As a matter of science policy, the EPA (1989a) assumes dose- and effect-additivity for noncarcinogenic effects. This assumption provides the justification for adding the hazard quotients (HQ) or HI in the risk characterization for noncancer effects resulting from exposure to multiple chemicals, pathways or media. The EPA (1989a), however, acknowledges that adding all HQ or HI values may overestimate hazard, because the assumption of additivity is probably appropriate only for those chemicals that exert their toxicity by the same mechanism.

Mechanism of toxicity data sufficient for predicting additivity with a high level of confidence are available for very few chemicals. In the absence of such data, EPA (1989a) assumes that chemicals that act on the same target organ may do so by the same mechanism of toxicity, unless the data clearly indicate otherwise. That is, target organ serves as a surrogate for mechanism of toxicity. When total HI for all media for a receptor exceeds 1 due to the contributions of several chemicals, it is appropriate to segregate the chemicals by route of exposure and mechanism of toxicity (i.e., target organ) and estimate separate HI values for each.

As a practical matter, since human environmental exposures are likely to involve near- or sub-threshold doses, the target organs chosen for a given chemical are the ones associated with the critical effect or with dose rates near the threshold. Target organ is also selected on the basis of duration of exposure (i.e., the target organ for chronic or subchronic exposure to low or moderate doses is selected rather than the target organ for acute exposure to high doses) and route of exposure. Because dermal RfD values are derived from oral RfD values, the oral target organ is adopted as the dermal target organ. For some chemicals, no target organ is identified. This occurs when no adverse effects are observed or when adverse effects such as reduced longevity or growth rate are not accompanied by recognized organ- or system-specific functional or morphologic alteration.

4.4 Dermal Toxicity Values

Dermal RfDs and SFs are derived from the corresponding oral values, provided there is no evidence to suggest that dermal exposure induces exposure route-specific effects that are not appropriately modeled by oral exposure data. In the derivation of a dermal RfD, the oral RfD is multiplied by the gastrointestinal absorption factor (GAF), expressed as a decimal fraction. The resulting dermal RfD, therefore, is based on absorbed dose. The RfD based on absorbed dose is the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than exposure doses. The dermal SF is derived by dividing the oral SF by the GAF. The oral SF is divided, rather than multiplied, by the GAF because SFs are expressed as reciprocal dose.

4.5 Sources of Toxicity Information Used in the Risk Assessment

Toxicity values are chosen using the following hierarchy:

- The EPA (2001) on-line IRIS data base containing toxicity values that have undergone the most rigorous Agency review

- The latest version of the annual HEAST, including all supplements (EPA, 1997c)

- Other EPA documents, memoranda, former Environmental Criteria and Assessment Office (ECAO), or National Center for Environmental Assessment (NCEA) derivations for the Superfund Technical Support Center.

Some of the more recent NCEA memoranda update values in the HEAST or in the IRIS data base, in which case the NCEA evaluation will take precedence over the other sources. All toxicity values, regardless of their source, are evaluated for appropriateness for use in RA.

When toxicity values are not located, the primary literature may be surveyed to determine whether sufficient data exist that would permit derivation of a toxicity value. The use of surrogate chemicals is also considered, if the chemical structure, adverse effects and toxic potency of the surrogate and chemical of interest are judged to be sufficiently similar.

GAFs, used to derive dermal RfDs and SFs from the corresponding oral toxicity values, are obtained from the following sources:

- Oral absorption efficiency data compiled by the NCEA for the Superfund Health Risk Technical Support Center of the EPA

- Federal agency reviews of the empirical data, such as Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles and various EPA criteria documents

- Other published reviews of the empirical data

- The primary literature.

GAFs obtained from reviews are compared to empirical (especially more recent) data, when possible, and are evaluated for suitability for use inr deriving dermal toxicity values from oral toxicity values. The suitability of the GAF increases when the following similarities are present in the oral toxicokinetic study from which the GAF is derived and in the key toxicity study from which the oral toxicity value is derived:

- The same strain, sex, age and species of test animal was used.

- The same chemical form (e.g., the same salt or complex of an inorganic element or organic compound) was used.

- The same mode of administration (e.g., diet, drinking water or gavage vehicle) was used.

- Similar dose rates were used.

The most defensible GAF for each chemical is used in the RA.

Individual toxicity profiles will be appended to the RA for all of the COPCs evaluated in the RA. Summary information sufficient to support the risk calculations will be provided in a table.

5.0 Risk Characterization

Risk characterization is the combination of the results of the exposure assessment and toxicity assessment to yield a quantitative expression of risk. Quantitative estimates are developed for individual chemicals, exposure pathways and exposure media for each receptor. The risk characterization is used to guide risk management decisions.

Generally, the risk characterization follows the methodology prescribed by the EPA (1989a), as modified by more recent information and guidance. The EPA methods are, appropriately, designed to be health-protective, and tend to overestimate, rather than underestimate, risk. The risk results are generally conservative, because risk characterization involves multiplication of the conservatisms built into the estimation of source-term and exposure-point concentrations, the exposure (intake) estimates and the toxicity dose-response assessments.

Risk characterization is limited to those site-related chemicals selected as COPCs; i.e., present at concentrations that exceed RBSCs (Section 2.1.5). Up to this point, the term risk has been used generically to mean the potential for the occurrence of adverse effects, either cancer or noncancer, to arise from exposure to chemicals. However, at this point in the discussion it is helpful to define terms more precisely. Therefore, in this section of the document, the term risk will be used to describe the potential for the occurrence of cancer. The potential for the occurrence of noncancer effects will be termed noncancer hazard.

5.1 Cancer Risk

The risk from exposure to potential chemical carcinogens is estimated as the probability of an individual developing cancer over a lifetime, and is called the incremental lifetime cancer risk (ILCR). In the low-dose range, which would be expected for most environmental exposures, cancer risk is estimated from the following linear equation (EPA, 1989a):

$$ILCR = (CDI)(SF) \qquad \text{Eq. 5.1}$$

where:

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

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

SF = cancer slope factor (risk per mg/kg-day).

The chronic daily intake (CDI) term in Equation 5.1 is equivalent to the "I" or "DAD" terms (intake or dose) in Equations 3.20 through 3.27 when these equations are evaluated for cancer intakes.

The use of Equation 5.1 assumes that chemical carcinogenesis does not exhibit a threshold, and that the dose-response relationship is linear in the low dose range. Because this equation could generate theoretical cancer risks greater than 1 for high dose levels, it is considered to be inaccurate at cancer risks greater than 1E-2. In these cases, cancer risk is estimated by the one-hit model (EPA, 1989a):

$$ILCR = 1 - e^{[(CDI)(SF)]} \qquad \text{Eq. 5.2}$$

where:

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

$-e^{(CDI)(SF)}$ = the exponential of the negative of the risk calculated using Equation 5.1

As a matter of policy, the EPA (1986) considers the carcinogenic potency of simultaneous exposure to low doses of carcinogenic chemicals to be additive, regardless of the chemicals' mechanisms of toxicity or sites of action (organs of the body). Cancer risk arising from exposure to multiple chemicals in a given exposure medium and pathway is estimated from the following equation (EPA, 1989a):

$$ILCR_p = ILCR_{(chem\,1)} + ILCR_{(chem\,2)} + \ldots ILCR_{(chem\,i)} \qquad \text{Eq. 5.3}$$

where:

$ILCR_p$ = total pathway risk of cancer incidence, calculated

$ILCR(_{chem\,i})$ = individual chemical cancer risk for the pathway.

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

For risk management purposes, a total cancer risk of 1E-6 is a point of departure below which cancer risks are considered to be insignificant. Cancer risks begween 1E-6 and 1E-4 fall within a risk management range. Cancer risks above 1E-4 are considered to be clearly unacceptable.

5.2 Noncancer Effects of Chemicals

The hazards associated with noncancer effects of chemicals are evaluated by comparing an exposure level or intake with an RfD. The hazard quotient (HQ), defined as the ratio of intake to RfD, is estimated as (EPA, 1989a):

$$HQ = I / RfD \qquad \text{Eq. 5.4}$$

where:

HQ = hazard quotient (unitless, calculated)
I = intake of chemical averaged over subchronic or chronic exposure period (mg/kg-day)
RfD = reference dose (mg/kg-day).

The I term in Equation 5.4 is equivalent to the "I" or "DAD" terms (intake or dose) in Equations 3.20 through 3.27 when these equations are evaluated for noncancer intakes.

Chemical noncancer hazards are evaluated using chronic RfD values. This approach is different from the probabilistic approach used to evaluate cancer risks. An HQ of 0.01 does not imply a 1-in -100 chance of an adverse effect, but indicates that the estimated intake is 100 times lower than the RfD. An HQ of unity indicates that the estimated intake equals the RfD. If the HQ is greater than unity, there may be concern for potential adverse health effects.

In the case of simultaneous exposure of a receptor to multiple chemicals, or to a given chemical by multiple pathways, a HI is calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + \ldots HQ_i \qquad \text{Eq. 5.5}$$

where:

HI = hazard index (unitless, calculated)
HQ_i = hazard quotient for the ith chemical, or for the ith pathway.

An HI may be calculated across all exposure pathways for a given chemical, across all chemicals for a given exposure pathway, across all chemicals and exposure pathways for a given exposure medium, or across all media to yield the total HI for a given receptor.

Calculating a total HI as the sum of HQ values is based on the assumption that the potential for noncancer effects is additive. EPA (1989a), however, acknowledges that the assumption of additivity is probably appropriate only for chemicals that induce adverse effects by the same mechanism (please see Section 4.3). Therefore, if the total HI for a receptor exceeds 1, individual HI values may be calculated for each target organ.

5.3 Risk-Based Remediation Criteria Development

RBRC development performed as part of the RA provides support for risk management decisions. RBRCs are site-specific risk-based concentrations that reflect the exposure and toxicity assumptions applied in the baseline RA. Consequently, the RBRCs are source medium-, receptor-, and chemical-specific.

The first step in RBRC development is selection of COCs. Either of two conditions results in designation of a COPC as a COC:

- The concentration of the COPC exceeds its medium-specific ARAR, provided one is available.
- The COPC contributes significantly to cancer risk or hazard as described below.

COCs based on cancer are selected for any *medium* for which the total ILCR for a given receptor (summed across chemicals and exposure pathways) exceeds 1E-6; COCs based on noncancer are selected for any *receptor* for which the total HI (summed across chemicals and exposure pathways) exceeds 1. An individual COPC in that medium must have an ILCR (summed across exposure pathways) exceeding 1E-6 to be selected as a cancer-based COC. An individual COPC in any medium must have an HI (summed across exposure pathways) exceeding 0.1 to be selected as a noncancer-based COC.

RBRCs are risk- or hazard-specific concentrations of chemicals developed only for the COCs in media selected by the criteria described above. RBRCs for cancer COCs are estimated for a given medium from the following equation:

$$RBRC_{coc} = \frac{ST_{coc}\,TR}{ILCR_{coc}} \qquad \text{Eq. 5.6}$$

where:

$RBRC_{coc}$	=	risk-based remediation criterion for a given COC, receptor and source medium (calculated)
ST_{coc}	=	source-term concentration of the COC in the given medium
TR	=	target risk level (1E-6, 1E-5)
$ILCR_{coc}$	=	total incremental lifetime cancer risk for a given COC, receptor and source medium.

RBRCs for noncancer COCs are estimated as follows:

$$RBRC_{coc} = \frac{ST_{coc}\,THI}{HI_{coc}} \qquad \text{Eq. 5.7}$$

where:

$RBRC_{coc}$	=	risk-based remediation criterion for a given COC, receptor and source medium (calculated)
ST_{coc}	=	source-term concentration of the COC in the given medium
THI	=	target hazard index (0.1, 1)
HI_{coc}	=	total hazard index for a given COC, receptor and source medium.

Concentration units are not provided in Equations 5.6 or 5.7; the RBRC units will be the same as the concentration units of the source-term concentration.

6.0 Uncertainty Analysis

This section explores the uncertainties inherent in the RA process. Uncertainty is a factor in each step of the data evaluation and exposure and toxicity assessments presented in the preceding sections. Uncertainties associated with earlier stages of the RA become magnified when they are concatenated with other uncertainties in the latter stages. It is not possible to eliminate all uncertainty; however, a recognition of the uncertainties is fundamental to the understanding and reasonable use of the RA results.

Generally, risk assessments carry two types of uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements, e.g., instrument uncertainty (accuracy and precision) associated with contaminant concentrations. The results of the RA reflect the accumulated variances of the individual measured values. A different kind of uncertainty stems from data gaps, i.e., additional information needed to complete the database for the assessment. Often, the data gap is significant, such as imprecision regarding the nature of and length of time a construction project may last, or the absence of information on the effects of human exposure to a chemical (EPA, 1992c).

EPA (1992c) guidance urges risk assessors to address or provide descriptions of individual risk to include the "high end" portions and "central tendency" of the risk distribution. One way of fulfilling this request, if either cancer or noncancer risk exceeds generally acceptable limits (cancer risk greater than 1E-5 or target organ-specific HI greater than 1), is to re-compute the ILCRs or HIs using central tendency (CT) values for as many intake model variables as possible. In contrast to the RME evaluation, which prevails in RAs and uses upper-end values for intake or contact rates, exposure frequency and exposure duration, the CT evaluation chooses average or mid-range values for these variables (EPA, 1991). The intent is to present a quantified risk/hazard estimate more typical for the receptor of interest.

The CT exposure evaluation, however, falls short of its stated intent for several reasons. First, the same source-term concentration is usually used for the CT evaluation as is used for the RME evaluation. EPA (1993) considers that the UCL or MDC selected as a conservative estimate of average for the RME is appropriate for the CT estimates. Second, there is little information available as to what constitutes a reliable CT estimate for most exposure variables (EPA, 1993), with the possible exception of a simple on-site residential scenario. Hence, RME values are still used. Third, no CT toxicity values are available, so the uncertainty about the toxicity assessment

is not included. A CT evaluation, therefore, usually provides little perspective, compared with the RME, particularly for exposure scenarios such as the trespasser and construction worker, for which no reliable estimation of most exposure variable values can be made. It should be stated that management decisions are generally based on RME rather than CT evaluations.

Another method of quantifying uncertainty, called Monte Carlo simulation, provides a more graphic illustration of the uncertainty about a risk/hazard estimate, because it presents the risk as a range with probability densities. To be meaningful, however, Monte Carlo simulation requires that the nature of the distributions of the variables that drive the risk assessment be well characterized. However, well characterized distributions are available for few exposure or toxicological variables, in which case the Monte Carlo simulation provides an incomplete illustration of the magnitude or the distribution of the uncertainty.

Because of the limitations of the CT analysis and the Monte Carlo approach, the uncertainty section will be limited to a qualitative discussion of the sources of uncertainty and their impact on the risk and hazard estimates.

7.0 Summary and Conclusions

This section will briefly summarize the RA protocol and results and interpret the results, in light of the uncertainty about their estimation, to draw realistic conclusions regarding risk to human health.

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Baseline Ecological Risk Assessment Work Plan
TNT Areas A and C
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List of Acronyms

ARP	assessment receptor profile
BAF	bioaccumulation factor
BCF	bioconcentration factor
BERA	baseline ecological risk assessment
bgs	below ground surface
BTAG	Biological Technical Advisory Group
CELRN	U.S. Army Corps of Engineers, Nashville District
COPEC	chemical(s) of potential ecological concern
DNT	dinitrotoluene
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ERAGS	ecological risk assessment guidance for superfund
ESCM	ecological site conceptual model
ET	Ecotox Threshold
FCM	food chain multiplier
HQ	hazard quotient
IT	IT Corporation
K_{oc}	soil adsorption coefficient
K_{ow}	octanol-water partition coefficient
LD_{50}	lethal dose 50%
LOAEL	lowest observed adverse effect level
MDC	maximum detected concentration
NASA	National Aeronautics and Space Administration
NOAEL	no observed adverse effect level
NOEL	no observed effect level
OEPA	Ohio Environmental Protection Agency
PBOW	Plum Brook Ordnance Works
RBSEV	risk-based screening ecotoxicity value
RTV	reference toxicity value
SQL	sample quantitation limit
SLERA	screening-level ecological risk assessment

List of Acronyms (Continued)

TNT	trinitrotoluene
UCL	upper confidence limit
UTL	upper tolerance limit

1.0 Introduction

Chemical contamination related to former U.S. Department of Defense (DOD) activities has been documented at the former Plum Brook Ordnance Works (PBOW) located near Sandusky, Ohio (U.S. Army Corps of Engineers [USACE], 2000a, b). PBOW operated from 1941 to 1945 as a manufacturing plant for 2,4,-trinitrotoluene (TNT), dinitrotoluenes (DNT), and pentolite. Some of the areas used by the DOD were decontaminated in the 1950s and 1960s; other areas have been decommissioned but not decontaminated. The site is currently owned by the National Aeronautics and Space Administration (NASA) and is operated as the Plum Brook Station of the John Glenn Research Center, which is headquartered in Cleveland, Ohio. In 1978 NASA declared approximately 2,152 acres of land as excess (IT Corporation [IT], 1997). The Perkins Township Board of Education acquired 46 acres of excess for use as a bus transportation center. The Ohio National Guard has an agreement with the U.S. Army's General Services Administration to use 604 acres of the facility. The areas surrounding PBOW are predominantly agricultural and residential. The facility is currently surrounded by a chain-link fence, and the perimeter is regularly patrolled. Access by authorized personnel is limited to established checkpoints. Public access is restricted, except during the annual deer hunting season.

A baseline ecological risk assessment (BERA) will be performed to provide an estimate of current and future ecological risk associated with potential hazardous substance releases within TNT Manufacturing Areas A and C at the former PBOW in Sandusky, Ohio. The results of the BERA will contribute to the overall characterization of the sites and serve as part of the baseline used to develop, evaluate, and select appropriate remedial alternatives. The BERA will be performed following the general guidelines of the *Tri-Service Procedural Guidelines for Ecological Risk Assessments* (Wentsel, et al., 1996), as well as the *Ecological Risk Assessment Guidance for Superfund (ERAGS): Process for Designing and Conducting Ecological Risk Assessments* (U.S. Environmental Protection Agency [EPA], 1997), and *Region 5 Biotechnical Assistance Group (BTAG) Ecological Risk Assessment Guidance Bulletin No. 1* (EPA, 1996a). The BERA is more appropriately termed a screening-level ecological risk assessment (SLERA), as it fits into Steps 1 and 2 of the ERAGS process (EPA, 1997), and the SLERA term will be used henceforth.

The primary objective of the SLERA is to determine whether unacceptable adverse risks are posed to ecological receptors as a result of potential hazardous substance releases. This objective

is met by characterizing the ecological communities in the vicinity of the sites, determining the particular hazardous substances being released, identifying pathways for receptor exposure, and estimating the magnitude of the likelihood of potential risk to identified receptors. The SLERA will address the potential for adverse effects to the vegetation, wildlife, aquatic life (including both fish and aquatic macroinvertebrates), endangered and threatened species, and wetlands or other sensitive habitats associated with the sites. There is limited habitat for fish in this area of concern, as the small streams within and adjacent to the area are intermittent.

Concentrations of chemicals will be measured in relevant environmental media, including soil, surface water, sediment, and groundwater. Using this information, concentration data will be used to perform a SLERA, including a problem formulation (Chapter 2.0); an exposure characterization (Chapter 3.0); an ecological effects characterization (Chapter 4.0); and a risk characterization (Chapter 5.0). These subtasks are described in more detail below.

IT Corporation will evaluate the chemicals of potential ecological concern (COPEC), the ecosystems and receptors at risk, the ecotoxicity of the contaminants known or suspected to be present, and observed or anticipated ecological effects. This evaluation will be conducted in two steps: (1) a screening assessment step and (2) a predictive assessment step. Ecological endpoints to be addressed in both steps will be identified. The results and conclusions of the screening assessment will determine whether a predictive assessment is needed. The criteria by which the need for a predictive assessment is measured will be formalized as null hypotheses to be accepted (in which case a predictive assessment is not needed) or rejected (in which case a predictive assessment is needed).

2.0 Problem Formulation

The screening assessment null hypotheses are stated as follows:

- Potential for adverse ecological effects to ecological entities at the sites is minimal or nonexistent due to the lack of viable habitat for potential ecological receptors.
- Potential for adverse ecological effects to ecological entities at the sites is minimal or nonexistent due to the lack of potential ecological receptors.
- Potential for adverse ecological effects to ecological entities at the sites is minimal or nonexistent due to the lack of potential exposure pathways.
- Potential for adverse ecological effects to ecological entities at the sites is minimal or nonexistent due to the lack of potential chemical stressors.

IT will qualify any determination of a lack of viable habitat or a lack of potential receptors with a statement addressing whether or not such absence is due to previous or ongoing site activities. If one or more of these null hypotheses are accepted, a predictive assessment is not triggered. All four null hypotheses must be rejected for a predictive assessment to be triggered. The first three null hypotheses are tested with the results of the ecological site description (Section 2.1), the pre-assessment reconnaissance (Section 2.2), the documentation of potential receptors of special concern and critical habitats (Section 2.3), and the determination of significant ecological threats (Section 2.4). The fourth null hypothesis will be tested with the results of COPEC selection (Sections 2.5 and 2.6).

If a predictive assessment is triggered, terrestrial and aquatic ecological conceptual site models will be developed, as appropriate, and additional problem formulation tasks will be performed as described in Sections 2.7 to 2.9.

2.1 Ecological Site Description

IT will describe the sites in sufficient detail to ensure that the U.S. Army Corps of Engineers, Nashville District (CELRN) technical specialist can be oriented to the sites. This information will be assembled from existing sources without conducting additional field studies. IT will contact natural resource personnel (e.g., federal or state officials) to obtain any relevant data or useful ecological information.

2.2 Pre-Assessment Reconnaissance (Biota Checklist)

IT will perform a site reconnaissance for the purpose of collecting qualitative information on the type, quality, and location of biological resources at TNT Areas A and C. The assessment duration will typically be about one day per site. This will be achieved as follows:

- Dominant plant species will be identified by a qualified botanist, and plant communities will be defined based on dominant species observed.

- Observations of fauna will be made by a qualified biologist or ecologist. Mammals will be identified by tracks, scat, burrows, and sightings. Bird, reptile, and amphibian identifications will be made by sightings. Fish and aquatic macroinvertebrates will be collected for identification as necessary, depending on characteristics of the sites.

- Areas will be examined for vegetative stress. Stress may be exhibited by stunted growth, poor foliage growth, tissue discoloration, and a loss of leaf coverage. Due to the seasonal component of this evaluation, the survey will be performed during late spring to late summer, as the schedule permits.

The purpose of these activities will be to select representative receptors, refine exposure scenarios for the risk assessment, and identify protected species or habitats of special concern in the study area.

The site reconnaissance will be performed by two IT biologists or ecologists. Prior to arrival at the sites, IT personnel will obtain relevant information on the sites, including topographic maps; township, county, or other appropriate maps; and location of potential ecological units such as streams, creeks, ponds, grasslands, forest, and wetlands on or near the sites. Additionally, the *Biological Inventory of Plum Brook Station, 1994* (National Aeronautics and Space Administration, 1995), which identifies and shows the locations of threatened and endangered species at PBOW, as well as results of extensive wildlife surveys, will be reviewed. IT personnel will complete a checklist similar to that on EPA's *Checklist for Ecological Assessment/Sampling* (EPA, 1997); in situ water column measurements (i.e., pH, temperature, dissolved oxygen, conductivity) will be collected by the field sampling team. The location of known or potential contaminant sources affecting the sites and the probable gradient of the pathway by which contaminants may be released from the sites to the surrounding environment will be identified. IT personnel will use the reconnaissance to evaluate the sites for more subtle clues of potential effects from contaminant release. IT will determine the designation of any waters potentially impacted by contaminant migration.

Ecological characterization of the study area will be based on a compilation of existing ecological information and site reconnaissance activities. Methods used to characterize ecological resources will include a site walkover for the identification of existing wildlife and vegetative communities; interviews with local, state, and PBOW resource personnel; and a review of environmental data obtained from various sources (e.g., Nature Conservancy, U.S. Fish and Wildlife Service). A photographic record will be made during the site reconnaissance. Information will be obtained on the presence of state-listed and federal-listed, threatened, and endangered species; species of special concern; and wildlife and fisheries resources. A botanist will search for threatened and endangered plant species (two botanical surveys are planned; one in the spring and one in the late summer or early fall). A checklist of biological species present at the sites will be developed using existing site investigation reports, environmental data sources mentioned previously, and information gathered during the site reconnaissance. Information on unique and special-concern habitats, preserves, wildlife refuge parks, and natural areas within the general vicinity will also be obtained.

The methods used to characterize natural resources will focus on aquatic and terrestrial resources at the sites and within the immediate vicinity. If not already in existence, general habitat maps will be prepared showing the types and extent of biological communities present within the immediate vicinity of the sites. These maps will be based on information collected during the site reconnaissance previously discussed.

2.3 Documentation of Potential Receptors of Special Concern and Critical Habitat

IT will determine if the sites have designated wetlands or critical or sensitive habitats for threatened or endangered species. This will be performed, in part, by reviewing National Wetland Inventory Maps and threatened and endangered species information requested from the Ohio Department of Natural Resources Division of Natural Areas and Preserves. The site reconnaissance will not include wetlands delineation activities.

2.4 Significant Ecological Threats

IT will determine whether significant ecological threats exist and whether these threats are related to chemical contamination caused by DOD activities. The initial screening of whether significant threats exist will be based on the qualitative absence of plant or animal life in areas expected to support these ecological components.

2.5 Review, Evaluation, and Presentation of Analytical Data

IT will review and evaluate any relevant historical chemical analytical data, as well as all previous and ongoing investigations. Data identified as being of acceptable quality for use in the SLERA will be summarized in a manner that presents the pertinent information to be applied in the SLERA. Any data rejected during the data evaluation as a result of the data evaluation (R-qualified data) will be identified along with the rejection rationale. Only validated data are proposed to be used in the SLERA.

2.6 Selection of Preliminary Chemicals of Potential Ecological Concern

IT will identify a subset of chemicals detected at the sites that have data of good quality and are not naturally occurring or a result of nonsite sources. The chemicals must also be present at sufficient frequency, concentration, and location to pose a potential risk to ecological receptors. Examples of screening criteria that will be used include the following: analytical detection limit; frequency of detection less than 5 percent; comparability with naturally-occurring inorganic background concentrations; role as an ecologically essential nutrient at site concentrations; and comparability with ecologically relevant screening criteria. This selection process is described in more detail in the following subsections.

2.6.1 Data Organization

The data for each chemical will be sorted by medium. For ecological impacts, soil from 0 to 6 feet below ground surface (bgs) will be considered. Although Ohio Environmental Protection Agency (OEPA) has recommended that only soils from 0 to 2 feet bgs be used in the SLERA, OEPA has agreed to the 0 to 6 foot interval, in order to maintain consistency with previous SLERAs performed for the Red Water Ponds and TNT Area B at PBOW. Chemicals that are not detected at least once in a medium will not be included in the risk assessment. Available background data will be determined for each medium. Potential sources of background information will include data from previous and current investigations, as well as monitoring wells in areas unaffected by site activities.

The analytical data may have qualifiers from the analytical laboratory quality control or from the data validation process that reflect the level of confidence in the data. Some of the more common qualifiers and their meanings are (EPA, 1989):

- U - Chemical was analyzed for but not detected; the associated value is the sample quantitation limit.
- J - Value is estimated, probably below the contract-required quantitation limit.
- R - Quality control indicates that the data are unusable (chemical may or may not be present).
- B - Concentration of chemical in sample is not sufficiently higher than concentration in the blank (using 5X, 10X rule).

"J" qualified data are used in the risk assessment; "R" and "B" qualified data are not. The handling of "U" qualified data (nondetects) is described later in this work plan.

2.6.2 Descriptive Statistical Calculations

Because of the uncertainty associated with characterizing contamination in environmental media, both the mean and the 95 percent upper confidence limit (UCL) of the mean are usually estimated for each chemical in each medium of interest. In general, "outliers" are included in the calculation of the UCL because high values in environmental data are seldom true statistical outliers. Inclusion of outliers increases the overall conservatism of the risk estimate and the likelihood of rejecting the null hypothesis.

Data sets will be tested for normality and lognormality based on the Shapiro-Wilks test (EPA, 1992a). Statistical analysis will be performed only on those chemicals whose maximum detected concentration (MDC) exceeds the risk-based screening ecotoxicity values (RBSEV). If statistical tests support the assumption that the data set is normally distributed, the UCL for a normal distribution is calculated. If the statistical analysis shows the data to be lognormally distributed, the UCL is calculated for a lognormal distribution. Note: RBSEVs are discussed in Section 2.6.5.

The UCL is calculated for a normal distribution as follows (EPA, 1992b):

$$UCL = \bar{x} + t_{1-\alpha,n-1}\, x\, (s/\sqrt{n})$$

where:

$\bar{x}$ = sample arithmetic mean
t_1 = critical value for student's t distribution
α = 0.05 (95 percent confidence limit for a one-tailed test)

n = number of samples in the set
s = sample standard deviation.

The UCL is calculated for a lognormal distribution as follows (Gilbert, 1987):

$$UCL = e^{\left(\bar{y} + (0.5 \bullet s_y^2) + \left[H_{0.95} \bullet \frac{s_y}{(n-1)^{0.5}}\right]\right)}$$

where:

$\bar{y}$ = $\sum y/n$ = sample arithmetic mean of the log-transformed data, y = ln x
s_y = sample standard deviation of the log-transformed data
n = number of samples in the data set
$H_{0.95}$ = value for computing the one-sided 95 percent UCL on a lognormal mean from standard statistical tables (Land, 1975).

A nonparametric confidence limit is used when the data set fits neither a normal nor a lognormal distribution. The nonparametric UCL is estimated as the 95 percent UCL rank order on the arithmetic mean of the data set. It is estimated by ranking the data observations from smallest to largest. The arithmetic mean is converted to a percentile by interpolation. The rank order of the observation selected as the UCL is estimated from the following equation (Gilbert, 1987):

$$u = p(n+1) + Z_{1-\alpha}\sqrt{np(1-p)}$$

where:

u = upper confidence limit
p = percentile corresponding to the arithmetic mean
n = number of samples in the set
α = confidence limit; 95 percent
$Z_{1-\alpha}$ = normal deviate variable.

Analytical results are presented as "nondetects" ("U" qualifier) whenever chemical concentrations in samples do not exceed the detection or quantitation limits for the analytical procedures for those samples. Generally, the detection limit is the lowest concentration of a chemical that can be "seen" above the normal, random noise of an analytical instrument or analytical method. To apply the previously mentioned statistical procedures to a data set with nondetects, a concentration value must be assigned to nondetects. Nondetects are assumed to be present at one-half the sample quantitation limit, although judgement is used in those cases where matrix

interference or other phenomena drive the sample quantitation limit unusually high. The UCL or the MDC, whichever is smaller, is selected as the source-term concentration and is understood to represent a conservative estimate of average for use in the risk assessment or in various transport models used to estimate exposure-point concentrations.

2.6.3 Frequency of Detection

Chemicals that are detected infrequently may be artifacts in the data that may not reflect site-related activity or disposal practices. These chemicals will not be included in the risk evaluation. Generally, chemicals that are detected only at low concentrations in less than 5 percent of the samples from a given medium are dropped from further consideration, unless their presence is expected based on historical information about the site (such as nitroaromatics in the present case). Chemicals detected infrequently at high concentrations may identify the existence of "hot spots" and will be retained in the evaluation, unless other information exists to suggest that their presence is unlikely to be related to site activities.

2.6.4 Natural Site Constituents (Background and Essential Nutrients)

Chemical concentrations will be compared to site-specific background concentrations (see next paragraph for details) as an indication of whether a chemical is present from site-related activity or as natural background. This comparison is generally valid for inorganic chemicals, but not for organic chemicals, because inorganic chemicals are naturally occurring and most organic chemicals are not. Statistical techniques are used as tools to aid the exercise of professional judgement in resolving site-related issues for metals, since metals are naturally present in most environmental media. The statistical techniques generally involve comparing the site data with background data.

The first statistical technique is the development of an upper tolerance limit (UTL) for background, and comparing the MDC to the UTL. Chemicals with MDCs less than the background UTL are eliminated from further consideration. If the MDC exceeds the UTL, the chemical is retained as a COPEC, or a more rigorous statistical analysis may be performed. The statistical analysis consists of comparing the site and background data sets to determine if both are drawn from the same population. The Wilcoxon Rank Sum test is used for this purpose. The UTL is the concentration, with a probability of 0.95 (or a confidence of 95 percent), that will capture (or cover) 95 percent of background samples if a large number of samples were taken. For this RA, background data will be calculated using data from *Statistical Evaluation of Background Soil*

Data (Chapter 4.0 in site investigation of Acid Areas, PBOW [IT, 1998]), and represents background data collected by both IT and Dames and Moore (1997). Between 12 and 26 soil sample results will be used in the determination of the UTL, depending on the analyte. Assuming that these site data truly reflect background, there is a 5 percent probability that any naturally occurring site analyte concentration will exceed the UTL.

The UTL will be calculated as follows (for a normal distribution):

$$UTL = \overline{X} + k(a)$$

where:

UTL	=	upper tolerance limit (confidence factor of 0.95 and coverage of 95 percent)
$\overline{x}$	=	arithmetic mean
a	=	standard deviation
k	=	tolerance factor.

The same equation is used to estimate the UTL for lognormal distributions, but the data are log-transformed before the arithmetic mean and standard deviation are calculated.

As recommended by OEPA, if the estimated UTL is greater than the MDC, the MDC will be used as the default background screening concentration. In addition, if the data are shown to be neither normal nor lognormal, a nonparametric distribution will be assumed and the MDC will be selected as the background UTL.

It must be understood that statistical analysis is only a tool to aid the exercise of professional judgement. Site data from uncontaminated areas with concentrations at the high end of background may "fail" statistical testing because of the limitations of sample size, i.e., the full range of actual background and site variation was not captured. Statistical testing is based on absolute values, but the approximately 20 metals generally analyzed together constitute only approximately 4 to 5 percent of a given sample. Apparently high values of one or more metals may arise from a diminished amount of other constituents in soil, e.g., silica or organic matter, that may be more abundant in background areas. Therefore, it may be necessary to normalize the metal concentrations in site and background data before performing comparisons.

Essential nutrients such as calcium, chloride, iodine, magnesium, phosphorus, potassium and sodium may be eliminated as COPECs, provided that their presence in a particular medium is judged to be unlikely to cause adverse effects on wildlife. However, as most nutrients do not have readily available ecological screening criteria, nutrients will be retained in the SLERA (if not background related) and assessed in an ecological effects characterization (as described in Section 4.0).

2.6.5 Comparison to Risk-Based Screening Ecotoxicity Values

A comparison will be made between MDCs of chemicals in media and RBSEV for ecological endpoints following recommendations received from OEPA and as discussed in EPA Region V BTAG Bulletin No. 1 (EPA, 1996a). Chemicals that exceed the RBSEVs, or for which no RBSEVs are available, will be retained as COPECs. The following RBSEVs, or RBSEV hierarchy (as noted), will be used for the ecological evaluation:

- ***Soil.*** Soil screening values will be selected using the following hierarchy: (1) *Preliminary Remediation Goals for Ecological Endpoints* (Efroymson et. al. 1997a); (2); *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process* (Efroymson, Suter, and Will, 1997b); (3) *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants* (Efroymson et. al. 1997c); and (4) *Ecological Data Quality Levels* (EDQLs; EPA, 1999). It should be noted that effects on heterotrophic processes may not be relevant to ecological receptors of concern at the sites.

- ***Groundwater.*** If groundwater is known to impact surface water at the sites, surface water RBSEVs will be used, as presented below.

- ***Surface Water.*** The lowest surface water screening value will be selected from the following three sources: (1) Ohio EPA Water Quality Criteria (WQC) for the protection of aquatic life; (2) *Preliminary Remediation Goals for Ecological Endpoints* (Efroymson et. al. 1997a); and (3) *Ecological Data Quality Levels* (EDQLs; EPA, 1999). A hierarchy will not be used because it would potentially eliminate important surface water COPECs, due to the fact that OEPA WQC do not consider food-chain effects.

- ***Sediment.*** Sediment screening values will be selected using the following hierarchy: (1) *Ecological Data Quality Levels* (EDQLs; EPA, 1999); (2) *Preliminary Remediation Goals for Ecological Endpoints* (Efroymson et. al. 1997a); and (3) *Guidelines for the Protection and Management of Aquatic*

Sediment Quality in Ontario (Ontario Ministry of the Environment and Energy; 1993).

Nonchemical stressors will also be assessed, using available surface water data collected on pH, turbidity, conductivity, dissolved oxygen, Eh, and temperature.

2.6.6 Summary of COPEC Selection

A table of COPECs will be prepared for each medium with the following information:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of detection limits
- Arithmetic mean (average) of site concentrations
- Distribution type
- UCL of the mean of the concentration
- Source-term concentration
- Appropriate RBSEV
- The background screening concentrations
- COPEC selection conclusion: NO (with rationale for exclusion), or YES (selected).

Footnotes in the table(s) will provide the rationale for selecting or rejecting a chemical as a COPEC.

An evaluation of all of the constituents that were eliminated will be performed to determine whether any should be reinstated as COPECs due to other considerations. Examples of these exceptions include: potential breakdown products, chemicals with detection limits greater than the RBSEV, chemicals known to have been used onsite historically, and chemicals with high bioconcentration and/or bioaccumulation factors. Chemicals not eliminated using the screening procedures previously presented will be considered COPECs and will be quantitatively evaluated in the SLERA. The physical, chemical, and toxicological properties of the identified COPEC risk drivers will be reviewed from the scientific literature and summarized in COPEC profiles. When possible, data and information directly relevant to the SLERA will be included in the COPEC profiles. COPEC-specific information pertaining to physiological, biological, or ecological effects that is used directly in the exposure and effects analysis of this SLERA may be presented and discussed in the COPEC profiles. In addition, justification for the use of surrogate chemical data in the absence of direct chemical data for COPECs may be presented and

discussed in the profiles. The COPEC profiles will be included in the final ecological risk assessment (ERA) report as an appendix.

2.7 Selection of Assessment Receptors

IT will select assessment receptors for evaluation during this SLERA. In order to focus the exposure characterization portion of the SLERA on species or components that are the most likely to be affected and on those that, if affected, are most likely to produce greater effects in the on-site ecosystem, IT will focus the selection process on species, groups of species, or functional groups, rather than on higher organization levels such as communities or ecosystems. Site biota will be organized into major functional groups. For terrestrial communities, the major groups are plants and wildlife, including terrestrial invertebrates, mammals, and birds. For aquatic and/or wetland communities, the major groups are flora and fauna, including vertebrates (water fowl and fish), aquatic invertebrates, and wetland/terrestrial mammals. Species presence and relative abundance will be determined during the site reconnaissance prior to identification of target species.

Primary criteria for selecting appropriate assessment receptors will include, but will not be limited to, the following:

- The assessment receptor will have a relatively high likelihood of contacting chemicals via direct or indirect exposure.
- The assessment receptor will exhibit marked sensitivity to chemicals.
- The assessment receptor will be a key component of ecosystem structure or function (e.g., importance in the food web, ecological relevance).
- The assessment receptor may be listed as rare, threatened, or endangered by a governmental organization; or the receptor will consist of critical habitat for rare, threatened, or endangered species.

Additional criteria for selection of assessment receptors will be used to identify species that offer the most favorable combination of characteristics for determining the implications of on-site contaminants. These criteria may include: (1) limited home range; (2) role in local nonhuman food chains; (3) potential high abundance and wide distribution at the sites; (4) sufficient toxicological information available in the literature for comparative and interpretive purposes; (5) sensitivity to COPECs; (6) relatively high likelihood of occurrence onsite following remediation;

(7) suitability for long-term monitoring; (8) importance to the stability of the ecological food chain or biotic community of concern; and (9) relatively high likelihood that they will be present at the sites or that habitats present at the sites could support the species.

It is important that sufficient toxicological information is available in the literature on the receptor species, or that a closely related species may be selected. While the ecological communities at the individual sites have species with many desirable characteristics for use as receptor species, not all of these species have been used extensively for toxicological testing.

Results of the assessment receptor selection process will be presented in detailed biological and ecological descriptions called assessment receptor profiles (ARP). Additionally, the biologically relevant criteria used to select each assessment receptor will be discussed and summarized in the ARP. The ARPs will be included in the final ERA report as an appendix.

2.8 Ecological Endpoint (Assessment and Measurement) Identification

The protection of ecological resources, such as habitats and species of plants and animals, is a principal motivation for conducting the SLERA. Potential ecological assessment and measurement endpoints will be proposed after the site reconnaissance and a thorough review of existing reports and site-related documents. The final assessment and measurement endpoints will be selected by agreement between risk assessors, risk managers, and regulatory agencies.

Unlike the human health risk assessment process, which focuses on individual receptors, the SLERA will focus on populations or groups of interbreeding nonhuman, nondomesticated receptors. In the SLERA process, the risks to individual receptors will be assessed only if they are protected under the Endangered Species Act, are species that are candidates for protection, or are species that are considered rare.

Given the diversity of the biological world and the multiple values placed on it by society, there is no universally applicable list of assessment endpoints. Suggested criteria that may be considered in selecting assessment endpoints suitable for a specific ecological risk assessment are: (1) ecological relevance; (2) susceptibility to the contaminant(s); (3) accessibility to prediction and/or measurement; and (4) definable in clear, operational terms (Suter, 1993). Selected assessment endpoints will reflect environmental values that are protected by law, are critical

resources, or have relevance to ecological functions that may be impaired. Both the entity and attribute will be identified for each assessment endpoint.

Assessment endpoints are inferred from effects to one or more measurement endpoints. The measurement endpoint is a measurable response to a stressor that is related to the valued attribute of the chosen assessment endpoint. It serves as a surrogate attribute of the ecological entity of interest (or of a closely related ecological entity) that can be used to draw a predictive conclusion about the potential for effects to the assessment endpoint.

Measurement endpoints for this SLERA will be based on toxicity values from the available literature and not statistical or arithmetic summaries of actual field or laboratory observations or measurements. When possible, receptors and endpoints will be concurrently selected by identifying those that are known to be adversely affected by chemicals at the sites, based on published literature. COPECs for those receptors and endpoints will be identified by drawing on the scientific literature to obtain information regarding potential toxic effects of site chemicals to site species. This process will ensure that a conservative approach is taken in selecting endpoints and evaluating receptors that are likely to be adversely affected by the potentially most toxic chemicals at the sites. This information may be included in the ARP for appropriate receptors.

2.9 Ecological Site Conceptual Model

IT will prepare a pictorial representation of the exposure characterization. This pictorial and any text necessary to clarify the representation will be the ecological site conceptual model (ESCM). The ESCM will trace the contaminant pathways through both abiotic components and biotic food web components of the environment. The ESCM will present all potential exposure pathways and will identify those pathways that are complete and incomplete. The ESCM will clearly identify the relationship between the measurement and assessment endpoints. It will be used as a tool for judging the appropriateness and usefulness of the selected measurement endpoints in evaluating the assessment endpoints, and for identifying sources of uncertainty in the exposure characterization. All existing data will be qualitatively reviewed for quality, usefulness, and uncertainty.

3.0 Exposure Characterization

IT will develop an estimate of the nature, extent, and magnitude of potential exposure of assessment receptors to COPECs that are present at or migrating from the sites, considering both current and reasonably plausible future uses of the sites. Exposure and chemical uptake will be modeled to produce upper-bound exposure estimates. Exposure characterization is critical in further evaluating the risks of compounds identified as COPECs during the selection process (Section 2.6). The exposure assessments will be conducted by characterizing the magnitude (concentration) and distribution (locations) of the contaminants detected in the media sampled during the investigation, evaluating pathways by which chemicals may be transported through the environment, and determining the points at which organisms found in the study area may contact contaminants.

3.1 Exposure Analysis

IT will perform an exposure analysis, which will combine the spatial and temporal distribution of the ecological receptors with those of the COPECs to evaluate exposure. The exposure analysis will focus on the chemical amounts that are bioavailable, and the means by which the ecological receptors are exposed (e.g., exposure pathways). The focus of the analysis will be dependent on the assessment receptors being evaluated as well as the assessment and measurement endpoints.

Calculation of plant uptake values is not necessary, as the plant toxicity data are expressed in concentration in the growth medium. For terrestrial faunal receptors, calculation of exposure rates relies upon determination of an organism's exposure to COPECs found in surface water, surface soil, and sediment. Exposure rates for terrestrial wildlife receptors will be based solely upon ingestion of contaminants from these media and consumption of other organisms. Given the scarcity of available data for wildlife dermal and/or inhalation exposure pathways, potential risk from these pathways will not be estimated. In addition, these pathways are generally considered to be incidental for most species, with the possible exceptions of burrowing animals and dust-bathing birds.

The first step in estimating exposure rates for terrestrial wildlife involves the calculation of feeding and watering rates for site receptors. EPA (1993) includes a variety of exposure information for a number of avian, herptile, and mammalian species. Information regarding

feeding and watering rates and dietary composition are available for many species, or may be estimated using allometric equations (Nagy, 1987). Data will be gathered on incidental ingestion of soil and will be incorporated for the receptor species. This information will be summarized and documented in the ARPs.

Algorithms will be evaluated for calculating exposure for terrestrial vertebrates that account for exposure via ingestion of contaminated water, incidental ingestion of contaminated soil, and ingestion of plants grown in contaminated soil. Singular algorithms will be developed for soil-to-plant uptake and for animal bioaccumulation. An assessment exposure via uptake by carnivores will also be included.

Literature values for animal-specific sediment ingestion will be used, if available. However, such values generally are not available in the literature. Where sediment ingestion rates cannot be found, the animal-specific incidental soil ingestion rate will be used for sediment ingestion as well, if the receptor's life history profile suggests a significant aquatic component (e.g., raccoons' use of surface water in foraging activities).

For aquatic faunal receptors, the calculation of exposure rates will depend on the determination of the contaminant concentration in water and on food-chain multipliers, bioconcentration factors (BCF), and bioaccumulation factors (BAF). If appropriate, an evaluation will be made of the time each organism spends associated with surface water or sediment pore water in order to modify exposure rates.

For species exposed to organic contaminants found in sediment, calculations have been performed to quantify interstitial (pore) water contaminant concentrations given a known sediment concentration. Suter (1993) notes an algorithm to calculate pore water concentrations for nonionic organic chemicals, as follows:

$$\text{Pore water concentration (milligrams per liter)} = (SC)/(F_{oc})\,(K_{oc})$$

where:

SC = sediment concentration (milligram per kilogram)
F_{oc} = fraction organic carbon in sediment (kg organic carbon/kg sediment)
K_{oc} = chemical-specific organic carbon partition coefficient (L/kg).

Ecological routes of exposure for biota may be direct (bioconcentration) or through the food web via the consumption of contaminated organisms (biomagnification). Direct exposure routes include dermal contact, absorption, inhalation, and ingestion. Examples of direct exposure include animals incidentally ingesting contaminated soil or sediment (e.g., during burrowing or dust-bathing activities); animals ingesting surface water; plants absorbing contaminants by uptake from contaminated sediment or soil; and the dermal contact of aquatic organisms with contaminated surface water or sediment.

Food web exposure can occur when terrestrial or aquatic fauna consume contaminated biota. Examples of food web exposure include animals at higher trophic levels consuming plants or animals that bioaccumulate contaminants. The concepts of bioconcentration, bioaccumulation, and biomagnification are used throughout this document. Definitions describing their application are presented in the Glossary of Terms (Appendix A).

Contamination of biota could result from exposure to one or more COPECs. Bioavailability is an important contaminant characteristic that influences the degree of chemical-receptor interaction. Bioavailable compounds are those that a receptor can take in from the environment. Bioavailability of a chemical is a function of several physical and chemical factors.

Exposure pathways consist of four primary components: source and mechanism of contaminant release, transport medium, potential receptors, and exposure route. A chemical may also be transferred between several intermediate media before reaching the potential receptor. All of these components will be addressed within the SLERA. If any of these components is not complete, then contaminants in those media do not constitute an environmental risk at that specific site. The major fate and transport properties associated with typical site contaminants will be outlined. These properties directly affect a contaminant's behavior in each of the exposure pathway components.

Adjustments will be made for potential biomagnification of contaminants through aquatic trophic levels. Food chain multipliers (FCM), derived by EPA (1995), will be used to assess the possibility of contaminant magnification through site receptors. The FCMs are multiplied by chemical-specific BCFs to obtain BAFs. The SLERA will either use laboratory-measured BCF

values obtained from the scientific literature or fish BCFs will be calculated for organic compounds using the following equation (EPA, 1995):

$$BCF = K_{ow}$$

where:

K_{ow} = chemical-specific octanol/water partition coefficient.

When possible, octanol-water partition coefficient (K_{ow}) values for appropriate COPEC will be obtained from the literature or from databases and will be listed among the fate and transport properties within the COPEC profiles.

The BCF is dependent upon a chemical-specific K_{ow} that relates to a chemical's tendency to partition to a polar versus nonpolar solution. EPA has established a relationship between the K_{ow} and the FCM such that as the K_{ow} increases, the FCM increases correspondingly.

For sediment or soil, the percent carbon present is critical to partitioning. For these matrices, the K_{ow} will be converted to a soil adsorption coefficient (K_{oc}) value (EPA, 1996b) as follows:

$$\log K_{oc} = 0.00028 + (0.983 \times \log K_{ow})$$

where:

K_{oc} = the partition constant relative to organic carbon.

This equation was chosen because it is the best fit for site-related compounds (semivolatile, nonionizing organic compounds).

Per EPA (1995) guidance, aquatic BAFs will be estimated by one of four methods (in order of preference):

- A measured BAF for an inorganic or organic chemical derived from a field study
- A predicted BAF for an organic chemical derived from a field-measured biota-sediment accumulation factor

- A predicted BAF for an inorganic or organic chemical derived from a laboratory-measured BCF and a FCM
- A predicted BAF for an organic chemical derived from a K_{ow} and a FCM.

The EPA guidance notes, however, that for chemicals for which no K_{ow} is available and for which no BCF is calculable, a default FCM of 1.0 should be used. Thus, for inorganics not thought to biomagnify and/or for which no literature value is available, this value of 1.0 will be used at each trophic level.

In addition to the aquatic food web, FCMs are also related to an organism's trophic status as predator/prey, producer/consumer, etc. in the terrestrial food web. Although exposures of terrestrial floral and faunal receptors are significant considerations for many hazardous waste sites, well accepted models for predicting the fate of many contaminants in terrestrial systems are less developed. Trophic level compartments and transfer between compartments based on uptake, storage, and loss processes are not as well defined in terrestrial systems as in aquatic systems. In addition, the relationship between K_{ow} and bioconcentration is less well delineated by trophic level in terrestrial ecosystems. For the current SLERA, soil-to-plant and food-to-muscle BAFs will be estimated for organic constituents using the log K_{ow} relationships developed by Travis and Arms (1988). Soil-to-insect BAFs will be based on log K_{ow} relationships developed by Connell and Markwell (1990). Inorganic constituent BAFs will be based on literature values such as those found in Baes, et al. (1984), International Atomic Energy Agency (1994), and Ma (1982). Site-specific BAFs, from the data reflected as per the Red Water Ponds Phase II Ecological Risk Assessment Work Plan (IT, 2000) will be used as available.

Media-Specific Exposure Pathways. Exposure to four categories of environmental media will be addressed in the SLERA, as discussed in the following subsections.

Soil Exposure Pathway. Soil exposure pathways are potentially important for terrestrial plants and animals at the sites. For nonburrowing animal exposure, soil samples obtained from a depth of 0 to 1 foot will be considered, as this would be the point of exposure. For burrowing animals, soil samples obtained from a depth of 0 to 6 feet bgs will be considered.

For plant exposure, soil samples taken from 0 to 6 feet bgs (or the water table surface) will be considered, because most feeder roots are located within this depth.

Environmental conditions such as soil moisture, soil pH, and cation exchange capacities significantly influence whether potential soil contaminants remain chemically bound in the soil matrix or whether they can be chemically mobilized (in a bioavailable form) and released for plant absorption. Generally, neutral to alkaline soils (soil pH of 6.5 or greater) restrict the absorption of toxic metals, making pathway completion to plants difficult. Literature values for soil-to-plant transfer rates for inorganic and organic soil contaminants and for organic soil contaminants will be used unless contaminant-specific information is available.

Sediment Exposure Pathway. Sediment generally consists of soil or other material settled out of suspension in surface water or native soils underlying flowing or standing surface water bodies. Potential contaminant sources for sediment include buried or stored waste, and contaminated surface water, groundwater, and soil. The release mechanisms include surface water runoff, groundwater discharge, and airborne deposition. Potential receptors of chemicals in contaminated sediment include aquatic flora and fauna. Direct exposure routes for contaminated sediment include contact by benthic-dwelling organisms such as catfish, uptake by aquatic flora, and ingestion by aquatic fauna. Indirect exposure pathways from sediment include consumption of bioaccumulated contaminants by consumers in the food chain. Chemical bioavailability of many nonpolar organic compounds (e.g., polychlorinated biphenyls and pesticides) decreases with increasing concentrations of total organic carbon in the sediment; however, these compounds can still bioaccumulate up the food chain (Landrum and Robbins, 1990).

Surface Water Exposure Pathway. Surface water represents a potential transport medium for COPECs. Potential sources for contaminated surface water include: buried or stored waste, stored or spilled fuel, contaminated soil and groundwater, and deposition of airborne contaminants. The release mechanisms include surface runoff, leaching, and groundwater seepage. Potential receptors of contaminated surface water include terrestrial and aquatic fauna and aquatic flora. Exposure routes for contaminated surface water include ingestion by terrestrial fauna and uptake and absorption by aquatic flora and fauna. Consumption of bioaccumulated contaminants constitutes a potential indirect exposure pathway for faunal receptors. Chemical

bioavailability of some metals and other chemicals is controlled by water hardness, pH, and total suspended solids.

Groundwater Exposure Pathway. Groundwater represents a potential transport medium for COPECs. Potential contaminant sources for groundwater include contaminated soil and buried or stored waste. The release mechanism for contaminants into groundwater is direct transfer of contaminants from waste materials to water as water passes through the materials.

Groundwater itself is not an exposure point. However, contaminant transport along the shallow groundwater pathway is considered an exposure route to aquatic life, wetlands, and some wildlife where the groundwater discharges to surface water. This pathway is of importance to aquatic and wetland receptors if groundwater is found to be discharging to surface water. It should be noted that groundwater concentrations will not be screening against surface water RBSEVs when either surface water data are available or groundwater is not discharging to the surface.

3.2 Exposure Characterization Summary

At the conclusion of the exposure characterization, the estimated chemical intakes for each exposed receptor group under each exposure pathway and scenario will be presented in tabular form. The presentation will include an identification of all pertinent factors. These intake estimates will be combined with the COPEC toxicity values, discussed in the following chapter, to derive estimates and characterize potential ecological risk. The uncertainties associated with the estimation of chemical intake will be summarized at the conclusion of the exposure characterization. The basis for each uncertainty will be identified, with the degree of uncertainty estimated qualitatively (low, medium, or high) or quantitatively, and the impact of the uncertainty will be estimated qualitatively (overestimate or underestimate, as appropriate).

4.0 Ecological Effects Characterization

The ecological effects characterization will include the selection of literature benchmark values and the development of reference toxicity values.

4.1 Selection of Literature Benchmark Values

IT will consult appropriate sources for literature benchmark values, such as (1) *Toxicological Benchmarks for Wildlife* (Sample et al., 1996); *Development of Toxicity Reference Values for Conducting Ecological Risk Assessments at Naval Facilities in California* (Engineering Field Activity, West, 1998); *Review of the Navy - EPA Region 9 BTAG Toxicity Reference Values for Wildlife* (CH2M-Hill, 2000); and (2) LD_{50} values from data bases such as the Registry of Toxic Effects Concentrations (extrapolated to chronic no observed adverse effect level [NOAEL] or lowest observed adverse effect level [LOAEL] values using recommended Tri-Service [Wentsel, 1996] uncertainty factors). The level of effort will be limited to documents that summarize the available ecotoxicological information and will not consist of a review of the primary toxicological literature (i.e., IT will not review details of toxicity test conditions to determine validity of the tests performed).

4.2 Development of Reference Toxicity Values

IT will develop or determine reference toxicity values (RTV) for the sites. These RTVs will focus on the growth, survival, and reproduction of species and/or populations. Empirical data may be available for the specific receptor-endpoint combinations in some instances. However, for some COPECs, data on surrogate species and/or on endpoints other than the NOAEL and LOAEL may have to be used. The NOAEL is a dose of each COPEC that will produce no known adverse effects in the test species. The NOAEL was judged to be an appropriate toxicological endpoint, since it would provide the greatest degree of protection to the receptor species. In addition, the LOAEL will be used as a point of comparison for decision-making for risk management purposes. In addition, in instances where data are unavailable for a site-associated COPEC, toxicological information for surrogate chemicals may have to be used. Safety factors will be used to adjust for these differences and extrapolate risks to the site's receptors at the NOAEL and/or LOAEL endpoint. This process is described in the following paragraphs.

Toxicity information pertinent to identified receptors will be gathered for those analytes identified as COPECs. Because the measurement endpoint will range from the NOAEL to the LOAEL, preference will be given to chronic studies noting concentrations at which no adverse effects were observed and ones for which the lowest concentrations associated with adverse effects were observed. As previously noted, where data are unavailable for the exposure of a receptor to a COPEC, data for a surrogate chemical (e.g., endrin for endrin aldehyde) will be gathered for use in the SLERA.

Using the relevant toxicity information, RTVs will be calculated for each of the COPECs. RTVs represent NOAELs and LOAELs with safety factors incorporated for toxicity information derived from studies other than no-effects or lowest-effects studies, and studies on species other than the receptors selected for this risk assessment. RTVs will be calculated using safety factors (Wentsel, et al., 1996) specified in Figure 4-1. Interclass toxicity extrapolations will not be performed, as physiological differences between classes are too great to be addressed with the use of simplistic safety factors. Separate factors are recommended to account for extrapolation to the no effects or lowest-effects endpoints, for study duration, and for extrapolation across taxonomic groups (e.g., species, genus, family, order). Additional safety factors will be employed for endangered species, as appropriate. These factors are multiplied together to derive a total safety factor. The reported effects dose is then adjusted to account for potential uncertainties by dividing by the total safety factor. Because NOAELs for the selected wildlife receptor species will most likely be based on NOAELs from test species, the latter will be converted to NOAELs specific to the selected wildlife receptors using a power function of the ratio of body weights, as described by Sample, et al. (1996). A body weight scaling factor of 0.25 will be used for mammals, whereas a body weight scaling factor of 0 will be used for birds, making the $NOAEL_W$ for birds the same as the $NOAEL_T$, as shown below:

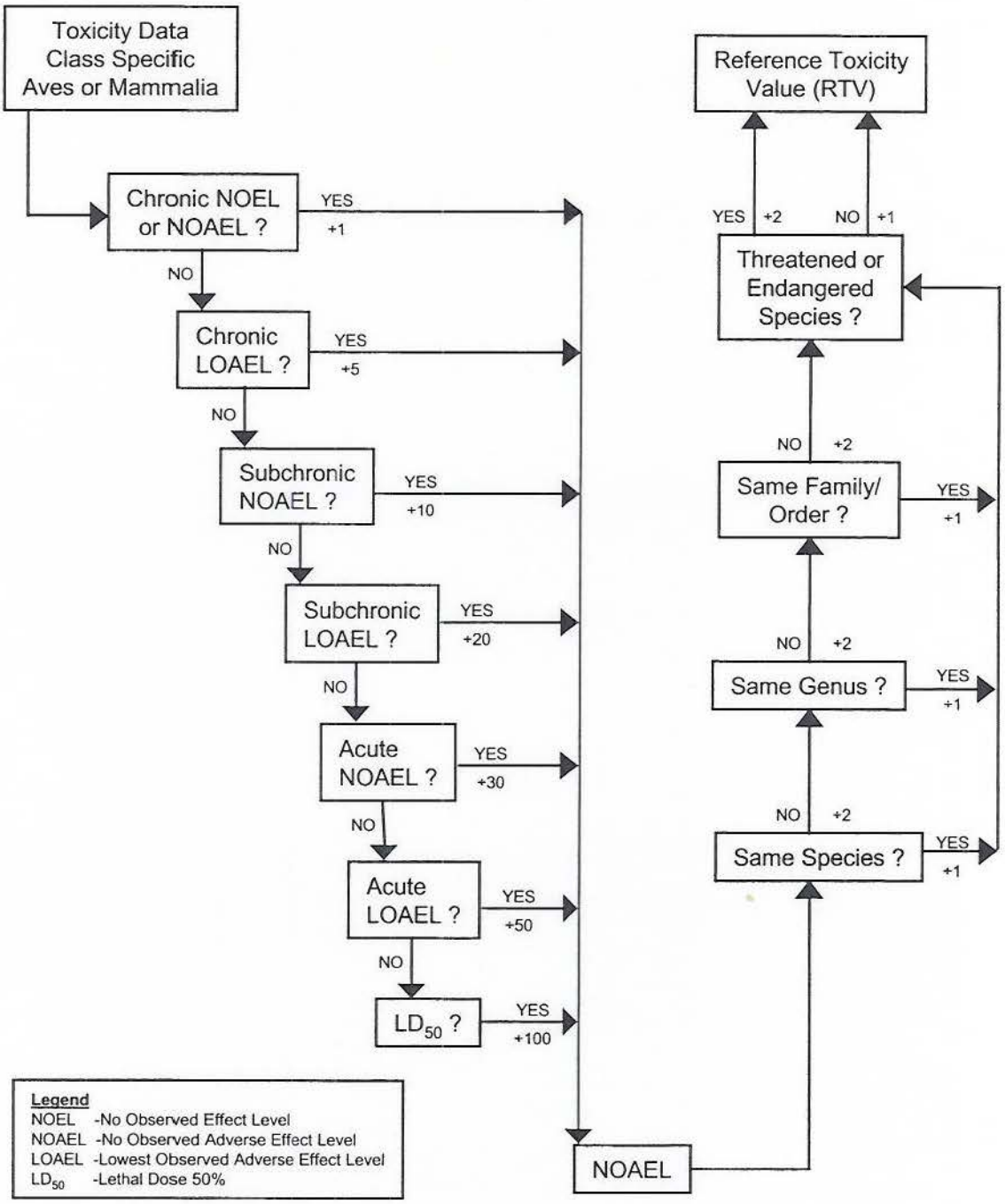
$$NOAEL_W = NOAEL_T \left(\frac{BW_T}{BW_W} \right)^s$$

where:

$NOAEL_W$ = the No Observed Adverse Effect Level for the wildlife indicator species (mg/kg-day)

Figure 4-1

Procedural Flow Chart for Deriving Reference Toxicity Values (RTVs) from Class-Specific Toxicity Data
Plum Brook Ordnance Works
Sandusky, Ohio



Credit: Adapted from *Tri-Service Procedural Guidelines for Ecological Risk Assessments*, 1996

$NOAEL_T$ = the No Observed Adverse Effect Level for the test species (mg/kg-day)
BW_T = the body weight of the test species (kg)
BW_W = the body weight of the wildlife indicator species (kg)
s = a body weight scaling factor (s = 1/4 for mammals and s = 0 for birds).

Exposure rate RTVs provide a reference point for the comparison of toxicological effects upon exposure to a contaminant. To complete this comparison, receptor exposure to site contaminants must be calculated, or as in the case of plant receptors, exposure is simply calculated as the soil concentration.

The equilibrium partitioning approach has been used by the EPA and Ontario Ministry of the Environment and Energy in the preparation of sediment quality criteria for the protection of aquatic life. These criteria will be used, as available, to assess sediment risks to aquatic receptors.

5.0 Risk Characterization

The risk characterization phase integrates information on exposure, exposure-effects relationships, and defined or presumed target populations. The result is a determination of the likelihood, severity, and characteristics of adverse effects of environmental stressors present at a site. A semiquantitative approach will be taken to estimating the likelihood of adverse effects occurring as a result of exposure of the selected site receptors to COPECs. RTVs and exposure rates will be calculated and used to generate hazard quotients (HQ) (Wentsel, et al., 1996) by dividing the receptor exposure rate for each contaminant by the calculated RTV. HQs are a means of estimating the potential for adverse effects to organisms of a contaminated site, and for assessing the potential that toxicological effects will occur among site receptors.

5.1 Risk Estimation

IT will estimate the potential risk associated with the sites. The potential risk estimation will be performed through a series of quantitative HQ calculations that compare receptor-specific exposure values with RTVs. It is important to note that HQs are not absolute risk measures, are not population-based statistics, and are not linearly scaled statistics. The HQs will be compared to HQ guidelines for assessing the potential risk posed from contaminants. HQs less than or equal to 1 present no probable risk; HQs greater than 1 but less than 10 present a low potential for environmental effects; HQs from 10 up to, but less than, 100 present a significant potential that effects could result from greater exposure; and HQs greater than 100 present the highest potential for expected effects (Wentsel, et al., 1996). It should be noted that Ohio Environmental Protection Agency considers HQs greater than 1.0 to be potentially significant.

The simple HQ ratios may be summed, where appropriate and scientifically defensible, to provide hazard index estimates for all chemicals and exposure pathways for a given receptor (e.g., organochlorine pesticides, polynuclear aromatic hydrocarbons and phthalates). The following criterion will be used to determine if HQs will be summed: for a given receptor, only HQs for those chemicals that have a similar mode of toxicological action will be summed. While individual contaminants may affect distinct target organs or systems within an organism, classes of chemicals may act in similar ways, thus being additive in effect.

5.2 Uncertainty Analysis

The results of the SLERA will be influenced to some degree by variability and uncertainty. In theory, investigators might reduce variability by increasing sample size of the media or species sampled. Alternatively, uncertainty within the risk analysis can be reduced by using species-specific and site-specific data (i.e., to better quantify contamination of media, vegetation, and prey through direct field measurements, toxicity testing of site-specific media, field studies using site-specific receptor species). Detailed media, prey, and receptor field studies are costly; thus, the preliminary scoping and predictive analyses of risk are conducted to limit the potential use of these resource-intensive techniques to only those COPECs that continue to show a relatively high potential for ecological risk. Since assessment criteria were developed based on conservative assumptions, the results of the screening and predictive assessments will err on the side of conservatism. This has the effect of maximizing the likelihood of accepting a false positive (Type I error: the rejection of a true null hypothesis) and simultaneously minimizing the likelihood of accepting a true negative (Type II error: the acceptance of a false null hypothesis). The use of soil data from 0 to 6 feet bgs may overestimate ecological effects, because many ecological receptors are only exposed to shallower soils. The uncertainty analysis will thus assess the soil depth of elevated concentrations of COPECs identified as risk drivers, and will evaluate the significance of these findings on the results of the SLERA (e.g., if COPEC hot spots only occur at deeper soil depths, realistic ecological exposure could be expected to be minimal).

A number of factors contribute to the overall variability and uncertainty inherent in ecological risk assessments. Variability is due primarily to measurement error; laboratory media analyses and receptor study design are the major sources of this kind of error. Uncertainty, on the other hand, is associated primarily with deficiency or irrelevancy of effects, exposure, or habitat data to actual ecological conditions at the sites. Species physiology, feeding patterns, and nesting behavior are poorly predictable; therefore, all toxicity information derived from toxicity testing, field studies, or observation will have uncertainties associated with them. Laboratory studies conducted to obtain site-specific, measured information often suffer from poor relevance to the actual exposure and uptake conditions onsite (i.e., bioavailability, exposure, assimilation, etc., are generally greater under laboratory conditions as compared to field conditions). Calculating an estimated value based on a large number of assumptions is often the only alternative to the accurate (but costly) method of direct field or laboratory observation, measurement, or testing. Finally, habitat- or site-specific species may be misidentified if, for example, the observational

assessment results are based on only one brief site reconnaissance performed on a relatively large site.

The uncertainty analysis will be presented in part as a table listing the assumptions made for the ERA; the direction of bias caused by each assumption (i.e., if the uncertainty results in an over-estimate or underestimate of risk); the likely magnitude of impact (quantitative [percent difference], or qualitative [high, medium, low, or unknown]); and, if possible, a description of recommendations for minimizing the identified uncertainties if the ERA progresses to higher level assessment phases (EPA, 1997). The uncertainty analysis will identify and, if possible, quantify the uncertainty in the individual preliminary scoping assessment, problem formulation, exposure and effects assessment, and risk characterization phases of this SLERA.

5.3 Risk Description

As part of the risk description, IT will complete the following: (1) summarize the ecological risk associated with the sites; and (2) interpret the ecological significance, which describes the magnitude of the identified risks and the accompanying uncertainty. The effect of additional data or analyses on uncertainty will also be discussed. A weight-of-evidence approach will be used to interpret the ecological significance of the findings.

6.0 Risk Summary and Identification of Preliminary Remedial Action Objectives

IT will summarize ecological risk associated with releases from the sites. This summary will be supported by tasks performed during the previous sections. Additionally, IT will make recommendations for further risk investigations, if appropriate and cost effective, and may develop site-specific remedial action objectives for the sites, if warranted.

7.0 Conclusions and Recommendations

Only the data, results, and conclusions of the various preliminary scoping and predictive assessment phases will be described. No recommendations concerning types of remedial actions to be conducted will be given other than to present the specific remedial action objectives. Conclusions and recommendations derived from the risk assessment will be based on the responses to the assessment hypotheses. The predictive assessment results will be summarized and presented in table format. These tables may serve as the foci of discussions with risk managers and regulatory agencies concerning the potential need for additional assessment at PBOW to reduce the uncertainty in the estimate of ecological risk.

8.0 References

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APPENDIX A

GLOSSARY OF TERMS

Appendix A

Glossary of Terms

Bioconcentration. For aquatic organisms, bioconcentration is the uptake and retention of a substance by an aquatic organism from the surrounding water through gill membranes or other external body surfaces. Terrestrial bioconcentration focuses on uptake and retention of contaminants from the surrounding medium on the organism level (as by the earthworm, for example).

Bioaccumulation. This refers to the uptake and retention of a substance by an aquatic organism from its surrounding medium and food (U.S. Environmental Protection Agency, 1995). Terrestrial bioaccumulation, as with aquatic bioaccumulation, is defined as an organism's uptake and retention of a substance from its surrounding medium and food.

Biomagnification. This refers to the process by which tissue concentrations of bioaccumulated toxic substances increase as the substances pass up through two or more trophic levels. The definition of this term is similar for both terrestrial and aquatic organisms.

References. U.S. Environmental Protection Agency (EPA), 1995, ***Final Water Quality Guidance for the Great Lakes System,*** 40 CFR Parts 9, 122, 123, 131, and 132.

Response to U. S Army Corps of Engineers Review Comments
Draft Baseline Ecological Risk Assessment Work Plan
TNT Areas A and TNT Area C
Plum Brook Ordnance Works, Sandusky, Ohio
October 2000

Comment 1. Section 1.0, 1st paragraph, 1st sentence. The word *combination* should be *contamination,* and the word *forme* should be *former.*

Response: Agreed.

Comment 2. 1st paragraph, 4th sentence. The *Lewis Research Center* has been renamed as the *John Glenn Research Center*, please revise.

Response: Agreed.

Comment 3. 2nd paragraph, 1st sentence. The phrase *Plum Brook Ordnance Works (PBOW)* is not necessary since the abbreviation *PBOW* was introduced in the first paragraph.

Response: Agreed.

Comment 4. Section 2.4, 1st sentence. The word *exists* should be *exist*, and *U.S. Department of Defense* could be revised to *DoD* since that acronym has been previously defined.

Response: Agreed.

Comment 5. Section 2.6.1, 1st paragraph, 2nd sentence. The words *below ground surface (bgs)* could be inserted after the word *feet*.

Response: Agreed.

Comment 6. Section 2.6.4, 3rd paragraph, last two sentences. These statements are repeated from the 2nd paragraph, and do not appear necessary. Maybe the 2nd and 3rd paragraphs could be combined?

Response: Agreed.

Comment 7. Section 2.8, 2nd paragraph, 2nd sentence. It appears that the word *individuals* should be replaced with *receptors*.

Response: Suggest text use "individual receptors."

Response to U. S Army Corps of Engineers Review Comments
Draft Baseline Human Health Risk Assessment Work Plan
TNT Areas A and TNT Area C
Plum Brook Ordnance Works, Sandusky, Ohio
October 2000

General Note: USACE reviewers were Janet K. Wolfe and Frank R. Albert, Jr.

Comment 1. Acronyms. MDC. *Minimum* should be revised to *maximum*, per Section 2.1.1. (FA)

Response: Agreed.

Comment 2. Section 1.0 , 2nd paragraph, 1st sentence. A general question is posed regarding the utilization of the deep and bedrock aquifer systems for drinking water. "in the area" seems to infer the PBOW site, but on-site contamination could have migrated to the Sandusky public water supply, which may draw from these aquifers. Should statements be added to address the evaluation of off-site receptors following the evaluation of on-site receptors? (FA)

Response: It is true that the potential for groundwater contamination to migrate off site was not addressed. In fact, the paragraph in question is provided only as introduction to the site. All groundwater evaluation and the protocol for its risk assessment will be postponed to a pending groundwater investigation.

Comment 3. 4th paragraph, 1st sentence. General question. Is the residential scenario plausible for the PBOW site (have PBOW personnel stated that this potential exists)? Or is this scenario developed to determine potential impacts to off-site users of the potentially contaminated aquifer(s)?

Response: The residential scenario is plausible in that the sites are physically suitable for residential use. The likelihood of residential development, however, may be another matter. Most regulatory bodies require inclusion of a residential scenario to provide the upper bound on risk. Evaluation of the residential scenario is usually required for unrestricted release. Please refer to Item 5 in Section 1.2 of the Scope of Work (listed as USACE, 2000a and 2000b in the References section of the risk assessment work plan), which explicitly includes residential use as a scenario to be evaluate. The residential scenario is developed to evaluate risks from on-site exposure, not off-site exposures.

Comment 4. Section 2.1.2, Evaluating Data Quality. It is stated that if more than one analytical method is used to determine results for a parameter, only the results from the analytical method having the lower reporting limits will be used. A statement should be included indicating that the results chosen for use in the risk assessment will be based on, in addition to reporting limit levels, the data quality of the results and qualifiers assigned to the data. (JW)

Response: The evaluation of data quality, including which data will or will not be used in the risk assessment, was discussed in the preceding paragraphs in Section 2.1.2. However, the first

sentence in the section is not sufficiently clear; it will be revised as follows: "The quality of the analytical data will be evaluated to select data for inclusion in the RA. Data quality is expressed by the assignment of qualifier codes during the analytical laboratory QC process or during third-party data evaluation."

Comment 5. Section 2.1.6. For clarity, additional explanation or justification could be added to the statement that adjusting the soil RBSCs upward to arrive at sediment RBSCs and downward to arrive at surface water RBSCs will reflect cancer risk of 1E-7 and non-cancer hazard index of 0.1 for this media. (JW)

Response: This comment pertains to the second paragraph in Section 2.1.4. Agreed, the description of RBSC development for sediment and surface water are confusing. It focuses unnecessarily on the cancer risk and HI bases of the PRGs rather than the RBSCs. The sentences relevant for sediment will be combined and simplified as follows. "Therefore, the soil RBSCs are adjusted upward by an order of magnitude for application to sediment, and are considered to reflect a cancer risk of 1E-7 and an HI of 0.1 because exposure to sediment is far less intensive than exposure to soil." In the same manner, the description of the surface water RBSCs will be revised as follows. "Therefore, the tap water RBSCs are adjusted upward by an order of magnitude for application to surface water, and are considered to reflect a cancer risk of 1E-7 and an HI of 0.1 because exposure to surface water is far less intensive than exposure to tap water."

Comment 6. The last statement on page 2-5 that states "...if 2,4-DNT in the water in a creek meandering across area A are comparable to upgradient concentrations, it is probably appropriate to conclude that 2,4-DNT is not a site-related chemical..." should be revisited. This may not be a good example to use to illustrate a non-site related compound site since TNT Area A was used as a manufacturing site for DNT and it is unclear where the various lines were flushed or where or how flush water was disposed (see Section 3.1.1). (JW)

Response: We believe 2,4-DNT is a good example because it is a plausible site-related chemical. The point of the statement in question is that concentration is the appropriate criterion for selecting or deselecting a chemical as site-related. We agree, however, that the first sentence on page 2-6 is not sufficiently clear and should be revised as follows. "Although the chemical is clearly related to former PBOW activities and its presence in other media such as soil or groundwater may reflect activities that took place at that particular site, its presence in the creek probably does not."

Comment 7. 3rd paragraph, 3rd sentence, grammatical comment. The word *include* should be *including*. (FA)

Response: Agreed.

Comment 8. 4th sentence. Question. Would any value be added by stating that Plum Brook Station performs controlled burning in various areas at the former PBOW?

Response: Agreed; this is useful information that strengthens the position! The following will be inserted after the sentence in question: "Plum Brook Station under NASA control routinely

performs controlled burning in various areas of the former PBOW facility. This burning may release PAHs to the atmosphere that travel downwind and deposit on soil at other areas such as TNT Areas A and C."

Comment 9. Section 2.2.1, Soil, Surface Water, Sediment, page 2-9. It is stated that analytical results associated with elevated detection limits exceeding the MDC due to matrix interference of sample dilution may be eliminated from the data set and not used in the estimation of the STC. If data is eliminated, this may affect the completeness of the data. Language could be included that addresses this issue. (JW)

Response: The purpose of the work plan is to describe the protocol that will be used, in order to obtain agreement from all interested parties. The size of the data sets and the effect on completeness from the elimination of data points cannot be assessed at this time, but this is seldom a significant matter. The point to be made at this stage of the evaluation is that detection limits will be scrutinized before they are incorporated into a statistical procedure. However, data points that are eliminated will be discussed in the Uncertainty section. The following will be added as the last sentence in the last paragraph in Section 2.2.1: "The impact of eliminated data points on the adequacy of the data set and the risk estimates will be discussed in the uncertainty section."

Comment 10. Section 2.2.2.2. A statement could be provided that justifies using the default DAF factor of 20 rather than developing site specific DALs when screening STCs to BSCs and generic SSLs. (JW)

Response: As noted above in response to Comment 2, all groundwater evaluation and the protocol for its risk assessment will be postponed to a pending groundwater investigation.

Comment 11. It is stated on page 2-11 that, for the DAF equation, default values from EPA or other sources will be used it site-specific values are unavailable. This could be interpreted as using a default DAF factor rather than calculating a site-specific number. You may want to revise to clarify that the default factors will not include the DAF factor. (JW)

Response: Please see response to Comment 10.

Comment 12. Section 3.1.1.1, last paragraph. It should be noted that the Engineering Building is located in the central portion of former TNT Area A and occupied by NASA employees. (FA)

Response: This is useful information. The following will be inserted as the penultimate sentence on page 3-2: "The Engineering Building is located in the central portion of TNT Area A and is occupied currently by NASA employees."

Comment 13. Section 3.1.1.2. You may want to state that there are no buildings nor use of TNT Area C by PBS to differentiate its use from that of TNT Area A (i.e., probability of office worker exposure at TNT Area A, but no current probability at TNT Area C). (FA)

Response: This is useful information. The following will be inserted as the second sentence of the second paragraph on page 3-3: "There are no buildings on site and the area is not currently used by NASA."

Comment 14. Section 3.1.2, 4th sentence. Should the term *sellite* be defined as *sellite (sodium sulfite, made from soda ash and sulfur)* since readers may not be readily familiar with this product? (FA)

Response: Excellent suggestion! The term "sellite" will be replaced with "sellite (sodium sulfite made from soda ash and sulfur)."

Comment 15. Section 3.1.3.1, 4th paragraph, 4th sentence. Question. Is direct contact with shallow groundwater not plausible because there is no evidence that it exits to the surface? (FA)

Response: The answer to the question is yes; contact with shallow groundwater is not plausible because it does not discharge to the surface. At the point that groundwater discharges to the surface it is considered to be surface water for the purposes of exposure evaluation.

Comment 16. Section 3.1.3.3, 6th paragraph, 4th sentence. The words *arms, forearms, and hands* are used. Should the word *arms* be *face* since this is exposure to a construction worker, and it is assumed that the head is covered with a hardhat? (FA)

Response: The paragraph in question describes construction worker exposure to surface water. The original assumption is exposure to arms (i.e., region associated with the femur), forearms (region associated with ulna and radius) and hands. Although exposure of the head and face is possible, it is more likely that the construction worker would choose to use potable water to rinse these body regions. No revision will be made.

Comment 17. 10th paragraph, 1st sentence. It appears that trenching and installation of underground utilities provides exposure to *soil* as well as *shallow groundwater*.

Response: Agreed, which is why the sentence says *significant* but not *primary* exposure to shallow groundwater. The sentence in question, however, will be revised to remove reference to shallow groundwater (please see response to Comment 10).

Comment 18. Section 3.1.3.6, 1st paragraph, 1st sentence. Should the phrase *site workers* be revised to *receptors*? Also, what is the difference between *office workers* and the indoor worker, referenced in Section 3.1.3.2? It is noted that there are office (indoor?) workers in the Engineering Building at TNT Area A. (FA)

Response: Agreed; this sentence is hopelessly confused as written – the failure to sufficiently refine boiler plate to fit the present situation. The first two sentences of this paragraph will be revised as follows: "Another plausible receptor group is delivery personnel. These receptors, however, would be less…"

Comment 19. 2nd paragraph. Although the off-site resident is not evaluated, is it not possible that off-site residents may have already been exposed to contaminated groundwater that has been

leaving the PBS property since the TNT manufacturing days? Should this paragraph be expanded to state when evaluation of off-site receptors might be performed, or is this covered with modeling/extrapolation of the effects to on-site receptors?

Response: Please see response to Comment No. 10.

Comment 20. Section 3.2.1.1, COPC Concentrations from Dust. The assumption that construction activities requiring intimate contact with soil for which D = 6E-4g/m^3 is appropriate may last for one-half of a construction period may result in underestimation. Activities such as excavating for environmental remediation may be more time intensive during a construction period. This issue could be revisited. (JW)

Response: The construction worker scenario is necessarily fraught with a great deal of uncertainty. No information is available regarding the most likely kinds of construction projects, and no guidance is provided by the EPA, USACE or OEPA for developing exposure assumptions (except for the upper estimate for soil ingestion provided by EPA). Therefore, essentially all construction worker exposure assumptions are based largely on hypothecation. The dust loading factors, however, are generally considered to be very conservative. Furthermore, the difference between the factors for intensive and less intensive exposure is less than an order of magnitude, which is small given the uncertainty about these estimates. It seems unlikely that the apportionment of time between intense exposure and less intense exposure to dust in air will contribute to any significant underestimation of risk. The uncertainty about exposure modeling parameters will be discussed in the Uncertainty section.

Comment 21. Section 3.2.1.2, page 3-18, bottom of page. The statement is made that no buildings are currently present on site; however, the Engineering Building, occupied by NASA is located in the central portion of TNT Area A. (FA)

Response: The actual presence of buildings is immaterial because the parameters required are difficult to measure and standard criteria are not available, and the present office building may not reflect houses and other buildings that may be built in the future. The first two sentences of the last paragraph on page 3-18 will be revised as follows: "Some of the building characteristics required for Equation 3.6 can be estimated from data provided for the potable-water-to-air volatilization model in Section 3.2.1.4."

Comment 22. Section 4.1, page 4-3, 2nd paragraph. The words *per kilogram* should be inserted after the words *per milligram(s)*. (FA)

Response: Agreed.

Comment 23. Section 5.0, 4th paragraph, 3rd sentence. The word *to* should be revised to *the* where it states *Therefore, in this section....to describe* ***the*** *potential for the occurrence of cancer.* (FA)

Response: Agreed.

Response to Comments
U. S. Army Center for Health Promotion and Preventive Medicine
Draft Baseline Human Health Risk Assessment Work Plan and
Draft Baseline Ecological Risk Assessment Work Plan
Remedial Investigations and Feasibility Studies
TNT Area A and TNT Area C,
Plum Brook Ordnance Works, Sandusky, Ohio
September 2000

Baseline Human Health Risk Assessment Work Plan Comments

1. Page 1-2, Section 1.0, L. Tannenbaum
   Introduction

   Comment: The bullet points on this page raise a few questions. First, there seems to be an overlap of the first two bullet points. For all intents and purposes, if a location has "no land use restrictions", then this is no different than saying that there will be residential use of that location. What is the difference between "Portions of the site" and "Parts of the facility"? Also, are the portions or parts of the facility that these bullet points mention, specifically known?

   Recommendation: Please address the need for clarifications regarding the information of the bullet points. Regarding the comment's last point, if for certain areas it *is* known that they will or could support residents, then these areas (only) should be evaluated under a residential exposure scenario.

   Response: The purpose of the bullets is to communicate the spectrum of potential future site uses identified by USACE in the SOWs for TNT Areas A & C, regardless of apparent overlap in the site uses and the receptor exposure scenarios developed to address them. In other words, the bullets are not intended to reflect the receptor exposure scenarios developed later in the work plan; rather, they provide the documentation. The overlap observed by the reviewer is dealt with in the first sentence in the summary below the bullets.

   Agreed, the difference between "Portions of the site" and "Parts of the facility" is not clear. The facility refers to the entirety of the former Plum Brook Ordnance Works; site refers to the area(s) under investigation. The first sentence of the third paragraph on page 1-1 will be revised as follows: "In this risk assessment work plan (RAWP) the term 'facility' refers to the entire former PBOW property, and the term 'site' refers to an area within PBOW under investigation, in this case TNT Area A or TNT Area C. Current use of the PBOW facility is classified…"

   The portions of the facility to which these bullets refer are not exactly known at this time. We disagree, however, that residential exposure evaluation should be reserved for *only* those portions that will or could be used for residential development. As implied by the reviewer, residential exposure evaluation is appropriate for *any* site for which no site-use restrictions are desired.

2. Page 1-2, Section 1.0, L. Tannenbaum
   Introduction

   Comment: The next-to-last guidance that is cited on the bottom of the page, has been greatly improved on.

   Recommendation: Please consider expanding the list of guidance documents to include EPA's 1997 multi-volume Exposure Factors Handbook.

   Response: The RAWP for TNT Areas A & C followed risk assessments for the Red Water Ponds Areas and TNT Area B, both of which had been reviewed by OEPA. One of the desires was to maintain consistency with the previous efforts, in part to capture the potential economy of scale and to facilitate regulatory approval. Generally, OEPA accepts the EPA (1991) *Standard Default Exposure Factors*, which continues to be cited as the primary guidance reference. It should be noted that consistency was not strived for at the expense of quality. The 1997 *Exposure Factors Handbook*, although not listed as a primary guidance document, was used to update some of the exposure variable values (please see Table 3-2) and is listed in the References section.

3. Page 2-1, Section 2.1.1, L. Tannenbaum
   Sorting the Analytical Data

   Comment: There are two difficulties in this Section's first paragraph. First, the soil data should be of two discrete zones. Although it is true that a construction or excavation worker might be exposed to soil of the continuum of 0 to 10 feet below ground, other receptors are not exposed to soil below the top foot or so. Second, the use of the term STC is troublesome here and in most other portions of the document (e.g., in Section 2.2.1, page 2-9). It appears at times be different from the exposure point concentration (epc), and at other times it appears to be used interchangeably with epc.

   Recommendation: Ensure that a distinction is made between surface and subsurface soil, specifically having the subsurface soil collections beginning at the lower end of the surface zone (here defined as 1 foot below ground surface). Do not evaluate a resident for exposure to soils of the 1 to 10 foot zone. If STC is to be maintained in the subject document, limit its usage to only the soil concentration that is a concern because of its potential to give rise to contaminated groundwater as a result of percolation through the soil strata. Only in this regard is there a "source" term.

   Response: Agreed that the distinction between surface and subsurface soil is not entirely clear. The second sentence in this section will be revised as follows: "Surface soil (0 to 1 foot below ground surface [bgs] and subsurface soil (starting at 1 foot extending to 10 feet bgs…"

Please see response to Comment 2 regarding OEPA review of previous PBOW risk assessments and consistency. The soil evaluations proposed in the RAWP reflect agreement with OEPA. Moreover, we disagree that the resident would not be directly exposed to subsurface soil. Residential development would necessitate grading at least, and may involve excavation for a basement, in which case subsurface soil would be brought to the surface.

We agree that several terms (COPC, STC, EPC, COC) introduced but not defined in Section 1.0 may be troublesome. They will be defined where they first occur. Therefore, the last paragraph of Section 1.0 will be revised as follows:

"The remainder of this document is organized as follows. Section 2.0, Data Evaluation, describes the selection of chemicals of potential concern (COPC) for each medium of interest, and estimation of source-term concentrations (STC) for each COPC in each medium. (Please note: to increase clarity, the acronym COPC will be used for the singular, and COPCs will be used for the plural.) COPCs are the chemicals that are identified as site-related (Section 2.1.5), potentially capable of contributing significantly to risk (Section 2.1.6), and are carried forward to quantitative evaluation in the RA. The STC is a conservative estimate of the average concentration of a COPC statistically calculated (Section 2.2) from the analytical results of all samples for a particular environmental medium, such as surface soil. It is the concentration to which receptors are exposed during *direct* contact with the medium, such as dermal contact with surface soil. The STC is also used as the input concentration for transport models that estimate concentrations in *indirect* media. For example, the STC in soil is input into the dust loading equation (Equation 3.1, Section 3.2.1.1) to estimate the concentration of COPC in dust-laden air."

"Section 3.0, Exposure Assessment, describes the exposure scenarios and the rationale by which plausible receptors are selected, the pathways by which they may be exposed, the exposure-point concentrations (EPC) of the COPCs, and the estimated dose or contact rates for each of the COPCs. The EPC is the concentration of chemical in an environmental medium to which receptors are exposed. Since it is calculated as a conservative estimate of average, it is identical to the STC when used for *direct* exposure pathways, such as dermal contact with surface soil. It is calculated with transport models for *indirect* exposure. In the example in the previous paragraph, the output from the dust loading equation is the EPC in air of a COPC identified in soil. It is assumed to reflect a conservative estimate of average because it is based on the STC, which is a conservative estimate of average."

"Section 4.0, Toxicity Evaluation, describes the adverse health effects associated with each of the COPCs, and the dose-response evaluation, i.e., the relationship between dose or contact rate and the magnitude of the adverse effect."

"Section 5.0, Risk Characterization, combines the output of the exposure analysis and the toxicity analysis to quantify cancer risk and noncancer hazard to each receptor, identifies chemicals of concern (COC), identifies applicable or relevant and appropriate requirements (ARAR) for the COCs, and develops risk-based remediation criteria (RBRC) for the COCs. (Please note: to increase clarity, the acronym COC will be used for the singular, and COCs will be used for the plural.) COCs are the chemicals that contribute significantly to

unacceptable risk or hazard estimates. ARARs are standards, criteria, guidelines or recommended concentrations from relevant federal and state environmental laws. They may or may not be entirely or partially risk based. RBRCs are concentrations which, if left in place, will not result in unacceptable risk estimates for the receptor scenario on which they are based.

"Section 6.0, Uncertainty Analysis, describes the uncertainty associated with the components of the RA. Section 7.0, Summary and Conclusions, briefly summarizes the RA protocol and results and interprets the results, in light of the uncertainty about their estimation, to draw realistic conclusions regarding risk to human health. Section 8.0, References, presents the references used in the preparation of this document."

In addition, the first paragraph in Section 2.1 will be revised as follows: "COPCs are the chemicals that are identified as site-related, potentially capable of contributing significantly to risk, and are carried forward to quantitative evaluation in the RA. The following subsections describe their identification." The following will be inserted as the first two sentences in Section 2.1.1: "Prior to initiation of an RA, a list of chemicals present in site samples will be compiled. This initial list includes all chemicals detected in any site medium."

The following will be inserted directly under ***2.2 Developing Source-Term Concentrations***: "The STC is a conservative estimate of the average concentration of a COPC statistically calculated from the analytical results of all samples for a particular environmental medium."

The first sentence in Section 3.2 will be revised as follows: "The EPC is defined as the concentration of COPC in an environmental medium to which a receptor is exposed. It is computed as a conservative estimate of average and is used to calculate COPC intake rates (Section 3.3). EPCs of COPCs in soil, surface water and sediment to which receptors are directly exposed are mathematically equivalent to the STCs, which were also computed as conservative estimates of average (Section 2.2). EPCs are calculated for indirect exposure media (e.g., air) by using STCs for the concentration terms in the equations that follow. The EPCs thus calculated for the indirect exposure media are considered to be conservative estimates of average."

4. Page 2-2, Section 2.1.1, L. Tannenbaum
   Sorting the Analytical Data

   Comment: The page's second sentence requires a modification.

   Recommendation: Please modify the sentence as: " . . . and the risk estimates or hazards are clearly . . ."

   Response: Throughout the document we speak generically about a risk assessment or risk estimates. We do not use the term "risk and hazard assessment," or distinguish cancer risk from noncancer hazard until the risk characterization section, where the distinction comes into play and is adequately explained (please see fourth paragraph on page 5-1). We feel that

to introduce the distinction here is unnecessary, would be distractingly verbose, and would require additional editing to ensure consistency (e.g., two sentences beyond the one mentioned by the reviewer would require the same revision).

5. Page 2-3 and 2-4, Section 2.1.4, L. Tannenbaum
   Risk-Based Screening

   Comment: The Army is consistent in its approach to risk-based screening, and where carcinogens in environmental media are being screened for inclusion in a risk assessment, the corresponding fixed level of risk is always 1×10^{-6}, not 1×10^{-7}. Using 1×10^{-7} is an unnecessary and overly conservative assumption that is inconsistent with mainstay EPA risk assessment practices. Use of the 1×10^{-7} screen will result in an excessively long list of chemicals being carried through a risk assessment, that will not be contributing sizably to the final cancer risk estimate. Second, the document describes a process whereby the risk assessment will use "residential" soil RBSCs only in determining COPCs. Since there will be both residential and non-residential site users, the "residential" numbers should only be used for the receptors for which they were developed. Similarly, industrial/non-residential numbers should be used for the COPC screening for construction workers, excavation workers, etc. Thus, there should necessarily be different COPC lists for the different receptor groups. Third, RBSCs should not be applied to surface water, especially when the document mentions that surface water is not expected to be used, and because the Erie County Health Department does not permit using surface water as private drinking water (page 1-1). Last, the Section's final paragraph is out of place as it is discussing screening levels within an ecological context.

   Recommendation: Please make the necessary text modifications regarding the proposed COPC screening using RBSCs that have a corresponding 1×10^{-7} cancer risk level. Consider replacing the 1×10^{-7} screen here and wherever else in the subject document it appears with 1×10^{-6} screen. If the 1×10^{-7} screen is to remain, caveat the text to the effect that it is Ohio EPA policy to use this screen and that the Army does not employ it. Ensure that the risk assessment does not only use "residential" RBSCs in screening for COPCs. Ensure that drinking water exposures for surface water are not evaluated. (See Comment #8.) Remove the Section's last paragraph, as the information is relevant to the ecological risk assessment work plan.

   Response: Agreed, that basing RBSCs on a cancer risk of 1E-7 is inconsistent with EPA and Army risk assessments. Whether it is "overly conservative," however, is a matter of opinion with which OEPA disagrees. We agree with the need to clarify the reason for the 1E-7 basis, but feel that nothing is gained by stating that the Army does not use it. The following will be added after the first sentence in the second paragraph in Section 2.1.4: "A cancer risk of 1E-7 is chosen to be consistent with OEPA's policy to quantify the risk of any chemicals that may contribute to a total cancer risk estimate above 1E-6, which is considered to be a point of departure. An HI of 0.1 is chosen to provide additional protection for simultaneous exposure to multiple chemicals."

We do not agree with the advisability of developing receptor-specific COPC lists. The industrial soil RBSCs may not be sufficiently conservative for all non-residential receptors. For example, the industrial soil RBSC is based on a soil incidental ingestion rate of 50 mg/day, but the groundskeeper is assumed to ingest 100 mg/day and the construction worker is assumed to ingest 290 mg/day.

We understand the reviewer's discomfort with using RBSCs to select COPCs in surface water; however, we do not feel that protectiveness is compromised. Exposure to surface water by the construction worker and the resident is limited to dermal contact, and there are no PRGs or other risk-based concentrations based on dermal exposure from which appropriate RBSCs can be developed. The use of modified tap water PRGs is based on the assumption that drinking water consumption represents greater exposure than dermal contact, and reflects the outcome of negotiations with OEPA. The alternative is to apply no RBSCs and select all chemicals in surface water as COPCs. Since we do not believe protectiveness is compromised, and since we believe OEPA will accept the approach, we will continue to use the modified tap water RBSCs.

The reviewer states that the final paragraph in this section is out of place because it is relevant to ecological risk assessment. Actually, it is not relevant to ecological risk assessment, because it does not address the health of aquatic organisms. It addresses exposure involving human consumption of fish, which is relevant for the human health risk assessment. Confusion about that point will be removed by revising the second sentence to read as follows: "The soil RBSCs, however, may not be sufficiently conservative to screen sediment in water bodies from which fish are harvested for human consumption, because…"

6. Page 2-5, Section 2.1.6, L. Tannenbaum
   Identifying Site-Related COPCs

   Comment: The three-risk assessment approach is to be discouraged, as it is not standard procedure for risk assessments within the Army. In short, background is given full consideration in risk assessments when constituent concentrations are used in the COPC screening process (i.e., to determine what are those constituents that rightfully should be carried through a risk assessment). There is no need to calculate a risk level associated with background, and even contemplating doing so demonstrates a basic mistrust, i.e., it entertains the notion that even background is not safe.

   Recommendation: Do not perform the three independent risk assessments as described. Instead follow RAGS methodology, and express the site risk for those chemicals that present in onsite media at concentrations that are statistically greater than in background. See Comment #12.

   Response: Agreed, that calculating separate risk estimates for background and site-related chemicals is not standard Army procedure. It was incorporated in the RAWP because OEPA policy at that time did not permit comparison with background for COPC selection. This approach, however, is not inconsistent with RAGS Part A, which states that chemicals present at background levels *may* (but not *must*) be eliminated from the risk assessment (page

5-19). RAGS Part A further states (page 5-19), "In some cases…background concentrations may present a significant risk, and…the background risk may be an important site characteristic to those exposed. The RPM will always have the option to consider the risk posed by…background chemicals *separately* (emphasis added)." In other words, estimating background risk separately, as proposed in the RAWP, is not inconsistent with RAGS.

The reviewer states that even contemplating estimating risk separately for background demonstrates mistrust; i.e., a suspicion that background risk estimates may exceed acceptable limits. The reason for associating unacceptable background risk with mistrust is unclear. Background risks exceeding acceptable limits is a common occurrence and has nothing to do with trust (note the quote from RAGS Part A in the previous paragraph). Background concentrations of several chemicals, including aluminum, arsenic, iron and manganese (and PAHs, when anthropogenic background data are available) regularly exceed acceptable risk-based limits. If an accusation of mistrust should be directed anywhere, it should be directed at overly conservative exposure assumptions and toxicity values.

Fortuitously, recent negotiations between the USACE risk assessor and OEPA resulted in modification of OEPA policy so that ambient concentrations now can be compared with background concentrations (metals only) to deselect chemicals from the COPC list. Section 2.1.6 will be renumbered as 2.1.4 (to precede description of risk-based screening) and will be rewritten to reflect the new policy. The protocol for the three separate risk assessments will be removed and the remaining text revised to state "site-related chemicals" rather than "site-related COPCs." Section 2.1.4 will be renumbered as 2.1.5, and Section 2.1.5 will be renumbered as 2.1.6. The renumbering reflects the appropriate order for steps in COPC selection: comparison with background to select site-related chemicals should precede risk-based screening.

The third paragraph in Section 5.0 will be deleted. The following will be added as the first sentence in the fourth paragraph: "Risk characterization is limited to those site-related chemicals selected as COPCs; i.e., present at concentrations that exceed RBSCs (Section 2.1.5)."

7. Page 2-9, Section 2.2.2.1, L. Tannenbaum
   Current Ground-water Conditions

   Comment: The concentrations of the most contaminated part of a ground-water plume is a biased measure, and should not be used in crafting an epc.

   Recommendation: Ensure that epc for ground-water constituents are based on the concentrations of all portions of a plume, averaged in an unbiased manner.

   Response: The implication that biased measures, estimates or assumptions should not be used in a risk assessment is contrary to the EPAs reasonable maximum exposure (RME) paradigm and accepted practice. For example, estimates of exposure frequency, exposure duration and intake rate are intentionally selected as upper bounds, deliberately imparting a

conservative bias to the risk assessment. STC or EPC estimations are predicated upon two basic assumptions:

- Data included in the estimation reflect the spatial area over which the receptor is expected to be randomly exposed.

- The estimated value is intended as a conservative estimate of average.

The latter is clearly biased toward protectiveness. A UCL of the mean is generally used for STC estimations for soil, surface water or sediment, because a data set can be identified that reflects the spatial area over which a receptor is expected to be randomly exposed. Generally, such a data set cannot be identified for groundwater data, because a well could be installed any place, such as the most contaminated part of the plume. In this case, including all the groundwater data in the EPC estimation as suggested by the reviewer would not be sufficiently protective. The method proposed in the RAWP is consistent with EPA guidance.

As a practical matter, groundwater will not be evaluated at this time. All references to the protocol for the groundwater evaluation will be removed from the work plan. The protocol for the groundwater evaluation will be developed at a later time.

8. Page 3-5, Section 3.1.3.1, L. Tannenbaum
   Groundskeeper

   Comment: The text states that "direct contact with shallow ground water is not plausible and is not considered further." However in Table 3-2 (page 6 of 8), exposure assessment variables are provided for one receptor to be evaluated in the forthcoming assessment.

   Recommendation: Ensure that all exposure assessment and other information supporting a dermal assessment for exposure to shallow ground water is removed from the work plan.

   Response: Please see response to Comment 7; all details of the groundwater evaluation will be removed from the work plan.

9. Page 3-8, Section 3.1.3.3, L. Tannenbaum
   Construction Worker

   Comment: Since construction projects are assumed to last 6 months, and a construction worker is on site for 250 days per year, realistically, he or she would be working on two independent projects on the installation (i.e., on entirely different land parcels) in the course of a given year. Will the risk assessment reflect that soil epcs for the construction worker are based on a mix of at least two discrete areas (i.e., land parcels)?

   Recommendation: Please provide an indication of any planned pro-rating of soil epcs for the construction worker in light of that individual's geographically varied exposures.

Response: The construction worker assumptions presented in the RAWP reflect discussions between USACE and OEPA. Construction projects are expected to be infrequent. It is assumed that the construction worker participates in only one construction project on the site, obviating the need to pro-rate EPCs to reflect multiple projects. The following will be added after the first sentence in Section 3.1.3.3: "Construction projects are expected to be infrequent. It is assumed that the construction worker participates in only one construction project on the site."

10. Pages 3-9 and 3-10, Section 3.1.3.3, L. Tannenbaum
    Construction Worker

    Comment: The text acknowledges that there is likely to be some double counting in the exposures of construction workers. How then will recognition of this phenomenon impact on the interpretation of risk and hazard findings, should they come out being unacceptable?

    Recommendation: Please address the query.

    Response: The last sentence in Section 3.1.3.3 will be replaced with the following: "Should construction worker risk estimates exceed acceptable limits, alternative risk assessment(s) will be performed using refined exposure assumptions based on the physical characteristics of the site. For example, an upland excavation and building project may be assumed for one or more areas of the site, a stream rerouting project may be assumed for another, and an underground utilities ditch may be assumed for yet another. This approach will more precisely reflect plausible exposure scenarios, reduce the likelihood of double counting, and more accurately identify risk-driving media and chemicals."

11. Page 3-13, Section 3.1.3.5, L. Tannenbaum
    Hunter

    Comment: With a total estimated exposure duration of only 14 days, it may not be appropriate to evaluate a hunter's exposure for incidental soil ingestion exposures (although venison consumption may very well be appropriate) to track. A 14-day exposure can barely be considered to be chronic, and therefore, one would knowingly be pursuing a path where chronic toxicity data will be applied in a sub-chronic context, a situation to be avoided. Also, enough Army studies have been conducted to demonstrate that deer do not load soil-borne chemicals into their tissues (edible portions). Evaluating the venison consumption pathway would seem to be unnecessary.

    Recommendation: Consider removing the work plan (and risk assessment), the evaluation of incidental soil ingestion for the hunter. Consider dispensing with the evaluation of risks and hazards from the venison consumption pathway, and instead reference the published Army studies that evaluated contaminant uptake in deer.

    Response: The hunter scenario is included in order to address a plausible food-chain pathway for TNT Areas A & C. The 14-day direct exposure evaluation is included so that no relevant pathways are excluded from the risk sums for the receptor. Agreed, that direct

exposure to soil on 14 days is more appropriately considered subchronic than chronic. This will have no effect on cancer risk estimates because cancer risk is based on cumulative dose averaged over a lifetime. However, it probably will lead to overestimating noncancer hazard. Technically, it would be more appropriate to use subchronic RfDs rather than chronic RfDs for the noncancer evaluation. However, EPA provides subchronic RfDs that differ from chronic RfDs for very few chemicals, and none of the subchronic RfDs are verified. In most cases, the chronic RfDs are simply adopted as the subchronic RfDs. Therefore, chronic RfDs will be used to evaluate direct exposure to soil, but the conservative bias imparted to the noncancer results will be discussed in the uncertainty section.

Agreed, that quantifying indirect exposure to soil by venison consumption is unlikely to yield significant risks. (In our experience, this pathway yields significant risks only when dioxins/dibenzofurans, PCBs or organochlorine pesticides are involved.) Including the pathway, however, allows demonstration of its insignificance, makes the risk assessment a more informative document, assuages any concern, warranted or otherwise, about the significance of the pathway, and reduces uncertainty about the site. The reviewer states that Army studies demonstrate the insignificance of this pathway, but references were not provided nor did were examples submitted with the comments. The hunter scenario will be evaluated as proposed in the RAWP.

12. Page 5-1, Section 5.0, L. Tannenbaum
Risk Characterization

Comment: Characterizing risk for chemicals that exceed RBSCs although the concentrations are comparable to background, is not consistent with RAGS methodology, contrary to what is stated here. Recall again (Comment #6) that there need not be a worry that background risk is being obscured, because RAGS methodology takes full note of chemical concentrations in background environmental media when establishing site COPCs.

Recommendation: Do not express risks for the background condition. Refer to Comment #6.

Response: Please see response to Comment No. 6.

Baseline Ecological Risk Assessment Work Plan Comments

13. General Comment, L. Tannenbaum

Comment: In several places, the text implies that ground water is to be screened against surface water benchmarks for ecological protection (e.g., page 3-7, first full Section). This is an inappropriate thing to do. Although it is true that ground water may discharge to surface water, and influence other water bodies, the appropriate way to address the concern (of contaminants in ground water affecting aquatic ecological receptors) is by sampling the receiving water body, and screening its concentrations.

Recommendation: Remove all references to the application of aquatic benchmarks to ground-water chemical concentrations, regardless of a dilution factor being factored in or not.

Response: There may be instances where shallow groundwater is discharging to surface water and no surface water samples were collected. In this situation, it would be appropriate to screen the shallow groundwater data using surface water benchmarks. Text will be altered to indicate that this aforementioned approach will be followed, and that at no time will groundwater concentrations be screened against surface water benchmarks when either surface water data are available or when groundwater is not discharging to the surface.

14. Page 1-1, Section 1.0, M. Hawkins
    Introduction

    Comment: "The BERA is more appropriately termed a screening-level ecological risk assessment." I would omit any use of BERA and simply state that this is a screening-level risk assessment.

    Recommendation: Please prevent confusion to the reader by omitting BERA from the introduction and simply use SLERA.

    Response: There is some confusion in using the term SLERA at the onset because an ERAGS SLERA is not strictly followed. The primary guidance document used in preparation of the Work Plan was the Tri-Service Procedural Guidelines (Wentsel et al., 1996), not ERAGS (USEPA, 1997). A SLERA implies maximum exposure point concentrations will be used and worst-case exposure parameters, when if fact this is not the case, as shown in Section 2.6.2. Recommend no text change.

15. Page 2-2, Section 2.2, M. Hawkins
    Pre-Assessment Reconnaissance (Biota Checklist)

    Comment: "Observations of fauna will be made." Will a biologist or ecologist be performing the qualitative evaluations? What time of the year (or day for that matter) will the qualitative assessment be performed and what is the duration of the assessment. Will qualitative observations be performed during different seasons? In other words, will there be multiple site visits for observations?

    Recommendation: Please provide additional information for the qualitative assessments.

    Response: Qualitative observations to be performed by a biologist or ecologist. In addition, a botanist will search for threatened and endangered plant species. Two botanical surveys will occur (in the spring and in the late summer/fall). Assessment durations will typically be about one day per site. It is important to note that PBOW has had extensive wildlife surveys performed by NOAA (1995), thus there are very detailed species lists available for multi-seasonal assessments. Text will be modified to add the previous information.

16. Page 2-7, Section 2.6.4, M. Hawkins
Natural Site Constituents (Background and Essential Nutrients)

Comment: Natural background was identified in the first paragraph; however, it wasn't clear from where the background information was obtained (i.e., from sources, from reference sites) until the third paragraph that stated "background data will be taken from Statistical Evaluation of Soil Data and represents background data collected by both IT and Dames and Moore (1997)." It would be useful to mention this up front in the first paragraph. Also, the last two sentences of the third paragraph (e.g., "Chemicals with MDCs less than background UTL will be eliminated from further consideration. If the MDC exceeds the UTL, the chemical will be retained as a COPEC.") can be omitted since this information is mentioned in the second paragraph.

Recommendation: Please explain where the background information was obtained in the first paragraph and delete it from the third paragraph. Also, delete the last two sentences of the third paragraph.

Response: Text will be changed as requested.

17. Page 2-9, Section 2.6.5, M. Hawkins
Comparison of Risk-Based Screening Ecotoxicity Values

Comment: A hierarchy approach for choosing Soil, Surface Water, and Sediment benchmarks would be appropriate. Given that several sources are used to select benchmarks, which source would be first choice, second choice, and so on? Additionally, several sources are available for use in selecting Soil, Sediment, and Surface Water benchmarks; however, only a few were mentioned. Please clarify why other sources were not used for benchmark selection.

Recommendation: Please develop a hierarchical approach to selecting benchmarks and either provide a rationale for only selecting a few sources, or provide other sources for use in selecting benchmarks.

Response: OEPA has recommended a hierarchical approach for selecting benchmarks, and this approach has been accepted with a few caveats. Please see response to OEPA Comment No. 16.

18. Page 3-6, Section 3.1, L. Tannenbaum
Exposure Analysis

Comment: The first sentence under "Sediment Exposure Pathway" is misleading. Sediment is the natural substrate of aquatic systems. The text here though, makes it appear as though it is mostly if not exclusively comprised of the site contaminants of concern.

Recommendation: Please consider rewording the sentence.

Response: Sentence will be reworded as follows: Sediment generally consists of soil or other materials settled out of suspension in surface water or native soils underlying flowing or standing surface water bodies.

19. Page 4-1, Section 4.1, M. Hawkins
Selection of Literature Benchmark Values

Comment: Other sources for selection of toxicological benchmarks for wildlife exist and include: the U.S. Navy (1997), in consultation with the U.S. EPA Region IX Biological Technical Advisory Group report, and a review of these toxicological benchmarks by CH2MHILL (2000). It is advisable to include these particular sources in your literature search for toxicological benchmarks for wildlife, as they are updated sources.

Recommendation: Please consider including the most recent sources for the selection of wildlife toxicological benchmarks in this section.

Response: Both of these references will be added to the Work Plan and their use will be considered. It should be noted that the U.S. Navy document was updated in 1998. It should also be noted that Navy guidance and U.S. EPA Region IX guidance do not strictly apply to PBOW, thus these two guidance documents may only be used for a COPEC when there is no available benchmark from Sample et al (1996).

20. Page 4-2, Section 4.2, L. Tannenbaum
Development of Reference Toxicity Values

Comment: The text at the bottom of the page, regarding body weight scaling for birds is potentially misleading. Because the exponent in the equation provided is to be 0 for the birds, the $NOAEL_W$ will be no different that the $NOAEL_T$.

Recommendation: Modify the last sentence before the equation as: ". . . factor of 0 will be used for birds, making the $NOAEL_W$ for birds the same as the $NOAEL_T$."

Response: Text will be changed as requested.

21. Figure 4-1, L. Tannenbaum

Comment: The original citation for the Figure (i.e., Ford et al.) should be provided here. Also, the nature of the "adaptation" of the Figure should be provided. Was the adaptation simply that the Figure was reprinted, or were any of the multipliers, etc. changed?

Recommendation: Please address the points raised in the comment.

Response: A citation for Ford et al. could not be found in the TriService document, from which Figure 4-1 was adapted. The adaptation that was used included correcting the

multiplier sign. The TriService document incorrectly shows a multiplication sign, whereas a division sign should be used (this was verified with study authors).

22. Page 5-1, Section 5.1, L. Tannenbaum
Risk Characterization

Comment: The text on HQs should give needed attention to the shortcomings of HQs.

Recommendation: Please expand the Section's first paragraph to indicate at a minimum that HQs are not risk measures, are not population-based statistics, and are not linearly-scaled statistics.

Response: Text will be changed as requested.

23. Page 6-1, Section 6.0, M. Hawkins
Risk Summary and Identification of Preliminary Remedial Action Objectives

Comment: "Finally, IT will develop site-specific remedial action objectives for the sites." Why develop site-specific remedial action objectives when you don't even know if risk exists at the sites. I would recommend initiating further site investigations via fieldwork (e.g., small mammal sampling, vegetative work), and then, based on field results, determine whether or not the chemicals at the sites pose risk to the receptors of interest.

Recommendation: Please omit the last sentence of the paragraph since it is too soon to tell whether remedial action objectives are necessary.

Response: We recommend the last two sentences should be modified as follows, as further site investigations may be more costly than cleanup to site-specific remedial action objectives.

"Additional, IT will make recommendations for further risk investigations, if appropriate and cost effective and may develop site-specific remedial action objectives for the sites, if warranted."

References

CH2Mhill, 2000, Review of the Navy-EPA Region 9 BTAG Toxicity Reference Values for Wildlife, Prepared for the U.S. Army Biological Technical Assistance Group and the U.S. Army Corps of Engineers.

Navy (Department of the Navy), 1997, Development of Toxicity Reference Values as Part of a Regional Approach for Conducting Ecological Risk Assessments at Naval Facilities in California, Engineering Field Activity West, Naval Facilities Engineering Command, San Bruno, California.

RESPONSE TO OHIO ENVIRONMENTAL PROTECTION AGENCY COMMENTS ON BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT WORK PLANS FOR RI/FS OF TNT AREAS A & C

Comments from R. Nabors, Site Coordinator, Division of Emergency and Remedial Response received January 11, 2001.

Comment 1: **Section 1.0 Introduction, page 1-1. The work plan states that current site use of the Plum Brook Ordnance Works (PBOW) is classified as industrial for the purposes of the human risk assessment at TNT Areas A and C. However, Section 1.0, page 1-2 states that future site use of TNT Areas A and C is considered industrial or residential for the purposes of the risk assessment. If portions of PBOW may be used for future residential purposes, then the risk assessment must be based on an evaluation of a residential scenario for the purposes of identifying receptors and exposure scenarios.**

Response 1: Agreed; the on-site resident is included as one of a number of plausible receptors under future site use as indicated throughout Section 3.0.

Comment 2: **Section 2.1.2 Evaluating Data Quality, Second Paragraph, page 2-3. The text states that "Only the results from one sampling method for each chemical will be used in the RA." The appropriate analytical method for each chemical must be determined and applied consistently at this site. The sampling and analysis plan must be submitted approved prior to data collection and analysis.**

Response 2: The SAP has been submitted and approved. Some overlap in chemicals analyzed by different analytical methods is not unusual. This issue was not addressed in the SAP because the need to choose between the results of different analytical methods does not become apparent until the results become available.

Comment 3: **Section 2.1.4 Risk-Based Screening, page 2-3. For reference, IT Corp will utilize USEPA Region IX preliminary remediation goals (PRGs) for the purposes of screening soil and ground water analytical results at TNT Areas A and C. This section states that the Region IX PRGs will be adjusted to reflect a cancer risk of $1x10^{-7}$ or a hazard index of 0.1. Ohio EPA requests that IT Corp explain the rationale for upwardly adjusting the PRGs for the purposes of this risk assessment. IT Corp should provide some text in Section 5.0 or 5.1 which states what lifetime cancer risk standard will be used to evaluate the summed risks for the purposes of the human health risk assessment ($1x10^{-6}$, $1x10^{-5}$ ...etc.).**

Response 3: The PRGs are adjusted downward, not upward as stated in the comment. The following will be added after the first sentence in the second paragraph in Section 2.1.4: "A cancer risk of 1E-7 is chosen to be consistent with OEPA's policy to quantify the risk of any chemicals that may contribute to a total cancer risk

estimate above 1E-6, which is considered to be a point of departure. An HI of 0.1 is chosen to provide additional protection for simultaneous exposure to multiple chemicals." The following will be added to Section 5.1: "For risk management purposes, a total cancer risk of 1E-6 is a point of departure below which cancer risks are considered to be insignificant. Cancer risks between 1E-6 and 1E-4 fall within a risk management range. Cancer risks above 1E-4 are considered to be clearly unacceptable."

Comment 4: **Section 2.1.5 Evaluating Essential Nutrients, last sentence, page 2-4. Define what criteria will be used to determine if other essential nutrients such as chloride, iodine, and phosphorus are at levels associated with adverse effects to human health?**

Response 4: An exposure analysis will be performed, whereby a daily dose of chemical from soil ingestion is calculated. The dose will be compared with levels known or expected to be safe or toxic, and/or with RDAs, depending on the availability of data.

Comment 5: **Section 2.1.6 Identifying Site-Related COPCs, page 2-5. All compounds that are retained after the screening steps are to be assessed as site related in the risk assessment. In general, comparison with naturally occurring levels is applicable only to inorganic chemicals because the majority of organic chemicals are not naturally occurring, even though they may be ubiquitous in the environment. Do not eliminate anthropogenic chemicals from the site risk evaluation because it is extremely difficult to conclusively show that such chemicals are present at a site due to operations not related to the site or surrounding areas. The presence of anthropogenic background chemicals can be discussed in the uncertainties section, however, these constituents should be retained and evaluated in the site-related risk. Compounds evaluated in background risk should include only those constituents that are naturally occurring inorganics detected in the samples collected from background locations. Background locations are considered to be unimpacted areas that are not influenced by site activity.**

The calculation of background risk can be presented and discussed in the uncertainty section of the risk assessment, but not in the main text of the report. The presentation of three different risk estimates (total, background and site-related) will create unnecessary confusion for the reader.

Response 5: Recent negotiations between USACE and OEPA resulted in modification of OEPA policy so that ambient concentrations now can be compared with background concentrations (metals only) to deselect chemicals from the COPC list. Section 2.1.6 will be renumbered as 2.1.4 (to precede description of risk-based screening) and will be rewritten to reflect the new policy. The protocol for the three separate risk assessments will be removed and the remaining text revised to state "site-related chemicals" rather than "site-related COPCs." Section 2.1.4 will be renumbered as 2.1.5, and Section 2.1.5 will be renumbered as 2.1.6. The renumbering reflects the appropriate order for steps in COPC selection:

comparison with background to select site-related chemicals should precede risk-based screening. The third paragraph in Section 5.0 will be deleted. The following will be added as the first sentence in the fourth paragraph: "Risk characterization is limited to those site-related chemicals selected as COPCs; i.e., present at concentrations that exceed RBSCs (Section 2.1.5)." Background data are insufficient to deselect organic compounds as site-related chemicals. Any comparison of ambient concentrations of organic compounds with anthropogenic background levels in the risk assessment will be done in the uncertainty section.

Comment 6: **Section 2.2 Developing Source Term Concentration, page 2-8, Equation 2.3. Ohio EPA recommends calculating the UCL for lognormally distributed data based on the H statistic as presented in guidance from EPA (1992a). This approach has been used consistently in Ohio.**

Response 6: Agreed; the EPA (1992a) protocol used in the risk assessments for the Red Water Ponds Areas and TNT Area B will be used instead of the updated (EPA, 1997) protocol.

Comment 7: **Section 2.2.2 Groundwater, page 2-9. Clarify whether or not exposure to groundwater is being evaluated in this assessment. In an August 29, 2000 email to Ohio EPA, it was decided that groundwater was going to be assessed at a later time under a site-wide groundwater evaluation. Therefore, a statement should be added to this work plan which explains that exposure to groundwater will be evaluated under the site-wide groundwater assessment. All references to the groundwater pathways in the conceptual site model should include a footnote stating that this pathway will be evaluated during the site-wide evaluation. Details of the groundwater assessment should be removed from this work plan and discussions reserved for the site-wide groundwater assessment work plan.**

Response 7: The work plan will be revised by the addition of statements and footnotes, wherever appropriate, indicating that exposure to groundwater will be evaluated at a later time. Details of the groundwater evaluation; i.e., development of source-term and exposure-point concentrations, and details of leaching and transfer models will be removed from the work plan.

Comment 8: **Section 2.2.2 Future Groundwater Conditions, page 2-10. Potential shallow/deep ground water contamination at TNT Areas A and C will be evaluated under current and future use scenarios.**

Current ground water use: evaluate current concentrations of COPCs in ground water.

Source term concentrations (STCs) in ground water will be determined by calculating the arithmetic mean of concentrations of COPCs obtained from the moist contaminated portion of the plume. In the absence of any identifiable plume, those COPCs which exceed associated risk based screening criteria will be included in the calculations.

STCs of COPCs in soil that exceed background screening criterion or soil screening levels will be modeled to determine the concentrations of these COPCs in ground water from leaching. The modeled ground water concentrations will then be compared to Region IX PRGs for potential inclusion in the future ground water conditions evaluations.

IT Corp states that evaluating ground water under a "future ground water condition scenario" is a matter of professional judgement (Section 2.2.2.2, page 2-10). Therefore, IT Corp should provide a quantitative or qualitative rationale for completing or not completing the "future conditions scenario" at TNT Areas A and C. IT Corp should consult with Ohio EPA to determine if and when the "future condition scenario" is warranted during implementation of the risk assessment. Ideally, where ground water is determined to be impacted the "current ground water condition" should include an evaluation of leaching from soil (i.e., future condition scenario) as COPC migration has already occurred.

Response 8: All details of the groundwater evaluation will be removed from this work plan. They will be developed in the work plan for groundwater evaluation at some time in the future.

Comment 9: Section 3.1.3.4 On-Site Resident, page 3-10. The third paragraph states that inhalation of VOCs from shallow ground water entrapped in a building was not evaluated for the on-site resident scenario. However, Figure 3-1 and Table 3-2 indicate that this pathway/receptor will be evaluated. IT Corp should revise the work plan accordingly.

Response 9: The details of the evaluation will be developed in the work plan for the groundwater evaluation to be prepared at some future date.

Comment 10: Section 5.0 Risk Characterization, third paragraph, page 5-1. This paragraph should be revised to reflect the comment #5 above.

Response 10: Agreed; please see response to Comment 5.

Comment 11: Section 6.0 Uncertainty Analysis, page 6-1. This section should be revised to reflect comment #5.

Response 11: Section 6.1 is not intended to identify all the sources of uncertainty that will be discussed in the risk assessment. As noted in response to Comment 5, the three-risk assessment approach is being deleted, so there will be no need to discuss a background risk assessment in the uncertainty section.

Ecological Risk Assessment Comments

Comment 12: Section 2.5 Review, Evaluation and Presentation of Analytical Data, page 2-4. Define the criteria to be used to determine if data is of acceptable quality for use in the SLERA.

Response 12: Text will be edited to define the criteria to be used; e.g., only validated data will be use.

Comment 13: Section 2.6 Selection of Preliminary Chemicals of Potential Ecological Concern, page 2-4. Clarify in the text of this section that the background comparison is applicable only for naturally occurring, inorganic compounds.

Response 13: Text will be edited as recommended.

Comment 14: Section 2.6.1 Data Organization, page 2-4. Ohio EPA considers exposures for ecological assessments to occur between 0-2 feet.

Response 14: Previous SLERAs performed for PBOW (e.g., Red Water Ponds, TNT Area B) have used 0 to 6 feet to address potentially burrowing animals at the site and the potential uptake of COPECs by deep-rooted vegetation from subsoil. We recommend that the 0 to 6 depth interval be retained for consistency, and that if any eco concerns are estimated for COPECs in soils from 2 to 6 feet, that the potential for actual exposure can be addressed in the SLERA Uncertainty Analysis.

Comment 15: Section 2.6.4 Natural Site Constituents (Background and Essential Nutrients), page 2-8. Remove all references to the "How Clean is Clean Policy" (Ohio EPA 1991). This policy was rescinded in 1999. Add text which states that the maximum detected concentration of a constituent will be used as the background screening concentration if the UTL exceeds the MDC. The reader is referenced to Section 2.1.3 of the human health work plan for a detailed discussion of normalized metal concentrations. Section 2.1.3 discusses the frequency of detection concepts. Revise the text to reference the reader to the appropriate section for this information. Define the criteria that will be used to determine if essential nutrients are at a level to cause adverse ecological effects. This determination should be made prior to eliminating constituents from the SLERA.

Response 15: Reference to OEPA (1991) document will be removed, as recommended. Use of the UTL as recommended (defaulting to the maximum detected concentration if the UTL is greater than the maximum) will be added to the text, to be consistent with the approach presented in the HHRA Work Plan. Nutrients without readily-available screening criteria will be retained for the SLERA, unless found to be background related. In the SLERA, TRVs for nutrients will be developed and used, based on appropriate data taken from livestock animal studies (e.g., poultry and cattle).

Comment 16: Section 2.6.5 Comparison to Risk-Based Screening Ecotoxicity Values, page 2-9. Ohio EPA recommends using the following hierarchy as screening sources:

a. For Soil.

Preliminary Remediation Goals for Ecological Endpoints, Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones. August 1997. ES/ER/TM-162, Oak Ridge National Laboratory, Oak Ridge, TN 37831.

Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litte Invertebrates and Heterotrophic Process: 1997 Revision. Efroymson, R.A., G.W. Suter II, and M.E. Will. EX/ER/TM-126/R2, Oak Ridge National Laboratory, Oak Ridge, TN 37831.

Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effective on Terrestrial Plants: 1997 Revision. Efroymson, R.A., G.W. Suter II, A.C. Wooten, and M.E, Well. ES/ER/TM-85/R3, Oak Ridge National Laboratory, Oak Ridge, TN 37831.

Ecological Data Quality Levels (EDQL), USEPA Region 5 Final Technical Approach for Developing EDQLs for RCRA Appendix IX Constituents and Other Significant Contaminants of Ecological Concern, April 1998.

For Sediment:

Site specific background concentrations

Ohio EPA Sediment Reference Values (SRV) – these are scheduled to be developed in Fall 1999.

Quality Levels (EDQL), USEPA Region 5 Final Technical Approach for Developing EDQLs for RCRA Appendix IX Constituents and Other Significant Contaminants of Ecological Concern, April 1998.

For Surface Water

The chemical specific water quality criteria are not screening values but are State water quality standards that must be used to evaluate surface water chemical parameters. Surface water concentrations are compared to the State of Ohio Water Quality Criteria (QAC-3745-1 07). If exceedences to the chemical specific water quality criteria are noted further evaluation of the water body is required. The outside mixing zone average criteria for human health and aquatic life should be compared against ambient samples averaged over a 30-day period. Single averaged samples are not to exceed the outside the mixing zone maximum. Biological criteria corresponding to the aquatic life habitat designation of the water body are to be in full

attainment. Site related nonchemical stressors that may be potentially impacting important ecological receptors are also to be listed as constituents of potential ecological concern and would include elevated total dissolved solids, extremes in pH concentrations, low dissolved oxygen levels, habitat modifications, and elevated temperatures.

Response 16: The recommended hierarchy will be used, except as noted below. Nonchemical stressors will also be assessed, as recommended, using available surface water data that were collected (i.e., pH, turbidity, conductivity, dissolved oxygen, Eh, and temperature).

- Based on IT conversations with OEPA's David Altfater, the OEPA Sediment Reference Values (SRVs) are not yet available.

- For TNT Areas A and C, no site-specific background surface water and sediment samples were collected.

- IT recommends ORNL sediment screening values be retained (Efroymson et al., 1997), as OEPA SRVs and site-specific background values are not available. In addition, screening values *from Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (OME, 1993) will be used as additional constituent values are available from this reference. These three sources will be used in the following hierarchy for the selection of sediment screening values: (1) USEPA Region V EDQLs; (2) Efroymson et al., (1997); and (3) OME (1993) values.

- Use of human health surface water criteria for ecological receptors is inappropriate.

- As surface water sample results averaged over a 30-day period are unavailable, the comparison with an average concentration OEPA WQC cannot be performed.

- IT recommends that the surface water screening values from Efroymson et al. (1997) be used as well, due to the fact that additional constituent values are available from this reference. State of Ohio WQC will be used to evaluate surface water parameters for direct contact, as recommended. The lowest surface water screening value from the three references (i.e., OEPA WQC, Efroymson et al. [1997], and USEPA Region V EDQLs) will be selected because both direct-contact effects and food-chain effects are to be assessed. Use of a hierarchy would potentially eliminate important surface water COPECs because OEPA WQC do not consider food-chain effects, and therefore a hierarchy will not be used.

Comment 17: Section 3-1 Exposure Analysis, page 3-1. Ohio EPA recommends collecting site-specific information (whenever possible) to use in the ecological risk model. The use of site-specific information will decrease uncertainty in the ecological risk estimates. For instance, pore water concentrations can be

measured directly rather than modeled to increase certainty in the risk assessment.

Response 17: Comment noted. Pore water concentrations were not measured directly, therefore this type of information is not available, and the modeling approach presented in the Work Plan will be followed.

Comment 18: Section 3-1 Soil Exposure Pathway, page 3-5. Ohio EPA evaluates exposure to soil from 0-2 feet for ecological organisms.

Response 18: See response to Comment No. 14.

Comment 19: General Comment for the Ecological Risk Work Plan. A conceptual site model (CSM) must be outlined in this work plan. The CSM is an integral part of the ecological risk assessment as it provides the framework from which the study design is constructed and assists in the development of a representative sampling and analysis plan. Historical and available data can be used to develop a preliminary CSM and this can be refined as new information is obtained. Indicator species must be identified along with site-specific assessment and measurement endpoints.

Response 19: The sampling and analysis for the sites has already occurred. Therefore, preparation of a CSM for the SLERA Work Plan at this point in time will not be able to "provide the framework from which the study design is constructed and assist in the development of a representative sampling and analysis plan." It is recommended that the CSM be provided in the draft SLERA Report. Indicator species to be used in the SLERA, if COPECs are selected, are proposed to be consistent with indicator species used in previous PBOW SLERAs performed for the Red Water Ponds and TNT Area B, assuming appropriate habitat exists. The wildlife receptors used for other PBOW sites have included the following: deer mouse (Peromyscus manicalatus), raccoon (Procyon lotor), Eastern cottontail (Sylvilagus floridanus), marsh wren (Cistothorus palustris), short-tailed shrew (Blarina brevicauda), white-tailed deer (Odocoileus virginianus), red-tailed hawk (Buteo jamaicensis), and the great blue heron (Ardea herodias). For direct contact with surface water and sediment, generic receptors such as aquatic benthic invertebrates, and finfish and crustaceans, have been used.