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DRAFT REPORT REMEDIAL INVESTIGATION HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS FIREFIGHTER TRAINING AREA, LIGHTER AMPHIBIOUS RESUPPLY CARGO (LARC) 60 MAINTENANCE AREA, AND AUTO CRAFT AREA FORT STORY VA

8/1/1997

MALCOLM PIRNIE

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DRAFT REPORT
REMEDIAL INVESTIGATION

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

FIREFIGHTER TRAINING AREA
LARC 60 MAINTENANCE AREA
AUTO CRAFT BUILDING AREA

FORT STORY, VIRGINIA

PREPARED FOR:

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT
BALTIMORE, MARYLAND

AND

U.S. ARMY TRANSPORTATION CENTER
FORT EUSTIS, VIRGINIA

CONTRACT DACA31-94-D-0017
DELIVERY ORDER NO. 17, 20 AND 24

AUGUST 1997

MALCOLM PIRNIE, INC.
11832 Rock Landing Drive, Suite 400
Newport News, Virginia 23606

0285-588-330

MALCOLM PIRNIE

MALCOLM PIRNIE, INC.
ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

August 19, 1997

Mr. Myron Price
USAED - Baltimore
10 South Howard Street
Room 10040
Baltimore, MD 21203-1715

Re: Draft Human Health and Ecological Risk Assessments
Remedial Investigations, Fort Story, Virginia
Contract DACA31-94-D-0017, Delivery Order Nos. 17, 20, and 24

Dear Mr. Price:

Malcolm Pirnie is pleased to provide to the U.S. Army Corps of Engineers (USACE), Baltimore District these **Draft Human Health and Ecological Risk Assessments for the Remedial Investigation (RI) Report** for the **Firefighter Training Area, LARC 60 Maintenance Area and Auto Craft Building Area sites** at **Fort Story, Virginia**. These risk assessments constitute Sections 6 and 7 of the RI Report.

Three copies of these assessments have been submitted to the Virginia Department of Environmental Quality (VDEQ) for their review and comment. Due to major revisions to the human health risk assessment (HHRA) (addition of groundwater as a potential drinking water source) and performance of a quantitative ecological risk assessment (ERA), additional review and comment is required by the Virginia Department of Environmental Quality (VDEQ) prior to finalizing the RI Report.

Upon receipt of their comments to the risk assessments, a final RI Report will be prepared which will address VDEQ's comments to both the previously submitted Draft RI Report and the revised risk assessments. Three copies of these assessments have also been submitted to Dan Musel at Fort Eustis.

It has been a pleasure to provide this document to the USACE. We look forward to further discussions relative to this project.

Very truly yours,

MALCOLM PIRNIE, INC.

Anthony K. Pace

Anthony K. Pace
Senior Project Engineer

djk
0285-588-450

Enclosures

AKPL0819.WPF/7.7

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RECYCLED PAPER

6.1 INTRODUCTION

This risk assessment presents an assessment of potential human health risk associated with contaminants detected at the three RI sites at Fort Story, Virginia. The objectives of the human health risk assessment (HHRA) are to (1) provide an analysis of baseline risks, currently and in the future, in the absence of any major action to control or mitigate site contamination, and (2) to assist in determining the need for and extent of remediation. It provides a basis for comparing a variety of remedial alternatives, and determining which will be the most protective of human health. The HHRA presents an assessment of potential human health risks associated with exposure to contaminants detected at or migrating from each of the three RI sites.

The baseline risk assessment will follow guidance provided in the following documents:

- *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Parts A and B)*, EPA, 1989a and 1989b
- *Risk Assessment Guidance for Superfund, Volume I: Human Health. Supplemental Guidance. "Standard Default Exposure Factors"*, EPA, 1991a
- *Selecting Exposure Routes and Contaminants of Concern by Risk-based Screening*, EPA Region III, 1993a
- *Risk-Based Concentration Table*, EPA Region III, January - June 1995, 1995a
- *Exposure Factors Handbook*, EPA, 1989c
- *Guidance for Data Useability in Risk Assessment, Part 2*, EPA, 1992a
- *Dermal Exposure Assessment: Principles and Applications*, Interim Report, EPA, 1992b

Objectives

The goal of the HHRA is to provide a framework for developing the risk information necessary to assist decision-making at the three RI sites. A site-by-site risk assessment will be conducted that includes the components of hazard identification, exposure assessment, toxicity assessment and risk characterization.

Preliminary screening may reduce the level of effort for this human health evaluation at some of the sites. Specific objectives of the process are to:

- Provide an analysis of baseline risks (human health) and help determine the need for remedial action at the three sites.
- Provide a basis for determining levels of chemicals that can remain at each of the sites and still be adequately protective of public and Fort Story personnel health.
- Provide a basis for comparing potential health impacts of various remedial alternatives at the sites.
- Provide a consistent process for evaluating and documenting public health threats at the sites.

HHRA Components

The HHRA process is site-specific. Therefore it may vary in both detail and the extent to which qualitative and quantitative analyses are used, depending on the complexity and particular circumstances of the site, as well as the availability of ARARs and other criteria, advisories and guidance. There are four components to the HHRA: (1) hazard identification; (2) exposure assessment; (3) toxicity assessment; and (4) risk characterization. Each step is described briefly as follows:

- **Hazard identification** involves gathering and analyzing the site data relevant to the human health evaluation and identifying the chemicals of potential concern (COPC) at each site that are the focus of the risk assessment process. The selection of such chemicals is based on a number of parameters, including the frequency of detection and concentration in each environmental medium, environmental fate and transport characteristics, intrinsic toxicity and the likelihood of human exposure via significant exposure routes.
- **Exposure assessments** are conducted to estimate the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures, and the pathways by which humans are exposed. In the exposure assessment, reasonable maximum estimates of exposure are developed for both current and future land-use assumptions. Conducting an exposure assessment involves analyzing contaminant releases, identifying exposed populations, identifying all potential pathways of exposure, estimating exposure point concentrations for specific pathways and estimating contaminant intakes for specific

pathways. The results of this assessment are pathway-specific intakes for current and future exposures to individual substances.

- **Toxicity assessments** consider the types of adverse health effects associated with chemical exposures, the relationship between magnitude of exposure and adverse effects and related uncertainties such as the weight of evidence of a particular chemical's carcinogenicity in humans. Qualitative and quantitative toxicity data for each COPC are summarized, and appropriate guidance levels with which to characterize risks are identified.

- **Risk characterization** summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk, both in quantitative expressions and qualitative statements. The likelihood and magnitude of adverse health risks are estimated in this step, in the form of noncancer hazard quotients and cancer risks.

6.2 FIREFIGHTER TRAINING AREA

6.2.1 Hazard Identification

Numerous groundwater, surface soil and sediment samples were collected from the Firefighter Training Area (FTA) and analyzed for various chemical contaminants. Figures 2-5 and 2-6 provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in Tables 6-1 through 6-6 to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select COPCs for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

The EPA Region III RBC for industrial soils, residential soils and tap water for non-carcinogenic compounds have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for each matrix (surface water, groundwater, soil and sediment), the RBCs have been adjusted.

Emphasis is given in the ensuing evaluation to chemical contamination in the surface soil throughout the site, sediment near the site and groundwater underlying the site as these environmental media are regarded as having the greatest potential for human contact. Chemical contamination in the subsurface soils are discussed in the context of the potential for exposure from future excavation of these soils and continued or further degradation of groundwater from leaching.

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III Risk-based Concentration (RBC) Criteria, EPA Region III Soil Screening Levels (SSL) - Transfers from Soil to Air, and Virginia Petroleum Program Criteria are included in Table 6-1 as TBC criteria for purposes of comparison. A total of 28 surface soil samples were collected during the field investigation.

VOCs and SOCs

All concentrations of VOCs and SOCs were less than EPA RBC criteria and SSLs, and therefore, are not selected as COPCs.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in only 1 of 28 surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethylbenzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA criteria.

TABLE 6–1
HAZARD ASSESSMENT FOR SURFACE SOILS – FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: Virginia Petroleum Program(1)	TBC Criteria: EPA SSLs Transfers to Air(2)	TBC Criteria: EPA RBC Criteria Industrial Soils(3)	TBC Criteria: EPA RBC Criteria Residential Soils(3)	EPA Carcinogen Class(4)	Potential Concern?
VOCs (ug/kg)								
Acetone	3/28	134 – 290	–	62,000,000	20,000,000	780,000	D	
Methylene Chloride	2/28	5.0 – 6.4	–	7,000	760,000	85,000	B2	
Methyl ethyl ketone	1/28	28	–	–	100,000,000	4,700,000	D	
Styrene	1/28	3	–	1,400,000	41,000,000	1,600,000	D	
Toluene	24/28	8.3 – 140	–	520,000	41,000,000	1,600,000	D	
Xylenes	1/28	7	–	320,000	100,000,000	16,000,000	D	
SOCs (ug/kg)								
Benzo(b)fluoranthene	1/28	97	–	23,000	7,800	880	B2	
Benzo(k)fluoranthene	1/28	86	–	–	78,000	8,800	B2	
Bis(2–EH)phthalate	1/28	110	–	210,000	410,000	46,000	B2	
Chrysene	1/28	94	–	3,600	780,000	88,000	B2	
Di–n–butylphthalate	1/28	150	–	100,000	20,000,000	780,000	D	
Fluoranthene	1/28	650	–	68,000	8,200,000	310,000	D	
Pyrene	1/28	720	–	56,000	6,100,000	230,000	D	
TPH (mg/kg)								
Total TPH	3/28	48 – 5,300	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	5/5	420 – 980	–	–	100,000	7,800	–	
Arsenic	4/5	1.2 – 1.6	–	380	61	2.3	–	
Arsenic (as carcinogen)	4/5	1.2 – 1.6	–	380	3.8	0.43	A	**Yes**
Barium	5/5	3.9 – 12	–	350,000	14,000	550	–	
Calcium	4/5	71 – 370	–	–	–	–	–	
Chromium	5/5	1.7 – 5.8	–	–	100,000	7,800	–	
Copper	5/5	3.2 – 13	–	–	7,600	290	D	
Iron	5/5	1,200 – 5,400	–	–	–	–	–	
Lead	5/5	7 – 33	–	–	400	–	B2	
Magnesium	5/5	62 – 190	–	–	–	–	–	
Manganese	5/5	10 – 34	–	–	1,000	39	D	
Mercury	2/5	0.011 – 0.013	–	–	61	2.3	D	
Potassium	1/5	160	–	–	–	–	–	
Vanadium	5/5	1.8 – 3.7	–	–	1,400	555	D	
Zinc	5/5	14 – 22	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers from Soil to Air/Groundwater (Jun – Dec 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jun – Dec 1995)

(4) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

Inorganics

Arsenic exceeded the carcinogenic RBC value for residential soils but did not exceed the industrial soils criteria. Arsenic concentrations in surface soils ranged from 1.2 to 1.6 mg/kg with a mean concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the surface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H.

Although consistent with background levels, for the purposes of risk analysis, arsenic is selected as a COPC based on its exceedance of the residential soils criteria for carcinogens.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in Table 6-2 along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC criteria. Only the dissolved inorganic data is presented in Table 6-2. Total inorganic data are influenced by percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment typically is not available for transport with flowing groundwater and would also be filtered out before use if drinking water wells were installed in this area.

Thirty-four (34) groundwater samples (24 DPT and 10 monitoring well samples) were collected from the upper aquifer during the field investigation. The number of results for each chemical may vary due to the analysis of different compounds at different locations.

VOCs

Although numerous VOCs were detected during groundwater sampling, only tetrachloroethene (PCE) (6.4 and 78 ug/l) and benzene (10 ug/l) were detected in excess of the screening criteria. However, benzene was only detected in 1 of 34 samples (3 percent detection frequency), and therefore due to infrequent detection, it is not selected as a COPC. Although PCE was detected in only 2 of 34 samples, it is selected as a COPC.

TABLE 6–2
HAZARD ASSESSMENT FOR GROUNDWATER
FIREFIGHTER TRAINING AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				TBC Criteria		EPA Carcinogen Class(7)	Potential Concern?
			EPA MCLs(1)	EPA Secondary MCLs(2)	Virginia GW Stds(3)	Va GW Protection Levels(4)	Virginia GW Criteria(5)	EPA RBC Criteria(6) Tap Water		
VOCs (ug/l)										
Acetone	2/27	27 – 28	–	–	–	–	–	370	D	
Benzene	1/34	10	5	–	–	5	–	0.36	A	
Carbon disulfide	3/27	5.0 – 8.3	–	–	–	1,000	–	100	–	
1,1–Dichloroethane	1/27	20	–	–	–	–	–	81	C	
Ethylbenzene	1/27	47	700	–	–	–	–	130	D	
Tetrachloroethene	2/34	6.4 – 78	5	–	–	7	–	1.1	B2	**Yes**
Toluene	1/27	20	1,000	–	–	1,000	–	75	D	
1,1,1–Trichloroethane	2/27	9.4 – 31	200	–	–	200	–	130	D	
Xylenes	3/27	25 – 200	10,000	–	–	–	–	1,200	D	
SOCs (ug/l)										
Bis(2–EH)phthalate	1/26	1	–	–	–	–	–	4.8	B2	
Fluorene	1/26	15	–	–	–	–	–	150	D	
2–Methylnaphthalene	1/26	120	–	–	–	–	–	–	–	
Naphthalene	2/26	11 – 60	–	–	–	–	–	150	D	
Phenanthrene	1/26	18	–	–	–	–	–	–	D	
TPH (mg/l)										
Total TPH	3/34	1.4 – 9.2	–	–	1	1	–	–	–	
Dissolved Metals (mg/l)										
Aluminum	2/3	0.12 – 0.25	–	0.05 – 0.2	–	–	–	3.7	–	
Barium	3/3	0.021 – 0.14	1	–	1	1	–	0.26	–	
Calcium	3/3	12 – 18	–	–	–	–	–	–	–	
Copper	1/3	0.025	1.3	–	1	1	–	0.14	D	
Iron	2/3	0.28 – 3.6	–	0.30	–	–	0.30	–	–	
Magnesium	3/3	1.7 – 5.8	–	–	–	–	–	–	–	
Manganese	2/3	0.011 – 0.081	–	0.05	–	–	0.05	0.018	D	**Yes**
Potassium	3/3	1.7 – 2.9	–	–	–	–	–	–	–	
Sodium	3/3	4.7 – 8.4	–	–	270	270	100	–	–	
Zinc	3/3	0.021 – 0.12	–	5	0.05	0.05	–	1.1	D	

Notes:

(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards (VR680–21–04)
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations (VR672–20–10)
(5) Virginia Water Quality Criteria for Groundwater (VR680–21–05)
(6) EPA Region III Risk–based Concentration Table for Tap Water (Jun – Dec 1995)

(7) Weight–of–Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

SOCs

SOCs were not detected in any of the groundwater samples in excess of screening criteria, and therefore, are not selected as COPC.

TPH

Although TPH exceeded the Virginia Groundwater Standard of 1 mg/l in 3 of 34 groundwater samples, low concentrations of BTEX and PAHs were present and below their respective risk screening criteria.

Inorganics

Several dissolved inorganics (aluminum, iron, and zinc) were detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, these standards were established for aesthetic qualities only for drinking water supplies. Because the concentrations of these dissolved inorganics were significantly lower than the EPA RBC criteria for human health risks, they are not selected as COPC. However, dissolved manganese exceeded the EPA RBC for tap water in one sample, and therefore, is selected as a COPC.

Sediment

Sediment sampling was conducted to evaluate the nature and extent of contamination in the sediment in the drainage area south of the site. Sediment samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for sediment cleanup, EPA Region III RBC Criteria and Virginia Petroleum Program Criteria are included in Table 6-3 as TBC criteria for purposes of comparison. A total of four sediment samples were collected during the field investigation.

VOCs and SOCs

All concentrations of VOCs and SOCs were less than EPA RBC criteria, and therefore, are not selected as COPC.

TPH

TPH exceeded the 100 mg/kg TBC criterion in three of four sediment samples. Because TPH is typically used as an indicator of contamination, it will not be used during this quantitative risk

TABLE 6–3
HAZARD ASSESSMENT FOR SEDIMENT
FIREFIGHTER TRAINING AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: Virginia Petroleum Program(1)	TBC Criteria: EPA Region III Soil Screening Levels Transfers to Air(2)	TBC Criteria: EPA Region III RBC Criteria Industrial Soils(3)	TBC Criteria: EPA Region III RBC Criteria Residential Soils(3)	EPA Carcinogen Class(4)	Potential Concern?
VOCs (ug/kg)								
Toluene	4/4	23 – 180	–	520,000	41,000,000	1,600,000	D	
SOCs (ug/kg)		BDL						
TPH (mg/kg)								
Total TPH	3/4	130 – 350	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	4/4	160 – 7600	–	–	100,000	7,800	–	
Arsenic	1/4	2.5	–	380	61	2.3	–	**Yes**
Arsenic (as carcinogen)	1/4	2.5	–	380	3.8	0.43	A	**Yes**
Barium	4/4	2.4 – 110	–	350,000	14,000	550	–	
Calcium	4/4	64 – 120	–	–	–	–	–	
Chromium	1/4	21	–	–	100,000	7,800	–	
Cobalt	1/4	2.6	–	–	12,000	470	–	
Copper	1/4	26	–	–	7,600	290	D	
Iron	4/4	230 – 17,000	–	–	–	–	–	
Lead	4/4	4.3 – 210	–	–	400	–	B2	
Magnesium	1/4	960	–	–	–	–	–	
Manganese	3/4	1.7 – 42	–	–	1,000	39	D	
Mercury	2/4	0.017 – 0.051	–	7	61	2.3	D	
Nickel	1/4	9.4	–	6.900	41,000	1,600	–	
Potassium	1/4	260	–	–	–	–	–	
Sodium	2/4	87 – 180	–	–	–	–	–	
Thallium	1/4	1.4	–	–	16	0.63	–	**Yes**
Vanadium	2/4	2 – 18	–	–	1,400	55	D	
Zinc	2/4	6 – 76	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers to Air (Jan 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jun – Dec 1995)

(4) Weight–of–Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

assessment. BTEX and PAH concentrations, as previously discussed, were lower than risk screening criteria.

Inorganics

Arsenic exceeded the non-carcinogenic and carcinogenic RBC values for residential soils but did not exceed the industrial soils criteria while, although only detected in one sample, thallium exceeded the RBC value for thallium compounds (e.g., thallium sulfate) for residential soils.

Arsenic was only detected in one sediment sample at a concentration of 2.5 mg/kg with a mean concentration of 1.1 mg/kg for all sediment values. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the sediment are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H. Sediment values for inorganics were compared against soils data because the samples were collected from lowlying area near the site and not from a stream. The sediment in that area of the site are more consistent with soils rather than typical sediments.

Although consistent with background levels, for the purposes of risk analysis, arsenic is selected as a COPC based on its exceedance of the residential soils criteria for carcinogens. Thallium is also selected as a COPC.

Subsurface Soils and Soil Leachability

To evaluate the potential exposures to subsurface soils (i.e., future excavation activities) and for the potential leaching of contaminants form soil to groundwater, as shown in Table 6-4, soil analytical data was compared against EPA Region III SSLs for Transfers from Soil to Groundwater and EPA RBC for industrial soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria and SSLs are included in Table 6-4 as TBC criteria for purposes of comparison. A total of 72 soil samples were collected during the field investigation.

TABLE 6–4
HAZARD ASSESSMENT FOR SUBSURFACE SOILS & SOIL LEACHABILITY – FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA SSLs Transfers to Groundwater(1)	TBC Criteria: EPA RBC Industrial Soils(2)	EPA Carcinogen Class(3)	Potential Concern?
VOCs (ug/kg)						
Acetone	34/72	27 – 18,000	8,000	20,000,000	D	
Methylene Chloride	4/72	3.1 – 6.4	10	760,000	B2	
Methyl ethyl ketone	9/72	28 – 110	–	100,000,000	D	
Styrene	2/72	2 – 3	2,000	41,000,000	D	
Toluene	59/72	6.4 – 140	5,000	41,000,000	D	
Xylenes	1/72	7	74,000	100,000,000	D	
SOCs (ug/kg)						
Benzo(b)fluoranthene	3/72	97	4,000	7,800	B2	
Benzo(k)fluoranthene	3/72	86	4,000	78,000	B2	
Bis(2–EH)phthalate	3/72	110	11,000	410,000	B2	
Chrysene	3/72	94	1,000	780,000	B2	
Di–n–butylphthalate	2/72	150 – 1,300	120,000	20,000,000	D	
Fluoranthene	3/72	600 – 1100	980,000	8,200,000	D	
Naphthalene	1/72	45	30,000	8,200,000	D	
Pyrene	3/72	440 – 720	1,400,000	6,100,000	D	
TPH (mg/kg)						
Total TPH	7/72	48 – 5,300	–		–	
Total Metals (mg/kg)						
Aluminum	14/14	250 – 980	–	100,000	–	
Arsenic	9/14	0.98 – 1.6	15	61	A	
Arsenic (as carcinogen)	9/14	0.98 – 1.6	15	3.8	A	
Barium	14/14	2.2 – 12	32	14,000	–	
Calcium	9/14	37 – 370	–	–	–	
Chromium	14/14	1.6 – 6.7	–	100,000	–	
Cobalt	1/14	0.44	–	12,000	–	
Copper	6/14	0.63 – 13	–	8,200	D	
Iron	14/14	740 – 5,400	–	–	–	
Lead	14/14	1.8 – 33	–	400	B2	
Magnesium	9/14	44 – 190	–	–	–	
Manganese	14/14	5.7 – 34	–	1,000	D	
Mercury	3/14	0.011 – 0.20	–	61	D	
Nickel	1/14	0.57	21	4,100	–	
Potassium	3/14	27 – 160	–	–	–	
Sodium	1/14	9.9	–	–	–	
Vanadium	14/14	1.1 – 3.7	–	1,400	D	
Zinc	14/14	2.3 – 22	42,000	61,000	D	

Notes:
(1) EPA Region III Soil Screening Levels for Transfers from Soil to Groundwater (Jun – Dec 1995)
(2) EPA Region III RBC for industrial soils (Jun – Dec 1995)
(3) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

VOCs

All concentrations of VOCs were less than EPA RBC criteria for industrial soils while acetone was the only VOC higher than the EPA SSLs. Acetone exceeded the SSL of 8,000 ug/kg in only 1 of 72 samples, and therefore, VOC contamination in site soils should not further degrade groundwater quality through potential leaching.

As discussed in Section 2.2.9, the high levels of acetone detected in several soil samples were the result of using isopropyl alcohol as a decontamination solution and not associated with site conditions. Acetone is a primary oxidation product of isopropyl alcohol.

SOCs and Inorganics

All concentrations SOCs and inorganics were less than EPA RBC criteria for industrial soils and the EPA SSLs, and therefore, are not selected as COPCs and should not further degrade groundwater quality through potential leaching.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 7 of 72 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethyl benzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA criteria.

Chemicals of Potential Concern

Arsenic in surface soil and sediment, thallium in sediment and dissolved manganese and PCE in groundwater are the COPCs identified during the hazard identification of the FTA media. Potential risk associated with each COPC will be further evaluated in the exposure assessment section.

6.2.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the surface soils, sediment and groundwater COPCs that are present at or migrating from the FTA.

Potentially Exposed Populations

As part of the exposure assessment, it is important to characterize the potentially exposed populations at or near the site with regard to the current situation and potential future conditions.

Current Situation

The site is currently used as a training area for heavy equipment operations and for unloading and loading of heavy equipment on the loading rack in the southeast corner of the site. Fort Story personnel are present at the site for approximately two days per week. However, because the only surface soils COPC identified was arsenic due to exceedance of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Although the site is not in a restricted area and not fenced, potential exposures to the general public and/or trespassers would not be significant because their presence on the site would not be expected to be for only a short time and not routine. During the four weeks that the investigations were conducted at the site, a few public and/or off-duty personnel were observed at the site walking their dogs or jogging. However, their time spent on-site was limited to less than 30 minutes during their visit. Therefore, there are **no exposed populations to the surface soils at the FTA site under the current situation**.

Groundwater is not used in the vicinity of the site for drinking, process, or production purposes. The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located approximately 4,000 feet (cross groundwater flow gradient) from the site at the LARC 60 Maintenance Area; the water is obtained for nonpotable uses only. As discussed in Section 5.0, migration potential is minimal due to the very low vertical gradient present across the FTA site. There has been little or no migration of contaminants in the groundwater over the past 5 years based on a comparison of data from Montgomery-Watson's study in 1990 and data from Malcolm Pirnie's study in 1995. VOC concentrations have decreased substantially due to numerous subsurface mechanisms such as biodegradation, volatilization, and dispersion. Therefore, there are **no exposed populations to the groundwater at the FTA site under the current situation.**

In addition to the discussion for surface soils provided above, there are no expected exposures to the sediment located in the lowlying wooded area south of the site. Therefore, there are **no exposed populations to the sediment in the wooded area south of the FTA site under the current situation.**

Future Land Use

Although construction or excavation activities could be conducted in the future, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. Therefore, **as for future conditions, potentially exposed populations include residential exposures to the contaminated media at the FTA site**.

Exposure Pathways

The potential exposure pathways for future land use at the FTA site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.
- Residential exposure (adults and children) to **contaminated soil** through ingestion of chemicals.
- Residential exposure (adults and children) to **contaminated sediment** through ingestion of chemicals.

Data Limitations and Uncertainties

The limitations and uncertainties associated with the analytical data for the site were reviewed during data validation to ensure that appropriate and reliable data are selected for use in estimating human exposure.

Samples and their duplicates are not considered as separate sampling events. Rather a chemical-specific value representing the maximum value of the sample and its duplicate is used. This may result in a conservative estimate of exposure. However, since relatively few duplicate samples were collected, the overall impact on risk estimates should be minimal.

For purposes of this HHRA, if a COPC was not detected in a sample, it is assumed to be present at 1/2 the practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant Intake

Evaluation of the exposure pathways described above involves the estimation of several parameters such as skin surface area available for contact; skin permeability factors; exposure time, frequency, and duration; soil-to-skin adherence factors; ingestion rates; as well as the contaminant concentrations in the specific media of concern. Table 6-5 represents a general equation for calculating chemical intakes (chronic daily intakes or CDI) and defines the intake variables in terms of chemical-related, population-related and evaluation-determined parameters.

The USEPA recommends that estimates of contaminant intake be developed to portray reasonable maximum exposures (RME) which might be expected to occur under current and future site conditions. Accordingly, the highest exposure that might reasonably be expected to occur at the site, one that is well above the average case of exposure but within the range of possibility should be considered.

The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the contaminant concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative" concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence limits, etc. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper

TABLE 6-5
GENERIC EQUATION FOR CALCULATING CHEMICAL INTAKES

$$I = [(C \times CR \times EFD)/BW] \times 1/AT$$

Where:

I = intake; the amount of chemical at the exchange boundary (mg/kg body weight-day)

C = chemical concentration; the "average" concentration contacted over the exposure period (e.g., mg/liters water)

CR = contact rate; the amount of contaminated medium contacted per unit time or event (e.g., liters/day)

EFD = exposure frequency and duration; describes how long and how often exposure occurs; often calculated using two terms (EF and ED)

EF = exposure frequency (day/year)

ED = exposure durations (years)

BW = body weight; the average body weight over the exposure period (kg)

AT = averaging time; time period over which exposure is averaged (days)

confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:

$$UCL = e^{\{x + 0.5s*s + Sh/\sqrt{(n-1)}\}}$$

where:

UCL = 95th percent upper confidence limit on the mean
e = constant (natural log)
x = the mean of the log transformed data
s = the standard deviation of the log transformed data
H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean
n = sample size

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be conducted for data sets of 5 or greater.

Therefore, for the groundwater COPC of manganese, the maximum concentration will be used because only 3 dissolved groundwater samples were collected.

Because exposures to the soil and sediment (actually soils from a lowlying area adjacent to the site) would be similar, these data sets will be combined for the risk analysis.

The 95th percentile UCL concentrations were computed for arsenic and thallium in surface soils and sediment and PCE in groundwater to estimate the mean concentration. UCL calculations are provided in Appendix I. The results of the UCL calculations with comparison to the maximum concentration detected are provided in Table 6-6.

TABLE 6-6
COMPARISON OF EXPOSURE CONCENTRATIONS
FIREFIGHTER TRAINING AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Surface Soils and Sediment		
Ingestion of Chemicals	mg/kg	mg/kg
Arsenic	2.5	**1.83**
Thallium	1.4	**0.80**
Groundwater		
Ingestion of and Dermal Contact with Chemicals	ug/l	ug/l
Manganese	**81**	NA
PCE	78	**4.41**
Inhalation of Chemicals Volatilized	mg/m^3	mg/m^3
PCE	5.20E-01	**2.94E-02**

Notes:
NA - Not applicable because insufficient number of samples to calculate 95th percentile UCL.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In Appendix J, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

Surface Soil and Sediment

Table 6-7 presents the parameters and assumptions used in assessing potential exposures to chemicals in surface soil and sediment. Minimal exposures due to dermal contact and inhalation are typically present for metals, and therefore, these exposure pathways are not evaluated. In addition, arsenic did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).

- The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

TABLE 6-7
RESIDENTIAL EXPOSURE:
INGESTION OF CHEMICALS IN SOIL

EQUATION:

Intake (mg/kg-day) = (CS x IR x CF x FI x EF x ED)/(BW x AT)

Where:

CS = Chemical concentration in soil (mg/kg)
IR = Ingestion rate (mg soil/day)
CF = Conversion factor (10^{-6} kg/mg)
FI = Fraction ingested from contaminated source (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CS = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 100 mg/day for adults estimated from all age groups greater than 6 years old
200 mg/day for children ages 1 through 6

CF = 10^{-6} kg/mg

FI = 0.5; assumes 50% of soil is contaminated

EF = 350 days per year with 15 days expected to be away from the residence

ED = 30 years based on the national upper-bound (90th percentile) at one residence for adults
6 years for children which assumes that the oldest child is under 6 and has lived at the residence since birth.

BW = 70 kg represents the average adult and 15 kg for children ages 1 through 6

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

- The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

  This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.2.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8 through 6-10 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of, dermal contact or inhalation, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

TABLE 6-8
RESIDENTIAL EXPOSURE
INGESTION OF CHEMICALS IN GROUND WATER

EQUATION:

Intake (mg/kg-day) = (CW x IR x EF x ED)/(BW x AT)

Where:

CW = Chemical concentration in water (mg/l)
IR = Ingestion rate (liters/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CW = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 2 liters/day for an adult
1 liter/day for a child

EF = 350 days/year for adults and children

ED = 30 years for adults
6 years for children

BW = 70 kg represents the average adult and 15 kg for children ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-9
RESIDENTIAL EXPOSURE
DERMAL CONTACT WITH CHEMICALS IN GROUND WATER

EQUATION:

Absorbed Dose (mg/kg-day) = (CW x SA x PC x ET x EF x ED x CF)/(BW x AT)

Where:

CW = Chemical concentration in water (mg/l)
SA = Skin surface area available for contact (cm^2)
PC = Chemical-specific dermal permeability coefficient (cm/hr)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CS = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

SA = 19,400 cm^2; represents the 50th percentile total body surface area, adult male
7,310 cm^2; represents the 50th percentile total body surface area, male child

PC = Chemical-specific values estimated from the octanol/water coefficient

ET = 0.3 hours/day

EF = 350 days/year

ED = 30 years for adults and 6 years for children

CF = 0.001 (1 liter/1000 cm^3)

BW = 70 kg represents the average adult and 15 kg the average child ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-10
RESIDENTIAL EXPOSURE
INHALATION OF AIRBORNE CHEMICALS IN GROUND WATER

EQUATION:

Intake (mg/kg-day) = (CA x IR x ET x EF x ED)/(BW x AT)

Where:

CA = Chemical concentration in air (mg/m^3)
IR = Inhalation rate (m^3/hour)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CA = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 0.83 m^3/hour for adults
0.50 m^3/hour for children

ET = 0.2 hours/day

EF = 350 days/year

ED = 30 years; represents the national upper-bound at one residence for adults
6 years for children ages 1 through 6

BW = 70 kg represents the average adult and 15 kg for child ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in Appendix I.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be $30m^3$ in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

Chemical concentration in air (mg/m^3) = CW x CF x WV x 1/RV
where:

CW = chemical concentration in water (ug/l)
CF = conversion factor (1E-03 mg/ug)
WV = volume of water (200 liters)
RV = room volume (30 m^3)

The concentration in air for the chemicals of potential concern are presented in Table 6-6. All concentration-in-air calculations are provided in Appendix I.

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.2.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.2.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves (1) determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and (2) characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used when available. These include verified reference doses (RfDs) for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slopes (CPSs) for the evaluation of cancer risk from lifetime exposure. Each of these are discussed below.

Sources of toxicological guidance information, in order of preference, include: (1) IRIS (Integrated Risk Information System) which is a USEPA database containing current health risk and regulatory information for many chemicals (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

The inherent toxicity of the COPC for the HHRA is briefly summarized in Appendix J.

Non-Carcinogenic Effects

The potential for non-cancer health effects associated with chemical exposure is evaluated by comparing an estimated intake (such as chronic daily intake or CDI) over a specified time period with

a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical.

The RfDs for the COPC used for the characterization of chronic non-cancer risk via oral exposure routes are presented in Table 6-11, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD and any uncertainty of modifying factors used in the derivation of the RfD.

The ratio of the estimate of the CDI to the health-protective criterion (CDI/RfD) is called the hazard quotient (USEPA, 1989a). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, the greater the level of concern.

RfDs for oral exposure are available for most chemicals. For dermal exposure, however, RfDs are not available. In their absence, the oral RfDs are used and adjusted to reflect absorbed dose. This allows for comparison between exposure estimated as absorbed doses and toxicity values expressed as absorbed doses.

Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. However, a RfDi does not currently exist for PCE so no non-carcinogenic evaluation of the risks associated with inhalation of volatilized chemicals in groundwater will be made.

Carcinogenic Effects

Regardless of the mechanism of effect, risk assessment methods generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk assessment methods require extrapolation from high dose animal studies to evaluate low dose exposures to humans. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis.

TABLE 6-11
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	Chronic RfD (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
ORAL ROUTE						
Arsenic	3.00E-04	Medium	Perpigmentation, keratosis and possible vascular complications	Oral/IRIS	3	1
Manganese	5.00E-03	Medium				
PCE	1.00E-02	Medium	Hepatotoxicity in mice, weight gain in rats	Gavage/IRIS	1,000 for HAS	1
Thallium	8.00E-05*					
INHALATION ROUTE						
Arsenic	---					
Manganese	1.43E-05			IRIS		
PCE	---					
Thallium	---					

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
H - Variation in human sensitivity
A - Animal to human extrapolation
S - Extrapolation from Lowest Observed Adverse Effect Level (LOAEL) to No Observed Adverse Effect Level (NOAEL)
* - RfD for thallium sulfate used for thallium.

TABLE 7-20

ESTIMATED TOXICITY TO TERRESTRIAL PLANTS AND SOIL/SEDIMENT INVERTEBRATES
FORT STORY, VIRGINIA

	FTA Site	LARC Site	Auto Craft Site	Phytotoxicity Value[1]	Invertebrate (Earthworm) Toxicity Value[2]	Exceeds Ecological Criteria?
Surface Soil (mg/kg)						
Acetone	2.20E-01	~	~	NA	NA	
Toluene	1.40E-01	~	~	2.00E+02	NA	No
Acenaphthene	~	~	4.40E-01	2.00E+01	NA	No
Benzo(a)anthracene	~	~	2.50E+00	NA	NA	
Benzo(b)fluoranthene	~	~	4.10E+00	NA	NA	
Benzo(k)fluoranthene	~	~	4.90E-01	NA	NA	
Benzo(g,h,i)perylene	~	~	2.00E+00	NA	NA	
Benzo(a)pyrene	~	~	3.40E+00	NA	NA	
Butylbenzylphthalate	~	~	5.50E-01	NA	NA	
Chrysene	~	~	2.00E+00	NA	NA	
Fluoranthene	6.50E-01	~	5.80E+00	NA	NA	
Indeno(1,2,3-cd)pyrene	~	~	1.50E+00	NA	NA	
Phenanthrene	~	~	1.30E+00	NA	NA	
Pyrene	7.20E-01	~	1.10E+01	NA	NA	
Chromium	5.80E+00	4.30E+00	9.00E+00	1.00E+00	1.00E+01	Yes (veg. - all sites)
Copper	1.30E+01	4.10E+01	1.80E+01	1.00E+02	5.00E+01	No
Iron	1.70E+04	~	9.10E+03	NA	2.00E+02	Yes (invert. - FTA and AC)
Lead	3.30E+01	1.20E+01	9.50E+01	5.00E+01	9.00E+02	Yes (veg. - AC Site)
Nickel	~	~	4.80E+00	3.00E+01	9.00E+01	No
Zinc	2.20E+01	3.30E+01	6.40E+01	5.00E+01	1.00E+02	Yes (veg. - AC Site)
Sediment (mg/kg)						
Toluene	1.80E-01	~	~	2.00E+02	NA	No
Aluminum	7.60E+03	6.50E+02	~	5.00E+01	6.00E+02	Yes (FTA and LARC)
Barium	1.10E+02	2.70E+00	~	5.00E+02	3.00E+03	No
Cobalt	2.60E+00	~	~	2.00E+01	1.00E+03	No
Iron	1.70E+04	9.40E+02	~	NA	2.00E+02	Yes (invert. - FTA and LARC)
Lead	2.10E+02	~	~	5.00E+01	9.00E+02	Yes (veg. - FTA Site)
Manganese	4.20E+01	6.90E+00	~	5.00E+02	1.00E+02	No
Thallium	1.40E+00	~	~	1.00E+00	NA	Yes (veg. - FTA Site)
Vanadium	1.80E+01	2.70E+00	~	2.00E+00	2.00E+01	Yes (veg. -FTA and LARC)

Notes:

~ = Not a COPC or was not tested at the site

NA = Not Available

References:

(1) Will and Suter, 1995b

(2) Will and Suter, 1995a

Estimates of exposure to contaminants via dietary sources were made for the receptors by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$$EE_{diet} = \sum_{k=1}^{m} (C_k \times FR_k \times NIR_k)$$

Where:

EE_{diet}	=	Estimated exposure through diet (e.g., in mg/kg BW-day)
C_k	=	Average contaminant concentration in the kth type of food (e.g., in mg/kg wet weight).
FR_k	=	Fraction of intake of the kth food type that is contaminated (unitless).
NIR	=	Normalized ingestion rate of the kth food type on a wet weight basis (e.g., in g/g-day).
m	=	Number of contaminated food types

The estimated exposure through ingestion of soil/sediment and food for each of the wildlife receptors is given in Tables 7-21 through 7-29. Full exposure calculations are presented in Appendix M.

7.7 Ecological Effects Assessment

7.7.1 Ecological Effects Summaries

Toxicity profiles summarizing the potential adverse ecological effects of each COPC were derived from the literature, and are included as Appendix K. The profiles provide discussions of the acute and chronic toxicity of the COPCs to plants and animals. Effects on growth, reproduction, and survival of terrestrial species are given, where available. Also included are significant fate and transport characteristics of the chemicals. These summaries, in addition to established criteria, were used to identify the critical effects of COPCs.

TABLE 7-21
KILLDEER ESTIMATED EXPOSURE - FTA SITE
FORT STORY, VIRGINIA

Chemical (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acetone	4.40E-05	3.98E-04	4.41E-05	4.87E-04
Toluene	2.31E-04	2.09E-03	2.18E-04	2.54E-03
Fluoranthene	8.34E-04	5.29E-03	1.02E-05	6.13E-03
Pyrene	9.24E-04	5.85E-03	1.13E-05	6.79E-03
Aluminum	9.75E+00	8.83E+01	3.91E-02	9.81E+01
Barium	1.41E-01	1.28E+00	2.12E-02	1.44E+00
Chromium	7.44E-03	6.74E-03	5.60E-05	1.42E-02
Cobalt	3.34E-03	3.02E-02	1.00E-04	3.36E-02
Copper	1.67E-02	3.62E-01	6.69E-03	3.86E-01
Iron	2.18E+01	1.97E+02	8.75E-02	2.19E+02
Lead	2.70E-01	2.32E+00	1.22E-02	2.60E+00
Manganese	5.39E-02	4.88E-01	1.35E-02	5.55E-01
Thallium	1.80E-03	1.63E-02	7.20E-06	1.81E-02
Vanadium	2.31E-02	2.09E-01	1.27E-04	2.32E-01
Zinc	2.82E-02	1.46E+00	4.25E-02	1.53E+00

Notes:
BW = Body Weight

TABLE 7-22
WHITE FOOTED MOUSE ESTIMATED EXPOSURE - FTA SITE
FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acetone	9.15E-05	3.98E-03	2.88E-03	6.95E-03
Toluene	4.80E-04	2.09E-02	1.42E-02	3.56E-02
Fluoranthene	1.73E-03	5.28E-02	6.66E-04	5.52E-02
Pyrene	1.92E-03	5.85E-02	7.38E-04	6.11E-02
Aluminum	2.03E+01	8.82E+02	2.55E+00	9.04E+02
Barium	2.93E-01	1.28E+01	1.39E+00	1.44E+01
Chromium	1.55E-02	6.73E-02	3.65E-03	8.64E-02
Cobalt	6.93E-03	3.02E-01	6.55E-03	3.15E-01
Copper	3.47E-02	3.62E+00	4.37E-01	4.09E+00
Iron	4.53E+01	1.97E+03	5.71E+00	2.02E+03
Lead	5.60E-01	2.31E+01	7.94E-01	2.45E+01
Manganese	1.12E-01	4.87E+00	8.82E-01	5.87E+00
Thallium	3.73E-03	1.62E-01	4.70E-04	1.67E-01
Vanadium	4.80E-02	2.09E+00	8.32E-03	2.14E+00
Zinc	5.87E-02	1.45E+01	2.77E+00	1.74E+01

Notes:
BW = Body Weight

TABLE 7-23
GRAY FOX ESTIMATED EXPOSURE - FTA SITE
FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acetone	8.20E-07	4.59E-05	2.22E-05	6.81E-05	6.89E-05
Toluene	4.30E-06	2.34E-04	1.71E-05	2.51E-04	2.55E-04
Fluoranthene	1.55E-05	3.10E-04	7.86E-07	3.11E-04	3.26E-04
Pyrene	1.72E-05	3.43E-04	8.71E-07	3.44E-04	3.61E-04
Aluminum	1.82E-01	5.11E+00	3.06E-03	5.11E+00	5.29E+00
Barium	2.63E-03	8.47E-02	1.66E-03	8.64E-02	8.90E-02
Chromium	1.39E-04	4.17E-04	4.38E-06	4.22E-04	5.60E-04
Cobalt	6.21E-05	1.79E-03	7.86E-06	1.80E-03	1.86E-03
Copper	3.11E-04	2.44E-02	5.24E-04	2.49E-02	2.52E-02
Iron	4.06E-01	1.14E+01	6.85E-03	1.14E+01	1.18E+01
Lead	5.02E-03	1.40E-01	9.53E-04	1.41E-01	1.46E-01
Manganese	1.00E-03	3.52E-02	1.06E-03	3.62E-02	3.72E-02
Thallium	3.35E-05	9.41E-04	5.64E-07	9.42E-04	9.75E-04
Vanadium	4.30E-04	1.21E-02	9.98E-06	1.21E-02	1.26E-02
Zinc	5.26E-04	1.06E-01	1.15E-02	1.18E-01	1.18E-01

Notes:
BW = Body Weight

TABLE 7- 24
NORTHERN BOBWHITE ESTIMATED EXPOSURE
LARC SITE, FORT STORY, VIRGINIA

Chemical (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Aluminum	7.29E+00	7.15E+00	1.74E-01	1.46E+01
Barium	3.03E-02	2.97E-02	2.71E-02	8.71E-02
Copper	4.60E-01	1.08E+00	1.10E+00	2.64E+00
Iron	1.05E+01	1.03E+01	2.52E-01	2.11E+01
Lead	1.35E-01	1.25E-01	3.62E-02	2.96E-01
Manganese	7.73E-02	7.59E-02	1.16E-01	2.69E-01
Vanadium	3.03E-02	2.97E-02	9.95E-04	6.10E-02
Zinc	3.70E-01	2.07E+00	3.32E+00	5.76E+00

Note:
BW = Body Weight

TABLE 7- 25
WHITE-FOOTED MOUSE ESTIMATED EXPOSURE
LARC SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Aluminum	1.73E+00	7.54E+01	2.18E-01	7.74E+01
Barium	7.20E-03	3.13E-01	3.40E-02	3.54E-01
Copper	1.09E-01	1.14E+01	1.38E+00	1.29E+01
Iron	2.51E+00	1.09E+02	3.16E-01	1.12E+02
Lead	3.20E-02	1.32E+00	4.54E-02	1.40E+00
Manganese	1.84E-02	8.00E-01	1.45E-01	9.64E-01
Vanadium	7.20E-03	3.13E-01	1.25E-03	3.22E-01
Zinc	8.80E-02	2.18E+01	4.16E+00	2.61E+01

Note:
BW = Body Weight

TABLE 7- 26
GRAY FOX ESTIMATED EXPOSURE - LARC SITE
FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Aluminum	4.27E-02	1.20E+00	1.80E-01	1.38E+00	1.42E+00
Barium	1.77E-04	5.72E-03	7.48E-04	6.47E-03	6.64E-03
Copper	2.69E-03	2.11E-01	2.73E-02	2.39E-01	2.41E-01
Iron	6.18E-02	1.74E+00	2.61E-01	2.00E+00	2.06E+00
Lead	7.88E-04	2.20E-02	3.16E-03	2.51E-02	2.59E-02
Manganese	4.53E-04	1.59E-02	1.91E-03	1.78E-02	1.82E-02
Vanadium	1.77E-04	5.00E-03	7.48E-04	5.75E-03	5.92E-03
Zinc	2.17E-03	4.38E-01	5.21E-02	4.90E-01	4.92E-01

Note:
BW = Body Weight

TABLE 7-27
KILLDEER ESTIMATED EXPOSURE- AUTO CRAFT SITE
FORT STORY, VIRGINIA

Chemical (mg/kg)	Estimated Exposure from Soil (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acenaphthene	8.73E-05	5.53E-04	1.07E-06	6.42E-04
Benz(a)anthracene	7.02E-04	4.45E-03	8.58E-06	5.16E-03
Benzo(b)fluoranthene	1.15E-03	7.29E-03	1.41E-05	8.46E-03
Benzo(k)fluoranthene	9.52E-05	6.03E-04	1.16E-06	6.99E-04
Benzo(g,h,i)perylene	5.62E-04	3.56E-03	6.87E-06	4.13E-03
Benzo(a)pyrene	9.55E-04	6.05E-03	1.17E-05	7.01E-03
Butylbenzylphthalate	1.06E-04	6.69E-04	1.29E-06	7.76E-04
Chrysene	5.62E-04	3.56E-03	6.87E-06	4.13E-03
Fluoranthene	1.63E-03	1.03E-02	1.99E-05	1.20E-02
Indeno(1,2,3-cd)pyrene	3.54E-04	2.24E-03	4.33E-06	2.60E-03
Phenanthrene	2.86E-04	1.81E-03	3.50E-06	2.10E-03
Pyrene	3.09E-03	1.96E-02	3.78E-05	2.27E-02
Chromium	2.53E-03	2.29E-03	1.90E-05	4.83E-03
Copper	5.05E-03	1.10E-01	2.03E-03	1.17E-01
Iron	2.55E+00	2.31E+01	1.02E-02	2.57E+01
Lead	2.67E-02	2.29E-01	1.20E-03	2.57E-01
Nickel	1.35E-03	2.32E-02	8.10E-04	2.53E-02
Zinc	1.80E-02	1.32E+02	2.70E-02	1.32E+02

Note:
BW = Body Weight

TABLE 7-28
WHITE-FOOTED MOUSE ESTIMATED EXPOSURE
AUTO CRAFT SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Soil (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acenaphthene	4.48E-04	1.36E-02	1.72E-04	1.43E-02
Benz(a)anthracene	3.60E-03	1.10E-01	1.38E-03	1.15E-01
Benzo(b)fluoranthene	5.90E-03	1.80E-01	2.27E-03	1.88E-01
Benzo(k)fluoranthene	4.88E-04	1.49E-02	1.88E-04	1.55E-02
Benzo(g,h,i)perylene	2.88E-03	8.77E-02	1.11E-03	9.17E-02
Benzo(a)pyrene	4.90E-03	1.49E-01	1.88E-03	1.56E-01
Butylbenzylphthalate	5.41E-04	1.65E-02	2.08E-04	1.72E-02
Chrysene	2.88E-03	8.77E-02	1.11E-03	9.17E-02
Fluoranthene	9.36E-04	2.85E-02	3.60E-04	2.98E-02
Indeno(1,2,3-cd)pyrene	1.81E-03	5.52E-02	6.97E-04	5.78E-02
Phenanthrene	1.47E-03	4.47E-02	5.64E-04	4.68E-02
Pyrene	1.04E-03	3.16E-02	3.98E-04	3.30E-02
Chromium	1.30E-02	5.64E-02	3.06E-03	7.24E-02
Copper	2.59E-02	2.71E+00	3.27E-01	3.06E+00
Iron	1.31E+01	5.70E+02	1.65E+00	5.85E+02
Lead	1.37E-01	5.65E+00	1.94E-01	5.98E+00
Nickel	6.91E-03	5.71E-01	1.31E-01	7.09E-01
Zinc	9.22E-02	3.25E+03	4.35E+00	3.25E+03

Note:
BW = Body Weight

TABLE 7-29
GRAY FOX ESTIMATED EXPOSURE -
AUTO CRAFT SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)
Acenaphthene	1.39E-06	2.78E-05	7.17E-08	2.79E-05	2.93E-05
Benz(a)anthracene	1.12E-05	2.24E-04	5.76E-07	2.24E-04	2.35E-04
Benzo(b)fluoranthene	1.84E-05	3.67E-04	9.45E-07	3.68E-04	3.86E-04
Benzo(k)fluoranthene	1.52E-06	3.03E-05	7.82E-08	3.04E-05	3.19E-05
Benzo(g,h,i)perylene	8.96E-06	1.79E-04	4.61E-07	1.79E-04	1.88E-04
Benzo(a)pyrene	1.52E-05	3.04E-04	7.84E-07	3.05E-04	3.20E-04
Butylbenzylphthalate	1.68E-06	3.36E-05	8.67E-08	3.37E-05	3.54E-05
Chrysene	8.96E-06	1.79E-04	4.61E-07	1.79E-04	1.88E-04
Fluoranthene	2.91E-06	5.81E-05	1.50E-07	5.83E-05	6.12E-05
Indeno(1,2,3-cd)pyrene	5.64E-06	1.13E-04	2.91E-07	1.13E-04	1.19E-04
Phenanthrene	4.57E-06	9.12E-05	2.35E-07	9.14E-05	9.60E-05
Pyrene	3.23E-06	6.44E-05	1.66E-07	6.45E-05	6.78E-05
Chromium	4.03E-05	1.21E-04	1.28E-06	1.23E-04	1.63E-04
Copper	8.06E-05	6.33E-03	1.36E-04	6.46E-03	6.54E-03
Iron	4.08E-02	8.14E-01	2.10E-03	8.16E-01	8.57E-01
Lead	4.26E-04	8.49E-03	2.19E-05	8.52E-03	8.94E-03
Nickel	2.15E-05	1.51E-03	5.44E-05	1.56E-03	1.58E-03
Zinc	2.87E-04	5.72E-03	1.48E-05	5.74E-03	6.02E-03

Note:
BW = Body Weight

7.7.2 Toxicity Reference Values

Toxicity reference values (TRVs) were derived for plants, soil/sediment invertebrates and other wildlife as described below.

Terrestrial Plants and Invertebrates - The TRVs used to evaluate the toxicity of a given COPC to terrestrial plants and soil invertebrates were derived from the available literature. Values were applied to both soil and sediment since toxicity values for sediment were unavailable. Phytotoxic values represent the lowest values from toxicity studies conducted in the field or in greenhouse and growth chamber settings (Will and Suter, 1994a). Soil TRVs based on microbial heterotroph and earthworm toxicity represent data provided by toxicity studies in the field or in laboratory settings (Will and Suter, 1994b).

Wildlife - TRVs for mammals and birds chosen as receptor species were derived based on methodology presented by Opresko et al. (1994). This general method is based on USEPA methodology for deriving human toxicity values from animal data. In this method, experimentally derived No Observed Adverse Effect Levels (NOAELs) or Lowest Observed Adverse Effect Levels (LOAELs) are used to estimate NOAELs for wildlife by adjusting the dose according to differences in body size. NOAELs for laboratory species, obtained from the literature, were converted to receptor species NOAELs as follows (Opresko et al., 1994):

$$NOAEL_r = NOAEL_t \, (bw_t / bw_r)^{1/3}$$

Where:
$NOAEL_r$ = receptor species NOAEL
$NOAEL_t$ = test species NOAEL
bw_r = receptor body weight
bw_t = test species body weight

The test species and receptor species NOAELs are provided for each of the COPC in Table 7-30.

7.8 RISK CHARACTERIZATION

In this section, the ecological risks posed by COPC at the sites are identified and summarized. Risk characterization involves two major steps: risk estimation and risk description (USEPA, 1992). The risks are estimated in Section 7.8.1 using general comparisons and hazard quotients (HQs) calculated with estimated exposure and toxicity reference values for each endpoint species. The ratios are summarized, and the principal uncertainties of the assessment

TABLE 7-30

NOAELS FOR BIRDS AND MAMMALS: ENVIRONMENTAL ASSESSMENT
FORT STORY, VIRGINIA

COPC	NOAELs[1] (mg/kg BW-day)					
	Test Species (Avian)	Killdeer	Northern Bobwhite	Test Species (Mammal)	White-footed Mouse	Gray Fox
Acetone	NA	NA	NA	10 (rat)	24.96	4.27
Toluene	NA	NA	NA	25.98 (rat)	28.78	4.97
PAHs	NA	NA	NA	1(mus)[2]	1.11	0.19
Aluminum	109.7 (rd)	130.5	107.01	1.93 (mus)	2.12	0.363
Barium	20.8 (chicks)	22.79	18.68	5.1 (rat)	12.73	2.18
Chromium	1 (bd)	2.39	-	2,737 (rat)	6,832.3	1,168.7
Cobalt	NA	NA	-	NA	NA	NA
Copper	47 (ck)	71.80	58.86	11.71 (mk)[3]	41.26	7.13
Iron	NA	NA	NA	NA	NA	NA
Lead	3.85 (ak)	4.21	3.45	8 (rat)	19.94	3.44
Manganese	977 (jq)	1,208.2	990.46	88 (rat)	219.67	37.58
Nickel	77.4 (duckling)	157.96	-	40 (rat)	99.85	17.07
Thallium	NA	NA	NA	0.0074 (rat)	0.018	0.003
Vanadium	11.4 (ma)[4]	26.61	21.81	0.21 (rat)	0.52	0.09
Zinc	3 (ma)[4]	7.0	5.74	160 (rat)	398.72	68.88

TABLE 7-30

NOAELS FOR BIRDS AND MAMMALS: ENVIRONMENTAL ASSESSMENT
FORT STORY, VIRGINIA

Notes:

NA = Not Available

(1) Source for NOAELS unless otherwise specified: Opresko et al., 1995
NOAELs for laboratory species converted to receptor species NOAELs as follows (Opresko et al., 1994):

$$NOAEL_r = NOAEL_t\ (bw_t/bw_r)^{1/3}$$

Where:
$NOAEL_r$ = receptor NOAEL
$NOAEL_t$ = test species NOAEL
bw_r = receptor body weight
bw_t = test species body weight

Body weights of test species (kg):

American Kestrel (ak) = 0.12
Black Duck (bd) = 1.25
Chicken (ck) = 0.328
Chicken (chicks) = 0.121
Japanese Quail (jq) = 0.174
Mallard (ma) = 1.17
Mallard Duckling (duckling) = 0.782
Mink (mk) = 1.0
Mouse (mus) = 0.03
Rat = 0.35
Ringed Dove (rd) = 0.155

(2) Value is for Benzo(a)pyrene
(3) Source: Heaton, 1992
(4) Source: Opresko et al., 1994

Reference unless otherwise noted:

Opresko et al., 1995.

are discussed in Section 7.8.2. The ecological significance of the findings and recommendations for further study are discussed in Section 7.9.

7.8.1 Hazard Quotients

FTA Site

The levels of chromium in the soil and aluminum, lead, thallium, and vanadium in sediment were found to exceed phytotoxicity values. The levels of iron in the soil and aluminum and iron in the sediment were found to exceed invertebrate toxicity values. Phytotoxicity and invertebrate toxicity values were not available for acetone, flouranthene or pyrene. Phytotoxicity values were not available for iron. Invertebrate toxicity values were not available for toluene.

The hazard quotients (HQs) for the maximum exposure case are summarized in Table 7-31. These HQs indicate if the maximum concentrations of the COPCs are likely to pose a risk to Killdeer, White-footed Mouse, or Gray Fox at the FTA site. HQs greater than 1 were calculated for aluminum, barium, lead, thallium, and vanadium for the White-footed Mouse. HQs greater than 1 were calculated for aluminum for the Gray Fox. No HQs were greater than 1 for the Killdeer. An HQ greater than 1 means that the total estimated exposure exceeds the species toxicity reference values. These results indicate that there is a potential for risk of exposure for the White-footed Mouse and the Gray Fox to the maximum concentrations of the contaminants whose HQs exceeded 1. Avian toxicity values were not available for toluene, fluoranthene, pyrene or thallium. Therefore, the potential risks of these COPCs to the Killdeer were not evaluated.

LARC 60 Site

The levels of chromium in the soil and aluminum and vanadium in sediment were found to exceed phytotoxicity values. The levels of aluminum and iron in the sediment were found to exceed invertebrate toxicity values. Phytotoxicity values were not available for iron.

The HQs for the maximum exposure case are summarized in Table 7-32. Results of the exposure calculations show that the levels of zinc resulted in an HQ of 1 for the Northern Bobwhite. The levels of aluminum resulted in HQs greater than 1 for the White-footed Mouse and the Gray Fox. These contaminants detected at the site may pose a risk to the species examined. The other contaminants are unlikely to pose a risk to the species examined. Avian and mammalian toxicity values were unavailable for iron. Therefore, the potential risk of this contaminant could not be estimated.

TABLE 7-31
SUMMARY OF EXPOSURE ESTIMATES AND HAZARD QUOTIENTS
FTA SITE, FORT STORY, VIRGINIA

Chemical	Killdeer			White-footed Mouse			Gray Fox		
	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ
	mg/kg BW-day			mg/kg BW-day			mg/kg BW-day		
Acetone	4.87E-04	NA	NA	6.95E-03	2.50E+01	2.79E-04	6.89E-05	4.27E+00	1.61E-05
Toluene	2.54E-03	NA	NA	3.56E-02	2.88E+01	1.24E-03	2.55E-04	4.97E+00	5.13E-05
Fluoranthene	6.13E-03	NA	NA	5.52E-02	1.11E+00	4.98E-02	3.26E-04	1.91E-01	1.71E-03
Pyrene	6.79E-03	NA	NA	6.11E-02	1.11E+00	5.52E-02	3.61E-04	1.91E-01	1.89E-03
Aluminum	9.81E+01	1.31E+02	7.52E-01	9.04E+02	2.12E+00	4.27E+02	5.29E+00	3.63E-01	1.46E+01
Barium	1.44E+00	2.28E+01	6.32E-02	1.44E+01	1.27E+01	1.13E+00	8.90E-02	2.18E+00	4.08E-02
Chromium	1.42E-02	2.39E+00	5.96E-03	8.64E-02	6.83E+03	1.26E-05	5.60E-04	1.17E+03	4.80E-07
Cobalt	3.36E-02	NA	NA	3.15E-01	NA	NA	1.86E-03	NA	NA
Copper	3.86E-01	7.18E+01	5.37E-03	4.09E+00	4.15E+01	9.86E-02	2.52E-02	7.09E+00	3.56E-03
Iron	2.19E+02	NA	NA	2.02E+03	NA	NA	1.18E+01	NA	NA
Lead	2.60E+00	4.21E+00	6.17E-01	2.45E+01	1.99E+01	1.23E+00	1.46E-01	3.44E+00	4.24E-02
Manganese	5.55E-01	1.21E+03	4.60E-04	5.87E+00	2.20E+02	2.67E-02	3.72E-02	3.76E+01	9.90E-04
Thallium	1.81E-02	NA	NA	1.67E-01	1.80E-02	9.26E+00	9.75E-04	3.20E-03	3.05E-01
Vanadium	2.32E-01	2.66E+01	8.73E-03	2.14E+00	5.20E-01	4.12E+00	1.26E-02	9.00E-02	1.40E-01
Zinc	1.53E+00	7.00E+00	2.18E-01	1.74E+01	3.99E+02	4.35E-02	1.18E-01	6.83E+01	1.73E-03

Notes:
BW = Body Weight
NA = Not Available
EE_{total} =Total Estimated Exposure from Soil + Food
NOAEL = No Observed Adverse Effects Level
HQ = Hazard Quotient
Shading indicates Hazard Quotients greater than 1

TABLE 7-32
SUMMARY OF EXPOSURE ESTIMATES AND HAZARD QUOTIENTS
LARC SITE, FORT STORY, VIRGINIA

Chemical (mg/kg)	Northern Bobwhite			White-footed Mouse			Gray Fox		
	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ
	mg/kg BW-day			mg/kg BW-day			mg/kg BW-day		
Aluminum	1.46E+01	1.07E+02	1.37E-01	7.74E+01	2.12E+00	3.65E+01	1.42E+00	3.63E-01	3.92E+00
Barium	8.71E-02	1.87E+01	4.66E-03	3.54E-01	1.27E+01	2.78E-02	6.64E-03	2.18E+00	3.05E-03
Copper	2.64E+00	5.89E+01	4.49E-02	1.29E+01	4.15E+01	3.11E-01	2.41E-01	7.09E+00	3.40E-02
Iron	2.11E+01	NA	NA	1.12E+02	NA	NA	2.06E+00	NA	NA
Lead	2.96E-01	3.45E+00	8.58E-02	1.40E+00	1.99E+01	7.02E-02	2.59E-02	3.44E+00	7.54E-03
Manganese	2.69E-01	9.90E+02	2.71E-04	9.64E-01	2.20E+02	4.39E-03	1.82E-02	3.76E+01	4.86E-04
Vanadium	6.10E-02	2.18E+01	2.80E-03	3.22E-01	5.20E-01	6.19E-01	5.92E-03	9.00E-02	6.58E-02
Zinc	5.76E+00	5.74E+00	1.00E+00	2.61E+01	3.99E+02	6.53E-02	4.92E-01	6.83E+01	7.20E-03

Notes:
BW = Body Weight
NA = Not Available
EE_{total} = Total Estimated Exposure from Media and Food
NOAEL = No Observed Adverse Effects Level
HQ = Hazard Quotient
Shading indicates Hazard Quotients greater than 1

Auto Craft Site

The levels of chromium, lead and zinc in the soil were found to exceed the phytotoxicity values. The levels of iron in the soil were found to exceed invertebrate toxicity values. Phytotoxicity and invertebrate toxicity values were not available for PAHs. Phytotoxicity values were unavailable for iron.

The HQs for the average exposure case for the SOCs and the maximum exposure case for metals are summarized in Table 7-33. The levels of zinc were found to exceed both Killdeer and White-footed Mouse toxicity values (HQ>1). Therefore, there is a potential for risk to the maximum concentrations of zinc to the White-footed Mouse and the Killdeer at the Auto Craft Site. The wildlife HQs were less than 1 for all other compounds where TRVs were available. These results indicate that the mean concentrations of the SOCs and the maximum concentrations of metals (except zinc) are unlikely to pose a risk to the Killdeer, White-footed Mouse, or Gray Fox at the Auto Craft Site. Avian toxicity values were not available for PAHs or iron. Mammalian toxicity values were not available for iron. Therefore, the potential risks of these COPCs were not evaluated.

7.8.2 Summary of Risks and Uncertainties

FTA Site

At the FTA site, potential risks of exposure to aluminum, barium, lead and thallium in sediment was identified for small mammals. The potential risk of exposure to aluminum in sediment was identified for terrestrial carnivores. In addition, potential risks of exposure to chromium in the soil and aluminum, lead, thallium, and vanadium in sediment were identified for plants. The potential risks of exposure to iron in the soil and sediment and aluminum in the sediment were found for soil/sediment invertebrates. These risks of adverse effects were identified for the maximum exposure scenario.

LARC 60 Site

At the LARC 60 site, the potential risks of exposure to zinc for avian species and aluminum for small mammals and terrestrial carnivores were identified. The potential risk of exposure to chromium in the soil and aluminum and vanadium in sediment were identified for plants. Lastly, potential risks of exposure to aluminum and iron in the sediment were identified for sediment invertebrates. These risks of adverse effects were identified for the maximum exposure scenario.

TABLE 7-33
SUMMARY OF EXPOSURE ESTIMATES AND HAZARD QUOTIENTS
AUTO CRAFT SITE, FORT STORY, VIRGINIA

Chemical	Killdeer			White-footed Mouse			Gray Fox		
	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ	EE_{total}	NOAEL	HQ
	mg/kg BW-day			mg/kg BW-day			mg/kg BW-day		
Acenaphthene	6.42E-04	NA	NA	1.43E-02	1.11E+00	1.29E-02	2.93E-05	1.91E-01	1.53E-04
Benz(a)anthracene	5.16E-03	NA	NA	1.15E-01	1.11E+00	1.03E-01	2.35E-04	1.91E-01	1.23E-03
Benzo(b)fluoranthene	8.46E-03	NA	NA	1.88E-01	1.11E+00	1.70E-01	3.86E-04	1.91E-01	2.02E-03
Benzo(k)fluoranthene	6.99E-04	NA	NA	1.55E-02	1.11E+00	1.40E-02	3.19E-05	1.91E-01	1.67E-04
Benzo(g,h,i)perylene	4.13E-03	NA	NA	9.17E-02	1.11E+00	8.27E-02	1.88E-04	1.91E-01	9.86E-04
Benzo(a)pyrene	7.01E-03	NA	NA	1.56E-01	1.11E+00	1.41E-01	3.20E-04	1.91E-01	1.68E-03
Butylbenzylphthalate	7.76E-04	NA	NA	1.72E-02	1.11E+00	1.56E-02	3.54E-05	1.91E-01	1.85E-04
Chrysene	4.13E-03	NA	NA	9.17E-02	1.11E+00	8.27E-02	1.88E-04	1.91E-01	9.86E-04
Fluoranthene	1.20E-02	NA	NA	2.98E-02	1.11E+00	2.69E-02	6.12E-05	1.91E-01	3.20E-04
Indeno(1,2,3-cd)pyrene	2.60E-03	NA	NA	5.78E-02	1.11E+00	5.21E-02	1.19E-04	1.91E-01	6.21E-04
Phenanthrene	2.10E-03	NA	NA	4.68E-02	1.11E+00	4.22E-02	9.60E-05	1.91E-01	5.03E-04
Pyrene	2.27E-02	NA	NA	3.30E-02	1.11E+00	2.98E-02	6.78E-05	1.91E-01	3.55E-04
Chromium	4.83E-03	2.39E+00	2.02E-03	7.24E-02	6.83E+03	1.06E-05	1.63E-04	1.17E+03	1.40E-07
Copper	1.17E-01	5.07E+01	2.30E-03	3.06E+00	4.13E+01	7.41E-02	6.54E-03	7.13E+00	9.18E-04
Iron	2.57E+01	NA	NA	5.85E+02	NA	NA	8.57E-01	NA	NA
Lead	2.57E-01	4.21E+00	6.11E-02	5.98E+00	1.99E+01	3.00E-01	8.94E-03	3.44E+00	2.60E-03
Nickel	2.53E-02	1.58E+02	1.60E-04	7.09E-01	9.99E+01	7.10E-03	1.58E-03	1.71E+01	9.27E-05
Zinc	1.32E+02	6.12E+00	2.15E+01	3.25E+03	3.99E+02	8.16E+00	6.02E-03	6.89E+01	8.75E-05

Notes:
BW = Body Weight
NA = Not Available
EE_{total} =Total Estimated Exposure from Soil + Food
NOAEL = No Observed Adverse Effects Level
HQ = Hazard Quotient
Shading indicates Hazard Quotients greater than 1

Auto Craft Site

At the Auto Craft site, potential risks of exposure to zinc were identified for ground-gleaning birds and small mammals. Potential risks of exposure to chromium, lead and zinc were identified for plants growing in the area. Potential risks of exposure to iron were identified for soil invertebrates. These risks of adverse effects were identified based on the maximum exposure scenario for all contaminants to plants and invertebrates and metals to wildlife. The risks of adverse effects were identified for average exposure conditions for semi-volatile organic compounds to wildlife.

Summary of Uncertainties

Uncertainty in the risk estimates may arise during any stage in the ecological risk assessment process. Incorrect assumptions may be made regarding the potential effects of a stressor, the ecosystems of concern, or the species residing within those ecosystems. Generally, care was taken to fully assess and incorporate field observations into the decision process during problem formulation to minimize these uncertainties.

Uncertainty associated with environmental sampling is generally related to the limitations of the sampling program in terms of the number and distribution of samples, while uncertainty associated with the analysis of the samples is generally related to systematic or random errors. The limited number of samples collected at the sites, and the limited testing of those samples, particularly for the metals at these sites add uncertainty to the contaminant values used for the exposure assessment.

The principal uncertainties in the exposure assessment have to do with quantitative estimates of exposure parameters such as BAFs. These parameters typically are chemical, species, and site specific. Exposure parameters for COPCs were taken from the literature or calculated from literature data. Data on contaminants in wild animals, as opposed to domestic or laboratory animals, were used when available. Generally, the reasonable worst case was assumed to provide a conservative estimate.

Another point of uncertainty lies in the assumption that each of the wildlife receptor species feeds only upon food items found in the study areas. For species with very small home ranges, this assumption is likely to be true. However, several of the receptors may consume food sources other than those considered in the assessment, the exclusion which could either over-or underestimate the potential risk. It is also possible, particularly due to the lack of forage within the sites, that the receptors may not feed entirely within the study areas. In addition, the average weights and daily intakes used for the receptor species do not take into account smaller

and larger individuals, and young of the species, which may be more or less sensitive to contaminants than average-sized adults.

The assumption that soil and sediment invertebrate uptake of compounds would be equal to published Earthworm Uptake Factors may also result in an over- or underestimation of potential risk. The amount of a contaminant which is taken up by earthworms from soil or sediment depends, in part, on site-specific soil and sediment conditions such as organic content, contaminant concentration, and presence of other chemicals in the soil or sediment. Uptake of contaminants by soil and sediment invertebrates may occur at different rates or under different conditions than earthworms. Microbial heterotroph toxicity data were used to the extent possible. Similarly, uptake of chemicals by vegetation is very dependent on the type of chemical, soil type, plant species, and other environmental factors.

Uncertainty arises when using any published toxicity results as TRVs. These uncertainties include extrapolating from acute or subchronic exposures to chronic exposure durations and extrapolating across different species, genera, orders, and families. The lack of published toxicity data adds uncertainty to the assessment.

In general, the risk assessment is likely to overestimate rather than underestimate the risks of adverse ecological effects at the sites, because of the conservative nature of the assumptions used. Overall, a generally conservative approach was taken in the evaluation to minimize the possibility of actual risk being greater than that predicted. Conservative steps taken include:

- The selection of COPC based on exceedence or lack of EPA Region III BTAG criteria and exceedence of site-specific and regional background data.
- The comparison of maximum chemical concentrations in site media with maximum background concentrations
- The use of maximum chemical concentrations, where appropriate.
- The use of average body weights and feeding rates and minumum home ranges for the endpoint species.

7.8.3 Ecological Significance

The FTA, LARC, and Auto Craft sites are potential sources of environmental contamination in soil and sediments. These potential effects are considered to have minimal ecological significance for the following reasons:

- In many cases, wildlife risks were identified for the maximum exposure case. The average concentrations are more representative of exposure for mobile species of wildlife, such as the White-footed Mouse.

- The sites are currently disturbed by military activities occurring on the base, particularly the FTA and LARC 60 sites. In addition, the Auto Craft site is paved and fenced. Therefore, the sites can support only a few individuals, and the potential impacts to plant or animal populations as a whole are minimal.

- The ecosystems in the general vicinity of the site do not appear to be impacted or stressed due to chemical contamination.

- Apex predators and wildlife with large home ranges are not likely to be adversely affected due to the comparatively limited extent of contamination.

7.9 CONCLUSIONS AND RECOMMENDATIONS

No further investigation is recommended for any of the sites examined at Fort Story. Very few chemicals were selected as COPCs and the environmental evaluation is likely to have overestimated the potential risk.

Results show that under certain scenarios, the potential does exist for risk to terrestrial vegetation, invertebrates, and mammals in the drainage ditch adjacent to the FTA site. The small sample size in this drainage area adds uncertainty and probably overestimates risk when extrapolating the maximum detections over the entire site. Because of the size of the drainage ditch compared to the home range of mammals and the lack of current visible impacts on vegetation and invertebrates, this risk is considered very low.

At the LARC site, there is a potential for risk to contaminants in sediment from the drainage ditch to mammals. In addition, zinc in the soil and sediment at the site may pose a risk to avian species. However, the estimated exposure of zinc under worst case conditions were equal to Killdeer toxicity levels. Under average conditions, zinc levels would probably not pose a risk to avian species. Ecologically, much of the site provides little value to wildlife for foraging or nesting habitat. Most of the wildlife activity would occur in the adjacent woodland area, or possibly at the former UST area. Therefore, the risks to wildlife associated with the ongoing activities at the LARC 60 site are considered low.

Assessment results at the Auto Craft site show that potential risk of exposure to metals does exist for terrestrial vegetation, invertebrates, ground-gleaning birds, and small mammals. One sample downgradient of the site was tested for metals. This small sample size adds uncertainty to the analysis through the possibility of under- or overestimation of risk. Because of the size of the site , minimal habitat value, and the lack of current visible impacts on vegetation; the risk of exposure to metals is considered low.

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APPENDIX H

BACKGROUND SOILS DATA

FTA SURFACE SOIL AND SEDIMENT COMPARISON

Parameters	Surface Soil Results (mg/kg)		Sediment Results (mg/kg)		Fort Story Background 95th UCL (1)	USGS Regional Soils Data (2)	
	Surface Soil Range	Mean	Sediment Range	Mean		Observed Range	Mean
Aluminum	420 – 980	676	160 – 7,600	2,120	Not analyzed	7,000 – > 100,000	33,000
Arsenic	1.2 – 1.6	1.3	2.5	1.1	2.1	< 0.2 – 73	5.4
Barium	3.9 – 12	8.4	2.4 – 110	30.6	5	15 – 1,000	300
Calcium	71 – 370	153	64 – 120	95	Not analyzed	< 100 – 160,000	3,200
Chromium	1.7 – 5.8	3.1	21	5.7	2.8	1 – 100	36
Cobalt	Not detected	– –	2.6	1.1	Not analyzed	< 3 – 70	7
Copper	3.2 – 13	5.9	26	7.6	1.4	< 1 – 150	14
Iron	1,200 – 5,400	2,700	230 – 17,000	4,488	Not analyzed	100 – > 100,000	15,000
Lead	7 – 33	24	4.3 – 210	59.1	7.1	< 7 – 300	14
Magnesium	62 – 190	112	960	262	Not analyzed	50 – 50,000	2,300
Manganese	10 – 34	24	1.7 – 42	11.9	Not analyzed	< 2 – 7,000	290
Mercury	0.011 – 0.013	0.008	0.017 – 0.051	0.045	0.01	0.01 – 0.34	0.096
Nickel	Not detected	– –	9.4	4.1	2	< 3 – 700	13
Potassium	160	74	260	110	Not analyzed	50 – 37,000	7,400
Sodium	Not detected	– –	87 – 180	80	Not analyzed	< 200 – 15,000	2,600
Thallium	Not detected	– –	1.4	0.8	Not analyzed	– –	– –
Vanadium	1.8 – 3.7	2.7	2 – 18	5	Not analyzed	< 5 – 300	46
Zinc	14 – 22	18	6 – 76	21	5.7	< 5 – 400	36

FTA SURFACE SOIL RESULTS

Parameters	Surface Soil Results (mg/kg)					Arithmetic Mean
Aluminum	420.00	850.00	980.00	490.00	640.00	676
Arsenic	0.55	1.50	1.60	1.20	1.40	1.25
Barium	3.90	9.00	12.00	8.00	9.20	8.42
Calcium	71.00	150.00	370.00	26.00	150.00	153.40
Chromium	1.70	2.30	3.10	5.80	2.50	3.08
Copper	3.50	5.70	4.30	13.00	3.20	5.94
Iron	1200.00	3200.00	2100.00	5400.00	1600.00	2700.00
Lead	7.00	33.00	33.00	15.00	31.00	23.80
Magnesium	88.00	100.00	190.00	62.00	120.00	112.00
Manganese	10.00	34.00	25.00	32.00	19.00	24.00
Mercury	0.0055	0.0055	0.0110	0.0050	0.0130	0.0080
Potassium	55.00	55.00	160.00	50.00	50.00	74.00
Vanadium	1.80	3.10	3.70	1.80	3.10	2.70
Zinc	18.00	14.00	22.00	15.00	22.00	18.20

FTA SEDIMENT RESULTS

Parameters	Sediment Results (mg/kg)					Arithmetic Mean
Aluminum	7600.00	560.00	160.00	160.00		2120.00
Arsenic	2.50	0.70	0.55	0.55		1.08
Barium	110.00	6.50	3.60	2.40		30.63
Calcium	120.00	120.00	64.00	77.00		95.25
Chromium	21.00	0.70	0.55	0.55		5.70
Cobalt	2.60	0.70	0.55	0.55		1.10
Copper	26.00	1.80	1.35	1.35		7.63
Iron	17000.00	440.00	230.00	280.00		4487.50
Lead	210.00	15.00	7.20	4.30		59.13
Magnesium	960.00	35.50	26.50	27.00		262.25
Manganese	42.00	0.70	3.10	1.70		11.88
Mercury	0.0510	0.0170	0.0550	0.0550		0.045
Nickel	9.40	2.85	2.15	2.15		4.14
Potassium	260.00	70.00	55.00	55.00		110.00
Sodium	180.00	87.00	26.50	27.00		80.13
Thallium	0.70	1.40	0.55	0.55		0.80
Vanadium	18.00	2.00	0.55	0.55		5.28
Zinc	76.00	6.00	1.05	1.10		21.04

LARC 60 SURFACE SOIL AND SEDIMENT COMPARISON

Parameters	Surface Soil Results (mg/kg)		Sediment Results (mg/kg)		Fort Story Background 95th UCL (1)	USGS Regional Soils Data (2)	
	Surface Soil Range	Mean	Sediment Range	Mean		Observed Range	Mean
Aluminum	250 – 2,700	814	310 – 650	2,120	Not analyzed	7,000 – > 100,000	33,000
Arsenic	1.1	0.6	Not detected	– –	2.1	< 0.2 – 73	5.4
Barium	1.8 – 19	6.9	1.4 – 2.7	2.1	5	15 – 1,000	300
Calcium	56 – 980	266	53 – 210	132	Not analyzed	< 100 – 160,000	3,200
Chromium	1.7 – 4.3	2.8	1.6 – 2.5	2.1	2.8	1 – 100	36
Cobalt	2.3	0.86	Not detected	– –	Not analyzed	< 3 – 70	7
Copper	2.5 – 41	13.2	3.8 – 9	6.4	1.4	< 1 – 150	14
Iron	400 – 1,100	770	310 – 940	675	Not analyzed	100 – > 100,000	15,000
Lead	3.1 – 12	8	8.2 – 14	11.1	7.1	< 7 – 300	14
Magnesium	77 – 1,400	341	110 – 250	180	Not analyzed	50 – 50,000	2,300
Manganese	2.4 – 120	29.4	3.4 – 6.9	5.2	Not analyzed	< 2 – 7,000	290
Mercury	Not detected	– –	Not detected	– –	0.01	0.01 – 0.34	0.096
Nickel	Not detected	– –	Not detected	– –	2	< 3 – 700	13
Potassium	1,200	280	Not detected	– –	Not analyzed	50 – 37,000	7,400
Sodium	Not detected	– –	70	51	Not analyzed	< 200 – 15,000	2,600
Thallium	Not detected	– –	Not detected	– –	Not analyzed	– –	– –
Vanadium	1.2 – 9.2	3.1	1.3 – 2.7	2	Not analyzed	< 5 – 300	46
Zinc	3.8 – 33	16.2	11 – 30	21	5.7	< 5 – 400	36

LARC 60 SURFACE SOIL RESULTS

Parameters	Surface Soil Results (mg/kg)					Arithmetic Mean
Aluminum	2700.00	310.00	440.00	250.00	370.00	814
Arsenic	1.10	0.50	0.50	0.50	0.50	0.62
Barium	19.00	3.90	3.70	1.80	5.90	6.86
Calcium	980.00	160.00	110.00	25.50	56.00	266.30
Chromium	4.30	2.40	2.30	1.70	3.20	2.78
Cobalt	2.30	0.50	0.50	0.50	0.50	0.86
Copper	9.10	41.00	1.30	2.50	12.00	13.18
Iron	510.00	1000.00	1100.00	400.00	840.00	770.00
Lead	7.60	11.00	6.40	3.10	12.00	8.02
Magnesium	1400.00	94.00	110.00	25.50	77.00	341.30
Manganese	120.00	12.00	7.20	2.40	5.60	29.44
Potassium	1200.00	50.00	50.00	50.00	50.00	280.00
Vanadium	9.20	1.60	1.90	1.20	1.80	3.14
Zinc	26.00	33.00	6.40	3.80	12.00	16.24

LARC 60 SEDIMENT RESULTS

Parameters	Sediment Results (mg/kg)			Arithmetic Mean
Aluminum	310.00	650.00		480.00
Barium	1.40	2.70		2.05
Calcium	53.00	210.00		131.50
Chromium	1.60	2.50		2.05
Copper	3.80	9.00		6.40
Iron	410.00	940.00		675.00
Lead	8.20	14.00		11.10
Magnesium	110.00	250.00		180.00
Manganese	3.40	6.90		5.15
Sodium	32.00	70.00		51.00
Vanadium	1.30	2.70		2.00
Zinc	11.00	30.00		20.50

APPENDIX I

HUMAN HEALTH RISK ASSESSMENT CALCULATIONS

95th percent UCL Calculations for Groundwater COPCs

Auto Craft Building Area
Fort Story, Virginia

Sample Point	Results	Natural Log	Chloroform	
7MW-2	2.5	0.9163	# Of Samples	9
7MW-3/MW-119*	11	2.3979	Mean of Log Transformed Data	1.080913
MW-120	2.5	0.9163	Standard Deviation	0.465623
DPT #1	2.5	0.9163	Variance	0.216805
DPT #2	2.5	0.9163	H Value	2.251
DPT #3	2.5	0.9163	**95th Percentile UCL**	**4.76**
DPT #4	2.5	0.9163	**for Chloroform**	
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		

Sample Point	Results	Natural Log	Bis(2-ethylhexyl)phthalate	
7MW-2	2.5	0.9163	# Of Samples	9
7MW-3/MW-119*	2.5	0.9163	Mean of Log Transformed Data	1.045530
MW-120	2.5	0.9163	Standard Deviation	0.365543
DPT #1	2.5	0.9163	Variance	0.133622
DPT #2	2.5	0.9163	H Value	2.11
DPT #3	2.5	0.9163	**95th Percentile UCL**	**3.99**
DPT #4	2.5	0.9163	**for Bis(2-ethylhexyl)phthalate**	
DPT #5	8	2.0794		
DPT #6	2.5	0.9163		

* – Highest concentration used for the deep/shallow well cluster at the site

CDI CALCULATIONS FOR SURFACE SOILS

AUTO CRAFT AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.3	100	1.00E–06	0.5	350	30	70	8.90E–07
Manganese (Adults)	170	100	1.00E–06	0.5	350	30	70	1.16E–04
Arsenic (Children)	1.3	200	1.00E–06	0.5	350	6	15	8.31E–06
Manganese (Children)	170	200	1.00E–06	0.5	350	6	15	1.09E–03
Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.3	100	1.00E–06	0.5	350	30	70	3.82E–07
Arsenic (Children)	1.3	200	1.00E–06	0.5	350	6	15	7.12E–07

CDI CALCULATIONS FOR GROUNDWATER
AUTO CRAFT AREA, FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Manganese (Adults)	0.08	2	350	30	70	2.19E–03
Bis (Adults)	0.00399	2	350	30	70	1.09E–04
Chloroform (Adults)	0.00476	2	350	30	70	1.30E–04
Manganese (Children)	0.08	1	350	6	15	5.11E–03
Bis (Children)	0.00399	1	350	6	15	2.55E–04
Chloroform (Children)	0.00476	1	350	6	15	3.04E–04

Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Bis (Adults)	0.00399	2	350	30	70	4.68E–05
Chloroform (Adults)	0.00476	2	350	30	70	5.59E–05
Bis (Children)	0.00399	1	350	6	15	2.19E–05
Chloroform (Children)	0.00476	1	350	6	15	2.61E–05

Non–Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Manganese (Adults)	0.08	19400	5.00E–04	0.3	350	30	0.001	70	3.19E–06
Bis (Adults)	0.00399	19400	3.16E–02	0.3	350	30	0.001	70	1.01E–05
Chloroform (Adults)	0.00476	19400	2.95E–02	0.3	350	30	0.001	70	1.12E–05
Manganese (Children)	0.08	7310	5.00E–04	0.3	350	6	0.001	15	5.61E–06
Bis (Children)	0.00399	7310	3.16E–02	0.3	350	6	0.001	15	1.77E–05
Chloroform (Children)	0.00476	7310	2.95E–02	0.3	350	6	0.001	15	1.97E–05

Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	IR	EF	ET	EF	ED	CF	BW	CDI
Bis (Adults)	0.00399	19400	3.16E–02	0.3	350	30	0.001	70	4.31E–06
Chloroform (Adults)	0.00476	19400	2.95E–02	0.3	350	30	0.001	70	4.80E–06
Bis (Children)	0.00399	7310	3.16E–02	0.3	350	6	0.001	15	1.52E–06
Chloroform (Children)	0.00476	7310	2.95E–02	0.3	350	6	0.001	15	1.69E–06

Non–Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	SA	ET	EF	ED	BW	CDI
Chloroform (Adults)	0.0317	0.83	0.2	350	30	70	7.21E–05
Chloroform (Children)	0.0317	0.5	0.2	350	6	15	2.03E–04

Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
Chloroform (Adults)	0.0317	0.83	0.2	350	30	70	3.09E–05
Chloroform (Children)	0.0317	0.5	0.2	350	6	15	1.74E–05

95th percent UCL Calculations for Soil and Sediment COPC

Firefighter Training Area
Fort Story, Virginia

Surface Soil/Sediment Sample Point	Arsenic Results	Natural Log		
SB−001	0.55	−0.5978	# Of Samples	9
SB−005	1.5	0.4055	Mean of Log Transformed Data	0.017819
SB−010	1.6	0.4700	Standard Deviation	0.534159
SB−015	1.2	0.1823	Variance	0.285326
SB−020	1.4	0.3365	H Value	2.359
SD−001	2.5	0.9163	**95th Percentile UCL**	**1.83**
SD−002	0.7	−0.3567		
SD−003	0.55	−0.5978		
SD−004	0.55	−0.5978		

Surface Soil/Sediment Sample Point	Thallium Results	Natural Log		
SB−001	0.55	−0.5978	# Of Samples	9
SB−005	0.55	−0.5978	Mean of Log Transformed Data	−0.488409
SB−010	0.55	−0.5978	Standard Deviation	0.305776
SB−015	0.5	−0.6931	Variance	0.093499
SB−020	0.5	−0.6931	H Value	2.033
SD−001	0.7	−0.3567	**95th Percentile UCL**	**0.80**
SD−002	1.4	0.3365		
SD−003	0.55	−0.5978		
SD−004	0.55	−0.5978		

95th percent UCL Calculations for Groundwater COPC

Firefighter Training Area
Fort Story, Virginia

Sample Point	PCE Results	Natural Log		
4MW-1	2.5	0.9163	# Of Samples	31
4MW-2S/4MW-2D*	2.5	0.9163	Mean of Log Transformed Data	1.057595
4MW-3	2.5	0.9163	Standard Deviation	0.624787
4MW-4	2.5	0.9163	Variance	0.390359
4MW-5/MW-112*	2.5	0.9163	H Value	2.033
MW-111	2.5	0.9163	**95th Percentile UCL**	**4.41**
MW-113A	2.5	0.9163		
MW-114A	2.5	0.9163		
DPT #1	2.5	0.9163		
DPT #2	6.4	1.8563		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	78	4.3567		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #14**	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #17	2.5	0.9163		
DPT #18	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #22	2.5	0.9163		
DPT #23	2.5	0.9163		

* – Highest concentration used for the deep/shallow well clusters present at the site.
** – Highest concentration used for two DPT depths sampled at this point.

CDI CALCULATIONS FOR SURFACE SOILS AND SEDIMENT

FIREFIGHTER TRAINING AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.83	100	1.00E–06	0.5	350	30	70	1.25E–06
Thallium (Adults)	0.8	100	1.00E–06	0.5	350	30	70	5.48E–07
Arsenic (Children)	1.83	200	1.00E–06	0.5	350	6	15	1.17E–05
Thallium (Children)	0.8	200	1.00E–06	0.5	350	6	15	5.11E–06
Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.83	100	1.00E–06	0.5	350	30	70	5.37E–07
Arsenic (Children)	1.83	200	1.00E–06	0.5	350	6	15	1.00E–06

CDI CALCULATIONS FOR GROUNDWATER

FIREFIGHTER TRAINING AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Manganese (Adults)	0.081	2	350	30	70	2.22E–03
PCE (Adults)	0.00441	2	350	30	70	1.21E–04
Manganese (Children)	0.081	1	350	6	15	5.18E–03
PCE (Children)	0.00441	1	350	6	15	2.82E–04

Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
PCE (Adults)	0.00441	2	350	30	70	5.18E–05
PCE (Children)	0.00441	1	350	6	15	2.42E–05

Non–Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Manganese (Adults)	0.081	19400	5.00E–04	0.3	350	30	0.001	70	3.23E–06
PCE (Adults)	0.00441	19400	2.40E–03	0.3	350	30	0.001	70	8.44E–07
Manganese (Children)	0.081	7310	5.00E–04	0.3	350	6	0.001	15	5.68E–06
PCE (Children)	0.00441	7310	2.40E–03	0.3	350	6	0.001	15	1.48E–06

Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
PCE (Adults)	0.00441	19400	2.40E–03	0.3	350	30	0.001	70	3.62E–07
PCE (Children)	0.00441	7310	2.40E–03	0.3	350	6	0.001	15	1.27E–07

Non–Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
PCE (Adults)	0.0294	0.83	0.2	350	30	70	6.69E–05
PCE (Children)	0.0294	0.5	0.2	350	6	15	1.88E–04

Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
PCE (Adults)	0.0294	0.83	0.2	350	30	70	2.87E–05
PCE (Children)	0.0294	0.5	0.2	350	6	15	1.61E–05

95th percent UCL Calculations for Soil COPCs

LARC 60 Maintenance Area
Fort Story, Virginia

Surface Soil Sample Point	Arsenic Results	Natural Log		
SB−001	1.1	0.0953	# Of Samples	5
SB−005	0.5	−0.6931	Mean of Log Transformed Data	−0.535456
SB−010	0.5	−0.6931	Standard Deviation	0.315383
SB−015	0.5	−0.6931	Variance	0.099466
SB−020	0.5	−0.6931	H Value	2.44
			95th Percentile UCL for Arsenic	**0.90**

Surface Soil Sample Point	Manganese Results	Natural Log		
SB−001	120	4.7875	# Of Samples	5
SB−005	12	2.4849	Mean of Log Transformed Data	2.368943
SB−010	7.2	1.9741	Standard Deviation	1.316568
SB−015	2.4	0.8755	Variance	1.733350
SB−020	5.6	1.7228	H Value	6.314
			95th Percentile UCL for Manganese	**1622.98**

95th percent UCL Calculations for Groundwater COPCs – LARC 60 Site

Sample Point	Results	Natural Log	cis 1,2-DCE	
6MW-1	2.5	0.9163	# Of Samples	25
6MW-2/MW-117*	20	2.9957	Mean of Log Transformed Data	1.259879
6MW-2S/6MW-2D*	2.5	0.9163	Standard Deviation	0.950236
6MW-3	2.5	0.9163	Variance	0.902948
MW-115	2.5	0.9163	H Value	2.445
MW-118	2.5	0.9163	**95th Percentile UCL**	**8.90**
DPT #1	2.5	0.9163	**for cis 1,2-DCE**	
DPT #2/DPT #17**	150	5.0106		
DPT #3	20	2.9957		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	3.5	1.2528		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	Ethylbenzene	
6MW-1	2.5	0.9163	# Of Samples	25
6MW-2/MW-117*	66	4.1897	Mean of Log Transformed Data	1.352869
6MW-2S/6MW-2D*	2.5	0.9163	Standard Deviation	1.221658
6MW-3	2.5	0.9163	Variance	1.492448
MW-115	2.5	0.9163	H Value	2.808
MW-118	2.5	0.9163	**95th Percentile UCL**	**16.43**
DPT #1	2.5	0.9163	**for Ethylbenzene**	
DPT #2/DPT #17**	530	6.2729		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	6.6	1.8871		
DPT #12	2.5	0.9163		
DPT #13	9.3	2.2300		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	PCE	
6MW-1	2.5	0.9163	# Of Samples	25
6MW-2/MW-117*	8.5	2.1401	Mean of Log Transformed Data	1.300377
6MW-2S/6MW-2D*	2.5	0.9163	Standard Deviation	0.987148
6MW-3	2.5	0.9163	Variance	0.974462
MW-115	2.5	0.9163	H Value	2.491
MW-118	2.5	0.9163	**95th Percentile UCL**	**9.87**
DPT #1	2.5	0.9163	**for PCE**	
DPT #2/DPT #17**	25	3.2189		
DPT #3	170	5.1358		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	16	2.7726		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	Toluene	
6MW-1	2.5	0.9163	# Of Samples	25
6MW-2/MW-117*	68	4.2195	Mean of Log Transformed Data	1.357217
6MW-2S/6MW-2D*	2.5	0.9163	Standard Deviation	1.454673
6MW-3	2.5	0.9163	Variance	2.116072
MW-115	2.5	0.9163	H Value	3.143
MW-118	2.5	0.9163	**95th Percentile UCL**	**28.46**
DPT #1	2.5	0.9163	**for Toluene**	
DPT #2/DPT #17**	2200	7.6962		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	6.4	1.8563		
DPT #10	2.5	0.9163		
DPT #11	2.5	0.9163		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

* – Highest concentration used for the deep/shallow well clusters present at the site.
** – Highest concentration used for two DPT depths sampled at this point.

95th percent UCL Calculations for Groundwater COPCs – LARC 60 Site

Sample Point	Results	Natural Log	TCE	
6MW–1	2.5	0.9163	# Of Samples	25
6MW–2/MW–117*	18	2.8904	Mean of Log Transformed Data	1.426818
6MW–2S/6MW–2D*	2.5	0.9163	Standard Deviation	1.230747
6MW–3	2.5	0.9163	Variance	1.514738
MW–115	2.5	0.9163	H Value	2.822
MW–118	2.5	0.9163	**95th Percentile UCL**	**18.05**
DPT #1	2.5	0.9163	**for TCE**	
DPT #2/DPT #17**	47	3.8501		
DPT #3	260	5.5607		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	62	4.1271		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	Xylenes	
6MW–1	2.5	0.9163	# Of Samples	25
6MW–2/MW–117*	290	5.6699	Mean of Log Transformed Data	1.496466
6MW–2S/6MW–2D*	2.5	0.9163	Standard Deviation	1.687983
6MW–3	2.5	0.9163	Variance	2.849286
MW–115	2.5	0.9163	H Value	3.513
MW–118	2.5	0.9163	**95th Percentile UCL**	**62.27**
DPT #1	2.5	0.9163	**for Xylenes**	
DPT #2/DPT #17**	2900	7.9725		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	37	3.6109		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

* – Highest concentration used for the deep/shallow well clusters present at the site.
** – Highest concentration used for two DPT depths sampled at this point.

CDI CALCULATIONS FOR SURFACE SOILS

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	0.9	100	1.00E–06	0.5	350	30	70	6.16E–07
Manganese (Adults)	120	100	1.00E–06	0.5	350	30	70	8.22E–05
Arsenic (Children)	0.9	200	1.00E–06	0.5	350	6	15	5.75E–06
Manganese (Children)	120	200	1.00E–06	0.5	350	6	15	7.67E–04
Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	0.9	100	1.00E–06	0.5	350	30	70	2.64E–07
Arsenic (Children)	0.9	200	1.00E–06	0.5	350	6	15	4.93E–07

CDI CALCULATIONS FOR GROUNDWATER

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater						
Chemical	**Conc**	**IR**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	0.04	2	350	30	70	1.10E–03
Manganese (Adults)	0.53	2	350	30	70	1.45E–02
cis 1,2–DCE (Adults)	0.0089	2	350	30	70	2.44E–04
Ethylbenzene (Adults)	0.0164	2	350	30	70	4.49E–04
PCE (Adults)	0.0099	2	350	30	70	2.71E–04
Toluene (Adults)	0.0285	2	350	30	70	7.81E–04
TCE (Adults)	0.0181	2	350	30	70	4.96E–04
Xylenes (Adults)	0.0623	2	350	30	70	1.71E–03
Arsenic (Child)	0.04	1	350	6	15	2.56E–03
Manganese (Child)	0.53	1	350	6	15	3.39E–02
cis 1,2–DCE (Child)	0.0089	1	350	6	15	5.69E–04
Ethylbenzene (Child)	0.0164	1	350	6	15	1.05E–03
PCE (Child)	0.0099	1	350	6	15	6.33E–04
Toluene (Child)	0.0285	1	350	6	15	1.82E–03
TCE (Child)	0.0181	1	350	6	15	1.16E–03
Xylenes (Child)	0.0623	1	350	6	15	3.98E–03
Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater						
Chemical	**Conc**	**IR**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	0.04	2	350	30	70	4.70E–04
PCE (Adults)	0.0099	2	350	30	70	1.16E–04
TCE (Adults)	0.0181	2	350	30	70	2.13E–04
Arsenic (Child)	0.04	1	350	6	15	2.19E–04
PCE (Child)	0.0099	1	350	6	15	5.42E–05
TCE (Child)	0.0181	1	350	6	15	9.92E–05

CDI CALCULATIONS FOR GROUNDWATER

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Arsenic (Adults)	0.04	19400	5.00E–04	0.3	350	30	0.001	70	1.59E–06
Manganese (Adults)	0.53	19400	5.00E–04	0.3	350	30	0.001	70	2.11E–05
cis 1,2–DCE (Adults)	0.0089	19400	2.29E–02	0.3	350	30	0.001	70	1.62E–05
Ethylbenzene (Adults)	0.0164	19400	3.16E–01	0.3	350	30	0.001	70	4.13E–04
PCE (Adults)	0.0099	19400	2.40E–03	0.3	350	30	0.001	70	1.89E–06
Toluene (Adults)	0.0285	19400	1.00E+00	0.3	350	30	0.001	70	2.27E–03
TCE (Adults)	0.0181	19400	8.32E–02	0.3	350	30	0.001	70	1.20E–04
Xylenes (Adults)	0.0623	19400	3.16E–01	0.3	350	30	0.001	70	1.57E–03
Arsenic (Child)	0.04	7310	5.00E–04	0.3	350	6	0.001	15	2.80E–06
Manganese (Child)	0.53	7310	5.00E–04	0.3	350	6	0.001	15	3.72E–05
cis 1,2–DCE (Child)	0.0089	7310	2.29E–02	0.3	350	6	0.001	15	2.86E–05
Ethylbenzene (Child)	0.0164	7310	3.16E–01	0.3	350	6	0.001	15	7.27E–04
PCE (Child)	0.0099	7310	2.40E–03	0.3	350	6	0.001	15	3.33E–06
Toluene (Child)	0.0285	7310	1.00E+00	0.3	350	6	0.001	15	4.00E–03
TCE (Child)	0.0181	7310	8.32E–02	0.3	350	6	0.001	15	2.11E–04
Xylenes (Child)	0.0623	7310	3.16E–01	0.3	350	6	0.001	15	2.76E–03

Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Arsenic (Adults)	0.04	19400	5.00E–04	0.3	350	30	0.001	70	6.83E–07
PCE (Adults)	0.0099	19400	2.40E–03	0.3	350	30	0.001	70	8.12E–07
TCE (Adults)	0.0181	19400	8.32E–02	0.3	350	30	0.001	70	5.15E–05
Arsenic (Child)	0.04	7310	5.00E–04	0.3	350	6	0.001	15	2.40E–07
PCE (Child)	0.0099	7310	2.40E–03	0.3	350	6	0.001	15	2.86E–07
TCE (Child)	0.0181	7310	8.32E–02	0.3	350	6	0.001	15	1.81E–05

CDI CALCULATIONS FOR GROUNDWATER

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater							
Chemical	**Conc**	**IR**	**ET**	**EF**	**ED**	**BW**	**CDI**
cis 1,2–DCE (Adults)	5.93E–02	0.83	0.2	350	30	70	1.35E–04
Ethylbenzene (Adults) *	1.09E–01	0.83	0.2	350	30	70	2.48E–04
PCE (Adults)	6.60E–02	0.83	0.2	350	30	70	1.50E–04
Toluene (Adults) *	1.90E–01	0.83	0.2	350	30	70	4.32E–04
TCE (Adults)	1.21E–01	0.83	0.2	350	30	70	2.75E–04
Xylenes (Adults)	4.15E–01	0.83	0.2	350	30	70	9.44E–04
cis 1,2–DCE (Child)	5.93E–02	0.5	0.2	350	6	15	3.79E–04
Ethylbenzene (Child) *	1.09E–01	0.5	0.2	350	6	15	6.97E–04
PCE (Child)	6.60E–02	0.5	0.2	350	6	15	4.22E–04
Toluene (Child) *	1.90E–01	0.5	0.2	350	6	15	1.21E–03
TCE (Child)	1.21E–01	0.5	0.2	350	6	15	7.74E–04
Xylenes (Child)	4.15E–01	0.5	0.2	350	6	15	2.65E–03
Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater							
Chemical	**Conc**	**IR**	**ET**	**EF**	**ED**	**BW**	**CDI**
cis 1,2–DCE (Adults)	5.93E–02	0.83	0.2	350	30	70	5.78E–05
PCE (Adults) *	6.60E–02	0.83	0.2	350	30	70	6.43E–05
TCE (Adults) *	1.21E–01	0.83	0.2	350	30	70	1.18E–04
cis 1,2–DCE (Child)	5.93E–02	0.5	0.2	350	6	15	3.25E–05
PCE (Child) *	6.60E–02	0.5	0.2	350	6	15	3.62E–05
TCE (Child) *	1.21E–01	0.5	0.2	350	6	15	6.63E–05

Notes:
* – Although CDIs are calculated above for all VOCs identified as COPCs in groundwater, only ethylbenzene and toluene have RfDs for inhalation while only PCE and TCE have CPSs for inhalation. Therefore, risks will only be quantified for these VOCs as shown on Tables 6–23 and 6–24 in the HHRA.

CONCENTRATION–IN–AIR CALCULATIONS
FORT STORY SITES, VIRGINIA

Concentration in Air = CW x CF x WV/RV

Chemical	Max	UCL	CF	WV	RV	CA–Max	CA–UCL
FIREFIGHTER TRAINING AREA							
PCE	78	4.41	0.001	200	30	5.20E–01	2.94E–02
LARC 60 MAINTENANCE AREA							
cis 1,2–DCE	150	8.9	0.001	200	30	1.00E+00	5.93E–02
Ethylbenzene	530	16.4	0.001	200	30	3.53E+00	1.09E–01
PCE	170	9.9	0.001	200	30	1.13E+00	6.60E–02
Toluene	2200	28.5	0.001	200	30	1.47E+01	1.90E–01
TCE	260	18.1	0.001	200	30	1.73E+00	1.21E–01
Xylenes	2900	62.3	0.001	200	30	1.93E+01	4.15E–01
AUTO CRAFT BUILDING AREA							
Chloroform	11	4.76	0.001	200	30	7.33E–02	3.17E–02

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. Dissolved results may be biased high based on the filtering limitations.

- VOC estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. Chloroform was detected infrequently (1 of 10 samples). Analysis with a lower PQL may more accurately estimate VOC concentrations and subsequent risk. It should be noted that the chloroform concentration (11 ug/l) detected was less than the USEPA MCL (100 ug/l) for total trihalomethanes indicating that the level present in the groundwater would meet acceptable criteria for a drinking water distribution system.

6.4.5 Auto Craft Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

- A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:
  - The total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is less than the criterion for adults but greater than the criterion of 1.0 for children with the majority (approximately 77 percent) of this risk associated with ingestion of manganese in groundwater which was the only exposure scenario above the criterion.

- A summary of the **Carcinogenic Risk** for future residential land use is provided below:
  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults. The greatest component for adults exposures is inhalation of chloroform in groundwater (60 percent of total risk) which was within the USEPA remediation goal.
  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 1 million for children. The greatest components for child exposures are ingestion of arsenic (although levels are consistent with background) in soils (36 percent of total risk) and inhalation of chloroform in groundwater (47 percent of total risk).

- Potential risk above acceptable criteria is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

- Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentration of chloroform in groundwater due to natural attenuation would be expected to decrease. It currently is below the USEPA MCL for total trihalomethanes.

- Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater and surface soils for future residential development.

7.1 OVERVIEW AND OBJECTIVES

This section presents an assessment of potential environmental risks associated with contaminants detected at 3 sites on Fort Story: FTA, LARC 60 , and Auto Craft Sites. The primary objective of the ecological risk assessment is to identify and characterize the potential risks posed to wildlife receptors as a result of contaminant releases. Secondary objectives are: to document dominant flora and fauna associated with the site; to determine the contaminants of potential concern being released from the site; to identify potential pathways for receptor exposure; and to determine if any response action might be necessary at the site, from an ecological perspective.

Statutory authority for this assessment is found in CERCLA as amended by the Superfund Amendments and Reauthorization Act (SARA). The evaluation follows guidance contained in the following documents:

- U.S. Environmental Protection Agency's (USEPA) *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual* (USEPA, 1989)
- *Framework for Ecological Risk Assessment* (USEPA, 1992)
- *Procedural Guidelines for Ecological Risk Assessments at U.S. Army Sites Volume I* (Wentsel et. al., 1994).

According to current USEPA guidance, the following steps were completed for the risk assessment at each site:

- Problem Formulation

  - Qualitative characterization of natural resources
  - Identification of chemicals of potential concern
  - Identification of potential exposure pathways
  - Identification of ecological endpoints
  - Development of conceptual ecological site model

- Exposure assessment providing quantitative or qualitative exposure scenarios for selected ecological receptors

- Ecological effects assessment summarizing toxicity reference values for selected ecological receptors

- Characterization of risk
- Estimation of risk uncertainty

Chemical analyses were performed on environmental media, including soil, sediment, surface water, and ground water, where applicable at each site. The conclusions derived from this study focus on identifying potential adverse risks to species, habitats, and populations in the environment, and is not a quantitative determination of risk. The risk assessment addresses potentially significant risks to the following biological groups and resources associated with the area: vascular vegetation, wildlife, threatened and endangered species, and wetlands. Significant habitats and wetlands on the base are identified. Cover types and species inventories for each investigated site and its immediately adjacent areas are also included.

As preceding sections of this RI have indicated, a substantial amount of site-specific data on chemical and physical information was developed to characterize the types, location, and concentrations of chemicals in the environmental media. Validated chemical analytical results were used in all ecological risk analyses. Contaminant toxicity levels to terrestrial and avian species were derived from technical literature. Chemical profiles for chemicals of potential concern are included in Appendix K.

7.2 Problem Formulation

Problem formulation is the first phase of ecological risk assessment and establishes the goals, breadth, and focus of the assessment (USEPA, 1992). The process involves a series of interrelated steps to identify potential stressors, pathways, and ecological effects. Ecological endpoints appropriate for the site are then derived, and an ecological conceptual site model is formulated. This model is a set of working hypotheses regarding the potential pathways and effects of site-related stressors on ecosystems of concern.

Problem formulation is based on information collected during the Remedial Investigation. This phase of the ecological risk assessment is presented in four parts: ecosystems of concern; potential stressors, exposure pathways, and ecological effects; ecological endpoints and; the conceptual model.

Initially, field studies were conducted and the ecology of the sites and surrounding areas were characterized. This characterization involved the identification of plant and animal communities as well as observations of any actual or potential effects of chemical and/or physical stress on these biological resources.

The second step in problem formulation involves the identification of the interrelationships between potential stressors, exposure pathways, and ecological effects for the identified ecosystems of concern. Chemical and/or physical stressors are identified, potential pathways for migration of contaminants from the site to the ecosystems of concern are discussed, and potential ecological effects are summarized.

7.2.1 Ecosystems of Concern

Firefighter Training Area

Site Description

The FTA site has been highly disturbed by past activities such as the existence of a hospital, firefighting activities, and current activities such as heavy equipment operation training. The woods adjacent to the site are used for infantry training and several small burned areas are evident. Additionally, since 1995, approximately 12,000 square feet of the site has been used for land farming of contaminated soil from an adjacent UST excavation. These soils are contaminated with several VOCs and the contaminants are being allowed to volatilize naturally. An impermeable liner was placed underneath and around the soil so that contaminants could not migrate from the land farming area.

Flora and Fauna

In April 1996, Malcolm Pirnie biologists conducted an inventory of vegetative species occurring within and adjacent to the site. The former Fire Training Pit has been dismantled and is currently covered by gravel. A few weed species grow through the gravel. The remaining southern end of the site is covered with low-growing vegetative species thriving in a sandy soil environment. The northern end of the site has sandy soil and is primarily unvegetated. Pine forests border the site on the west and south, with a road and a vegetated berm separating the forest from the site. A low area occurs in the forest to the south of the site, but standing water does not usually collect in the area. The woods contain several tall vegetated sand dunes and run south and west to Shore Drive. Dominant vegetation at the former FTA site is listed in Table 7-1.

Indicators and observations of wildlife usage in the FTA site included the following: Eastern Cottontail (*Sylvilagus floridanus*), Eastern Bluebird (*Sialis sialis*), and the European Starling (*Sturnus vulgaris*). Greater Yellowlegs (*Tringa melanoleuca*) were observed foraging in a temporary pool immediately adjacent to the land farming area. Observations of wildlife usage in the wooded area adjacent to the site included the following: Raccoon (*Procyon lotor*), Common Mole (*Condylura cristata*), Gray Squirrel (*Sciurus carolinensis*), Blue-gray Gnatcatcher

Table 7-1
Dominant Vegetation at the FTA Site
Fort Story, Virginia

Common Name	Scientific Name
Vegetation at the FTA Site	
Clover	*Trifolium sp.*
Grasses	*Poa sp.*
Aster	*Aster sp.*
Mustard	Family *Cruciferae*
Pixie	*Diapensia sp.*
Wild Onion	*Allium canadense*
Common Dandelion	*Taraxacum officinale*
Vegetation in the Adjacent Woodland Area	
Live Oak	*Quercus virginiana*
Loblolly Pine	*Pinus taeda*
Water Oak	*Quercus nigra*
Sweet Bay	*Magnolia virginiana*
Lowbush Blueberry	*Vaccinium angustifolium*
Red Maple	*Acer ruburm*
American Holly	*Ilex opaca*
Sweet Gum	*Liquidambar styraciflua*
Common Greenbrier	*Smilax rotundifolia*
Broom Sedge	*Andropogon virginicus*
Virginia Pine	*Pinus virginiana*
Black Locust	*Robinia pseudo-acacia*
Black Cherry	*Prunus serotina*
European Honeysuckle	*Locinaria xylosteum*
Southern Cane	*Arudinaria gigantea*
Wax Myrtle	*Myrica cerifera*

(*Polioptila coerulea*), Killdeer (*Charadrius vociferus*), Pine Warbler (*Dendroica discolor*), and Cardinal (*Richmondena cardinalis*). A detailed list of wildlife species expected to occur in the vicinity of Fort Story is included as Appendix L.

LARC 60 Maintenance Area

Site Description

The LARC 60 site is an active heavy equipment maintenance and operation area which includes three subsites: the Sandbox and adjacent wash rack, an oil/water separator, and a former UST area. Because the majority of the site is covered with asphalt, concrete, or has little to no vegetative cover, there are limited habitats for wildlife. The Sandbox is an unvegetated sandy area that is used as a heavy equipment operating area. A small wooded island occurs within the western end of the Sandbox. A chain link fence borders the northern end of the Sandbox, and a mixed pine/deciduous forest is located beyond the fence. There is a drainage ditch immediately north of the fence which collects storm water runoff from the Sandbox, the adjacent wash rack, and the wooded area. The oil/water separator is located at the west end of Building 1083 and is surrounded by asphalt paving. This area would not be attractive to wildlife. The former UST area is covered with gravel and sand and a few weedy species. The remaining area between the subsites is covered with buildings, asphalt, or concrete pavement. Wildlife species most frequently associated with the site would probably nest in the wooded area to the north of the Sandbox or to the west of the former UST site. Because of the proximity of the sites and similar lack of vegetation, the three subsites were assessed together.

Flora and Fauna

In April 1996, Malcolm Pirnie biologists conducted an inventory of vegetative species occurring within and immediately adjacent to the LARC 60 site. A few weedy species grow on the sand and gravel surface of the former UST area. These species are listed in Table 7-2. Similar vegetative species occur in the woodlands surrounding the site and in the wooded island in the Sandbox. The areas are predominantly covered by pines, Live Oak, and Water Oak. The dominant vegetative species are also included in Table 7-2.

Indicators and observations of wildlife usage of the LARC 60 site, adjacent wooded area, and adjacent drainage ditch include the following: Bobwhite (*Colinus virginianus*), Green-backed Heron (*Butorides virescens*), Cardinal (*Richmondena cardinalis*), American Crow (*Corvus brachyrhynchos*), Mallard (*Anas platyrhynchos*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), Common Grackle (*Quiscalus quiscula*), House Finch (*Carpodacus mexicanus*), and Brown-headed Nuthatch (*Sitta pusilla*).

Table 7-2
Dominant Vegetation at the LARC 60 Site
Fort Story, Virginia

Common Name	Scientific Name
Vegetation at the Former UST Area	
Clover	*Trifolium sp.*
Grasses	*Poa sp.*
Aster	*Aster sp.*
Wild Onion	*Allium canadense*
Vegetation in the Adjacent Wooded Area	
Live Oak	*Quercus virginiana*
Loblolly Pine	*Pinus taeda*
Water Oak	*Quercus nigra*
Red Bay	*Persea borbonia*
Highbush Blueberry	*Vaccinium corymbosum*
Red Maple	*Acer ruburm*
American Holly	*Ilex opaca*
Inkberry	*Ilex glabra*
Common Greenbrier	*Smilax rotundifolia*
Broom Sedge	*Andropogon virginicus*
Virginia Pine	*Pinus virginiana*
Vegetation Associated with the Drainage Ditch in the Adjacent Wooded Area	
Soft Rush	*Juncus effusus*
Seed Box	*Ludwigia alternifolia*
Virginia Sweet Spires	*Itea virginica*
Highbush Blueberry	*Vaccinium corymbosum*
Broom Sedge	*Andropogon virginicus*
Wax Myrtle	*Myrica cerifera*

Auto Craft Building Area

Site Description

The Auto Craft Site contains a small building and an asphalt parking lot completely enclosed by a chain link fence. A small weeded area now marks a former building, which was partially destroyed by fire, then dismantled. Downgradient of the site, between the site and Atlantic Avenue, lies a small grassy area. No wetlands or streams are located in the vicinity of the site.

Flora and Fauna

In April 1996, Malcolm Pirnie biologists conducted a vegetative inventory of the species occurring within the area. The few vegetative species occurring within the fenced area and the dominant grassy species occurring downgradient of the site are listed in Table 7-3. In addition, the species in the wooded area to the east of the site are listed. Because of the lack of vegetative species within the site itself, it is likely that wildlife will forage and nest within the adjacent wooded area.

Indicators and observations of wildlife within and adjacent to the site include the following: Common Grackle (*Quiscalus quiscula*), Mourning Dove (*Zenaidura macroura*), Killdeer (*Charadrius vociferus*), House Wren (*Troglodytes aedon*), Blue-grey Gnatcatcher (*Polioptila coerulea*), American Crow (*Corvus brachyrhynchos*), White-throated Sparrow (*Zonotrichia albicollis*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), and Common Mole (*Condylura cristata*).

7.2.2 Threatened and Endangered Species

According to the Natural Heritage Listing, dated May 1995, three endangered species are known to occur in Virginia Beach (Horne Engineering Services, 1995). They are the Bald Eagle (*Haliaeetus leucocephalus*), Dismal Swamp Shrew (*Sorex longirostris fisheri*), and the Loggerhead Sea Turtle (*Caretta caretta*).

There is no suitable habitat or nesting area for these three species in or adjacent to the three sites. The Bald Eagle nests along inland waters and the Chesapeake Bay in relatively secluded areas. It requires large snags for perching and roosting, which do not occur within or near the sites. The Dismal Swamp Shrew is found in swampy forests near the interior waters of Virginia Beach and closer to the Dismal Swamp area of the City of Chesapeake, Virginia. The sandy coastal areas of the FTA site are not suitable habitat for the Dismal Swamp Shrew. The Loggerhead Turtle is known to nest along the beach areas of Virginia Beach. Each site is in

Table 7-3
Dominant Vegetation at the Auto Craft Site
Fort Story, Virginia

Common Name	Scientific Name
Vegetation in the Auto Craft Site	
Grasses	*Poa sp.*
Aster	*Aster sp.*
Wild Onion	*Allium canadense*
Vegetation in the Adjacent Grassy Area	
Grasses	*Poa sp.*
Aster	*Aster sp.*
Wild Onion	*Allium canadense*
Pixie	*Diapensia sp.*
Clover	*Trifolium sp.*
Vegetation in the Adjacent Wooded Area	
Live Oak	*Quercus virginiana*
Water Oak	*Quercus nigra*
Red Bay	*Persea borbonia*
American Holly	*Ilex opaca*
Common Greenbrier	*Smilax rotundifolia*
Wax Myrtle	*Myrica cerifera*

developed areas, at least 1,200 feet from the Chesapeake Bay. Therefore, the turtle would not nest in any of the sites.

7.3 POTENTIAL STRESSORS, EXPOSURE PATHWAYS AND ECOLOGICAL EFFECTS

The next step in problem formulation involves the identification of the interrelationships between potential stressors, exposure pathways, and ecological effects for the identified ecosystems of concern. Chemical and/or physical stressors are identified, potential pathways for migration of contaminants from the site to the ecosystems of concern are discussed, and potential ecological effects are summarized.

Contaminants in surface soil and sediment samples were compared to USEPA Region III Biological Technical Assistance Group (BTAG) Screening Levels for Ecological Risks (USEPA, 1995) (Table 7-4). Contaminants detected in sediments were also compared to current Federal regional guidelines. Contaminants detected in surface water were compared with available Federal and Virginia standards to determine which chemicals may be of concern with respect to target wildlife receptors. Virginia State Surface Water (Freshwater) Quality Standards, USEPA Region III BTAG Screening Levels for Aquatics in Surface Water (USEPA, 1995), and USEPA Ambient Water Quality Criteria for chronic effects in fresh water (USEPA, 1991) were utilized (Table 7-5).

The range, mean and maximum soil and sediment concentrations of metals at the sites were also compared with the 95th UCL background concentrations analyzed at Fort Story and the observed range and mean USGS regional background concentrations. Site-specific and regional background values are presented in Table 7-6 and in Appendix H. VOCs, SOCs, Pesticides, and TPHs were chosen as contaminants of potential concern (COPC) if EPA Region III BTAG screening criteria (screening criteria) were exceeded or lacking. Inorganics were chosen as contamints of potential concern if EPA Region III BTAG screening criteria and site-specific and regional background values (background) were exceeded. Some metals exceeded screening criteria but were lower than measured background levels. These contaminants were not selected as contaminants of potential concern. Minerals detected, such as calcium, sodium, potassium, and magnesium are naturally occurring components of soil, sediment and water. Therefore, they are not considered to be potentially of concern. Sample results for the three sites compared to applicable screening criteria and background concentrations are presented in Tables 7-7 through 7-12.

TABLE 7-4
CHEMICAL-SPECIFIC ARARs AND TBC FOR SOIL AND SEDIMENT

Parameters	TBC Criteria			
	EPA Region III BTAG Screening Levels for Soil		EPA Region III BTAG Screening Levels for Sediment	
	Flora (mg/kg)	Fauna (mg/kg)	Flora (mg/kg)	Fauna (mg/kg)
VOCs				
Acetone	-	-	-	-
Methylene chloride	<0.30	<0.30	-	-
Methyl ethyl ketone	-	-	-	-
Styrene	0.1	0.1	-	-
Toluene	-	0.10	-	-
Trichloroethylene	<0.30	<0.30	-	-
Xylene	<0.10	<0.10	-	0.04
SOCs				
Acenaphthene	0.10	0.10	0.016	0.016
Benz(a)anthracene	0.10	0.10	0.261	0.261
Benzo(b)fluoranthene	0.10	0.10	3.2	3.2
Benzo(k)fluoranthene	0.10	0.10	-	-
Benzo(g,h,i)perylene	0.10	0.10	0.67	0.67
Benzo(a)pyrene	-	0.10	0.43	0.43
Bis(2-EH)phthalate	-	-	-	1.3
Butylbenzylphthalate	-	-	-	0.063
Chrysene	0.10	0.10	0.384	0.384
Di-n-butylphthalate	-	-	-	1.4
Fluoranthene	0.10	0.10	0.60	0.60
Indeno(1,2,3-cd)pyrene	0.10	0.10	0.60	0.60
Phenanthrene	0.10	0.10	0.24	0.24
Pyrene	0.10	0.10	0.665	0.665
Inorganics				
Aluminum	1.00	-	-	-
Arsenic	328	-	8.2	8.2
Barium	440	440	-	-
Chromium	0.02	0.0075	0.005	260
Cobalt	100	220	-	-
Copper	15	-	-	34
Iron	3,260	12	-	-
Lead	2	0.01	-	46.7
Manganese	330	330	-	-
Mercury	0.058	0.058	0.15	0.15
Nickel	2	-	20.9	20.9
Thallium	0.001	-	-	-
Vanadium	0.5	58	-	-
Zinc	10	-	-	150

Source:
EPA Region III BTAG Screening Levels for Ecological Risks (August 1995)

TABLE 7- 5
CHEMICAL-SPECIFIC ARARs AND TBC FOR SURFACE WATER

	ARARs				TBC Criteria	
	Virginia Surface Water (Freshwater) Quality Standards [1]		Federal Ambient Water (Freshwater) Quality Criteria [2]		EPA Region III BTAG Screening (Freshwater) [3]	
Parameters	**Acute (ug/l)**	**Chronic (ug/l)**	**Acute (ug/l)**	**Chronic (ug/l)**	**Flora (ug/l)**	**Fauna (ug/l)**
VOCs						
Acetone	-	-	-	-	-	9,000,000
Total Metals						
Aluminum	-	-	-	-	460	25
Iron	-	-	-	-	-	320
Lead	14	0.54	82	3.2	-	3.2
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	14,500
Zinc	-	-	120	110	30	110

Notes:
(1) Virginia Surface Water Quality Standards (VR 680-21-01.14)
(2) Federal Ambient Water Quality Criteria (40 CFR 131)
(3) EPA Region III BTAG Screening Levels for Aquatics in Surface Water (August 1995)

TABLE 7-6
SITE SPECIFIC AND REGIONAL BACKGROUND CONCENTRATIONS
FORT STORY, VIRGINIA

Parameters	Fort Story Background 95th UCL [1]	USGS Regional Soils Data [2]	
		Observed Range	Mean
Aluminum	Not analyzed	7,000 ->100,000	33,000
Arsenic	2.1	<0.2 - 73	5.4
Barium	5	15 - 1,000	300
Calcium	Not analyzed	<100 - 160,000	3,200
Chromium	2.8	1 - 100	36
Cobalt	Not analyzed	<3 - 70	7
Copper	1.4	<1 - 150	14
Iron	Not analyzed	100 - >100,000	15,000
Lead	7.1	<7 - 300	14
Magnesium	Not analyzed	50 - 50,000	2,300
Manganese	Not analyzed	<2 - 7,000	290
Mercury	0.01	0.01 - 0.34	0.096
Nickel	2	<3 - 700	13
Potassium	Not analyzed	50 - 37,000	7,400
Sodium	Not analyzed	<200 - 15,000	2,600
Thallium	Not analyzed	~	~
Vanadium	Not analyzed	<5 - 300	46
Zinc	5.7	<5 - 400	36

Notes:

(1) James M. Montgomery, Inc. 1992.

(2) Comor et al, 1975.

TABLE 7-7
ECOLOGICAL ASSESSMENT FOR SURFACE SOIL
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels (1)		Fort Story Background 95th UCL (1)	USGS Regional Soils Data (2)		Exceed or Lacking Criteria?
			Flora	Fauna		Observed Range	Mean	
VOCs (ug/kg)								
Acetone	3/28	140 - 220	-	-				Yes
Methylene chloride	2/28	5.0 - 6.4	-	<300.0				
Methyl ethyl ketone	1/28	28.0	-	-				Yes
Styrene	1/28	3.0	-	100.0				
Toluene	25/28	8.3 - 140	-	100.0				Yes
Xylenes	1/28	7	-	-				Yes
SOCs (ug/kg)								
Benzo(b)fluoranthene	1/28	97	100.0	100.0				
Benzo(k)fluoranthene	1/28	86	100.0	100.0				
bis(2-EH)phthalate	1/28	110	-	-				Yes
Chrysene	1/28	94	100.0	100.0				
Di-n-butylphthalate	1/28	150	-	-				Yes
Fluoranthene	2/28	75 - 650	100.0	100.0				Yes
Pyrene	2/28	64 - 720	100.0	100.0				Yes
TPH (mg/kg)								
TPH as Heavy Oils	3/28	48 - 5300	-	-				Yes
Inorganics (mg/kg)								
Aluminum	5/5	420 - 980	1.0	-	Not analyzed	7,000 ->100,000	33,000	Yes
Arsenic	4/5	1.2 - 1.6	328.0	-	2.1	<0.2 - 73	5.4	Yes
Barium	5/5	3.9 - 12.0	440.0	440.0	5	15 - 1,000	300	
Calcium	4/5	71 - 370	-	-	Not analyzed	<100 - 160,000	3,200	
Chromium	5/5	1.7 - 5.8	0.02	0.0075	2.8	1 - 100	36	Yes
Copper	5/5	3.2 - 13	15.0	-	1.4	<1 - 150	14	Yes
Iron	5/5	1,200 - 5,400	3,260.0	12.0	Not analyzed	100 - >100,000	15,000	Yes
Lead	5/5	7.0 - 33.0	2	0.01	7.1	<7 - 300	14	Yes
Magnesium	5/5	62 - 190	-	-	Not analyzed	50 - 50,000	2,300	
Manganese	5/5	10 - 34	330.0	330.0	Not analyzed	<2 - 7,000	290	
Potassium	1/5	160	-	-	Not analyzed	50 - 37,000	7,400	
Vanadium	5/5	1.8 - 3.7	0.5	58.0	Not analyzed	<5 - 300	46	
Zinc	5/5	14 - 22	10.0	-	5.7	<5 - 400	36	Yes

Note:
(1) EPA Region III BTAG Screening Levels for Ecological risks (Aug. 1995)

TABLE 7-8
ECOLOGICAL ASSESSMENT FOR SEDIMENT
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels [1]		Exceed or Lacking Criteria?
			Flora	Fauna	
VOCs (ug/kg)					
Toluene	4/4	23 - 180	-	-	**Yes**
SOCs (ug/kg)		BDL			
TPH (mg/kg)					
Total TPH	3/4	130 - 350	-	-	**Yes**
Metals (mg/kg)					
Aluminum	4/4	160 - 7600	-	-	**Yes**
Arsenic	1/4	2.5	8.2	8.2	
Barium	4/4	2.4 - 110	-	-	**Yes**
Calcium	4/4	64 - 120	-	-	
Chromium	1/4	21	0.005	260.0	**Flora**
Cobalt	1/4	2.6	-	-	**Yes**
Copper	1/4	26	-	34.0	
Iron	4/4	230 - 17,000	-	-	**Yes**
Lead	4/4	4.3 - 210	0.0125	46.7	**Yes**
Magnesium	1/4	960	-	-	
Manganese	3/4	1.7 - 42	-	-	**Yes**
Mercury	2/4	0.017 - 0.051	0.15	0.15	
Potassium	1/4	260	-	-	
Sodium	2/4	87 - 180	-	-	
Thallium	1/4	1.4	-	-	**Yes**
Vanadium	2/4	2 - 18	-	-	**Yes**
Zinc	2/4	6 - 76	-	150.0	

Note:
(1) EPA Region III BTAG Screening Levels for Ecological Risks (Aug. 1995)

TABLE 7-9
ECOLOGICAL ASSESSMENT FOR SURFACE SOIL
FT. STORY - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels (1)		Fort Story Background 95th UCL (2)	USGS Regional Soils Data (3)		Exceed or Lacking Criteria?
			Flora	Fauna		Observed Range	Mean	
VOCs (ug/kg)								
Acetone	1/22	36	-	-				Yes
Methylene Chloride	7/22	5.2 - 160	-	<300.0				
Toluene	1/22	6.0	-	100.0				
Trichloroethene	2/22	5.9 - 6.4	-	<300.0				
SOCs (ug/kg)	0/22	BDL						
TPH (mg/kg)								
Total TPH	19/22	42 - 1500	-	-				Yes
Metals (mg/kg)								
Aluminum	5/5	250 - 2,700	1.0	-	Not analyzed	7,000 ->100,000	33,000	Yes
Arsenic	1/5	1.1	328.0	-	2.1	<0.2 - 73	5.4	Yes
Barium	5/5	1.8 - 19	440.0	440.0	5	15 - 1,000	300	
Calcuim	4/5	56 - 980	-	-	Not analyzed	<100 - 160,000	3,200	
Chromium	5/5	1.7 - 4.3	0.02	0.0075	2.8	1 - 100	36	Yes
Cobalt	1/5	2.30	100.0	220.0	Not analyzed	<3 - 70	7	
Copper	4/5	2.5 - 41	15.0	-	1.4	<1 - 150	14	Yes
Iron	5/5	400 - 1,100	3,260.0	12.0	Not analyzed	100 - >100,000	15,000	Yes
Lead	5/5	3.1 - 12	2	0.01	7.1	<7 - 300	14	Yes
Magnesium	4/5	77 - 1,400	-	-	Not analyzed	50 - 50,000	2,300	
Manganese	5/5	2.4 - 120	330.0	330.0	Not analyzed	<2 - 7,000	290	
Potassium	1/5	1,200	-	-	Not analyzed	50 - 37,000	7,400	
Vanadium	5/5	1.2 - 9.2	0.5	58.0	Not analyzed	<5 - 300	46	Flora
Zinc	5/5	3.8 - 33	10.0	-	5.7	<5 - 400	36	Yes

Notes:
(1) EPA Region III BTAG Screening Levels for Ecological risks (Aug 1995)
(2) James M. Montgomery, Inc. 1992.
(3) Comor et al, 1975.

TABLE 7-10
ECOLOGICAL ASSESSMENT FOR SEDIMENT
FT. STORY - LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels (1)		Exceed or Lacking Criteria?
			Flora	Fauna	
VOCs (ug/kg)	0/2	BDL			
SOCs (ug/kg)	0/2	BDL			
TPH (mg/kg)					
Total TPH	2/2	530 - 2700	-	-	**Yes**
Inorganics (mg/kg)					
Aluminum	2/2	310 - 650	-	-	**Yes**
Barium	2/2	1.4 - 2.7	-	-	**Yes**
Calcium	2/2	53 - 210	-	-	
Chromium	2/2	1.6 - 2.5	0.005	260	**Flora**
Copper	2/2	3.8 - 9.0	-	34	
Iron	2/2	310 - 940	-	-	**Yes**
Lead	2/2	8.2 - 14	-	46.7	
Magnesium	2/2	110 - 250	-	-	
Manganese	2/2	3.4 - 6.9	-	-	**Yes**
Sodium	1/2	70.00	-	-	
Vanadium	2/2	1.3 - 2.7	-	-	**Yes**
Zinc	2/2	11 - 30	-	150.0	

Notes:
(1) EPA Region III BTAG Screening Levels for Ecological Risks (August 1995)

TABLE 7-11
ECOLOGICAL ASSESSMENT FOR SURFACE WATER
FT. STORY - LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria		ARARs				Exceed or Lacking Criteria
			EPA Region III BTAG Screening (Freshwater) (1)		Virginia SW (Freshwater) Quality Standards(2)		Federal AWQC (Freshwater)(3)		
			Flora	Fauna	Acute	Chronic	Acute	Chronic	
VOCs (ug/l)									
Acetone	2/2	30 - 35	-	9,000,000	-	-	-	-	
SOCs (ug/l)	0/2	BDL							
TPH (mg/l)									
Total TPH	0/2	BDL							
Total Metals (ug/l)									
Aluminum	2/2	0.39 - 0.42	460	25	-	-	-	-	
Calcium	2/2	11 - 12	-	-	-	-	-	-	
Iron	2/2	0.84 - 1.4	-	320	-	-	-	-	
Lead	2/2	0.0078 - 0.009	-	3.2	14	0.54	82	3.2	
Magnesium	2/2	15 - 17	-	-	-	-	-	-	**Yes**
Manganese	2/2	0.083 - 0.14	-	14,500	-	-	-	-	
Potassium	2/2	9.1 - 9.4	-	-	-	-	-	-	
Sodium	1/2	120.0	-	-	-	-	-	-	
Zinc	2/2	0.04 - 0.062	30	110	-	-	120	110	

Notes:
(1) EPA Region III BTAG Screening Levels for Aquatics in Surface Water (Aug 1995)
(2) Virginia Surface Water Quality Standards (VR 680-21-01.14)
(3) Federal Ambient Water Quality Criteria (40 CFR 131)

TABLE 7-12
ECOLOGICAL ASSESSMENT FOR SURFACE SOIL
FT. STORY - AUTO CRAFT SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA Region III BTAG Screening Levels (1)		Fort Story Background 95th UCL (2)	USGS Regional Soils Data (3)		Exceed or Lacking Criteria?
			Flora	Fauna		Observed Range	Mean	
VOCs (ug/kg)								
Methylene chloride	1/6	41	-	<300.0				
Methyl ethyl ketone	1/6	55	-	-				Yes
Toluene	6/6	7.9 - 34	-	100.0				
Trichloroethene	1/6	33	-	<300.0				
SOCs (ug/kg)								
Acenaphthene	1/6	440.0	100.0	100.0				Yes
Benz(a)anthracene	1/6	2,500	100.0	100.0				Yes
Benzo(b)fluoranthene	1/6	4,100	100.0	100.0				Yes
Benzo(k)fluoranthene	1/6	490	100.0	100.0				Yes
Benzo(g,h,i)perylene	1/6	2,000	100.0	100.0				Yes
Benzo(a)pyrene	1/6	3,400	-	100.0				Yes
Butylbenzylphthalate	1/6	550	-	-				Yes
Chrysene	1/6	2,000	100.0	100.0				Yes
Fluoranthene	1/6	5,800	100.0	100.0				Yes
Indeno(1,2,3-cd)pyrene	1/6	1,500	100.0	100.0				Yes
Phenanthrene	1/6	1,300	100.0	100.0				Yes
Pyrene	1/6	11,000	100.0	100.0				Yes
TPH (mg/kg)								
Total TPH	3/6	220 - 390	-	-				Yes
Metals (mg/kg)								
Aluminum	1/1	5,200	1.0	-	Not analyzed	7,000 ->100,000	33,000	Yes
Arsenic	1/1	1.30	328.0	-	2.1	<0.2 - 73	5.4	Yes
Barium	1/1	82	440.0	440.0	5	15 - 1,000	300	
Calcuim	1/1	1,200	-	-	Not analyzed	<100 - 160,000	3,200	
Chromium	1/1	9	0.02	0.0075	2.8	1 - 100	36	Yes
Cobalt	1/1	4.40	100.0	220.0	Not analyzed	<3 - 70	7	
Copper	1/1	18	15.0	-	1.4	<1 - 150	14	Yes
Iron	1/1	9,100	3,260.0	12.0	Not analyzed	100 - >100,000	15,000	Flora
Lead	1/1	95	2.0	0.01	7.1	<7 - 300	14	Yes
Magnesium	1/1	2,400	-	-	Not analyzed	50 - 50,000	2,300	
Manganese	1/1	170	330.0	330.0	Not analyzed	<2 - 7,000	290	
Mercury	1/1	0.022	-	0.058	0.01	0.01 - 0.34	0.096	
Nickel	1/1	4.8	2.0	-	2	<3 - 700	13	Yes
Potassium	1/1	2,700	-	-	Not analyzed	50 - 37,000	7,400	
Sodium	1/1	64	-	-	Not analyzed	<200 - 15,000	2,600	
Vanadium	1/1	18	0.5	58.0	Not analyzed	<5 - 300	46	Yes
Zinc	1/1	64	10.0	-	5.7	<5 - 400	36	Yes

Note:
(1) EPA Region III BTAG Screening Levels for Ecological Risks (Aug 1995)
(2) James M. Montgomery, Inc. 1992.
(3) Comor et al, 1975.

7.3.1 Potential Stressors

FTA Site

Both physical and chemical stressors do exist at the FTA site and in the surrounding wooded area. Physical stress is caused by the training activities in the area and former use of the site. These activities have prevented the revegetation of the northern end of the site and caused small burned areas in the woods. However, the physical disturbance occurs in a small area and chances of the physical stressor adversely effecting the surrounding areas and wildlife is minimal and is not considered long-term. Therefore, the physical stressors will not be addressed further in this assessment.

A detailed description of the extent of sampling conducted at the Site and full results are provided in Sections 2 and 4 of this report, respectively. Soil samples were taken in the northern area where stained soils were present, in the Former Fire Training Pit area, and in the Solvent Plume Area associated with the adjacent UST site. Sediment samples were taken within the drainage area in the woods located south of the site. No surface water was associated with the site.

Surface Soils

A total of 28 soil samples were analyzed for VOC, SOC and TPH contamination. Sampling locations are depicted in Figure 2-6. Toluene was detected in 25 of the 28 samples and was found to exceed the EPA Region III BTAG screening criteria in 1 of the samples. This sample was taken from the southeastern end of the site near the former UST area. Therefore, toluene was retained as a COPC. Acetone, methyl ethyl ketone, and xylenes were also detected in the samples, and lacked screening criteria. These compounds, except for acetone, were found at low frequency (i.e., < 5% frequency) and at low levels and were therefore, not considered to be of concern. Acetone lacks EPA Region III BTAG screening criteria and was retained as a COPC.

Of the SOCs detected in the samples, fluoranthene and pyrene values exceeded screening criteria. Each was detected in 2 samples and exceeded screening criteria in 1. This sample was taken from the southeastern edge of the site, adjacent to the road. These contaminants were retained as COPCs. Bis(2-EH)phthalate and di-n-butylphthalate lacked screening criteria but were detected at low frequency. Therefore, they were not considered of concern. Total Petroleum Hydrocarbons (TPH) as heavy oils was detected in 3 samples; the highest being from the southeastern edge of the site, immediately north of the road. Polycyclic Aromatic Hydrocarbons (PAHs), more toxic components of TPH, were not detected at levels which exceeded screening criteria in samples which contained TPH. Therefore, due to the low

frequency of detection and absence of detection of its components, TPH as heavy oils was not retained as a COPC.

A total of 5 soil samples were analyzed for contamination of metals. Minerals detected, such as calcium, sodium, potassium, and magnesium are naturally occurring components of soil, sediment and water. Therefore, they were not considered to be potentially of concern. Several metals were detected with high frequency at levels that exceeded screening criteria. These metals included chromium, iron, and lead. Aluminum, arsenic, copper, and zinc lacked screening criteria. Concentrations of aluminum, arsenic, and iron detected were consistent with measured site-specific and/or USGS regional background concentrations. Concentrations of chromium detected were within USGS regional background concentrations but exceeded site specific background concentrations. Contaminants that exceeded or lacked criteria values and background concentrations were retained as contaminants of potential concern. Therefore, chromium, copper, lead and zinc were considered a COPC in surface soils at the FTA site.

The compounds chosen as contaminants of potential concern for surface soils for the FTA Ecological Risk Assessment are shown in Table 7-13.

Sediment

Sediment samples were taken from 4 locations in the adjacent woodland. All samples were analyzed for VOC, SOC, TPH, and metal concentrations. Toluene was detected in all 4 samples and exceeded screening criteria in 1 sample. This sample was taken closest to the former UST site. TPH as heavy oils was detected in 3 samples, but no PAHs were found above the detection limits. Metals were detected in several samples that exceeded or lacked USEPA Region III screening criteria. Site-specific and regional background concentrations were not available for sediment. Therefore, aluminum, barium, cobalt, iron, lead, manganese, thallium, and vanadium were retained as COPCs for sediment because they were detected at concentrations that either exceeded or lacked screening criteria.

The compounds chosen as chemicals of potential concern for sediment for the FTA Ecological Risk Assessment are shown in Table 7-14.

LARC 60 Site

Both physical and chemical stressors exist at the LARC 60 site and in the surrounding wooded area. Physical stress is caused by the training activities in the area which include driving the LARCs and other heavy equipment in the Sandbox. These activities prevent vegetation from becoming established in the Sandbox and have caused some stress on the vegetation in the small wooded island. However, the physical disturbance occurs in a small area and chances

TABLE 7-13
COPCs and EXPOSURE POINT CONCENTRATIONS - SURFACE SOILS
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
VOCs (mg/kg)				
Acetone	3/28	0.14 - 0.22	2.20E-01	3.43E-02
Toluene	25/28	.0083 - 0.140	1.40E-01	4.81E-02
SOCs (mg/kg)				
Fluoranthene	2/28	0.075 - 0.650	6.50E-01	NA
Pyrene	2/28	0.064 - 0.720	7.20E-01	NA
Metals (mg/kg)				
Chromium	5/5	1.7 - 5.8	5.80E+00	NA
Copper	5/5	3.2 - 13	1.30E+01	NA
Lead	5/5	7.0 - 33.0	3.30E+01	NA
Zinc	5/5	14 - 22	2.20E+01	NA

Notes: Shading indicates concentration selected for exposure calculations. The maximum of the soil and sediment values were used. Where COPC concentrations are not shaded, the higher sediment values were used in the exposure calculations.

TABLE 7-14
COPCs and EXPOSURE POINT CONCENTRATIONS - SEDIMENT
FORT STORY - FTA SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
VOCs (mg/kg)				
Toluene	4/4	.023 - 0.180	1.80E-01	NA
METALS (mg/kg)				
Aluminum	4/4	160 - 7600	7.60E+03	NA
Barium	4/4	2.4 - 110	1.10E+02	NA
Cobalt	1/4	2.6	2.60E+00	NA
Iron	4/4	230 - 17,000	1.70E+04	NA
Lead	4/4	4.3 - 210	2.10E+02	NA
Manganese	3/4	1.7 - 42	4.20E+01	NA
Thallium	1/4	1.4	1.40E+00	NA
Vanadium	2/4	2 - 18	1.80E+01	NA

Notes: Shading indicates concentration selected for exposure calculations. The maximum of the soil and sediment values were used where contaminants were detected in both media. Where COPC concentrations are not shaded, the higher soil values were used in the exposure calculations.

of the physical stressor adversely effecting the surrounding areas and wildlife is minimal and is not considered long-term. Therefore, the physical stressors will not be addressed further within the scope of this assessment.

Soil samples were taken from the Sandbox, adjacent wooded area, the wash rack, the oil/water separator, and the former UST site. Sediment and surface water samples were taken within the drainage ditch in the woods north of the Sandbox.

Surface Soils

A total of 22 soil samples were analyzed for VOCs, SOCs, and TPH concentrations. Five soil samples were also analyzed for metal concentrations. Sampling locations are depicted in Figure 2-9. Although VOCs were detected in some of the surface soil samples, none of the concentrations exceed EPA Region III BTAG screening criteria. Acetone was detected in 1 sample and lacked screening criteria. However, due to the low frequency and the low level at which it was detected, it was not considered to be of concern. Total TPH was detected in 19 of the 22 samples. These samples were taken from the former UST area, the wash rack, the Sandbox and the adjacent wooded area. However, no PAHs were measured above detection limits. Total TPH was not retained as a COPC, since the more toxic components of TPHs were not detected.

Several metals were detected with high frequency at concentrations that exceeded EPA Region III BTAG screening criteria. Metals that exceeded criteria included chromium, iron, and lead. In addition, aluminum, arsenic, copper, and zinc lacked faunal screening criteria. Of these compounds, aluminum, arsenic, iron and vanadium concentrations fell within site specific and USGS regional background concentrations. Therefore, these compounds were not considered to be potentially of concern. Chromium, lead, and zinc concentrations fell within regional background but exceeded measured site-specific concentrations. Therefore, these compounds were retained as COPCs for surface soils. Copper concentrations exceeded both site-specific and regional background concentrations and was retained as a COPC.

The compounds chosen as contaminants of potential concern for surface soil and the LARC 60 Site Ecological Risk Assessment are presented in Table 7-15.

Sediment

A total of 2 sediment samples were taken from the small drainage ditch adjacent to the site and analyzed for VOCs, SOCs, TPH and metal concentrations. VOC and SOCs were not detected in the samples. Total TPH was detected in both samples. Because PAHs were not detected in the samples, TPH was not considered to be of potential concern. No metals detected

TABLE 7- 15
COPC - SURFACE SOILS CONCENTRATION
FORT STORY - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
Metals (mg/kg)				
Chromium	5/5	1.7-4.3	4.30E+00	NA
Copper	4/5	2.5 - 41	4.10E+01	NA
Lead	5/5	3.1 - 12	1.20E+01	NA
Zinc	5/5	3.8 - 33	3.30E+01	NA

Notes: Shading indicates concentration selected for exposure calculations.

exceeded EPA Region III BTAG screening criteria. Several metals detected lacked screening criteria. No background values were available for sediment. All contaminants that lacked screening criteria were retained as COPCs.

Compounds selected as contaminants of potential concern for sediment for the LARC 60 site Ecological Risk Assessment are presented in Table 7-16.

Surface Water

Two surface water samples were taken from the adjacent drainage ditch. Acetone was detected in both samples at levels below screening criteria. SOCs and TPHs were not detected in either sample. No metals were detected at levels which exceeded available screening criteria. Calcium, magnesium, manganese, potassium, and sodium do not have screening criteria. These constituents are naturally occurring in water and were found at low levels in the samples taken. Therefore, they were not considered to be of concern. No COPCs were selected for surface water at the LARC 60 Site.

Auto Craft Site

Very little physical disturbance occurs at the site. Since the site is currently used as a vehicle impoundment lot, there is little human activity. Therefore, impacts from physical disturbance will not be considered for this site.

A total of 6 surface soil samples were taken from within the fenced area, downgradient of the site, and in the grassy areas to the west of the site. All samples were tested for VOC, SOC and TPH concentrations. One sample was further tested for metal concentrations. The VOCs detected were found to be at levels below EPA Region III BTAG screening criteria. Methyl ethyl ketone lacks screening criteria. However, because it was detected in only 1 sample at a low level and has a low toxicity, it was not considered to be of concern.

Several SOCs that were detected from the soil sample taken from within the fenced area were found to be above screening criteria. These were retained as COPCs. SOCs were not detected in any other sample. Total TPH was detected in three of the samples, all of which were sampled in the grassy area downgradient from the fenced auto craft area. Because several PAHs were considered of concern due to their detected level in the auto craft area and their lack of detection in the grassy areas, the less toxic TPH was not considered of potential concern.

Several metals were detected in the sample analyzed at levels which exceeded available screening criteria. Several metals lacked screening criteria. The majority of these metals which exceeded or lacked criteria were detected at concentrations that fell below measured site-

TABLE 7- 16
COPC - SEDIMENT CONCENTRATION
FORT STORY - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
Metals (mg/kg)				
Aluminum	2/2	310 - 650	6.50E+02	NA
Barium	2/2	1.4 - 2.7	2.70E+00	NA
Iron	2/2	310 - 940	9.40E+02	NA
Manganese	2/2	3.4 - 6.9	6.90E+00	NA
Vanadium	2/2	1.3 - 2.7	2.70E+00	NA

Notes: Shading indicates concentration selected for exposure calculations.

specific or USGS regional background levels. These compounds included chromium, cobalt, and nickel. Although the level of iron detected fell below regional background levels, it was retained as a COPC because its detection level far exceeded the levels detected at the FTA and LARC 60 sites. The level of copper detected in 1 sample fell within regional background concentrations but far exceeded the Fort Story background concentrations. Therefore, copper was retained as a COPC. Lead and zinc were selected as COPCs because the levels detected exceeded screening criteria, site-specific background concentrations, and regional background concentrations. Neither sediment nor surface water existed at the site.

The compounds chosen as contaminants of potential concern for the Auto Craft Ecological Risk Assessment are shown in Table 7-17.

7.3.2 Exposure Pathways

Several ecologically relevant migration pathways for contaminants exist at the Site. Wildlife may have incidental contact with or ingestion of contaminants while foraging, nesting, or engaging in other activities in the site. Chemical contaminants can also adversely affect plants and animals in surrounding habitats via the food chain.

Upon their release, some site contaminants are persistent and may be transformed to more bioavailable forms and mobilized in the food chain. Mobilization of contaminants in the terrestrial food chain could occur through the following pathways:

- Root uptake from contaminated soil by herbaceous plants,
- Bioaccumulation from vegetation or animal prey at the base of the food chain by wildlife.
- Contact and absorption, incidental ingestion, and feeding on contaminated food by invertebrates, and
- Drinking of contaminated surface water by wildlife

Based on these pathways, the following general classes of ecological receptors potentially might be exposed to contaminants at the Fort Story sites.

- Terrestrial plants growing within and adjacent to the sites,
- Terrestrial invertebrates likely to occur in surface soils and benthic invertebrates occurring within the sediments,

TABLE 7-17
COPCs and EXPOSURE POINT CONCENTRATIONS - SURFACE SOILS
FORT STORY - AUTO CRAFT SITE

Parameter	Frequency of Detection	Range of Detection	Maximum Concentration	95th UCL Concentration
SOCs (mg/kg)				
Acenaphthene	1/6	0.44	4.40E-01	3.11E-01
Benz(a)anthracene	1/6	2.50	2.50E+00	2.95E+00
Benzo(b)fluoranthene	1/6	4.10	4.10E+00	1.18E+01
Benzo(k)fluoranthene	1/6	0.49	4.90E-01	3.39E-01
Benzo(g,h,i)perylene	1/6	2.00	2.00E+00	2.00E+00
Benzo(a)pyrene	1/6	3.40	3.40E+00	5.33E+00
Butylbenzylphthalate	1/6	0.55	5.50E-01	3.76E-01
Chrysene	1/6	2.00	2.00E+00	2.00E+00
Fluoranthene	1/6	5.80	5.80E+00	1.76E+01
Indeno(1,2,3-cd)pyrene	1/6	1.50	1.50E+00	1.26E+00
Phenanthrene	1/6	1.30	1.30E+00	1.02E+00
Pyrene	1/6	11.00	1.10E+01	8.91E+01
Metals (mg/kg)				
Chromium	1/1	9.0	9.00E+00	NA
Copper	1/1	18	1.80E+01	NA
Iron	1/1	9,100	9.10E+03	NA
Lead	1/1	95	9.50E+01	NA
Nickel	1/1	4.8	4.80E+00	NA
Zinc	1/1	64	6.40E+01	NA

Note: Shading indicates concentration selected for exposure calculations

- Birds that forage or nest within the areas,
- Small mammals that reside and/or feed in the vicinity of the areas, and
- Other higher trophic level wildlife species (e.g., carnivores) that feed within the vicinity of the sites.

7.3.3 Ecological Effects

As discussed earlier, several site contaminants are present in soil, sediment, and surface water and exceed ecological concern levels and therefore, may have adverse effects on biota in the vicinity of the sites.

FTA Site

The COPCs for the FTA site include the following:

- **Surface Soil** - acetone, toluene, fluoranthene, pyrene, chromium, copper, lead, and zinc
- **Sediment** - toluene, aluminum, barium, cobalt, iron, lead, manganese, thallium, and vanadium

LARC 60 Site

The COPCs for the LARC 60 site include the following:

- **Surface Soil** - chromium, copper, lead, and zinc
- **Sediment** - aluminum, barium, iron, manganese, and vanadium
- **Surface Water** - none

Auto Craft Site

The COPCs for the Auto Craft site include the following:

- **Surface Soil** - acenaphthene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, butylbenzylphthalate, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, chromium, copper, iron, lead, nickel, and zinc

Descriptions of the environmental fate and transport of these chemicals, as well as bioaccumulation potential and toxicity, with regard to various aquatic and terrestrial organisms, are included as Appendix K of this document.

7.4 ECOLOGICAL ENDPOINTS

Based on the potential pathways and receptors identified and described in Section 7.3, detrimental effects (i.e., reduced vigor or population decline) in vegetation, invertebrates, small mammals, birds, and carnivores were selected as the assessment endpoints for the Sites.

Endpoint species considered representative of the local wildlife populations that would use and frequent each Site are presented below. The species were selected based on their potential exposure (i.e., site usage, food habitats, home range size) and susceptibility to adverse effects of the site contaminants.

7.4.1 FTA Site

Following is a brief description of the habitat requirements and diet of the terrestrial endpoint species selected for the FTA Site. In addition, the reasons for selection of these species are discussed.

- **Herbaceous Vegetation.** Plants that occur in pine/oak woodland and disturbed areas of the northeastern United States are likely to occur at the Site. These plants include herbaceous species that serve as an important food source for songbirds, small mammals, and larger herbivores. The measurement endpoints for terrestrial vegetation are published phytotoxicity reference values for each contaminant.

- **Soil/Sediment Invertebrates.** Invertebrates that are common in sandy soils in Southeastern Virginia are likely to occur within and adjacent to the site. In addition, sediment invertebrates that favor intermittent streams and pools or damp soils are likely to occur within the drainage area adjacent to the site. These invertebrates are an important food source for ground gleaning birds and small mammals. The measurement endpoints for soil/sediment invertebrates are published toxicity reference values for each contaminant.

- **Killdeer (*Charadrius vociferus*).** The Killdeer is common in Virginia, migrating out of the area in winter months. A typical density measured during the breeding season is 3.9 pairs per 100 acres, yielding an approximate home range of 25.6 acres per pair (10.36 hectares). Breeding Killdeer prefer open meadows, edges of pasture, and dry uplands.

In all areas, sparse or closely cropped vegetation is required. Preferred food items include insects (especially beetles and grasshoppers), centipedes, spiders, worms, and seeds (Degraaf and Rudis, 1986).

The Killdeer has been selected to represent the ground-gleaning insectivorous bird community at the FTA site. Although the Killdeer is considered an insectivorous bird and may not represent other avian species that concentrate on seeds and worms, it represents avian food-chain exposure most likely at the site. The FTA site does not provide suitable forage habitat for avian species that prefer worms. Insectivorous birds such as the Killdeer are more likely to frequent the site.

Measurement endpoints for the Killdeer are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **White-footed Mouse (*Peromyscus leucopus*).** This common small mammal occurs throughout Virginia and occupies home ranges from 0.054 to 0.072 hectares. It is found in a variety of habitats including interiors and edges of deciduous and coniferous forests, scrub areas, clearings, pastures, stream-side thickets, and buildings. The White-footed Mouse consumes arthropods, seeds, and other vegetation. It is active throughout the year and usually nests off the ground. (USEPA, 1993).

The White-footed Mouse has been selected to represent the small mammal community at the FTA site. As a receptor with an omnivorous diet, the mouse is representative of herbivorous and insectivorous small mammals present within the boundaries of the site. Due to the scarcity of vegetation on the site itself, larger herbivores such as rabbits are unlikely to make significant use of the area.

Measurement endpoints for the White-footed Mouse are derived from rodent toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Gray Fox (*Urocyon cinereoargenteus*).** Gray Foxes are present throughout the United States, except in the northwest and northern prairies. Foxes are secretive and nocturnal, and will often climb trees to evade predators. Gray foxes prey on small mammals but will also eat insects, fruits, acorns, birds, and eggs. The home range of this species varies from 57 and 855 hectares (USEPA, 1993). This species is similar in size and habits of the Red Fox (*Vulpes vulpes*).

The Gray Fox has been selected to represent the terrestrial carnivore community at the Site. Although the Merlin and Red-tailed Hawk may also represent other potential endpoint species in the carnivore category, their home ranges are typically much larger than that of the fox, and their use of the FTA site is likely to be restricted.

Measurement endpoints for the fox are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

7.4.2 LARC 60 Site

Following is a brief description of the habitat requirements and diet of the terrestrial endpoint species selected for the LARC 60 Site. In addition, the reasons for selection of these species are discussed. Because the drainage ditch is so small in relation to the entire site, a semi-aquatic endpoint species was not selected. Selected species already described in Section 7.4.1 are not repeated here.

- **Herbaceous Vegetation**

- **Soil/Sediment Invertebrates**

- **White-footed Mouse**. Representative of the small mammal community.

- **Northern Bobwhite (*Coilnus virginianus*).** Bobwhite Quail are ground-dwelling birds that occupy a number of habitats in Virginia. They are poor fliers, seldom leave the ground and do not migrate. Their range may encompass several hectares and they prefer grasslands, idle fields and pastures during breeding season while concentrating in wooded areas with an understory adjacent to open fields during winter seasons. Bobwhites forage in areas with open vegetation, some bare ground and light litter. Nearby dry powdery soils are important for dust bathing. Seeds from weeds, woody plants, insects and invertebrates and grasses comprise the majority of the bobwhite's diet throughout the year. In the winter, green vegetation can dominate the diet. Quail consume little grit (USEPA, 1993).

  The Northern Bobwhite was selected to represent the ground-gleaning avian community at the site. Their habit of dustbathing make them a more likely candidate for exposure to contaminants in the Sandbox, in addition to exposure realized through habits such as foraging and nesting.

  Measurement endpoints for the Northern Bobwhite are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Gray Fox**. Representative of the terrestrial carnivores which use the site.

7.4.3 Auto Craft Site

Following is a list of the terrestrial endpoint species selected for the Auto Craft Site. Since the species selected are similar to those selected for the FTA and LARC sites, their habitat descriptions are not repeated here.

- **Herbaceous Vegetation**
- **Soil Invertebrates**
- **Killdeer**
- **White-footed Mouse**
- **Gray Fox**

7.5 ECOLOGICAL CONCEPTUAL SITE MODEL

Following current USEPA guidance (USEPA, 1992), a conceptual model was developed to evaluate how chemical stressors from the Site may affect ecological components of the natural environment (Figure 7-1). This model illustrates the relationship between the ecosystem at risk, including the assessment endpoint species, and the chemical stressors. In addition, the contaminated media, exposure routes, and environmental transport are identified in the conceptual site model.

Ecological receptors evaluated in this risk assessment include representative species of terrestrial habitats (herbaceous plants, soil and sediment invertebrates, small mammals, small birds, and carnivores). Effects evaluated are based on published scientific studies and include the estimated/calculated, or predicted effects of the contaminants of concern on the survival, growth, and reproduction of these receptors.

7.6 EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION

This section includes site-specific information pertinent to the assessment of potential ecological exposures to contaminants at the Site. General discussions of ecosystems of concern, pathways and COPCs are provided in Sections 7.2 and 7.3.

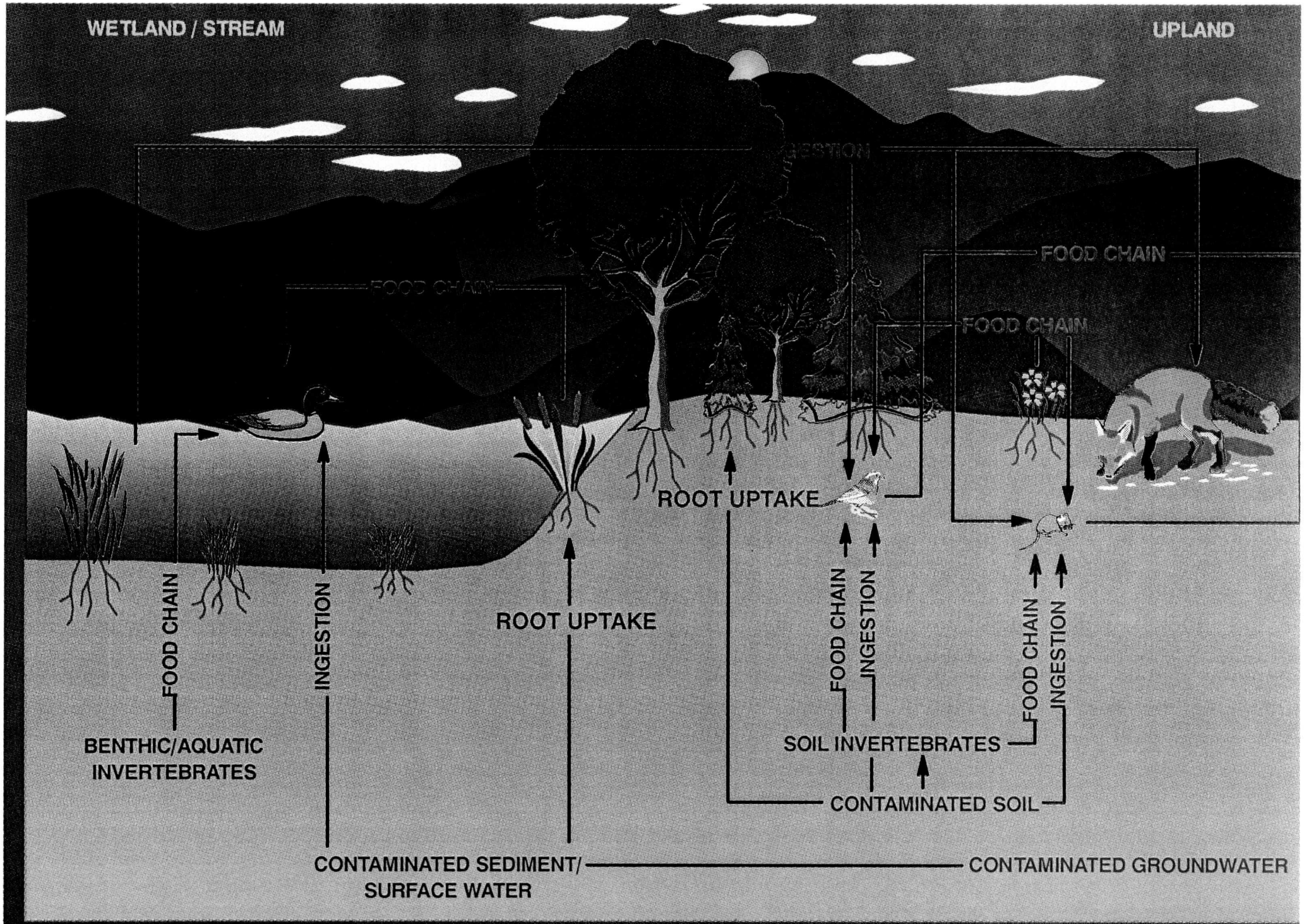

Figure 7-1 POTENTIAL EXPOSURE PATHWAYS FOR ECOLOGICAL RECEPTORS AT THE FORT STORY SITE

7.6.1 Exposure Point Concentrations

Exposure media of ecological concern at the sites include surface soils and sediment. Surface water only exists at the LARC 60 site. Groundwater is not considered because the potential for exposure to groundwater is minimal. The maximum exposure case is considered for terrestrial vegetation, because it is immobile and for soil/sediment invertebrates because they have low mobility. In these cases, the maximum value best represents the most exposure received and therefore is a conservative estimate of the exposure experienced by the population. The average exposure case is considered for terrestrial wildlife receptors, since they are mobile and are not likely to be exposed to only the maximum concentrations of contaminants. Exposure point concentrations (EPCs) calculated for the average exposure case are the 95 percent upper-confidence limit (95% UCL) of the arithmetic mean of COPC concentrations in surface soil and sediment. When the 95% UCL concentrations of surface soil and sediment data could not be calculated due to the small sample size for each subsite (5 samples or fewer), the maximum concentrations of COPC in these media were used. When the same contaminant occurred in surface soil and sediment and wildlife receptors would be exposed to both media, the largest concentration was selected for exposure calculations. Exposure point concentrations for the COPC used in exposure calculations are highlighted in Tables 7-13 through 7-17.

7.6.2 Exposure Scenarios and Pathways

As explained previously, three wildlife scenarios were selected for the quantitative risk assessment at each site: a small mammal, an omnivorous bird, and a terrestrial carnivore. The exposure parameters used to estimate exposure through incidental ingestion of soil and sediment, and exposure through food-chain receptors, are provided in Table 7-18.

The exposure parameters were derived or obtained from published sources (primarily the USEPA's Wildlife Exposure Factors Handbook, USEPA, 1993). Average body weights and minimum home ranges were used to project a conservative estimate of exposure. The rate of incidental ingestion of sediment was assumed to be the same as the rate of ingestion of soil. Soil ingestion for the Northern Bobwhite is unknown. Since the Bobwhite is a ground-gleaning bird and it frequently dustbathes, the ingestion rate for soil was assumed to be equal to the American Woodcock, an insectivorous species with a high soil consumption rate. An exposure duration rate was included to allow for the Killdeer, a migratory species, which may not be exposed to a site for an entire year.

To estimate exposure through the terrestrial and wetland food chains, bioaccumulation factors (BAFs) for plants (plant uptake factors or PUFs) and soil/sediment invertebrates (IUFs) were derived from published sources. Using these BAFs, tissue levels in potential food items of the

TABLE 7-18

EXPOSURE FACTORS FOR ECOLOGICAL RECEPTORS
FORT STORY - FTA, LARC, AND AUTO CRAFT SITES

Receptor	Exposure Factors [1]									
			Dietary Composition (% diet)							
	NIR_f (g/g-day)	IR (kg/day)(dw)	Vegetation	Invertebrates	Birds	Small Mammals	Soil/Sediment Ingestion	Body Weight (kg)	Home Range (hectares)	Exposure Duration[2]
Killdeer	0.134	0.0123	10%[3]	90%[3]	-	-	10%[4]	0.092 [5]	10.36 [6]	0.66
Northern Bobwhite	0.078	0.018	14%	86%	-	-	10.4 (Woodcock)	0.167	3.6	1
White-footed Mouse	0.20	0.003	42%	58%	-	-	<2%	0.0225	0.61	1
Gray Fox	0.09	0.24	7%	0%	46.50%	46.50%	2.80%	4.5	96	1

Notes:
NIR_f = Ingestion rate of food, normalized to body weight.
IR = Daily ingestion rate of food.
[1] Reference: USEPA, 1993 (unless otherwise noted)
[2] = Fraction of year spent in region, 0-1 (unitless), Killdeer is migratory
[3] = Martin et. al., 1961.
[4] = Beyer et. al., 1992.
[5] = Dunning Jr., 1993.
[6] = DeGraaf and Rudis, 1986.

Area of Sites:

FTA	1.5 Ha
Auto Craft	.33 Ha
LARC	4.2 Ha

endpoint species were calculated. When soil and sediment invertebrate uptake values were not available, it was assumed that the uptake rate of contaminants was similar to that of earthworms. Where no BAFs were available, the plant and/or invertebrate tissue concentrations were assumed to be equal to the soil or sediment concentration. Concentrations in the prey of Gray Fox (small mammals) were assumed to be equal to the concentrations in their food source. Plant uptake factors and invertebrate uptake factors are provided in Table 7-19.

7.6.3 Exposure Estimates

The estimated exposures for terrestrial herbaceous vegetation and terrestrial invertebrates were derived from maximum surface soil and sediment concentrations of COPCs, as shown in Table 7-20.

Estimates of exposure to contaminants in soil/sediment via ingestion were made for the receptors by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$$EE_{soil/sediment} = (C \times FS \times IR_{total}(\text{dry weight}) \times FR) / BW$$

Where:

$EE_{soil/sediment}$	=	Estimated exposure through ingestion of soil/sediment (mg/kg BW-day)
C	=	Contaminant concentration in soil/sediment in the area of concern (mg/kg dry weight)
FS	=	Fraction of soil/sediment in diet (as percentage of diet on a dry-weight basis divided by 100; unitless)
IR_{total}	=	Food ingestion rate on a dry-weight basis (kg/day)
FR	=	Fraction of total food intake from the area of concern (unitless)
BW	=	Body weight (kg)

The food ingestion rate on a dry-weight basis was estimated based on body weight (USEPA, 1993):

Birds: IR_{total} (kg/day) = $0.0582\ BW^{0.651}$ (kg)
Mammals: IR_{total} (kg/day) = $0.0687\ BW^{0.822}$ (kg)

TABLE 7-19

PLANT AND INVERTEBRATE UPTAKE FACTORS
FORT STORY, VIRGINIA

Chemical	Plant Uptake Factor	Reference	Invertebrate (Earthworm) Uptake Factor	Reference
PAHs	0.0122(a)	(b)	0.7(a)	(c)
Acetone	1	(f)	1	(f)
Toluene	0.94	(b)	1	(f)
Aluminum	0.004	(e)	1	(f)
Barium	0.15	(e)	1	(f)
Chromium	0.0075	(e)	0.1	(d)
Cobalt	0.03	(e)	1	(f)
Copper	0.4	(e)	2.4	(h)
Iron	0.004	(e)	1	(f)
Lead	0.045	(e)	0.95	(g)
Manganese	0.25	(e)	1	(f)
Nickel	0.06	(e)	1.9	(g)
Thallium	0.004	(e)	1	(f)
Vanadium	0.0055	(e)	1	(f)
Zinc	1.5	(e)	5.7	(g)

Notes:

(a) Value is for benzo[a]pyrene.
(b) Calculated as $PUF = 38.9(Kow)^{-0.58}$, fromTravis and Hattemer-Frey, 1988.
(c) Beyer, 1990.
(d) Ma, 1982.
(e) Baes et al., 1984
(f) Assumed to equal soil concentration (PUF, EUF = 1) since uptake information was not found for this chemical.
(g) Gish and Christensen, 1973.
(h) Beyer et. al., 1982

Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and cancer effects posed by multiple chemicals. This approach assumes that subthreshold exposures to several chemicals at the same time could result in an adverse health effect. It assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect by the same mechanism of action. In this evaluation, the hazard quotients of a mixture of chemicals which can have different effects are used as a screening-level approach, as recommended by the USEPA (USEPA, 1989a). This approach is likely to overestimate the potential for effects.

For the assessment of carcinogenic risks, the individual risks associated with exposure to each contaminant are summed. This represents an approximation of the precise equation for combining risks which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens. This additive approach assumes independence of action by the contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.3.4 Risk Characterization

The final step in the HHRA is the characterization of risk. Here the toxicity and exposure assessments are summarized and combined into quantitative and qualitative expressions of risk. Potential noncarcinogenic effects are characterized by comparing intakes and toxicity values, while carcinogenic risks are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

The USEPA (1989a) recommends absorption efficiency adjustments to ensure that the site exposure estimate (CDI) and the toxicity criteria (RfD and CPS) are both expressed as absorbed doses or both

expressed as intakes (administered doses). All CDI calculations are provided in Appendix I. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-23 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in Table 6-23. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in Table 6-23, the total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for both adults and children. Thus, adverse non-carcinogen health effects in these residential populations are likely. The majority of this risk is associated with ingestion of arsenic and manganese in groundwater. In addition, exposure to arsenic and manganese in groundwater is the only exposure scenario above the criterion.

Cancer Risks

Table 6-24 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 7 in 10 thousand for adults and 3 in 10 thousand for children. These values are greater than the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component for adult and child exposures is ingestion of the COPC (especially arsenic) in groundwater. In addition, exposure to arsenic, PCE and TCE in groundwater is the only exposure scenario above the criterion.

TABLE 6–23
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg–day)	CDI Adjusted For Absorption	RfD (mg/kg–day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	6.16E–07	No	3.00E–04	2.05E–03	1.85E–02
	Manganese	8.22E–05	No	5.00E–03	1.64E–02	
Ingestion of COPC in Groundwater	Arsenic	1.10E–03	No	3.00E–04	3.67E+00	6.71E+00
	Manganese	1.45E–02	No	5.00E–03	2.90E+00	
	cis 1,2–DCE	2.44E–04	No	1.00E–02	2.44E–02	
	Ethylbenzene	4.49E–04	No	1.00E–01	4.49E–03	
	PCE	2.71E–04	No	1.00E–02	2.71E–02	
	Toluene	7.81E–04	No	2.00E–01	3.91E–03	
	TCE	4.96E–04	No	6.00E–03	8.27E–02	
	Xylenes	1.71E–03	No	2.00E+00	8.55E–04	
Dermal Contact with COPC in Groundwater	Arsenic	1.59E–06	Yes	3.00E–04	5.30E–03	4.76E–02
	Manganese	2.11E–05	Yes	5.00E–03	4.22E–03	
	cis 1,2–DCE	1.62E–05	Yes	1.00E–02	1.62E–03	
	Ethylbenzene	4.13E–04	Yes	1.00E–01	4.13E–03	
	PCE	1.89E–06	Yes	1.00E–02	1.89E–04	
	Toluene	2.27E–03	Yes	2.00E–01	1.13E–02	
	TCE	1.20E–04	Yes	6.00E–03	2.00E–02	
	Xylenes	1.57E–03	Yes	2.00E+00	7.85E–04	
Inhalation of Volatilized COPC in Groundwater	Ethylbenzene	2.48E–04	No	2.86E–01	8.67E–04	4.66E–03
	Toluene	4.32E–04	No	1.14E–01	3.79E–03	
					Total Exposure Hazard Index	**6.78E+00**

TABLE 6–23
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg–day)	CDI Adjusted For Absorption	RfD (mg/kg–day)	Hazard Quotient	Pathway Hazard Index
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	5.75E–06	No	3.00E–04	1.92E–02	1.73E–01
	Manganese	7.67E–04	No	5.00E–03	1.53E–01	
Ingestion of COPC in Groundwater	Arsenic	2.56E–03	No	3.00E–04	8.53E+00	
	Manganese	3.39E–02	No	5.00E–03	6.78E+00	
	cis 1,2–DCE	5.69E–04	No	1.00E–02	5.69E–02	
	Ethylbenzene	1.05E–03	No	1.00E–01	1.05E–02	1.56E+01
	PCE	6.33E–04	No	1.00E–02	6.33E–02	
	Toluene	1.82E–03	No	2.00E–01	9.10E–03	
	TCE	1.16E–03	No	6.00E–03	1.93E–01	
	Xylenes	3.98E–03	No	2.00E+00	1.99E–03	
Dermal Contact with COPC in Groundwater	Arsenic	2.80E–06	Yes	3.00E–04	9.33E–03	
	Manganese	3.72E–05	Yes	5.00E–03	7.44E–03	
	cis 1,2–DCE	2.86E–05	Yes	1.00E–02	2.86E–03	
	Ethylbenzene	7.27E–04	Yes	1.00E–01	7.27E–03	8.38E–02
	PCE	3.33E–06	Yes	1.00E–02	3.33E–04	
	Toluene	4.00E–03	Yes	2.00E–01	2.00E–02	
	TCE	2.11E–04	Yes	6.00E–03	3.52E–02	
	Xylenes	2.76E–03	Yes	2.00E+00	1.38E–03	
Inhalation of Volatilized COPC in Groundwater	Ethylbenzene	6.97E–04	No	2.86E–01	2.44E–03	1.31E–02
	Toluene	1.21E–03	No	1.14E–01	1.06E–02	
					Total Exposure Hazard Index	**1.59E+01**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

TABLE 6-24
CANCER RISK ESTIMATES
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	CPS $(mg/kg-day)^{-1}$	Chemical-Specific Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	2.64E-07	No	1.50E+00	3.96E-07	3.96E-07
Ingestion of COPC in Groundwater	Arsenic	4.70E-04	No	1.50E+00	7.05E-04	7.13E-04
	PCE	1.16E-04	No	5.20E-02	6.03E-06	
	TCE	2.13E-04	No	1.10E-02	2.34E-06	
Dermal Contact with COPC in Groundwater	Arsenic	6.83E-07	Yes	1.50E+00	1.02E-06	1.63E-06
	PCE	8.12E-07	Yes	5.20E-02	4.22E-08	
	TCE	5.15E-05	Yes	1.10E-02	5.66E-07	
Inhalation of Volatilized COPC in Groundwater	PCE	6.43E-05	No	2.03E-03	1.31E-07	8.39E-07
	TCE	1.18E-04	No	6.00E-03	7.08E-07	
					Total Exposure Hazard Index	**7.16E-04**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	4.93E-07	No	1.50E+00	7.39E-07	7.39E-07
Ingestion of COPC in Groundwater	Arsenic	2.19E-04	No	1.50E+00	3.29E-04	3.32E-04
	PCE	5.42E-05	No	5.20E-02	2.82E-06	
	TCE	9.92E-05	No	1.10E-02	1.09E-06	
Dermal Contact with COPC in Groundwater	Arsenic	2.40E-07	Yes	1.50E+00	3.60E-07	5.74E-07
	PCE	2.86E-07	Yes	5.20E-02	1.49E-08	
	TCE	1.81E-05	Yes	1.10E-02	1.99E-07	
Inhalation of Volatilized COPC in Groundwater	PCE	3.62E-05	No	2.03E-03	7.35E-08	4.71E-07
	TCE	6.63E-05	No	6.00E-03	3.98E-07	
					Total Exposure Hazard Index	**3.34E-04**

Notes:
CDI = Chronic Daily Intake
CPS – Cancer Potency Slope
Chemical specific Risk = CDI x CPS

Uncertainty

Some uncertainty is inherent in the process of conducting predictive, quantitative health risk assessments. Environmental sampling and analysis, fate and transport modeling and human exposure modeling are all prone to uncertainty, as are the available toxicity values used to characterize risk. Such uncertainty is generally related to the limitations of the sampling in terms of the number and distribution of samples and analytical information in terms of systematic or random errors used to characterize a site, the estimation procedures and the input variables and assumptions used in the assessment.

There are uncertainties in every step of the risk assessment process; uncertainties that relate to this human health evaluation may be noted. Selection of the chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. Additional uncertainties are inherent in the exposure assessment for individual chemicals and exposure routes.

There is also some uncertainty in the derivation of health effects criteria in the toxicity assessment. In most cases, the criteria are derived from the extrapolation from laboratory animal data to the human condition. This may have the effect of either overestimating or underestimating the risk.

For the LARC 60 site, some important uncertainties that may influence the results of the HHRA include:

- Although a limited data set for arsenic and manganese in soils at the site was available, as previously stated in Section 6.3.1, arsenic and manganese concentrations in soils are consistent with background soils data.

- Limited data set for dissolved arsenic and manganese in groundwater. Only 4 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 530 ug/ for manganese and 40 ug/l for arsenic were used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved metals would present a larger data set and provide for a more accurate analysis of risk.

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. Dissolved results may be biased high based on the filtering limitations.

- VOC estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. These VOCs were detected infrequently (cis 1,2-DCE - 4 of 33 samples, ethyl benzene 4 of 29 samples, PCE - 3 of 33 samples, toluene - 3 of 29 samples, TCE - 4 of 33 samples and xylenes - 3 of 29 samples). Analysis with a lower PQL may more accurately estimate VOC concentrations and subsequent risk.

6.3.5 LARC 60 Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

- A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

  - The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for adults and children with the majority (approximately 97 percent) of this risk associated with ingestion of arsenic and manganese in groundwater. However, ingestion of arsenic and manganese from groundwater is the only adult and child exposure scenario above the criterion.

- A summary of the **Carcinogenic Risk** for future residential land use is provided below:

  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 7 in 10 thousand for adults. The greatest component for adults exposures is ingestion of arsenic in groundwater (98 percent of total risk). In addition, exposure to contaminated groundwater from arsenic, PCE and TCE is greater than the USEPA remediation goal.

  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 10 thousand for children. The greatest components for child exposures are ingestion of arsenic in groundwater (98 percent of total risk). In addition, exposure to contaminated groundwater from arsenic, PCE and TCE is greater than the USEPA remediation goal.

- Potential risk is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

- Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentrations of VOCs in groundwater due to natural attenuation would not be expected to be above USEPA MCLs at that time.

- Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater. However, under the current land use, there are no risks from the metals in the groundwater.

6.4 AUTO CRAFT BUILDING AREA

6.4.1 Hazard Identification

Numerous groundwater and surface soil samples were collected from this site and analyzed for various chemical contaminants. Figures 2-9 and 2-10 provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in Tables 6-25 through 6-27 to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select chemicals of potential concern for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

Emphasis is given in the ensuing evaluation to chemical contamination in the surface soil throughout the site and groundwater underlying the site as these environmental media are regarded as having the greatest potential for human contact. Chemical contamination in the subsurface soils are

discussed in the context of the potential for exposure from future excavation of these soils and continued or further degradation of groundwater from leaching.

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III RBC Criteria, EPA Region III SSLs, and Virginia Petroleum Program Criteria are included in Table 6-25 as TBC criteria for purposes of comparison. A total of six surface soil samples were collected during the field investigation.

VOCs

All concentrations of VOCs were less than EPA RBC criteria, and therefore, are not selected as COPC.

SOCs

As shown in Table 6-25, the concentrations of several PAHs including benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene in surface soils exceeded EPA RBC criteria for residential soils, however, as stated in Section 4.5.1.1, their concentrations are related to the presence of an asphalt parking lot placed on top of surface soils around the former building. Because they are not believed to be related to activities at the site, they are not selected as COPC. The presence of PAHs would be expected in all shallow soils beneath asphalted areas at other locations (bowling lanes parking lot, admin building parking lots, etc.) at Fort Story as well. Each of these areas would not be considered a "hazardous waste site" requiring a human health risk assessment and potential remediation.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in three of six surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. BTEX and PAHs, hazardous constituents of petroleum products, will be the compounds evaluated in determining petroleum contamination risk, and as stated previously, their concentrations were less than EPA RBC criteria.

TABLE 6–25
HAZARD ASSESSMENT FOR SURFACE SOILS – AUTO CRAFT SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: Virginia Petroleum Program[1]	TBC Criteria: EPA SSLs Transfers to Air[2]	TBC Criteria: EPA RBC Criteria Industrial Soils[3]	TBC Criteria: EPA RBC Criteria Residential Soils[3]	EPA Carcinogen Class[4]	Potential Concern?
VOCs (ug/kg)								
Methylene Chloride	1/6	41	–	7,000	760,000	85,000	B2	
Methyl ethyl ketone	1/6	55	–	–	100,000,000	4,700,000	D	
Toluene	6/6	7.9 – 34	–	520,000	41,000,000	1,600,000	D	
Trichloroethene	1/6	33	–	3,000	520,000	58,000	B2	
SOCs (ug/kg)								
Acenaphthene	1/6	440	–	120,000	12,000,000	470,000	–	
Benzo(a)anthracene	1/6	2500	–	27,000	7,800	880	B2	
Benzo(b)fluoranthene	1/6	4100	–	23,000	7,800	880	B2	
Benzo(k)fluoranthene	1/6	490	–	–	78,000	8,800	B2	
Benzo(g,h,i)perylene	1/6	2000	–	–	–	–	–	
Benzo(a)pyrene	1/6	3400	–	11,000	780	88	B2	
Butylbenzyphthalate	1/6	550	–	530,000	410,000,000	16,000,000	C	
Chrysene	1/6	2000	–	3,600	780,000	88,000	B2	
Fluoranthene	1/6	5800	–	68,000	8,200,000	310,000	D	
Indeno(1,2,3–cd)pyrene	1/6	1500	–	280,000	7,800	880	B2	
Phenanthrene	1/6	1300	–	–	–	–	D	
Pyrene	1/6	11,000	–	56,000	6,100,000	230,000	D	
TPH (mg/kg)								
Total TPH	3/6	220 – 390	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	1/1	5,200	–	–	100,000	7,800	–	
Arsenic	1/1	1.3	–	380	61	2.3	–	
Arsenic (as carcinogen)	1/1	1.3	–	380	3.8	0.43	A	**Yes**
Barium	1/1	82	–	350,000	14,000	550	–	
Calcium	1/1	1200	–	–	–	–	–	
Chromium	1/1	8.6	–	–	100,000	7,800	–	
Cobalt	1/1	4.4	–	–	12,000	470	–	
Copper	1/1	18	–	–	7,600	290	D	
Iron	1/1	9,100	–	–	–	–	–	
Lead	1/1	95	–	–	400	–	B2	
Magnesium	1/1	2,400	–	–	–	–	–	
Manganese	1/1	170	–	–	1,000	39	D	**Yes**
Mercury	1/1	0.022	–	–	61	2.3	D	
Nickel	1/1	4.8	–	6,900				
Potassium	1/1	2,700	–	–	–	–	–	
Sodium	1/1	64	–	–	–	–	–	
Vanadium	1/1	18	–	–	1,400	555	D	
Zinc	1/1	64	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers from Soil to Air (Jun – Dec 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jun – Dec 1995)
(4) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

Inorganics

Arsenic and manganese exceeded the RBC values for residential soils but did not exceed the industrial soils criteria.

Arsenic was detected in the only surface soil sample collected at a concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic level detected in the surface soils is consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H.

Manganese was detected in the only surface soil sample collected at a concentration of 170 mg/kg. Although no background 95th percentile UCL was established by Montgomery Watson during performance of the PA/SI, the USGS regional soils data indicates an observed range of less than 0.2 to 7,000 mg/kg with a mean of 290 mg/kg. Therefore, the manganese level detected in the surface soils is consistent with regional background soils.

Although consistent with background levels, for the purposes of risk analysis, arsenic and manganese are selected as COPCs based on their exceedance of the residential soils criteria.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in Table 6-26 along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC Criteria. Only the dissolved inorganic data is presented in Table 6-26. Total inorganic data are influenced by the percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment is not available for transport with flowing groundwater and would also be filtered out if drinking water wells were installed in this area.

Ten (10) groundwater samples (6 DPT and 4 monitoring well samples) were collected from the upper aquifer during the field investigation. The number of results for each chemical may vary due to the analysis of different compounds at different locations.

TABLE 6–26
HAZARD ASSESSMENT FOR GROUNDWATER
AUTO CRAFT BUILDING AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				TBC Criteria		EPA Carcinogen Class(7)	Potential Concern?
			EPA MCLs(1)	EPA Secondary MCLs(2)	Virginia GW Stds(3)	Va GW Protection Levels(4)	Virginia GW Criteria(5)	EPA RBC Criteria(6) Tap Water		
VOCs (ug/l)										
Chloroform	1/10	11	100	–	–	5	–	0.15	B2	**Yes**
Methylene chloride	1/10	3.9	5	–	–	600	–	4.1	B2	
SOCs (ug/l)										
Bis(2–EH)phthalate	1/10	8	–	–	–	–	–	4.8	B2	**Yes**
Di–n–butylphthalate	1/10	5	–	–	–	–	–	370	–	
TPH (mg/l)										
Total TPH	0/10	BDL	–	–	1	1	–	–	–	
Dissolved Metals (mg/l)										
Calcium	2/2	5.8 – 31	–	–	–	–	–	–	–	
Iron	2/2	0.11 – 8.1	–	0.30	–	–	0.30	–	–	
Magnesium	2/2	3.7 – 4.6	–	–	–	–	–	–	–	
Manganese	1/2	0.08	–	0.05	–	–	0.05	0.018	D	**Yes**
Potassium	2/2	2.1 – 15	–	–	–	–	–	–	–	
Sodium	2/2	11 – 15	–	–	270	270	100	–	–	

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards (VR680–21–04)
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations (VR672–20–10)
(5) Virginia Water Quality Criteria for Groundwater (VR680–21–05)
(6) EPA Region III Risk–based Concentration Table for Tap Water (Jun – Dec 1995)
(7) Weight–of–Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

VOCs

Chloroform was detected in excess of the Virginia Groundwater Protection Level and EPA RBC criteria. Although chloroform was detected in only 1 of 10 samples and in a concentration less than the 100 ug/l MCL for total trihalomethanes, it is selected as a COPC. Although detected, methylene chloride concentrations were less than the EPA screening criteria.

SOCs

Two SOCs were detected during groundwater sampling however only bis(2-ethylhexyl)phthalate was detected in excess of the EPA RBC criteria. Therefore, it is selected as a COPC.

TPH

TPH was not detected in any of the groundwater samples.

Inorganics

Dissolved iron was detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, these standards were established for aesthetic qualities only, and therefore, iron is not selected as a COPC.

Dissolved manganese was detected at a concentration greater than the EPA RBC, and therefore, is selected as a COPC.

Subsurface Soils and Soil Leachability

To evaluate the potential exposures to subsurface soils (i.e., future excavation activities) and for the potential leaching of contaminants form soil to groundwater, as shown in Table 6-27, soil analytical data was compared against EPA Region III SSLs for Transfers from Soil to Groundwater and EPA RBC for industrial soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria and SSLs are included in Table 6-27 as TBC criteria for purposes of comparison. A total of 18 soil samples were collected during the field investigation.

TABLE 6–27
HAZARD ASSESSMENT FOR SUBSURFACE SOILS AND SOIL LEACHABILITY
AUTO CRAFT BUILDING AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA SSLs Transfers to Groundwater(1)	TBC Criteria: EPA RBC Industrial Soils(2)	EPA Carcinogen Class(3)	Potential Concern?
VOCs (ug/kg)						
Acetone	1/18	31	8,000	20,000,000	D	
Ethylbenzene	1/18	1.6	5,000	20,000,000	D	
Methylene Chloride	1/18	41	10	760,000	B2	
Methyl ethyl ketone	4/18	55 – 100	–	100,000,000	D	
Styrene	1/18	6	2,000	41,000,000	D	
Toluene	10/18	7.9 – 34	5,000	41,000,000	D	
Trichloroethene	1/18	33	20	520,000	B2	
Xylenes	1/18	16	74,000	100,000,000	D	
SOCs (ug/kg)						
Acenaphthene	2/18	70 – 440	200,000	12,000,000	–	
Anthracene	1/18	250	4,300,000	61,000,000	–	
Benzo(a)anthracene	2/18	360 – 2,500	700	7,800	B2	
Benzo(b)fluoranthene	2/18	480 – 4,100	4,000	7,800	B2	
Benzo(k)fluoranthene	2/18	490 – 770	4,000	78,000	B2	
Benzo(g,h,i)perylene	1/18	2,000	–	–	–	
Benzo(a)pyrene	2/18	940 – 3,400	4,000	780	B2	
Butylbenzyphthalate	2/18	230 – 550	68,000	410,000,000	C	
Chrysene	2/18	520 – 2,000	1,000	780,000	B2	
Dibenz(a,h)anthracene	1/18	130	11,000	0.78	B2	
Fluoranthene	2/18	900 – 5,800	980,000	8,200,000	D	
Fluorene	1/18	65	160,000	8,200,000	D	
Indeno(1,2,3–cd)pyrene	2/18	260 – 1,500	35,000	7,800	B2	
Naphthalene	1/18	8.2	30,000	8,200,000	D	
Phenanthrene	2/18	890 – 1,300	–	–	D	
Pyrene	2/18	1,600 – 11,000	1,400,000	6,100,000	D	
TPH (mg/kg)						
Total TPH	6/18	72 – 390	–		–	
Total Metals (mg/kg)						
Aluminum	4/4	440 – 5200	–	100,000	–	
Arsenic	4/4	1.1 – 1.5	15	61	–	
Arsenic (as carcinogen)	4/4	1.1 – 1.5	15	3.8	A	
Barium	4/4	2.8 – 82	32	14,000	–	
Beryllium	1/4	0.058	180	1.3	B2	
Cadmium	1/4	0.18	6	100	D	
Calcium	3/4	84 – 1200	–	–	–	
Chromium	4/4	2.3 – 8.6	–	100,000	–	
Cobalt	2/4	0.79 – 4.4	–	12,000	–	
Copper	2/4	5 – 18	–	8,200	D	
Iron	4/4	1200 – 9100	–	–	–	
Lead	4/4	1.7 – 95	–	400	B2	
Magnesium	4/4	96 – 2400	–	–	–	
Manganese	4/4	10 – 170	–	1,000	D	
Mercury	3/4	0.011 – 0.10	3	61	D	
Nickel	1/4	1.1	21	4,100	–	
Potassium	3/4	130 – 2700	–	–	–	
Sodium	2/4	20 – 64	–	–	–	
Vanadium	4/4	1.8 – 18	–	1,400	D	
Zinc	4/4	4.5 – 64	42,000	61,000	D	

Notes:
(1) EPA Region III Soil Screening Levels for Transfers from Soil to Groundwater (Jun – Dec 1995)
(2) EPA Region III RBC for Industrial Soils (Jun – Dec 1995)
(3) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no human evidence
C = Possible human carcinogen
D = Not classified as to carcinogenicity

VOCs

All VOC concentrations were less than the EPA RBC for industrial soils.

Methylene chloride and PCE exceeded EPA SSLs but were detected in only 1 of 18 samples collected and only in shallow soils (0 to 1 foot depth) at one location beneath the asphalt parking lot. The potential for impacts to groundwater quality through leaching is minimal.

SOCs

Benzo(a)pyrene and dibenz(a,h)anthracene exceeded EPA RBC for industrial soils. However, these contaminants were only detected in shallow soils at one location beneath the asphalt parking lot and as previously discussed, are related to asphalt leaching rather than site conditions..

Benzo(a)anthracene, chrysene, and benzo(b)flouranthene exceeded EPA SSLs. However, these contaminants were only detected in shallow soils (0 to 1 foot depth) at one location beneath the asphalt parking lot. Their concentration greatly decreases with depth and the potential for impacts to groundwater quality through additional leaching is minimal.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 6 of 18 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, BTEX and PAHs, which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. Except for the soils impacted by the asphalt leaching, their concentrations were less than EPA RBC and SSL criteria.

Inorganics

Barium was detected in only 1 of 4 samples (82 mg/kg at surface soil sample at soil boring #4) above the 32 mg/kg EPA SSL. The USGS reports the observed barium range in their study was 15 to 1,000 mg/kg with a mean of 300 mg/kg. The barium concentration of 82 mg/kg was detected in the surface soil sample (0 to 1 foot sample) at soil boring #4 while only 7.9 mg/kg of barium was detected in the subsurface soil at the same boring collected at a depth of 2 to 4 feet below land surface indicating little leaching of barium through the unsaturated zone since the site activities ceased over 7 years ago. Therefore, the barium levels do not indicate a potential leaching problem.

Chemicals of Potential Concern

Arsenic and manganese in surface soils and chloroform, bis(2-ethylhexyl)phthalate, and dissolved manganese in groundwater are the COPCs identified during the hazard identification of the Auto Craft media.

Potential risk associated with the COPC will be further evaluated in the exposure assessment section.

6.5.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the groundwater COPC that are present at or migrating from the Auto Craft site.

Potentially Exposed Populations

As part of the exposure assessment, it is important to characterize the potentially exposed populations at or near the site with regard to the current situation and potential future conditions.

Current Situation

The fenced, paved area of the site is currently used as a vehicle impoundment area. The grassy areas located north of the site are unused properties. Fort Story personnel are present at the site for approximately one day per week for only a few minutes. However, because the only surface soil COPCs identified were arsenic and manganese due to exceedance of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Although the grassy areas north of the site are not fenced, potential exposures to the general public and/or trespassers would not be significant because their presence on the site would not be expected to be for only a short time and not routine. There is a sidewalk located along Atlantic Avenue but during our field investigations, little pedestrian traffic was observed. Therefore, there are **no exposed populations to the surface soils at the Auto Craft site under the current situation**.

Groundwater is not used in the vicinity of the site for drinking, process, or production purposes. The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile

of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located approximately 4,500 feet (cross groundwater flow gradient) from the site at the LARC 60 Maintenance Area of which water is obtained for nonpotable uses only. Therefore, there are **currently no exposed populations to the groundwater at the Auto Craft site.**

Future Land Use

Although construction or excavation activities could be conducted in the future, except for PAHs resulting from asphalt leaching, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. In addition, there are several undeveloped areas adjacent to the site where additional base housing could be constructed. Therefore, **as for future conditions, potentially exposed populations include residential exposures to the surface soils and groundwater at the LARC 60 site.**

Exposure Pathways

The potential exposure pathways for future land use at the Auto Craft site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.

- Residential exposure (adults and children) to **contaminated soil** through ingestion of chemicals.

Data Limitations and Uncertainties

The limitations and uncertainties associated with the analytical data for the site were reviewed during data validation to ensure that appropriate and reliable data are selected for use in estimating human

exposure.

Samples and their duplicates are not considered as separate sampling events. Rather a chemical-specific value representing the maximum value of the sample and its duplicate is used. This may result in a conservative estimate of exposure. However, since relatively few duplicate samples were collected, the overall impact on risk estimates should be minimal.

For purposes of this HHRA, if a COPC was not detected in a sample, it is assumed to be present at 1/2 the practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant Intake

Evaluation of the exposure pathways described above involves the estimation of several parameters such as skin surface area available for contact; skin permeability factors; exposure time, frequency, and duration; soil-to-skin adherence factors; ingestion rates; as well as the contaminant concentrations in the specific media of concern. Table 6-5 represents a general equation for calculating chemical intakes (chronic daily intakes or CDI) and defines the intake variables in terms of chemical-related, population-related and evaluation-determined parameters.

The USEPA recommends that estimates of contaminant intake be developed to portray reasonable maximum exposures (RME) which might be expected to occur under current and future site conditions. Accordingly, the highest exposure that might reasonably be expected to occur at the site, one that is well above the average case of exposure but within the range of possibility should be considered.

The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the contaminant concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative" concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence

limits, etc. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:

$$UCL = e^{\{x + 0.5s^*s + Sh/\sqrt{(n-1)}\}}$$

where:

UCL = 95th percent upper confidence limit on the mean
e = constant (natural log)
x = the mean of the log transformed data
s = the standard deviation of the log transformed data
H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean
n = sample size

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be conducted for data sets of 5 or greater.

Therefore, for the surface soil COPCs of arsenic and manganese, the maximum concentration will be used because only 1 surface soil sample was collected.

Therefore, for the groundwater COPC of manganese, the maximum concentration will be used because only 2 dissolved groundwater samples for metals analysis were collected.

The 95th percentile UCL concentrations were computed for chloroform and bis(2-ethylhexyl)phthalate in groundwater to estimate the mean concentration. These UCL calculations

are provided in Appendix I. The results of the UCL calculations with comparison to the maximum concentration detected are provided in Table 6-28.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In Appendix J, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

Surface Soil

Table 6-7 presents the parameters and assumptions used in assessing potential exposures to chemicals in surface soil. Minimal exposures due to dermal contact and inhalation are typically present for metals, and therefore, these exposure pathways are not evaluated. In addition, arsenic and manganese did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).

- The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest

TABLE 6-28
COMPARISON OF EXPOSURE CONCENTRATIONS
AUTO CRAFT AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Surface Soils		
Ingestion of Chemicals	mg/kg	mg/kg
Arsenic	**1.3**	NA
Manganese	**170**	NA
Groundwater		
Ingestion of and Dermal Contact with Chemicals	ug/l	ug/l
Manganese	**80**	NA
Bis(2-ethylhexyl)phthalate	8	**3.99**
Chloroform	11	**4.76**
Inhalation of Chemicals Volatilized	mg/m^3	mg/m^3
Chloroform	7.33E-02	**3.17E-02**

Notes:
NA - Not applicable because insufficient number of samples to calculate the 95th percentile UCL.

child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

  This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.4.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8 through 6-10 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of, dermal contact or inhalation, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in Appendix I.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

    - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

    - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be $30m^3$ in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume,

over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

Chemical concentration in air (mg/m^3) = CW x CF x WV x 1/RV
where:

CW = chemical concentration in water (ug/l)
CF = conversion factor (1E-03 mg/ug)
WV = volume of water (200 liters)
RV = room volume (30 m^3)

The concentration in air for the chemicals of potential concern are presented in Table 6-20. All concentration-in-air calculations are provided in Appendix I.

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

- When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.4.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.4.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves (1) determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and (2) characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used when available. These include verified reference doses (RfDs) for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slopes (CPSs) for the evaluation of cancer risk from lifetime exposure. Each of these are discussed below.

Sources of toxicological guidance information, in order of preference, include: (1) IRIS (Integrated Risk Information System) which is a USEPA database containing current health risk and regulatory information for many chemicals (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

The inherent toxicity of the COPC for the HHRA is briefly summarized in Appendix J.

Non-Carcinogenic Effects

The potential for non-cancer health effects associated with chemical exposure is evaluated by comparing an estimated intake (such as chronic daily intake or CDI) over a specified time period with a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical.

The RfDs for the COPC used for the characterization of chronic non-cancer risk via oral exposure routes are presented in Table 6-29, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD and any uncertainty of modifying factors used in the derivation of the RfD.

The ratio of the estimate of the CDI to the health-protective criterion (CDI/RfD) is called the hazard quotient (USEPA, 1989a). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, the greater the level of concern.

RfDs for oral exposure are available for most chemicals. For dermal exposure, however, RfDs are not available. In their absence, the oral RfDs are used and adjusted to reflect absorbed dose. This allows for comparison between exposure estimated as absorbed doses and toxicity values expressed as absorbed doses.

Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. However, a RfDi is not available for chloroform.

Carcinogenic Effects

Regardless of the mechanism of effect, risk assessment methods generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk assessment methods require extrapolation from high dose animal studies to evaluate low dose exposures to humans. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk

TABLE 6-29
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	Chronic RfD (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
ORAL ROUTE						
Arsenic	3.00E-04	Medium	Perpigmentation, keratosis and possible vascular complications	Oral/IRIS	3	1
Manganese	5.00E-03	Medium				
Bis(2-EH)phthalate	2.00E-02					
Chloroform	1.00E-02					
INHALATION ROUTE						
Arsenic	---					
Manganese	1.43E-05			IRIS		
Bis(2-EH)phthalate	---					
Chloroform	---					

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
H - Variation in human sensitivity
A - Animal to human extrapolation
S - Extrapolation from Lowest Observed Adverse Effect Level (LOAEL) to No Observed Adverse Effect Level (NOAEL)

that is consistent with some proposed mechanisms of carcinogenesis.

Through application of this approach, the USEPA has derived estimates of incremental excess cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and the fitting of those dose-response data to a low dose extrapolation model. The CPS (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in Table 6-30 and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in Table 6-30.

To arrive at an estimate of incremental cancer risk, the following equation is used (USEPA, 1989a):

Risk = CDI x CPS
where:

Risk = a unitless probability (e.g., 2×10^{-5} or 2 in 100 thousand) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
CPS = Cancer Potency Slope expressed in $(mg/kg\text{-}day)^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). This approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values.

CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. However, a CPSi is available for chloroform.

TABLE 6-30
TOXICITY VALUES: CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	CPS $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification	Type of Cancer	SF Basis	SF Source
ORAL ROUTE					
Arsenic	1.50E+00	A	Gross tumors	Oral	IRIS
Bis(2-EH)phthalate	1.40E-02	B2			
Chloroform	6.10E-03	B2			
INHALATION ROUTE					
Arsenic	1.51E+01	A			
Bis(2-EH)phthalate	---	B2			
Chloroform	8.05E-02	B2			

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
NCEA - EPA Provisional Guidance

Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and cancer effects posed by multiple chemicals. This approach assumes that subthreshold exposures to several chemicals at the same time could result in an adverse health effect. It assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect by the same mechanism of action. In this evaluation, the hazard quotients of a mixture of chemicals which can have different effects are used as a screening-level approach, as recommended by the USEPA (USEPA, 1989a). This approach is likely to overestimate the potential for effects.

For the assessment of carcinogenic risks, the individual risks associated with exposure to each contaminant are summed. This represents an approximation of the precise equation for combining risks which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens. This additive approach assumes independence of action by the contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.4.4 Risk Characterization

The final step in the HHRA is the characterization of risk. Here the toxicity and exposure assessments are summarized and combined into quantitative and qualitative expressions of risk. Potential noncarcinogenic effects are characterized by comparing intakes and toxicity values, while carcinogenic risks are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

The USEPA (1989a) recommends absorption efficiency adjustments to ensure that the site exposure estimate (CDI) and the toxicity criteria (RfD and CPS) are both expressed as absorbed doses or both

expressed as intakes (administered doses). All CDI calculations are provided in Appendix I. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-31 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in Table 6-31. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in Table 6-31, the total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is less than the criterion of 1.0 for adults but greater than the criterion for children. Thus, adverse non-carcinogen health effects in this residential population (children) are likely. The majority of this risk is associated with ingestion of manganese in groundwater. In addition, ingestion of manganese in groundwater is the only exposure scenario above the criterion.

Cancer Risks

Table 6-32 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults and 3 in 1 million for children. These values are within the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component for adult exposure is inhalation of chloroform in groundwater which was the only exposure scenario within the USEPA remediation goal. For child exposures, both ingestion of arsenic in soils and inhalation of chloroform in groundwater were within the USEPA remediation goal.

TABLE 6-31
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	8.90E-07	No	3.00E-04	2.97E-03	3.50E-02
	Manganese	1.60E-04	No	5.00E-03	3.20E-02	
Ingestion of COPC in Groundwater	Manganese	2.19E-03	No	5.00E-03	4.38E-01	
	Bis(2-ethylhexyl)phthalate	1.09E-04	No	2.00E-02	5.45E-03	4.56E-01
	Chloroform	1.30E-04	No	1.00E-02	1.30E-02	
Dermal Contact with COPC in Groundwater	Manganese	3.19E-06	Yes	5.00E-03	6.38E-04	
	Bis(2-ethylhexyl)phthalate	1.01E-05	Yes	2.00E-02	5.05E-04	2.26E-03
	Chloroform	1.12E-05	Yes	1.00E-02	1.12E-03	
Inhalation of Volatilized COPC in Groundwater	Chloroform	7.21E-05	No	---	---	---
					Total Exposure Hazard Index	**4.94E-01**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	8.31E-06	No	3.00E-04	2.77E-02	2.46E-01
	Manganese	1.09E-03	No	5.00E-03	2.18E-01	
Ingestion of COPC in Groundwater	Manganese	5.11E-03	No	5.00E-03	1.02E+00	
	Bis(2-ethylhexyl)phthalate	2.55E-04	No	2.00E-02	1.28E-02	1.07E+00
	Chloroform	3.04E-04	No	1.00E-02	3.04E-02	
Dermal Contact with COPC in Groundwater	Manganese	5.61E-06	Yes	5.00E-03	1.12E-03	
	Bis(2-ethylhexyl)phthalate	1.77E-04	Yes	2.00E-02	8.85E-03	1.19E-02
	Chloroform	1.97E-05	Yes	1.00E-02	1.97E-03	
Inhalation of Volatilized COPC in Groundwater	Chloroform	2.03E-04	No	---	---	---
					Total Exposure Hazard Index	**1.32E+00**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

TABLE 6–32
CANCER RISK ESTIMATES
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg–day)	CDI Adjusted For Absorption	CPS $(mg/kg–day)^{-1}$	Chemical–Specific Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	3.82E–07	No	1.50E+00	5.73E–07	5.73E–07
Ingestion of COPC in Groundwater	Bis(2–ethylhexyl)phthalate Chloroform	4.68E–05 5.59E–05	No No	1.40E–02 6.10E–03	6.55E–07 3.41E–07	9.96E–07
Dermal Contact with COPC in Groundwater	Bis(2–ethylhexyl)phthalate Chloroform	4.31E–06 4.80E–06	Yes Yes	1.40E–02 6.10E–03	6.03E–08 2.93E–08	8.96E–08
Inhalation of Volatilized COPC in Groundwater	Chloroform	3.09E–05	No	8.05E–02	2.49E–06	2.49E–06
					Total Exposure Hazard Index	**4.15E–06**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	7.12E–07	No	1.50E+00	1.07E–06	1.07E–06
Ingestion of COPC in Groundwater	Bis(2–ethylhexyl)phthalate Chloroform	2.19E–05 2.61E–05	No No	1.40E–02 6.10E–03	3.07E–07 1.59E–07	4.66E–07
Dermal Contact with COPC in Groundwater	Bis(2–ethylhexyl)phthalate Chloroform	1.52E–06 1.69E–06	Yes Yes	1.40E–02 6.10E–03	2.13E–08 1.03E–08	3.16E–08
Inhalation of Volatilized COPC in Groundwater	Chloroform	1.74E–05	No	8.05E–02	1.40E–06	1.40E–06
					Total Exposure Hazard Index	**2.97E–06**

Notes:
CDI = Chronic Daily Intake
CPS – Cancer Potency Slope
Chemical specific Risk = CDI x CPS

Uncertainty

Some uncertainty is inherent in the process of conducting predictive, quantitative health risk assessments. Environmental sampling and analysis, fate and transport modeling and human exposure modeling are all prone to uncertainty, as are the available toxicity values used to characterize risk. Such uncertainty is generally related to the limitations of the sampling in terms of the number and distribution of samples and analytical information in terms of systematic or random errors used to characterize a site, the estimation procedures and the input variables and assumptions used in the assessment.

There are uncertainties in every step of the risk assessment process; uncertainties that relate to this human health evaluation may be noted. Selection of the chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. Additional uncertainties are inherent in the exposure assessment for individual chemicals and exposure routes.

There is also some uncertainty in the derivation of health effects criteria in the toxicity assessment. In most cases, the criteria are derived from the extrapolation from laboratory animal data to the human condition. This may have the effect of either overestimating or underestimating the risk.

For the Auto Craft site, some important uncertainties that may influence the results of the HHRA include:

- Limited data set for arsenic and manganese in soils at the site. Only 1 surface soil sample was analyzed for metals. However, these levels were consistent with background soils data as discussed in Section 6.4.1.

- Limited data set for dissolved manganese in groundwater. Only 2 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 80 ug/ for manganese was used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved metals would present a larger data set and provide for a more accurate analysis of risk.

Through application of this approach, the USEPA has derived estimates of incremental excess cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and the fitting of those dose-response data to a low dose extrapolation model. The CPS (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in Table 6-12 and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in Table 6-12.

To arrive at an estimate of incremental cancer risk, the following equation is used (USEPA, 1989a):

Risk = CDI x CPS
where:

Risk = a unitless probability (e.g., 2×10^{-5} or 2 in 100 thousand) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
CPS = Cancer Potency Slope expressed in $(mg/kg\text{-}day)^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). This approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values.

CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. However, there does exist a CPSi for PCE, and therefore, an evaluation of carcinogenic risk for the inhalation of volatilized chemicals will be made.

Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and

TABLE 6-12
TOXICITY VALUES: CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	CPS $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification	Type of Cancer	SF Basis	SF Source
ORAL ROUTE					
Arsenic	1.50E+00	A	Gross tumors	Oral	IRIS
Manganese	---				
PCE	5.20E-02	B2	Liver	Gavage	NCEA
Thallium	---				
INHALATION ROUTE					
Arsenic	1.51E+01	A			
Manganese	---				
PCE	2.03E-03	B2	Leukemia, liver	---	NCEA
Thallium	---				

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
NCEA - EPA Provisional Guidance

cancer effects posed by multiple chemicals. This approach assumes that subthreshold exposures to several chemicals at the same time could result in an adverse health effect. It assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect by the same mechanism of action. In this evaluation, the hazard quotients of a mixture of chemicals which can have different effects are used as a screening-level approach, as recommended by the USEPA (USEPA, 1989a). This approach is likely to overestimate the potential for effects.

For the assessment of carcinogenic risks, the individual risks associated with exposure to each contaminant are summed. This represents an approximation of the precise equation for combining risks which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens. This additive approach assumes independence of action by the contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.2.4 Risk Characterization

The final step in the HHRA is the characterization of risk. Here the toxicity and exposure assessments are summarized and combined into quantitative and qualitative expressions of risk. Potential noncarcinogenic effects are characterized by comparing intakes and toxicity values, while carcinogenic risks are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

The USEPA (1989a) recommends absorption efficiency adjustments to ensure that the site exposure estimate (CDI) and the toxicity criteria (RfD and CPS) are both expressed as absorbed doses or both expressed as intakes (administered doses). All CDI calculations are provided in Appendix I. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-13 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in Table 6-13. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in Table 6-13, the total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is less than the criterion of 1.0 for adults but greater than the criterion of 1.0 for children. Thus, adverse non-carcinogen health effects in this residential population (children) is likely. The majority of this risk is associated with ingestion of manganese in groundwater. In addition, exposure to manganese in groundwater is the only exposure scenario above the criterion.

Cancer Risks

Table 6-14 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults and 3 in 1 million for children. These values are within the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component (only component within the USEPA remediation goal) for adults exposures is ingestion of PCE in groundwater (3 in 1 million). The ingestion of arsenic in surface soils (1.5 in 1 million) and ingestion of PCE in groundwater (1.3 in 1 million) are the greatest exposure pathways for children. Risks associated with both of these child exposure scenarios are within the USEPA remediation goal.

Uncertainty

Some uncertainty is inherent in the process of conducting predictive, quantitative health risk assessments. Environmental sampling and analysis, fate and transport modeling and human

TABLE 6–13
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg–day)	CDI Adjusted For Absorption	RfD (mg/kg–day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic Thallium	1.25E–06 5.48E–07	No No	3.00E–04 8.00E–05	4.17E–03 6.85E–03	1.10E–02
Ingestion of COPC in Groundwater	Manganese PCE	2.22E–03 1.21E–04	No No	5.00E–03 1.00E–02	4.44E–01 1.21E–02	4.56E–01
Dermal Contact with COPC in Groundwater	Manganese PCE	3.23E–06 8.44E–07	Yes Yes	5.00E–03 1.00E–02	6.46E–04 8.44E–05	7.30E–04
Inhalation of Volatilized COPC in Groundwater	PCE	6.69E–05	No	---		
					Total Exposure Hazard Index	**4.68E–01**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic Thallium	1.17E–05 5.11E–06	No No	3.00E–04 8.00E–05	3.90E–02 6.39E–02	1.03E–01
Ingestion of COPC in Groundwater	Manganese PCE	5.18E–03 2.82E–04	No No	5.00E–03 1.00E–02	1.04E+00 2.82E–02	1.06E+00
Dermal Contact with COPC in Groundwater	Manganese PCE	5.68E–06 1.48E–06	Yes Yes	5.00E–03 1.00E–02	1.14E–03 1.48E–04	1.28E–03
Inhalation of Volatilized COPC in Groundwater	PCE	1.88E–04	No	---		
					Total Exposure Hazard Index	**1.17E+00**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

TABLE 6–14
CANCER RISK ESTIMATES
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg–day)	CDI Adjusted For Absorption	CPS $(mg/kg–day)^{-1}$	Chemical–Specific Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	5.37E–07	No	1.50E+00	8.06E–07	8.06E–07
Ingestion of COPC in Groundwater	PCE	5.18E–05	No	5.20E–02	2.69E–06	2.69E–06
Dermal Contact with COPC in Groundwater	PCE	3.62E–07	Yes	5.20E–02	1.88E–08	1.88E–08
Inhalation of Volatilized COPC in Groundwater	PCE	2.87E–05	No	2.03E–03	5.83E–08	5.83E–08
					Total Exposure Hazard Index	**3.58E–06**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	1.00E–06	No	1.50E+00	1.50E–06	1.50E–06
Ingestion of COPC in Groundwater	PCE	2.42E–05	No	5.20E–02	1.26E–06	1.26E–06
Dermal Contact with COPC in Groundwater	PCE	1.27E–07	Yes	5.20E–02	6.60E–09	6.60E–09
Inhalation of Volatilized COPC in Groundwater	PCE	1.61E–05	No	2.03E–03	3.27E–08	3.27E–08
					Total Exposure Hazard Index	**2.80E–06**

Notes:
CDI = Chronic Daily Intake
CPS – Cancer Potency Slope
Chemical specific Risk = CDI x CPS

exposure modeling are all prone to uncertainty, as are the available toxicity values used to characterize risk. Such uncertainty is generally related to the limitations of the sampling in terms of the number and distribution of samples and analytical information in terms of systematic or random errors used to characterize a site, the estimation procedures and the input variables and assumptions used in the assessment.

There are uncertainties in every step of the risk assessment process; uncertainties that relate to this human health evaluation may be noted. Selection of the chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. Additional uncertainties are inherent in the exposure assessment for individual chemicals and exposure routes.

There is also some uncertainty in the derivation of health effects criteria in the toxicity assessment. In most cases, the criteria are derived from the extrapolation from laboratory animal data to the human condition. This may have the effect of either overestimating or underestimating the risk.

For the FTA site, some important uncertainties that may influence the results of the HHRA include:

- Although a limited data set for arsenic in soils at the site was available, as previously stated in Section 6.2.1, arsenic concentrations in soils are consistent with Fort Story and USGS regional background soils data.

- Limited data set for dissolved manganese in groundwater. Only 3 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 81 ug/l was used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved manganese would present a larger data set and provide for a more accurate analysis of risk.

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. As shown on the Groundwater Sampling Form in Appendix C of the RI report for monitoring well 4MW-2S where the 81 ug/l dissolved manganese result was detected, the sample collected was

extremely turbid (310 NTUs) which may impact filter efficiency due to the passing of some turbid under the filter into the sample container. Dissolved results may be biased high based on the filtering limitations.

- PCE estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. PCE was not detected in 29 of the 31 groundwater sampling locations at the site. Analysis with a lower PCE PQL may more accurately estimate PCE concentrations and subsequent risk.

6.2.5 FTA Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

- A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:
  - The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is less than the criterion of 1.0 for adults.
  - The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for children. However, ingestion of manganese from groundwater is the only child exposure scenario above the criterion.
- A summary of the **Carcinogenic Risk** for future residential land use is provided below:
  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults. The greatest component for adults exposures is ingestion of PCE in groundwater (2.69 in 1 million - 75 percent of total risk) which is within the USEPA remediation goal.
  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 1 million for children. The greatest components for child exposures are ingestion of arsenic (although detected at levels consistent with background) in surface soils (1.5 in 1 million - 54 percent of total risk) and ingestion of PCE in groundwater (1.26 in 1 million - 45 percent of total risk). These child exposure scenarios are within the USEPA remediation goal.

- Potential risk is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

- Concentrations of volatile organics decreased by about one order of magnitude from the 1991 PA/SI sampling event to the 1995 RI sampling event with natural attenuation expected to continue this trend. Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentrations of PCE in groundwater due to natural attenuation would not be expected to be above USEPA MCLs at that time.

- Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater. However, under current land use, there are no risks from the metals in the groundwater.

6.3 LARC 60 MAINTENANCE AREA

6.3.1 Hazard Identification

Numerous groundwater, surface soil, surface water and sediment samples were collected from this site and analyzed for various chemical contaminants. Figures 2-7 and 2-8 provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in Tables 6-15 through 6-19 to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select COPCs for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

Emphasis is given in the ensuing evaluation to chemical contamination in the surface soil throughout the site, sediment and surface water near the site and groundwater underlying the site as these environmental media are regarded as having the greatest potential for human contact. Chemical contamination in the subsurface soils are discussed in the context of the potential for exposure from future excavation of these soils and continued or further degradation of groundwater from leaching.

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III Risk-based Concentration (RBC) Criteria EPA Region III SSLs and Virginia Petroleum Program Criteria are included in Table 6-15 as TBC criteria for purposes of comparison. A total of 22 surface soil samples were collected during the field investigation.

VOCs and SOCs

All concentrations of VOCs and SOCs were less than EPA RBC criteria and SSLs, and therefore, they are not selected as COPC.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 17 of 22 surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. BTEX and PAHs, which are hazardous constituents of petroleum products, will be the primary compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA criteria.

Inorganics

Arsenic and manganese exceeded the RBC values for residential soils but did not exceed the industrial soils criteria.

Arsenic was detected in only 1 of 5 surface soil samples at a concentration of 1.1 mg/kg with a mean concentration of 0.6 mg/kg for all surface soil samples. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4

TABLE 6–15
HAZARD ASSESSMENT FOR SURFACE SOILS
LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: Virginia Petroleum Program(1)	TBC Criteria: EPA Region III Soil Screening Levels Transfers to Air(2)	TBC Criteria: EPA Region III RBC Criteria Industrial Soils(3)	TBC Criteria: EPA Region III RBC Criteria Residential Soils(3)	EPA Carcinogen Class(4)	Potential Concern?
VOCs (ug/kg)								
Acetone	1/22	36	–	62,000,000	20,000,000	780,000	D	
Methylene Chloride	7/22	5.2 – 160	–	7,000	760,000	85,000	B2	
Toluene	3/22	5.1 – 12	–	520,000	41,000,000	1,600,000	D	
Trichloroethene	2/22	5.9 – 6.4	–	3,000	520,000	58,000	B2	
SOCs (ug/kg)	0/22	BDL						
TPH (mg/kg)								
Total TPH	19/22	42 – 1,500	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	5/5	250 – 2,700	–	–	100,000	7,800	–	
Arsenic	1/5	1.1	–	380	61	2.3	–	
Arsenic (as carcinogen)	1/5	1.1	–	380	3.8	0.38	A	**Yes**
Barium	5/5	1.8 – 19	–	350,000	14,000	550	–	
Calcium	4/5	56 – 980	–	–	–	–	–	
Chromium	5/5	1.7 – 4.3	–	–	100,000	7,800	–	
Cobalt	1/5	2.3	–	–	12,000	470	–	
Copper	4/5	2.5 – 41	–	–	7,600	290	D	
Iron	5/5	400 – 1,100	–	–	–	–	–	
Lead	5/5	3.1 – 12	–	–	400	–	B2	
Magnesium	4/5	77 – 1,400	–	–	–	–	–	
Manganese	5/5	2.4 – 120	–	–	1,000	39	D	**Yes**
Potassium	1/5	1,200	–	–	–	–	–	
Vanadium	5/5	1.2 – 9.2	–	–	1,400	55	D	
Zinc	5/5	3.8 – 33	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers from Soil to Air (Jan 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jan 1995)
(4) Weight–of–Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in amimals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

mg/kg. Therefore, the arsenic levels detected in the surface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H.

Manganese concentrations in surface soils ranged from 2.4 to 120 mg/kg with a mean concentration of 29 mg/kg. Although no background 95th percentile UCL was established by Montgomery Watson during performance of the PA/SI, the USGS regional soils data indicates an observed range of less than 0.2 to 7,000 mg/kg with a mean of 290 mg/kg. Therefore, the manganese levels detected in the surface soils are consistent with regional background soils.

Although consistent with background levels, for the purposes of risk analysis, arsenic and manganese are selected as COPCs based on their exceedance of the residential soils criteria.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in Table 6-16 along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC Criteria. Only the dissolved inorganic data is presented in Table 6-16. Total inorganic data are influenced by percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment is not available for transport with flowing groundwater and would also be filtered out if drinking water wells were installed in this area.

Thirty-three (33) groundwater samples (25 DPT and 8 monitoring well samples) were collected from the upper aquifer during the field investigation. Groundwater samples were also collected from three temporary well points during a free-product investigation. However, because no QA/QC samples were collected and data validation was not conducted, these results will not be used during the risk assessment process. The number of results for each chemical may vary due to the analysis of different compounds at different locations.

VOCs

Acetone, carbon disulfide, methylene chloride, and vinyl acetate were detected in only 1 of 29 samples and in concentrations less than risk screening criteria, and therefore, they are not selected as COPC.

TABLE 6–16
HAZARD ASSESSMENT FOR GROUNDWATER – LARC 60 SITE

Parameters	Frequency of Detection	Range of Detection	ARARs				TBC Criteria		EPA Carcinogen Class[7]	Potential Concern?
			EPA MCLs[1]	EPA Secondary MCLs[2]	Virginia GW Stds[3]	Va GW Protection Levels[4]	Virginia GW Criteria[5]	EPA RBC Criteria[6] Tap Water		
VOCs (ug/l)										
Acetone	1/29	30	–	–	–	–	–	370	D	
Carbon disulfide	1/29	10	–	–	–	1,000	–	100	–	
Chloroform	1/29	4.6	100	–	–	5	–	0.15	B2	
cis 1,2–Dichloroethene	4/33	3.5 – 150	70	–	–	–	–	6.1	–	**Yes**
Ethylbenzene	4/29	6.6 – 530	700	–	–	–	–	130	D	**Yes**
p–Isopropyl toluene	1/1	2.3	–	–	–	–	–	–	–	
Methylene chloride	1/29	2.7	5	–	–	600	–	4.1	B2	
MIBK	2/29	50 – 54	–	–	–	–	–	290	D	
Tetrachloroethene	3/33	8.5 – 170	5	–	–	7	–	1.1	B2	**Yes**
Toluene	3/29	6.4 – 2,200	1,000	–	–	1,000	–	75	D	**Yes**
Trichloroethene	4/33	18 – 260	5	–	–	5	–	1.6	B2	**Yes**
1,2,4–Trimethylbenzene	1/1	5.6	–	–	–	–	–	30	–	
1,3,5–Trimethylbenzene	1/1	4.3	–	–	–	–	–	30	–	
Vinyl acetate	1/29	220	–	–	–	–	–	3,700	–	
Xylenes	3/29	37 – 2,900	10,000	–	–	–	–	1,200	D	**Yes**
SOCs (ug/l)										
Acenaphthene	1/25	1	–	–	–	–	–	220	D	
Bis(2–EH)phthalate	1/25	2	–	–	–	–	–	4.8	B2	
m&p–cresol	1/25	12	–	–	–	700	–	–	–	
Di–n–butylphthalate	1/25	2	–	–	–	–	–	370	D	
Fluorene	1/25	1	–	–	–	–	–	150	D	
2–Methylnaphthalene	4/25	3 – 57	–	–	–	–	–	–	–	
Naphthalene	3/25	2.8 – 81	–	–	–	–	–	150	D	
Phenanthrene	1/25	2	–	–	–	–	–	–	–	
TPH (mg/l)										
Total TPH	6/32	0.18 – 33	–	–	1	1	–	–	–	
Dissolved Metals (mg/l)										
Arsenic	1/4	0.04	0.05	–	0.05	0.05	–	0.0011	–	**Yes**
Arsenic (as carcinogen)	1/4	0.04	0.05	–	0.05	0.05	–	0.000045	A	**Yes**
Barium	4/4	0.012 – 0.07	1	–	1	1	–	0.26	–	
Calcium	4/4	6.3 – 36	–	–	–	–	–	–	–	
Iron	3/4	5.8 – 9	–	0.30	–	–	0.30	–	–	
Magnesium	4/4	4.0 – 6.3	–	–	–	–	–	–	–	
Manganese	3/4	0.084 – 0.53	–	0.05	–	–	0.05	0.018	D	**Yes**
Potassium	4/4	1.7 – 11	–	–	–	–	–	–	–	
Sodium	4/4	9.8 – 33	–	–	270	270	100	–	–	
Zinc	1/4	0.026	–	5	0.05	0.05	–	1.1	D	

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards (VR680–21–04)
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations (VR672–20–10)
(5) Virginia Water Quality Criteria for Groundwater (VR680–21–05)
(6) EPA Region III Risk–based Concentration Table for Tap Water (Jun – Dec 1995)

(7) Weight–of–Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

Chloroform was detected in only 1 of 29 samples but at a concentration greater than the EPA RBC of 0.15 ug/l. However, because of its infrequent detection (3 percent), it is not selected as a COPC.

MIBK was detected in two samples but in concentrations less than risk screening criteria, and therefore, it is not selected as a COPC.

p-Isopropyl toluene, 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene were detected in one QA split sample analyzed by the USACE NED lab but in concentrations less than risk screening criteria, and therefore, they are not selected as COPC.

Ethyl benzene, xylenes, toluene, PCE, cis 1,2-dichloroethene (cis 1,2-DCE), and TCE were detected in excess of screening criteria, and therefore, they are selected as COPC.

SOCs

SOCs were not detected in any of the groundwater samples in excess of screening criteria, and therefore, are not selected as COPC.

TPH

Although TPH exceeded the Virginia Groundwater Standard of 1 mg/l in 4 of 32 groundwater samples, only one of the petroleum product hazardous constituents, toluene, exceeds risk screening criteria. The risk associated with petroleum hydrocarbons will be further evaluated based on toluene as previously discussed.

Inorganics

Dissolved manganese was detected at a concentration greater than the risk screening criteria in 1 of 4 samples collected, and therefore, is selected as a COPC.

Although detected at concentrations less than the EPA MCL and Virginia Groundwater Quality Standards and Protection Levels, dissolved arsenic was detected in 1 of 4 samples in excess of the EPA RBC criteria as a non-carcinogen and carcinogen, and therefore, is selected as a COPC.

Dissolved iron was detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, as these standards were established for aesthetic qualities only for drinking water supplies, iron is not selected as a COPC. No other dissolved inorganics were detected in concentrations greater than risk screening criteria.

Sediment

Sediment sampling was conducted to evaluate the nature of contamination in the sediment in the drainage ditch north of the Sandbox. Sediment samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for sediment cleanup, EPA Region III RBC Criteria for industrial and residential soils and Virginia Petroleum Program Criteria are included in Table 6-17 as TBC criteria for purposes of comparison. A total of two sediment samples were collected during the field investigation.

VOCs and SOCs

No VOCs or SOCs were detected in sediment samples at the site, and therefore, they are not selected as COPC.

TPH

TPH exceeded the 100 mg/kg TBC criterion in both sediment samples. Because TPH is typically used as an indicator of contamination, it will not be used during this quantitative risk assessment. BTEX and PAH concentrations, as previously discussed, were not detected.

Inorganics

All concentrations of inorganics were less than EPA RBC criteria, and therefore, are not selected as COPC.

Surface Water

Surface water sampling was conducted to evaluate the nature of contamination in the surface water in the drainage ditch north of the Sandbox. Samples were collected from the surface of the standing water in the ditch. Virginia Surface Water Quality Standards and EPA Ambient Water Quality Criteria are included in Table 6-18 as ARARs for purposes of comparison. A total of two surface water samples were collected during the field investigation.

VOCs

Acetone was the only VOC detected in surface water samples. No surface water quality standards have been established for acetone, however, concentrations (30 and 35 ug/l) were less than EPA RBC criteria of 37,000 ug/l for tap water. Therefore, acetone is not selected as a COPC.

TABLE 6–17
HAZARD ASSESSMENT FOR SEDIMENT
LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria			EPA Carcinogen Class(3)	Potential Concern?
			Virginia Petroleum Program(1)	RBC Criteria for Industrial Soils(2)	RBC Criteria for Residential Soils(2)		
VOCs (ug/kg)	0/2	BDL					
SOCs (ug/kg)	0/2	BDL					
TPH (mg/kg)							
Total TPH	2/2	530 – 2,700	100	–	–	–	
Total Metals (mg/kg)							
Aluminum	2/2	310 – 650	–	100,000	7,800	–	
Barium	2/2	1.4 – 2.7	–	14,000	550	–	
Calcium	2/2	53 – 210	–	–	–	–	
Chromium	2/2	1.6 – 2.5	–	100,000	7,800	–	
Copper	2/2	3.8 – 9.0	–	7,600	290	D	
Iron	2/2	310 – 940	–	–	–	–	
Lead	2/2	8.2 – 14	–	400	–	B2	
Magnesium	2/2	110 – 250	–	–	–	–	
Manganese	2/2	3.4 – 6.9	–	1,000	39	D	
Sodium	1/2	70	–	–	–	–	
Vanadium	2/2	1.3 – 2.7	–	1,400	55	D	
Zinc	2/2	11 – 30	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Jan 1995)
(3) Weight–of–Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6–18
HAZARD ASSESSMENT FOR SURFACE WATER
LARC 60 MAINTENANCE AREA

Parameters	Frequency of Detection	Range of Detection	ARARs: Virginia SW (Freshwater) Quality Standards(1)		ARARs: Federal AWQC (Freshwater)(2)		EPA Carcinogen Class(4)	Potential Concern?
			Water/Fish	Fish Cons.	Water/Fish	Fish Cons.		
VOCs (ug/l)								
Acetone	2/2	30 – 35	–	–	–	–	D	
SVOCs (ug/l)	0/2	BDL						
Total TPH (mg/l)	0/2	BDL						
Total Metals (mg/l)								
Aluminum	2/2	0.39 – 0.42	–	–	–	–	–	
Calcium	2/2	11 – 12	–	–	–	–	–	
Iron	2/2	0.84 – 1.4	0.30	–	–	–	–	**Yes**
Lead	2/2	0.0078 – 0.009	0.015	–	0.050	–	B2	
Magnesium	2/2	15 – 17	–	–	–	–	–	
Manganese	2/2	0.083 – 0.14	0.05	–	–	–	D	**Yes**
Potassium	2/2	9.1 – 9.4	–	–	–	–	–	
Sodium	1/2	120	–	–	–	–	–	
Zinc	2/2	0.04 – 0.062	5	–	–	–	D	

Notes:
(1) Virginia Surface Water Quality Standards (VR 680–21–01.14)
(2) Federal Ambient Water Quality Criteria (40 CFR 131)

SOCs and TPH

No TPH or SOCs were detected in surface water samples at the site, and therefore, they are not selected as COPC.

Inorganics

Iron and manganese concentrations were greater than Virginia surface water quality criteria for human health consumption of water and fish, and therefore, they are selected as COPC.

No other inorganics were detected at concentrations greater than water quality standards.

Subsurface Soils and Soil Leachability

To evaluate the potential exposures to subsurface soils (i.e., future excavation activities) and for the potential leaching of contaminants form soil to groundwater, as shown in Table 6-19, soil analytical data was compared against EPA Region III SSLs for Transfers from Soil to Groundwater and EPA RBC for industrial soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria and SSLs are included in Table 6-19 as TBC criteria for purposes of comparison. A total of 49 soil samples were collected during the field investigation.

VOCs

All concentrations of VOCs were less than EPA RBC criteria for industrial soils.

PCE concentrations exceeded the SSLs in only 1 of 49 soil samples collected and was detected in only 3 of 49 soil samples. Although PCE is a groundwater COPC, soil results indicate that the majority of the PCE has already volatilized and/or leached out due to a high percolation rate due to the presence of medium to fine grained sands present at the LARC 60 site. Two DPT groundwater points were sampled adjacent to SB-20 where the one PCE exceedance (71 ug/kg) occurred with no PCE detected in groundwater. The source of the PCE in the groundwater is the area near the former UST pit not the area near SB-20 which is located in the Sandbox. The one exceedance occurred at a depth of 4 to 5 feet below grade which is at the water table interface in this area, and therefore, due to the high percolation rate and mixing in the groundwater, it is unlikely that the PCE

TABLE 6-19
HAZARD ASSESSMENT FOR SUBSURFACE SOILS AND SOIL LEACHABILITY - LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA SSLs Transfers to Groundwater (1)	TBC Criteria: EPA RBC Industrial Soils (2)	EPA Carcinogen Class (3)	Potential Concern?
VOCs (ug/kg)						
Acetone	5/49	36 - 200	8,000	20,000,000	D	
sec-Butyl benzene	1/4	2.6	270	2,000,000	D	
Ethylbenzene	1/4	2.3	5,000	20,000,000	D	
Isopropyl benzene	1/4	1.7	65,000	8,200,000	D	
p-Isopropyl toluene	1/4	9.1	-	-	-	
Methylene Chloride	18/49	5.2 - 220	10	760,000	B2	
Methy ethyl ketone	4/49	31 - 44	-	100,000,000	D	
n-Propyl benzene	1/4	4.3	-	-	-	
Styrene	3/49	1.8 - 9.2	2,000	41,000,000	D	
Tetrachloroethene	3/49	8.8 - 71	40	110,000	B2	
Toluene	8/49	5.1 - 13	5,000	41,000,000	D	
1,2,3-Trichlorobenzene	1/4	2.7	-	-	-	
Trichloroethene	5/49	5.9 - 16	20	520,000	B2	
1,2,4-Trimethylbenzene	1/4	29	-	10,000,000	-	
1,3,5-Trimethylbenzene	1/4	26	260	10,000,000	-	
Xylenes	1/49	11	74,000	100,000,000	D	
SOCs (ug/kg)						
Benzo(a)anthracene	1/49	27	700	7,800	B2	
Benzo(b)fluoranthene	1/49	36	4,000	7,800	B2	
Benzo(k)fluoranthene	1/49	47	4,000	78,000	B2	
Benzo(g,h,i)perylene	1/49	24	-	-	-	
Benzo(a)pyrene	1/49	35	4,000	780	B2	
Bis(2-EH)phthalate	1/49	51	11,000	410,000	B2	
Chyrsene	1/49	33	1,000	780,000	B2	
Di-n-butylphthalate	1/49	59	120,000	20,000,000	D	
Fluoranthene	1/49	55	980,000	8,200,000	D	
Naphthalene	1/49	4	30,000	8,200,000	D	
Pyrene	1/49	50	1,400,000	6,100,000	D	
TPH (mg/kg)						
Total TPH	31/49	42 - 1,500	-		-	
Total Metals (mg/kg)						
Aluminum	11/11	250 - 2700	-	100,000	-	
Arsenic	3/11	0.86 - 1.1	15	61	-	
Arsenic (as carcinogen)	3/11	0.86 - 1.1	15	3.8	A	
Barium	11/11	1.8 - 19	32	14,000	-	
Cadmium	1/11	0.18	6	1,000	B1	
Calcium	8/11	43 - 980	-	-	-	
Chromium	11/11	1.5 - 4.3	-	100,000	-	
Cobalt	2/11	0.79 - 2.3	-	12,000	-	
Copper	7/11	2.5 - 41	-	8,200	D	
Iron	11/11	400 - 1100	-	-	-	
Lead	11/11	1.3 - 17	-	400	B2	
Magnesium	8/11	56 - 1400	-	-	-	
Manganese	11/11	2.4 - 120	-	1,000	D	
Mercury	1/11	4.6	3	61	D	
Nickel	1/11	0.81	21	4,100	-	
Potassium	2/11	37 - 1200	-	-	-	
Silver	1/11	0.51	-	1,000	D	
Sodium	1/11	11	-	-	-	
Vanadium	10/11	1.2 - 9.2	-	1,400	D	
Zinc	11/11	3 - 33	42,000	61,000	D	

Notes:
(1) EPA Region III Soil Screening Levels for Transfers from Soil to Groundwater (Jun - Dec 1995)
(2) EPA Region III RBC for Industrial Soils (Jun - Dec 1995)
(3) Weight-of-Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in amimals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogencity

at that location still exists or could be detected in groundwater. Therefore, additional impacts to groundwater quality through further leaching would not be anticipated.

Although the methylene chloride concentrations detected in site soils exceeded the SSLs, no methylene chloride has been detected in groundwater at the site which indicates that currently no significant leaching has occurred even though the sands are highly permeable. A more detailed description of methylene chloride leachability is provided on page 5-14.

SOCs and Inorganics

SOC and inorganic concentrations did not exceed EPA RBC for industrial soils or EPA Region III SSLs for Transfers to Groundwater.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 29 of 49 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethyl benzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA RBC and SSL criteria.

Chemicals of Potential Concern

COPC identified during the hazard identification of the LARC 60 site media include the following:

Media	COPC
Surface Soils	Arsenic and Manganese
Groundwater	cis 1,2-DCE, ethyl benzene, xylenes PCE, TCE, toluene, arsenic and manganese
Surface Water	Iron and Manganese

Potential risk associated with the COPC will be further evaluated in the exposure assessment section.

6.3.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the surface soils, groundwater and surface water COPCs that are present at or migrating from the LARC 60 site.

Potentially Exposed Populations

As part of the exposure assessment, it is important to characterize the potentially exposed populations at or near the site with regard to the current situation and potential future conditions.

Current Situation

The site is currently a heavy equipment maintenance facility with numerous maintenance facilities and outdoor staging areas for heavy equipment. The site is fenced with the two entrance gates locked during off-duty hours (typically 6:00 pm to 6:00 am). Fort Story personnel are present at the site for five days per week. However, because the only surface soils COPCs identified were arsenic and manganese due to exceedance of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Because the site is fenced, potential exposures to the general public and/or trespassers are not significant. Therefore, there are **no exposed populations to the surface soils at the LARC 60 site under the current situation.**

The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located at the site of which water is obtained for nonpotable uses only. The well is screened in a deeper aquifer below the confining unit present at a depth of approximately 40 feet below land surface at the site. No COPC were identified in the two deep monitoring wells at the site which are screened at a depth of 30 to 40 feet below land surface. Based on a comparison of data from Montgomery-Watson's study in 1990 and data from Malcolm Pirnie's study in 1995, VOC concentrations have decreased substantially due to numerous subsurface mechanisms such as biodegradation, volatilization, and dispersion. Therefore, there are **currently no exposed populations to the groundwater at the LARC 60 site**.

Based on vertical elevations established for the two surface water locations in the ditch, the ditch intersects the shallow water table. The elevations were consistent with the groundwater elevations in that area as shown on Figure 3-6. Due to shallow water table elevation fluctuations during the dry season, it is expected that at certain times of the year that no surface water will be present in the drainage ditch. No flow or discharge point is present, therefore, no impacts to other surface water bodies or potential receptors have been identified. There are no current personnel exposures to the surface water and no trespassers into this area would be anticipated. The surface water in the ditch when present is not used for drinking water or fish consumption. Therefore, there are **currently no exposed populations to the surface water at the LARC 60 site**.

Future Land Use

Although construction or excavation activities could be conducted in the future, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. Therefore, **as for future conditions, potentially exposed populations include residential exposures to the surface soils and groundwater at the LARC 60 site.**

Although the iron and manganese levels in surface water exceeded the Virginia surface water quality standards for consumption of fish and water, it is not expected that the water would be consumed even if this drainage area was present after future residential development. Therefore, for the future land use scenario, **no potentially exposed populations** were identified for the surface water in this drainage ditch.

Exposure Pathways

The potential exposure pathways for future land use at the LARC 60 site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.

- Residential exposure (adults and children) to **contaminated soil** through ingestion of chemicals.

Data Limitations and Uncertainties

The limitations and uncertainties associated with the analytical data for the site were reviewed during data validation to ensure that appropriate and reliable data are selected for use in estimating human exposure.

Samples and their duplicates are not considered as separate sampling events. Rather a chemical-specific value representing the maximum value of the sample and its duplicate is used. This may result in a conservative estimate of exposure. However, since relatively few duplicate samples were collected, the overall impact on risk estimates should be minimal.

For purposes of this HHRA, if a COPC was not detected in a sample, it is assumed to be present at 1/2 the practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant Intake

Evaluation of the exposure pathways described above involves the estimation of several parameters such as skin surface area available for contact; skin permeability factors; exposure time, frequency, and duration; soil-to-skin adherence factors; ingestion rates; as well as the contaminant concentrations in the specific media of concern. Table 6-5 represents a general equation for calculating chemical intakes (chronic daily intakes or CDI) and defines the intake variables in terms of chemical-related, population-related and evaluation-determined parameters.

The USEPA recommends that estimates of contaminant intake be developed to portray reasonable maximum exposures (RME) which might be expected to occur under current and future site conditions. Accordingly, the highest exposure that might reasonably be expected to occur at the site, one that is well above the average case of exposure but within the range of possibility should be

considered.

The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the contaminant concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative" concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence limits, etc. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:

$$UCL = e^{\{x + 0.5s^*s + Sh/\sqrt{(n-1)}\}}$$

where:

UCL = 95th percent upper confidence limit on the mean
e = constant (natural log)
x = the mean of the log transformed data
s = the standard deviation of the log transformed data
H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean
n = sample size

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be conducted for data sets of 5 or greater.

Therefore, for the groundwater COPCs of arsenic and manganese, the maximum concentration will

be used because only 4 dissolved groundwater samples were collected.

The 95th percentile UCL concentrations were computed for arsenic and manganese in surface soils and the numerous VOCs in groundwater to estimate the mean concentration. These UCL calculations are provided in Appendix I. The results of the UCL calculations with comparison to the maximum concentration detected are provided in Table 6-20.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In Appendix J, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

Surface Soil

Table 6-7 presents the parameters and assumptions used in assessing potential exposures to chemicals in surface soil. Minimal exposures due to dermal contact and inhalation are typically present for metals, and therefore, these exposure pathways are not evaluated. In addition, arsenic and manganese did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).

- The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence.

TABLE 6-20
COMPARISON OF EXPOSURE CONCENTRATIONS
LARC 60 MAINTENANCE AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Surface Soils		
Ingestion of Chemicals	mg/kg	mg/kg
Arsenic	1.1	**0.90**
Manganese	**120**	1,623
Groundwater		
Ingestion of and Dermal Contact with Chemicals	ug/l	ug/l
Arsenic	**40**	NA
Manganese	**530**	NA
cis 1,2-DCE	150	**8.9**
Ethylbenzene	530	**16.4**
PCE	170	**9.9**
Toluene	2,200	**28.5**
TCE	260	**18.1**
Xylenes	2,900	**62.3**
Inhalation of Chemicals Volatilized	mg/m^3	mg/m^3
cis 1,2-DCE	1.00E+00	**5.93E-02**
Ethylbenzene	3.53E+00	**1.09E-01**
PCE	1.13E+00	**6.60E-02**
Toluene	1.47E+01	**1.90E-01**
TCE	1.73E+00	**1.21E-01**
Xylenes	1.93E+01	**4.15E-01**

Notes:
NA - Not applicable because insufficient number of samples to calculate the 95th percentile UCL.

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

  This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.3.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8 through 6-10 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of, dermal contact or inhalation, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in Appendix I.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

    - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

    - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be $30m^3$ in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume,

over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

Chemical concentration in air (mg/m^3) = CW x CF x WV x 1/RV
where:

CW = chemical concentration in water (ug/l)
CF = conversion factor (1E-03 mg/ug)
WV = volume of water (200 liters)
RV = room volume (30 m^3)

The concentration in air for the chemicals of potential concern are presented in Table 6-20. All concentration-in-air calculations are provided in Appendix I.

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.

- The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

- When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.3.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.3.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves (1) determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and (2) characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used when available. These include verified reference doses (RfDs) for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slopes (CPSs) for the evaluation of cancer risk from lifetime exposure. Each of these are discussed below.

Sources of toxicological guidance information, in order of preference, include: (1) IRIS (Integrated Risk Information System) which is a USEPA database containing current health risk and regulatory information for many chemicals (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

The inherent toxicity of the COPC for the HHRA is briefly summarized in Appendix J.

Non-Carcinogenic Effects

The potential for non-cancer health effects associated with chemical exposure is evaluated by comparing an estimated intake (such as chronic daily intake or CDI) over a specified time period with a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical.

The RfDs for the COPC used for the characterization of chronic non-cancer risk via oral exposure routes are presented in Table 6-21, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD and any uncertainty of modifying factors used in the derivation of the RfD.

The ratio of the estimate of the CDI to the health-protective criterion (CDI/RfD) is called the hazard quotient (USEPA, 1989a). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, the greater the level of concern.

RfDs for oral exposure are available for most chemicals. For dermal exposure, however, RfDs are not available. In their absence, the oral RfDs are used and adjusted to reflect absorbed dose. This allows for comparison between exposure estimated as absorbed doses and toxicity values expressed as absorbed doses.

Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. A RfDi is only available for ethyl benzene and toluene.

Carcinogenic Effects

Regardless of the mechanism of effect, risk assessment methods generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk assessment methods require extrapolation from high dose animal studies to evaluate low dose exposures to humans. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk

TABLE 6-21
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	Chronic RfD (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
ORAL ROUTE						
Arsenic	3.00E-04	Medium	Perpigmentation, keratosis and possible vascular complications	Oral/IRIS	3	1
Manganese	5.00E-03	Medium				
cis 1,2-DCE	1.00E-02					
Ethylbenzene	1.00E-01					
PCE	1.00E-02	Medium	Hepatotoxicity in mice, weight gain in rats	Gavage/IRIS	1,000 for HAS	1
Toluene	2.00E-01					
TCE	6.00E-03					
Xylenes	2.00E+00					
INHALATION ROUTE						
Arsenic	---					
Manganese	1.43E-05			IRIS		
cis 1,2-DCE	---					
Ethylbenzene	2.86E-01					
PCE	---					
Toluene	1.14E-01					
TCE	---					
Xylenes	---					

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
H - Variation in human sensitivity
A - Animal to human extrapolation
S - Extrapolation from Lowest Observed Adverse Effect Level (LOAEL) to No Observed Adverse Effect Level (NOAEL)

that is consistent with some proposed mechanisms of carcinogenesis.

Through application of this approach, the USEPA has derived estimates of incremental excess cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and the fitting of those dose-response data to a low dose extrapolation model. The CPS (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in Table 6-22 and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in Table 6-22.

To arrive at an estimate of incremental cancer risk, the following equation is used (USEPA, 1989a):

Risk = CDI x CPS
where:

Risk = a unitless probability (e.g., 2×10^{-5} or 2 in 100 thousand) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
CPS = Cancer Potency Slope expressed in $(mg/kg\text{-}day)^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). This approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values.

CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. A CPSi is only available for PCE and TCE.

TABLE 6-22
TOXICITY VALUES: CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	CPS $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification	Type of Cancer	SF Basis	SF Source
ORAL ROUTE					
Arsenic	1.50E+00	A	Gross tumors	Oral	IRIS
PCE	5.20E-02	B2	Liver	Gavage	NCEA
TCE	1.10E-02	B2			
INHALATION ROUTE					
Arsenic	1.51E+01	A			
PCE	2.03E-03	B2	Leukemia, liver	---	NCEA
TCE	6.00E-03	B2			

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
NCEA - EPA Provisional Guidance

PERMEABILITY COEFFICIENTS FOR DERMAL ABSORPTION
CHEMICALS OF POTENTIAL CONCERN

HUMAN HEALTH RISK ASSESSMENT
FORT STORY, VIRGINIA

CHEMICALS	MOLECULAR WEIGHT	log(Kow)	PERMEABILITY ALGORITHM	PERMEABILITY COEFFICIENT
Arsenic				5.00E-04**
Bis(2-ethylhexyl)phthalate	390.6	3.98	log Kp = -1.5	3.16E-02
Chloroform	119.38	1.97	log Kp = -3.5+log(Kow)	2.95E-02
cis 1,2-Dichloroethene	96.95	1.86	log Kp = -3.5+log(Kow)	2.29E-02
Ethylbenzene	106.16	3.15	log Kp = -0.5	3.16E-01
Manganese				5.00E-04**
Tetrachloroethene	165.83	2.88	log Kp = -5.5+log(Kow)	2.40E-03
Toluene	92.1	2.75	Published EPA Coefficient	1.00E+00
Trichloroethene	131.4	2.42	log Kp = -3.5+log(Kow)	8.32E-02
Xylenes	106.17	3.16	log Kp = -0.5	3.16E-01

Note:
** - Default to water coefficient.

Permeability algorithm obtained from USEPA document "Dermal Exposure Assessment: Principles and Applications", January 1992, Interim Report.

APPENDIX J

HUMAN HEALTH TOXICOLOGICAL DATA

APPENDIX J
TOXICOLOGICAL PROFILES
FOR CHEMICALS OF POTENTIAL CONCERN

HUMAN HEALTH RISK ASSESSMENT
FORT STORY, VIRGINIA

ARSENIC

Low levels of exposure to inorganic arsenic may produce injury in several body tissues (ATSDR, 1989a). When ingested, a common effect is irritation of the digestive tract leading to pain, nausea, vomiting and diarrhea. Other effects characteristic of oral exposure include decreased production of red and white blood cells, abnormal heart function, blood vessel damage, liver and/or kidney injury and impaired nerve function that causes a "pins and needles" sensation in the feet and hands.

Direct dermal contact with arsenic compounds, frequently from inorganic arsenic dusts in the air, may result in mild to severe irritation of the skin, eyes and throat.

The single most characteristic effect of oral exposure to this compound is a pattern of skin abnormalities. Although these skin changes, called hyperkeratoses, are not considered to be a health concern, a small number of hyperkeratoses may ultimately progress to skin cancer. In addition, arsenic ingestion has been reported to increase the risk of cancer in the liver, bladder, kidney and lung.

Of much greater concern is the ability of inhaled arsenic to increase the risk of lung cancer. This has been observed mostly from high levels of airborne arsenic in or around smelters, but lower levels may increase lung cancer as well.

Based on increased lung cancer mortality in populations exposed primarily through inhalation and on increased skin cancer incidence in several areas consuming drinking water with high arsenic concentrations, the USEPA has designated arsenic as a Group A carcinogen (known human carcinogen).

BIS(2-ETHYLHEXYL)PHTHALATE

Subacute oral administration of high doses of bis(2-ethylhexyl)phthalate can produce hepatomegaly, hepatic peroxisome proliferation and induction of peroxisomal enzymes in rats (Fawell and Hunt, 1988). It also has effects on lipid metabolism in the liver and other tissues, and has been shown to induce hepatic mixed function oxidase activity in rats. At low concentration however, prolonged oral exposure of animals have not been shown to cause serious effects.

No information on the toxicity of bis(2-ethylhexyl)phthalate is available for dermal exposure of animals or humans.

The evidence for the genotoxicity of bis(2-ethylhexyl)phthalate is very weak. The International Agency for Research on Cancer indicates that there is sufficient evidence to substantiate the carcinogenicity of bis(2-ethylhexyl)phthalate in experimental animals, but insufficient evidence exist for humans (NTP, 1989).

It has been hypothesized that this compound is a non-genetic carcinogen; its ability to produce tumors may relate to proliferation of peroxisomes. There is evidence that compounds which induce peroxisome proliferation in the liver of rodents do not have the same activity in humans, and hence the hepatocarcinogenicity observed in rodents may not be indicative of a carcinogenic potential in humans (Fawell and Hunt, 1988).

However, it has been classified by USEPA as a Group B2 probable human carcinogen.

CHLOROFORM

Chloroform is toxic to the central nervous system, liver and kidneys (ATSDR, 1989b). Short-term exposure to high concentrations of chloroform in the air can cause fatigue, dizziness and headache. Long-term exposure to high levels of chloroform through inhalation and ingestion can cause jaundice and burning urination.

Limited data from experiments in animals indicate that chloroform may have reproductive and developmental effects. In animals, high doses of chloroform have caused cancer in the liver and kidney.

The USEPA has classified chloroform as a Group B2 probable human carcinogen via both oral and inhalation exposure.

1,2-DICHLOROETHENE

1,2-dichloroethene (1,2-DCE) is a volatile organic compound consisting of a mixture of cis- and trans- isomers. Although the proportion of each depends upon the manufacturer's specification, the properties of the mixture are expected to be similar to those of the individual isomers. Human health effects due to chronic exposure to 1,2-DCE have not been extensively studies. However, liver, heart, and lung effects have been reported for animals subjected to chronic exposures to the trans isomeric form only (ATSDR, 1990a).

Direct skin contact with 1,2-DCE has not been shown to cause serious health effects. Acute exposure to trans 1,2-DCE has been known to cause drowsiness, headache, tiredness and nausea.

1,2-DCE has not been studied for cancer effects in humans and animals.

ETHYL BENZENE

Ethyl benzene is primarily an irritant to the skin, eyes and upper respiratory tract. (Little, 1985) System absorption causes central nervous system depression. Inhalation of ethyl benzene might exacerbate the symptoms of obstructive airway diseases (e.g., emphysema) due to its irritant properties or reflex bronchospasm. Aspiration of small amounts causes extensive edema and hemorrhage of lung tissue. Redness and inflammation may result from skin contact with liquid ethyl benzene.

Ethyl benzene is not known to be toxic to the liver or kidneys, however, concern for these organs has been expressed since they are the primary routes of metabolism and excretion, respectively.

No data are available regarding development of cancer in humans following inhalation, oral or dermal exposure to ethyl benzene. USEPA has classified ethyl benzene in Group D, not classified as to carcinogenicity.

MANGANESE

Manganese poisoning in humans may result from occupational contact where manganese is absorbed via inhalation. Manganese fumes and dusts result in pneumonia development early on and this condition is reversible. The form of pneumonia does not respond to antibiotic therapy but resolves when the insult is removed.

Chronic manganese intoxication results in central nervous system disorders and associated degenerative pathology of the ganglion cells in the putamen, pallidium, central caudate and thalamus. Clinically, chronic manganese intoxication resembles Parkinson's disease with rigor, tremors and akinesia.

There is no human data for the carcinogenicity of manganese or any of its salts. Based on animal studies, the USEPA has classified manganese as Class D.

TETRACHLOROETHENE

Most of the information on chronic effects of tetrachloroethene (PCE) in humans have been established primarily from occupational data. Common symptoms of acute occupational exposure, include dizziness, sleepiness, irritation of the eyes, nose and throat. Effects upon the central nervous system are generally the most noticeable following acute or excessive occupational exposures. Effects upon the kidney and liver have been observed and generally occur after an elapsed period of exposure to high concentrations. Liver effects attributed to exposure to PCE at high levels include cirrhosis of the liver, toxic hepatitis, liver cell necrosis and enlarged liver. However, chronically exposed individuals may develop tolerance (ATSDR, 1990b).

PCE can be absorbed through the human skin, but the toxicological importance is less than for trichloroethene (Fawell and Hunt, 1988).

PCE has been reported to cause cancer in some animal species but not reported evidence currently implicates cancer to human. The USEPA recently classified it as a Group B2 probable human carcinogen.

THALLIUM

Human health effects may be observed through exposure to thallium through inhalation, significant skin absorption and ingestion (ECDIN, 1984). Inhalation of thallium results in nausea, vomiting, loss of hair, abdominal colic, pain in legs and chest, nervousness and irritability. Thallium may be absorbed through the eyes with long term or repeated exposures resulting in effects on vision.

Severe symptoms associated with acute poisoning may result via ingestion with doses as low as 6 mg/kg of body while doses of 14 mg/kg are often fatal. When large doses are taken, paraesthesia, lethargy, delirium, myocardial abnormalities, convulsions, and coma appear soon after ingestion. In less severe cases, the onset of symptoms may be insidious. Vomiting and abdominal pain are common.

Chronic poisoning via ingestion may result in excitation and insomnia as initial symptoms with leg joint pain, weakness, and polyneuritis occuring after exposure for weeks or months. Loss of hair, anorexia, vomiting, weight loss, depression, hysterical laughter, cardiac disturbances and albuminuria are also noted.

Thallium is recognized by NIOSH as a neurotoxic agent which may cause birth defects, specifically skeletal deformities, low birth weight and premature birth.

TOLUENE

Inhalation of toluene results in depression of the central nervous system; toluene does not appear to exert other systemic effects at low concentrations (ATSDR, 1989c). Humans exposed to toluene in the range of 100 to 500 ppm experience fatigue, confusion, incoordination, impairment to reaction time, perception, and motor control and function effects. The liver and kidney do not appear to be primary target organs for toluene exposure.

Because there is no evidence that toluene is a carcinogen, the USEPA designates toluene as Group D.

TRICHLOROETHENE

Kidney and liver are the principal target organs of oral exposure to trichloroethene (TCE). It has been reported that an association may exist between leukemia incidence in humans and exposure to well water contaminated with chlorinated hydrocarbons, including TCE.
TCE has been reported to cause long-term health effects due to dermal exposure by humans. Skin irritation, burns and rashes may result from acute exposure to high levels of this chemical. TCE may act as a sensitizer, as well as a primary irritant.

Acute inhalation exposure to TCE is associated with central nervous system effects including depression (narcosis) (ATSDR, 1989d). Other symptoms include drowsiness, headache, dizziness, nausea, confusion, facial numbness and blurred vision. Liver damage, include necrosis, has resulted from acute occupational exposure. Kidney dysfunction and failure have also been associated with acute occupational and intentional exposure, and anorexia, nausea, vomiting and intolerance of fatty foods have been associated with long-term exposures.

Available evidence indicates that TCE is carcinogenic in animals. The USEPA has classified it as a Group B2 probably human carcinogen.

XYLENES

Short and long term exposure may result in nervous system effects including headache, mental confusion, narcosis, dizziness, and impaired short-term memory (ATSDR, 1990c). Other short-term effects may include nose and throat irritation; at high doses, lung congestion has been reported. Nausea, vomiting and gastric discomfort have been reported as symptoms resulting from inhalation exposure. There are no indications that xylene is associated with adverse hematological effects. Dermal effects may include skin irritation, dryness and scaling. Exposure to vapors may cause ocular irritation.

No data are available regarding development of cancer in humans following inhalation, oral or dermal exposure to xylene.

USEPA has classified xylene in Group D, not classified as to carcinogenicity.

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APPENDIX K

TOXICITY PROFILES:
ECOLOGICAL RISK ASSESSMENT

ACETONE

Fate and Transport

Acetone has a high vapor pressure and therefore would be expected to volatilize readily, but because of its high water solubility, volatilization is probably limited. Once in the atmosphere, it is apparently oxidized. Acetone has a low octanol/water partition coefficient and therefore is probably not readily adsorbed. Biodegradation is probably important in determining the fate of acetone in the environment because of its aliphatic nature (Clement Associates, 1985).

Toxicity

The toxicity of acetone to aquatic organisms is low. The LC_{50} value for sunfish was reported to be 14.2 g/l, and the threshold concentration for immobilization of *Daphnia magna* was reported to be over 9 g/l (Clement Associates 1985). Acetone is also of low acute toxicity in rats. LD_{50} values range from 1.34 - 9.57 g/kg for various age groups. An oral LD_{50} for acetone in rats was reported as 8.46 g/kg (Fawell and Hunt, 1988).

ALUMINUM

Fate and Transport

Aluminum is often taken up and concentrated in root tissue. According to the Draft Toxicological Profile for Aluminum (ATSDR, 1991), it is unclear to what extent aluminum is taken up into root food crops and leafy vegetables, however, it is not bioconcentrated in plants. In addition, aluminum is not expected to biomagnify in terrestrial food chains.

The potential for accumulation of aluminum has been studied in several aquatic species. Bioconcentration of aluminum in fish is a function of the water quality. Brook Trout have been shown to accumulate slightly more aluminum as pH levels increase. In Smallmouth Bass, aluminum accumulation was higher in gill tissues than other tissues. Aluminum concentrations were also highest in the gill tissues and lowest in the muscles of rainbow trout. No information was found on the biomagnification of aluminum in aquatic food chains.

Toxicity

Most studies of the health effects of aluminum to animals involved oral and inhalation exposure. Few studies are available regarding respiratory effects in animals. Two studies that involved exposure of rats, guinea pigs and hamsters to aluminum chlorohydrate, reported reactions similar to that of dust exposure, sometimes accompanied by pneumonia.

According to the Draft Toxicological Profile for Aluminum (ATSDR 1991), the effects of aluminum on the development of laboratory animals are controversial. Some studies show decreases in pup growth and neurological development, while others do not. In mice, aluminum chloride has not been shown to produce adverse effects in pups, when administered during gestation. However, aluminum lactate in food during gestation produced weight decreases and lowered birth weights in pups, but it was difficult to determine whether these effects were permanent. Studies on pups that were exposed to aluminum after they were born also have mixed results. Aluminum is fatal to laboratory animals (rats, mice) only at very high doses.

BARIUM

Fate and Transport

Barium is likely to precipitate out of solution as an insoluble salt in aquatic media. Waterborne barium can also adsorb to suspended particulate matter. Sedimentation of suspended solids removes a large portion of the barium from surface water. The uptake of barium by fish and marine organisms is another removal mechanism; barium levels in sea water range from 2 to 63 mg/l with a mean concentration of about 13 mg/l. According to the Draft Toxicological Profile for Barium (ATSDR, 1990), this compound was found to bioconcentrate in marine plants by a factor of 1,000 times the level present in water. BCFs of marine animals, plankton, and in brown algae of 100, 120, and 260, respectively, have also been reported.

In soils, barium may be taken up by vegetation or transported through soil with precipitation, however, this transport pathway has not been comprehensively studied. Relative to the amount of barium found in soils, little is bioconcentrated by plants. Barium is not very mobile in soil systems, and the rate of its transportation depends on soil material, such as high capacity and calcium carbonate. Barium is more mobile and is more likely to be leached from soils in the presence of chloride due to the increased solubility of barium chloride. The mobility of this compound in soil is reduced by the precipitation of barium carbonate and sulfate.

Toxicity

Barium has been associated with several adverse effects in experimental animals. The cardiovascular system may be one of the primary targets of barium toxicity. Exposure of animals to barium has also been associated with respiratory, gastrointestinal, musculoskeletal, neurological, developmental and reproductive effects. Most studies with experimental animals were performed with rats and mice. Reduced life span was observed in chronic oral studies with mice, and acute parenteral administration of barium compounds to animals has resulted in paralysis of the respiratory muscles. Similar effects have been shown in animals in cases of acute inhalation and ingestion (ATSDR, 1990).

CHROMIUM

Fate and Transport

Hexavalent chromium is quite soluble, existing in solution as a component of a complex anion. It is not sorbed to any significant degree by clays or hydrous metal oxides. The anionic form varies according to pH and may be a chromate, hydrochromate or dichromate. Because all anionic forms are so soluble, they are quite mobile in the aquatic environment. Chromium (VI) is efficiently removed by activated carbon and thus may have some affinity for organic materials in natural water. Most chromium (III) in the aquatic environment is hydrolyzed and precipitates as chromium hydroxide. Sorption to sediments and bioaccumulation will remove much of the remaining chromium (III) from solution. Chromium (III) is adsorbed only weakly to inorganic materials. Chromium (III) and chromium (VI) are readily interconvertible in nature depending on microenvironmental conditions such as pH, hardness, and the types of other compounds present (Clement Associates, 1985).

Chromium (III) tends to be adsorbed strongly onto clay particles and organic particulate matter, but can be mobilized if it is complexed with organic molecules. Hexavalent compounds are not strongly adsorbed by soil components and chromium (VI) is mobile in groundwater. Chromium (VI) is quickly reduced to chromium (III) in poorly drained soils having a high content of organic matter. Chromium (VI) of natural origin is rarely found in soils (Clement Associates, 1985).

Toxicity

Acute toxicity values for chromium (VI) are available for freshwater animal species in 27 genera and range from 23.07 µg/l for a cladoceran to 1,870,000 µg/l for a stonefly. All five tested species of daphnids are especially sensitive. The few data that are available indicate that the acute toxicity of chromium (VI) decreases as hardness and pH increase (USEPA, 1986).

Acute values for chromium (III) are available for 20 freshwater animal species in 18 genera ranging from 2,221 µg/l for a mayfly to 71,060 µg/l for caddisfly. Hardness has a significant influence on toxicity, with chromium (III) being more toxic in soft water (USEPA, 1986).

The chronic value for chromium (VI) for both rainbow trout and brook trout is 264.6 µg/l, which is much lower than the chronic value of 1,987 µg/l for the fathead minnow. In three chronic tests, a temporary reduction in growth occurred at low concentrations. Six chronic tests with five species of daphnids gave chronic values that range from <2.5 to 40 µg/l. Except for the fathead minnow, all the chronic tests were conducted in soft water. Green algae are quite sensitive to chromium (VI). The bioconcentration factor obtained with rainbow trout is less than 3. Growth of chinook salmon was reduced at a measured concentration of 16 µg/l (USEPA, 1986).

A life-cycle test for chromium (III) with *Daphnia magna* in soft water gave a chronic value of 66 µg/l. In a comparable test in hard water the lowest test concentration of 44 µg/l inhibited reproduction of *Daphnia magna*, but this effect may have resulted from ingested precipitated chromium. In a life-cycle test with the fathead minnow in hard water the chronic value was 1,025 µg/l. Toxicity data are available for only two freshwater plant species. A concentration of 9,900 µg/l inhibited growth of roots of Eurasian watermilfoil. A freshwater green alga was affected by a concentration of 397 µg/l in soft water. No bioconcentration factor has been measured for chromium (III) with freshwater organisms (USEPA, 1986).

Chromium is essential for regulating carbohydrate metabolism in mammals. Chromium deficiency has been described in rats, guinea pigs, and squirrel monkey; signs include reduced growth, decreased life span, elevated serum cholesterol, increased formation of aortic plaques, and signs resembling those of diabetes mellitus. Chromium has proved effective in counteracting the deleterious effects of cadmium in rats and of vanadium in chickens. It is beneficial but not essential to growth in higher plants. Residues in plants seldom exceed a few parts per million, except in plants living on infertile serpentine soils containing high Cr concentrations, or grown on soils smended with sewage sludge. Plants with elevated Cr residues show no toxic effects, although concentrations in excess of 1 ppm in the aqueous medium may inhibit germination of the seed and growth of roots and shoots (Eisler, 1986).

Among warm-blooded organisms, hexavalent chromium was fatal to dogs in 3 months at 100 mg/kg in their food and killed most mammalian experimental animals at injected doses of 1 to 5 mg Cr/kg body weight, but had no measurable effect on chickens at dietary levels of 100 mg/kg or a 32-day period. Trivalent chromium compounds were generally less toxic than hexavalent chromium compounds, but significant differences may occur in uptake of anionic and cationic Cr (III) species, and this difference may affect survival (Eisler, 1986). For birds and mammals, dietary levels of 10.0 mg Cr+3/kg adversely affected young black ducks, and 5.1 mg Dr+6/kg in food and water of mice was associated with elevated tissue residues. Available evidence suggests that organs and tissues of fish and wildlife that contain greater than 4.0 mg total Cr/kg dry weight should be viewed as presumptive evidence of Cr contamination (Eisler, 1986).

COBALT

Fate and Transport

Cobalt is naturally occurring in the environment and has an essential role in biological organisms. Cobalt is essential to plants for biological nitrogen fixation. It is very insoluble in its oxide, hydroxide and carbonate states. In acid conditions, dissolution and leaching are more likely to occur. Cobalt concentrations are generally highest in the soil horizon where organic material and clays are richest. Cobalt sorbed by soil oxides was not readily desorbed, and rapidly became non-isotopically exchangeable with solution cobalt, whereas the cobalt sorbed by humic acid was relatively easily desorbed, and a large proportion remained isotopically exchangeable. Uptake of cobalt by plants is a function of the concentration of cobalt in the soil solution and the exchange sites of the cation exchange complex. Soil drainage status also has a major influence on the amount of cobalt available for plant uptake. In poorly drained soils, the amount of extractable cobalt is generally greater than in well drained areas, and plant uptake is significantly increased. Experiments have shown that most of the cobalt in the soil is contained in or associated with manganese in mineral form (Alloway, 1993).

Toxicity

Cobalt has both beneficial and harmful effects on plant and animal life. Cobalt is part of vitamin B_{12}, which is essential to mammalian life. Cobalt is used to treat anemia. Sheep and cattle found grazing in pastures with low cobalt concentrations in the vegetation lost appetite, became weak and emaciated, suffered severe anemia, and died (Alloway, 1993). Excessive cobalt in animals can cause lung, skin and heart effects. Soluble cobalt compounds have been shown to be generally more toxic than insoluble compounds.

Oral LD_{50} values for cobalt compounds in Winstar rats ranged from 91 mg cobalt /kg as cobalt fluoride to 317 mg cobalt /kg as cobalt carbonate. Cobalt fluoride and cobalt bromide appeared to be the most toxic of the tested cobalt compounds. An LD_{50} of 3,672 mg cobalt/ kg was also found for tricobalt tetroxide, a highly insoluble cobalt compound. Sublethal oral doses resulted in respiratory, cardiovascular, gastrointestinal, hematological, musculoskeletal, hepatic, renal, ocular, thyroid, hypothermic, body weight, developmental, and reproductive effects (ATSDR, 1992).

COPPER

Fate and Transport

Copper has two oxidation states, +1 (cuprous) and +2 (cupric). Cuprous copper is unstable in aerated water over the pH range of most natural waters (6 to 8) and oxidizes to the cupric state. Several processes determine the fate of copper in the aquatic environment: formation of complexes, especially with humic substances; sorption to hydrous metal oxides, clays, and organic materials; and bioaccumulation. Copper has a strong affinity for hydrous iron and manganese oxides, clays, carbonate minerals, and organic matter. Sorption to these materials, both suspended in the water column and in the sediment, results in relative enrichment of the solid phase and reduction in dissolved levels (Clement Associates, 1985).

Because many copper compounds and complexes are readily soluble, copper is among the more mobile heavy metals in soil and other surface environments. The major process that limits the environmental mobility of copper is adsorption to organic matter, clays and other materials (Clement Associates, 1985).

The bioconcentration factor (BCF) of copper in fish obtained in various field studies is 10-100 indicating a low potential for bioconcentration. The BCF is higher in molluscs, such as oysters, where it may reach 30,000. However, abundant evidence has shown that there is no biomagnification in the food chain. Studies have been performed on bottom-feeding fish such as suckers and bullheads, as well as on herbivorous, omnivorous and carnivorous animals.

Toxicity

Acute toxicity data are available for species in 41 genera of freshwater animals. At a hardness of 50 mg/l, the genera range in sensitivity from 16.74 µg/l for the squawfish, *Ptychocheilus*, to 10,240 µg/l for the stonefly, *Acroneuria*. Data for eight aquatic species indicate that acute toxicity decreases as hardness increases. Additional data for several species indicate that toxicity also decreases with increases in alkalinity and total organic carbon (USEPA, 1986).

Chronic values are available for 15 freshwater species and range from 3.873 µg/l for brook trout to 60.36 µg/l for northern pike. Fish and invertebrate species seem to be about equally sensitive to the chronic toxicity of copper. Toxicity tests have been conducted on copper with a wide range of freshwater plants and the sensitivities are similar to those of animals. Copper does not appear to bioconcentrate very much in the edible portion of freshwater aquatic species (USEPA, 1986).

Sheep are very susceptible to copper toxicosis, and poisoning may be acute or chronic. The toxic dose is about 200 mg/kg. Copper intake of 1.5 g/day for 30 days is known to be fatal for many breeds of sheep. Swine develop copper poisoning at levels of 250 mg/kg in the diet unless zinc and iron levels are increased. Cattle are much more resistant to copper than sheep or swine (Clement Associates, 1985).

IRON

Fate and Transport

Iron is an essential element required by both plants and animals. The ferrous, or bivalent (Fe^{++}), and the ferric, or trivalent (Fe^{+++}) irons are the primary forms of concern in the aquatic environment, although other forms may be in organic and inorganic wastewater streams. Prime pollution sources are industrial wastes, mine drainage waters, and iron-bearing groundwaters. In the presence of dissolved oxygen, iron in water is precipitated as a hydroxide, $Fe(OH)_3$ or occasionally as ferric oxide (Fe_2O_3). Both of these precipitates form as gels or flocs that may be detrimental, when suspended in water, to fishes and other aquatic life. They can settle to form flocculent materials that cover stream bottoms thereby destroying bottom-dwelling invertebrates, plants or incubating fish eggs.

Toxicity

A 96-hour LC_{50} value of 0.32 mg/l (320 µg/l) was obtained for mayflies, stoneflies, and caddisflies (USEPA 1979). Iron was found to be toxic to carp at concentrations of 0.9 mg/l (900 µg/l) when the pH of the water was 5.5, and both pike and trout died at iron concentrations of 1 to 2 mg/l (1,000 to 2,000 µg/l) (USEPA 1976). The USEPA (1986) has established a criterion of 1,000 µg/l for fresh water, based upon laboratory tests. Data obtained under laboratory conditions suggest a greater toxicity for iron than that obtained in natural ecosystems, due to variations in alkalinity, pH, hardness, temperature and the presence of ligands which change the valence state and solubility, and therefore the toxicity of the metal.

LEAD

Fate and Transport

Natural compounds of lead are not usually mobile in normal surface or groundwater because the lead leached from ores is adsorbed by ferric hydroxide or combines with carbonate or sulfate ions to form insoluble compounds. The transport of lead in the aquatic environment is influenced by the speciation of the ion. Lead exists mainly as the divalent cation in most unpolluted waters and becomes adsorbed into particulate phases. Volatilization of lead compounds probably is not important in most aquatic environments (Clement Associates, 1985).

Sorption processes appear to exert a dominant effect on the distribution of lead in the environment. Adsorption to inorganic solids, organic materials, and hydrous iron and manganese oxides usually controls the mobility of lead and results in a strong partitioning of lead to the bed sediments in aquatic systems. The sorption mechanism most important in a particular system varies with geological setting, pH, Eh, availability of ligands, dissolved and particulate ion concentrations, salinity, and chemical composition (Clement Associates, 1985).

Lead does not seem to be biomagnified in food chains, yet it may accumulate in plants such as fungi, as well as earthworms, millipedes, terrestrial birds and mammals, freshwater invertebrates and fish. In aquatic environments, lead concentrations are usually highest in benthic organisms and algae, and lowest in upper-trophic-level predators like carnivorous fish. High BCFs were determined in studies using oysters, freshwater algae and marine algae. Bioconcentration factors are available for four freshwater invertebrate and two fish species and range from 42 to 1,700. Available bioconcentration factors for saltwater species range from 17.5 to 2,570.

Toxicity

The acute and chronic toxicity of lead to several species of freshwater animals has been shown to decrease as the hardness of water increases. At a hardness of 50 mg/l the acute sensitivities of 10 species range from 142.5 µ/l for an amphipod to 235,900 µg/l for a midge. Freshwater algae are affected by concentrations of lead above 500 µg/l. Data on the chronic effects of lead freshwater animals are available for two fish and two invertebrate species. The lowest and highest available chronic values (12.26 and 128.1 µg/l) are both for a cladoceran, but in soft and hard water, respectively (USEPA, 1986).

Among sensitive species of birds, survival was reduced at doses of 50 to 75 mg Pb^{2+}/kg body weight or 28 mg organolead/kg body weight, reproduction was impaired at dietary levels of 50 mg Pb^{2+}/kg, and signs of poisoning were evident at doses as low as 2.8 mg organolead/kg body weight. In general, forms of lead other than shot (or ingestible lead object), or routes of administration other than ingestion, are unlikely to cause clinical signs of lead poisoning in birds. Data for toxic and sublethal effects of lead on mammalian wildlife are missing. For sensitive species of domestic and laboratory animals, survival was reduced at acute oral lead doses of 4 mg/kg body weight (rat), at chronic oral doses of 5 mg/kg body weight (dog), and at dietary levels of 1.7 mg/kg body weight (horse). Sublethal effects were documented in monkeys exposed to doses as low as 0.1 mg Pb/kg body weight daily or fed diets containing 0.5 mg Pb/kg. In general, organolead compounds were more toxic than inorganic lead compounds, food chain biomagnification of lead was negligible, and younger organisms were most susceptible (Eisler, 1988).

MANGANESE

Fate and Transport

Manganese is an abundant element which occurs as a component of over 100 minerals, including various sulfides, oxides, carbonates, silicates, phosphates, and borates. Soils derive virtually all their

manganese content from the parent materials and concentrations are related to those materials, with lower concentrations found in sandstone materials (20-500 mg/kg), moderate concentrations found in limestones (400-600 mg/kg), and highest concentrations found in igneous and metamorphic rocks (200-1000 mg/kg). In soils, manganese commonly occurs as the oxide minerals birnessite and vernadite. The various oxides of manganese show a strong tendency to form mixed crystals with other transition metals, including cobalt (Alloway, 1993).

The availability of manganese for plant uptake is largely governed by the supply of H^+ ions and electrons (Alloway, 1993). The transport and partitioning in water is controlled by the solubility of the specific chemical form present, which is determined by pH, Eh (oxidation-reduction potential), and the characteristics of available anions. The metal may exist in water in any of four oxidation states (2+, 3+, 4+, or 7+). Divalent manganese (Mn^{++}) predominates in most waters with pH 4-7, but may becomes oxidized at pH greater than 8 or 9. The principal anion associated with Mn^{++} in water is usually carbonate (CO_3^{-2}). Sorption of manganese to soils and sediments is highly variable and depends mainly on the cation exchange capacity and the organic composition of the soil. Generally the soil adsorption constants increase as a function of the organic content and the ion exchange capacity of the soil. At low concentrations, manganese may be fixed by clays and will not be released into solution readily. At higher concentrations, manganese may be desorbed by ion exchange mechanisms with other ions in solution. Lastly, the oxidation state of manganese in soils and sediments may be altered by microbial activity. Studies have shown that Mn^{++} in suspensions of silt or clay loams from several areas of the United States was oxidized by microorganisms, leading to the precipitation of manganese minerals (ATSDR, 1992).

Toxicity

Manganese compounds are required for good health in animals. Manganese deficiency has been linked with impaired growth, skeletal abnormalities, impaired reproductive function in females, testicular degeneration in males, and altered metabolism of carbohydrates. Excessive manganese can cause adverse effects. However, most studies have shown that manganese has low acute oral toxicity. Doses as high as 2,300 mg/kg/day have been tolerated by rats for 6 months without lethality. Oral administration of highly concentrated manganese solutions (16,000-44,000 mg/l) can cause lethality in animals. No effects were seen in mice or rats exposed to average oral doses of 810 or 930 mg/kg/day. In rats fed manganese orally, some minor neurological effects were seen in doses as low as 14 mg/kg for up to 8 months . Decreased litter weights were seen in rats dosed with 1,240 mg/kg during the first 20 days of gestation. Repeated intramuscular injection of rats and mice with suspensions of metallic manganese did not result in tumors (ATSDR, 1992).

NICKEL

Fate and Transport

Nickel is a highly mobile metal in aquatic systems because many nickel compounds are highly soluble in water. However, the insoluble sulfide is formed under reducing conditions and in the presence of sulfur. In natural, unpolluted waters, sorption and coprecipitation processes involving hydrous iron and manganese oxides are probably at least moderately effective in limiting the mobility of nickel. In more organic-rich, polluted waters, it appears that little sorption of nickel is likely. The lack of other controls on nickel mobility probably makes incorporation into bed sediments an important fate of nickel in surface waters (Clement Associates, 1985).

In general, nickel is not accumulated in significant amounts by aquatic organisms. Bioconcentration factors are usually on the order of 100 to 1,000. Uptake of nickel from the soil by plants can also occur. Bioconcentration factors in freshwater range from 0.8 for fish muscle to 193 for a cladoceran. In saltwater, bioconcentration factors range from 261.8 with an oyster to 675 with a brown alga.

Toxicity

Acute values with twenty-one freshwater species in 18 genera range from 1,101 µg/l for a cladoceran to 43,240 µg/l for a fish. Fishes and invertebrates are both spread throughout the range of sensitivity. Acute values with four species are significantly correlated with hardness. Data are available concerning the chronic toxicity of nickel to two invertebrates and two fishes in freshwater. Data available for two species indicate that chronic toxicity decreases as hardness increases. The measured chronic values ranged from 14.77 µg/l with *Daphnia magna* in soft water to 526.7 µg/l with the fathead minnow in hard water (USEPA, 1986).

Nickel appears to be quite toxic to freshwater algae, with concentrations as low as 50 µg/l producing significant inhibition. Bioconcentration factors for nickel range from 0.8 for fish muscle to 193 for a cladoceran (USEPA, 1986).

TOTAL PAHs

Fate and Transport

Polynuclear Aromatic Hydrocarbons (PAHs) occur as a result of natural processes, such as forest fires and volcanic activity, and anthropogenic activities, such as catalytic cracking, manufacturing of asphalt and coal tar pitch, heating and power generation, and internal combustion engines. PAHs released to the atmosphere are subject to short- and long-term transport. Atmospheric residence time and transport distance depend on the size of the particles to which PAHs are sorbed and the molecular weight of the PAH.

Much of the PAHs released into the atmosphere eventually reaches the soil by direct deposition of by deposition on vegetation. In sediments, PAHs can biodegrade, biotransform, or accumulate in aquatic organisms, specifically bottom-dwelling vertebrates. PAHs in soil can biodegrade or accumulate in terrestrial plants, through roots or foliage. Specific transport and partitioning are determined by: water solubility; vapor pressure; concentration; and molecular weight of the PAH. The half-life for PAHs differs according to physical properties. For example, the half-life in soil for Benz(a)anthracene ranges from 102 days to 1.86 years while the half life for Benzo(b)fluoranthene ranges from 360 days to 1.67 years. (Howard, 1990). PAHs may accumulate in terrestrial animals through the food chain or by ingestion of soil. PAHs can also enter groundwater and be transported within an aquifer. In surface water, these compounds can volatilize, photodegrade, oxidize, biodegrade, bind to particles, or accumulate in aquatic organisms. Because of their low solubility, PAHs in aquatic systems are usually found sorbed to particles that either have settled to the bottom or are suspended in the water column. PAHs tend to be removed from the water column by volatilization to the atmosphere, binding to sediments or by being accumulated or sorbed onto aquatic biota.

Bioconcentration factors (BCFs) of PAHs in fish and crustaceans have frequently been reported to be in the range of 100-2000 (ATSDR, 1989), and exposure to PAHs has been linked to the development of tumors in fish. The ability of fish to metabolize PAHs may explain why benzo(a) pyrene is frequently not detected or found at only low levels in fish from environments heavily contaminated with PAHs. According to the Draft Toxicological Profile for PAHs (ATSDR, 1989), one study ranked the amount of benzo-(a)pyrene metabolism by aquatic organisms as follows: fish > shrimp > crustaceans > clams. Half lives for elimination of PAHs in fish ranged from 1.5 days to 9 days.

Toxicity

Numerous PAH compounds are distinct in their ability to produce tumors in skin and most epithelial tissues of practically all animal species tested. Certain carcinogenic PAHs are capable of passage across skin, lungs, and intestine, and can enter the rat fetus, for example, following intragastric or

intravenous administration to pregnant dams. Acute and chronic exposure to various carcinogenic PAHs have resulted in destruction of hematopoietic and lymphoid tissues, ovotoxicity, anitspermatogonic effects, adrenal necrosis, changes in intestinal and respiratory epithelia, and other effects. For the most part, however, tissue damage occurs at dose levels that would also be expected to induce carcinomas. Laboratory studies with mice have shown that many carcinogenic PAHs adversely affect the immune system, thus directly impacting an organism's general health; in general, the more carcinogenic the PAH, the greater (Eisler, 1987).

No studies were located regarding either deaths in animals following dermal exposure or neurological effects to PAHs in animals, although the skin is susceptible to PAH induced toxicity in animals. The developmental toxicity data in animals for PAHs are limited. Available animal studies exclusively discuss the reproductive effects of benzo(a)pyrene, adverse effects such as decreased fertility and total sterility in mice (F1 progeny of CD-1). Effects of hepatic injury have also been observed in animals. In one study, a simple injection of pyrene resulted in minimal swelling of the liver. Longer administration of PAHs has been reported to result in adverse hepatic effects in animals. Adverse hematological effects have also been observed in animals following exposure to PAHs. PAHs tend to exert their adverse effects on rapidly proliferating tissues, such as the bone marrow forming elements and the lymphatic system.

For avian wildlife, data are missing on PAH background concentrations and on acute and chronic toxicity. Studies with mallard embryos and PAHs applied to the egg surface showed toxic and adverse sublethal effects at concentrations between 0.036 and 0.18 μg PAH/kg whole egg (Eisler, 1987).

A growing literature exists on uptake, retention, and translocation of PAHs by aquatic plants and animals. Authorities generally agree that: most species of aquatic organisms studied to date rapidly accumulate PAHs from low concentrations in the ambient medium; uptake of PAHs is highly species specific, being higher in algae, molluscs, and other species which are incapable of metabolizing PAHs; bioconcentration factors tend to increase as the molecular weight of the PAH increases, with increasing octanol/water partition coefficient values, with time until approaching an apparent equilibrium level (sometimes within 24 hours), and with increases in dissolved organic matter in the medium, lipid content of the organism, and a variety of endogenous and exogenous factors (Eisler, 1987).

THALLIUM

Fate and Transport

Thallium is a nonvolatile heavy metal which is relatively stable in the environment. If released to the atmosphere, thallium may exist as an oxide, hydroxide, sulfate or as the sulfide Tl_2S. These thallium compounds are not volatile. It has been speculated that thallium sulfate and TlOH will partition into water vapor because they are soluble in water and thus, precipitation may remove these forms of thallium from the atmosphere. Thallium oxides are less soluble in water, and may be subject to only atmospheric dispersion and gravitational settling. The atmospheric half-life of suspended thallium particles is unknown. Thallium may partition from water to soils and sediments. Thallium may be bioconcentrated by organisms from water. It is also absorbed by plants from soil and thereby enters the terrestrial food chain. Little is known about the transformation and degradation of thallium in water or soil (ATSDR, 1992).

There are limited animal data on the effects of oral exposure to thallium. The lowest acute oral LD_{50}s reported ranged from 12 (guinea pig) to 29 (rat) mg/kg (as thallium acetate) and 5 (guinea pig) to 30 (dog and rabbit) mg/kg (as thallic oxide). Rats exposed for 15 weeks to diets containing thallium showed increased mortality at a dose of 4.5 mg/kg/day (as thallic oxide) and 2.3 mg/kg/day (as thallium acetate). Other subchronic and chronic studies using sublethal doses caused electrocardiographic changes in rabbits (lethal dose), hair loss in rats, degenerative changes in cranial and peripheral nerves in rats, and abnormalities in testicular morphology, function, or biochemistry in rats. Subchronic oral exposure also

caused dominant lethal mutations in rats. No studies were located regarding carcinogenic or immunological effects in animals following oral exposure to thallium (ATSDR, 1992).

TOLUENE

Fate and Transport

Toluene released to the soil will be lost by evaporation from near-surface soil and by leaching to the ground water. Toluene is expected to exhibit very high to moderate mobility in soil, depending on site specific characteristics of soil type, load, flow rate and other loss factors such as evaporation and biodegradation. Biodegradation occurs both in soil and ground water , but is apt to be slow, especially at high concentrations, which may be toxic to microorganisms. The presence of acclimated microbial populations may allow rapid biodegradation. It will not significantly hydrolyze in soil or water under normal environmental conditions. Toluene released to water will be lost by both volatilization to the atmosphere and biodegradation. The predominant process will depend on water temperature, mixing conditions, and the existence of acclimated microorganisms at the site. It will not significantly hydrolyze, directly photolyze, absorb to sediment, or bioconcentrate in aquatic organisms. Toluene released to the atmosphere will degrade by reaction with photochemically produced hydroxyl radicals or be washed out in rain. It will not be subject to direct photolysis. The half-life of toluene in soil ranges from 4 days to 22 days (Howard, 1990). Limited data indicate that toluene has a moderate tendency to bioaccumulate in the food chain. Toluene does have some tendency to accumulate in fatty tissues. (ATSDR, 1989)

There are limited animal data on the effects of oral exposure to toluene. The available oral exposure data focus on acute oral lethality studies. Reported acute oral LD_{50}s ranged from 5,580 mg/kg to 7,300 mg/kg for the adult rat. Age may play a role in the acute lethality of toluene. No studies were located regarding immunological, reproductive, genetic, or carcinogenic effects following acute oral exposure to toluene. Subchronic oral exposure effects included increased relative heart weights in rats exposed to toluene at 1250 mg/kg/day for 13 weeks and myocardial degeneration in mice exposed to 5000 mg/kg/day for 13 weeks. Various other subchronic studies (oral exposure for 13 weeks) reported increased liver and kidney weights in mice and rats, hemorrhages in the urinary bladder of rats, and increased relative brain weight in mice and brain necrosis in rats (ATSDR, 1989).

VANADIUM

Fate and Transport

The size distribution of vanadium-bearing particles in the atmosphere is altered during long-range transportation. Large particles like man-made ore-processing dust settle near their source, whereas smaller particles like those emitted from oil-fueled power plants have a longer residence time. In the course of biogeochemical movement between soil and water these particulates are adsorbed to hydroxides or associated with organic compounds and are deposited on the sea bed. The transport of vanadium in both water and soil is influenced by: pH; redox potential; and the presence of particulates. Some marine organisms, particularly the ascidians (sea squirts), bioconcentrate vanadium very efficiently, attaining concentrations approximately 10,000 times greater than the ambient sea water. According to the Draft Toxicological Profile for Vanadium (ATSDR 1990), upon the death of the organism, the body burden adds to the accumulation of vanadium in silt.

In general, marine plants and invertebrates contain higher levels of vanadium than terrestrial plants and animals. Furthermore, in the terrestrial environment, bioconcentration is more commonly observed amongst the lower plant phyla than in the higher, seed-producing phyla. The uptake of vanadium in the above-ground parts of many plants is low, although root concentrations have some correlation with levels in the soil. Certain legumes, such as Astralagus preussi, have been shown to be

vanadium accumulators. Also Amanita muscaria, a poisonous mushroom, has been demonstrated to contain levels up to 112 ppm. Vanadium is fairly mobile in neutral or alkaline soils, but its mobility decreases in acidic soils.

Toxicity

Animal health effects have been studied mostly on the rat, mouse and rabbit. The absorption of vanadium through the gastrointestinal tract of animals is low. Minor renal effects have been shown in rats, after oral exposure, and in rabbits after inhalation exposure. Minimal or no studies were located regarding neurological, immunological, or genotoxic effects in animals. Other studies have shown that long-term vanadium exposure has results in diminished weight gains and gross pathological changes in animals. Acute studies with rats showed the highest vanadium concentration to be located in the skeleton. High concentrations of vanadium over short periods of time caused rabbits to experience conjunctivitis and some fatty tissue degeneration of the liver. Studies in animals support the findings that vanadium primarily effects the respiratory system.

ZINC

Fate and Transport

Zinc can occur in both suspended and dissolved forms. Dissolved zinc may occur as the free (hydrated) zinc ion or as dissolved complexes and compounds with varying degrees of stability and toxicity. Suspended zinc may be dissolved following minor changes in water chemistry or may be sorbed to suspended matter. The predominant fate of zinc in aerobic aquatic systems is sorption of the divalent cation by hydrous iron and manganese oxides, clay minerals and organic material. Concentrations of zinc in suspended and bed sediments always exceed concentrations in ambient water. Zinc tends to be more readily sorbed at higher pH than lower pH and tends to be desorbed from sediments as salinity increases (Clement Associates, 1985).

Microcosm studies generally indicate that zinc is not biomagnified. Although biota seem to be a minor sink compared to sediments, this compound is actively bioaccumulated in aquatic systems. Zinc has been found to accumulate in freshwater animal tissues from 51 to 1,130 times the concentration present in the water. A 1981 study reported zinc BCF values of 1000 for both aquatic plants and fish. Steady-state bioconcentration factors for twelve saltwater species range from 3,692 to 23,820.

Toxicity

Acute toxicity values are available for 43 species of freshwater animals and data for eight species indicate that acute toxicity decreases as hardness increases. Additional data indicate that toxicity increases as temperature increases. Chronic values for two invertebrates ranges from 46.73 µg/l for *Daphnia magna* to >5,243 µg/l for the caddisfly, *Clistoronia magnificia*. Chronic values for seven fish species ranged from 36.41 µg/l for the flagfish, *Jordanella floridae*, to 854.7 µg/l for the brook trout, *Salvelinus fontinalis* (USEPA, 1986).

The sensitivity range of freshwater plants to zinc is greater than that for animals. Growth of the alga, *Selenastrum capricornutum*, was inhibited by 30 µg/l. On the other hand, with several other species of green algae, 4-day EC_{50}s exceeded 200,000 µg/l. Zinc was found to bioaccumulate in freshwater animal tissues from 51 to 1,130 times the concentration present in the water (USEPA, 1986).

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APPENDIX L

WILDLIFE SPECIES OF THE FORT STORY/CAPE HENRY REGION

SELECTED LIST OF WILDLIFE OF THE FORT STORY/CAPE HENRY REGION
(excluding fish and marine life)

Common Name	Scientific Name	Common Name	Scientific Name
Mammals			
Bobcat	*Lynx rufus*	Meadow-jumping Mouse	*Zapus hudsonius*
Common Mole*	*Condylura cristata*	Mink	*Mustela vison*
Cotton Mouse	*Peromyscus gossypinus*	Muskrat	*Ondata zibethicus*
E. Cottontail Rabbit*	*Sylvilagus floridanus*	Otter	*Lutra canadensis*
Evening Bat	*Nycticelus humeralis*	Raccoon*	*Procyon lotor*
Golden Mouse	*Peromyscus nuttalli*	Red Bat	*Lasiurus borealis*
Gray Fox	*Urocyon cinereoargenteus*	Red Fox	*Vulpes fluva*
Gray Squirrel*	*Sciurus carolinensis*	Red Squirrel	*Tamiasciurus hudsonicus*
Least Shrew	*Cayptositis parva*	Rice Rat	*Oryxomys palustris*
Lemming Mouse	*Synaptomys cooperi*	Short-tailed Shrew	*Blarina brevicauda*
Little Brown Bat	*Myotis lucifungus*	Silver-haired Bat	*Lasionycteris noctivagens*
Long-tailed Weasel	*Mustela frenata*	Southern Flying Squirrel	*Glaucomys volanus*
Marsh Rabbit	*Sylvilagus palustris*	Virginia Opossum	*Didelphis marsupialis*
Meadow Mouse	*Microtus pennsylvanicus*	White-footed Mouse*	*Peromyscus leucopus*
Birds			
Acadian Flycatcher	*Empidonax flaviventris*	Belted Kingfisher	*Megaceryle alcyon alcyon*
American Bittern	*Botaurus lentiginosus*	Black and White Warbler	*Mniotilta varia*
American Coot	*Fulica americana*	Black Duck	*Anas rubripes*
American Crow*	*Corvus brachyrhynchos*	Black Vulture	*Coragyps atratus*
American Kestrel	*Falco sparverius*	Black-bellied Plover	*Squatorola squatarola*
American Redstart	*Setophaga ruticilla*	Black-billed Cuckoo	*Coccyzus erythrophthalmus*
American Widgeon	*Mareca americana*	Black-crowned Night Heron	*Nycticorax nycticorax hoactile*
Baltimore Oriole	*Icterus galbula*	Black-throated Blue Warbler	*Dendroica caerulescens*
Barn Owl	*Tyto alba*	Black-throated Green Warbler*	*Dendroica virens*
Barn Swallow	*Hirundo rustica erythrogaster*	Blue Jay	*Cyanocitta cristata*
Bay-breasted Warbler	*Dendroica castanea*	Blue-gray Gnatcatcher*	*Polioptila caerulea*
caerulea			

Birds (continued)

Bobwhite*	*Colinus virginianus*
Boat-tailed Grackle*	*Cassidix mexicanus*
Bobolink	*Dolichonyx oryzivorus*
Broad-winged Hawk	*Buteo platypterus platypterus*
Brown Creeper	*Certhia familiaris*
Brown Thrasher	*Toxostoma rufum*
Brown-headed Nuthatch*	*Sitta pusilla*
Cape Warbler	*Dendroica tigrina*
Cardinal*	*Richmondena cardinalis*
Carolina Chickadee	*Parus carolinensis*
Carolina Wren*	*Thryothorus ludoviclianus*
virescens	
Catbird*	*Dumetella carolinensis*
Cedar Waxwing	*Bombycilla cedrorum*
faxoni	
Chimney Swift	*Dhoetura pelagica*
Chipping Sparrow	*Spizella passerina*
Chuck-wills-widow	*Caprimulgus caroliniensis*
Common Grackle*	*Quiscalus quiscula*
Common Loon	*Gavia immer*
Common Merganser	*Mergus merganser*
Common Nighthawk	*Chordeiles minor*
Common Tern	*Sterma hirundo hirundo*
Common Yellowthroat	*Geothlypis trichas*
Cooper's Hawk	*Accipiter cooperii*
Cowbird	*Molothrus ater ater*
Downy Woodpecker	*Dendrocopus pubenscens*
Eastern Bluebird*	*Sialis sialis*
Eastern Kingbird	*Tyrannus tyrannus*
Eastern Meadowlark	*Sturnella magna*
Eastern Phoebe	*Sayomis phoebe*
Eastern Wood Pewee	*Contopus virens*
Glouse Sparrow	*Passer domesticus*
European Starling*	*Sturnus vulgaris*
Fish Crow*	*Corvus ossifragus*

Flicker	*Colaptes auratus*
Gannet	*Morus bassanus*
Golden-crowned Kinglet*	*Regulus satrapa satrapa*
Goldfinch	*Spinus tristis*
Great Blue Heron	*Ardea herodias*
Great-crested Flycatcher*	*Myiarchus crinitus*
Great Egret	*Casmerodinus albus*
Great Horned Owl	*Bubo virginianus*
Greater Scaup	*Aythya valisineria*
Greater Yellowlegs*	*Tringa melanoleuca*
Green-backed Heron	*Butorides virescens*
Hairy Woodpecker	*Dendrocopus villosus*
Hermit Thrush	*Hylocichla guttata*
Herring Gull*	*Larus argentatus*
Hooded Merganser	*Lophodytes cucullatus*
Hooded Warbler	*Wilsonia citrina*
House Finch*	*Carpodacus mexicanus*
House Wren*	*Troglodytes aedon*
Indigo Bunting	*Passerina cyanea*
Kentucky Warbler	*Oporonis formosus*
Killdeer*	*Charadrius vociferus*
King rail	*Rallus elagans elegans*
Laughing Gull*	*Larus atricilla*
Least Tern	*Sterna albifrons*
Little Blue Heron	*Florida caerulea caerulea*
Loggerhead Shrike	*Lanius ludovicianus*
Louisiana Waterthrush	*Seiurus motacilla*
Magnolia Warbler	*Dendroica magnolia*
Mallard*	*Anas platyrhynchos*
Marsh Hawk	*Circus cyaneus*
Marsh Wren	*Troglodytes aedon*
Mourning Dove*	*Zenaidia macroura*
Myrtle Warbler	*Dendroica coronata*

Birds (continued)

Orchard Oriole	*Icterus spurius*
Osprey*	*Pandion haliaetus carolinensis*
Ovenbird	*Seiurus aurocapillus*
Parula Warbler	*Parula americana*
Pied-billed Grebe	*Podilymbus podiceps podiceps*
Pileated Woodpecker*	*Hylatomus pileatus*
Pine Warbler	*Dendroica pinus*
Piping Plover	*Charadius melodus*
Prairie Warbler*	*Dendroica discolor*
Prothonotary Warbler*	*Protonotaria citrea*
Purple Finch	*Carpodacus purpureus*
Purple Martin	*Progne subis subis*
Red-winged Blackbird	*Agelaius phoeniceus*
Red-bellied Woodpecker	*Centurus carolinus*
Red-breasted Merganser	*Mergus serrator*
Red-breasted Nuthatch	*Sitta canadensis*
Red-eyed Vireo	*Vireo olivaceus*
Red-shouldered Hawk	*Buteo lineatus*
Red-tailed Hawk	*Buteo jamaicensis*
Redhead	*Aythya americana*
Ring-billed Gull*	*Larus delawarensis*
Robin*	*Turdus migratorius*
Ruby-crowned Kinglet	*Regulus calendula*
Ruby-throated Hummingbird	*Archilochus colubris*
Rufous-sided Towhee*	*Pipilo erythrophthalmus*
Scarlet Tanager	*Piranga olivacea*
Screech Owl	*Otus asio*
Sedge Wren	*Cistothorus platensis*
Semi-palmated Sandpiper	*Piranga oilvacea*
Sharp-shinned Hawk	*Accipiter striatus*
Slate-colored Junco	*Junco hyemalis*
Snowy Egret	*Leucophoyx thula*
Song Sparrow	*Melospiza melodia*
Spotted Sandpiper	*Actitis macularia*
Summer Tanager	*Piranga rubra*
Swamp Sparrow	*Melospiza georgia*
Tree Sparrow	*Spizella arborea*
Tree Swallow	*Iridoprocne bicolor*
Tufted Titmouse*	*Parus bicolor*
Turkey Vulture	*Cathartes aura*
White-breasted Nuthatch	*Sitta carolinensis*
White-eyed Vireo	*Vireo griseus*
White-throated Sparrow*	*Zonotrichia albicollis*
Wilson's Snipe	*Capella gallinago delicata*
Winter Wren	*Troglodytes troglodytes*
Wood Duck	*Axis sponsa*
Wood Thrush	*Hylocichla mustelina*
Yellow Warbler	*Dendroica petechia*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Yellow-billed Cuckoo	*Coccyzus americanus*
Yellow-breasted Chat	*Icteria virens*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Yellow-throated Vireo	*Vireo Flavifrons*
Yellow-throated Warbler	*Dendroica dominica*

Reptiles and Amphibians

Bronze Frog	*Rana clamitans clamitans*
Carpenter Frog	*Rana virgatipes*
Common Snapping Turtle	*Chelydra serpertina*
Eastern Box Turtle	*Terrapene carolina carolina*
Eastern Cottonmouth	*Agkistrodon piscivorous*
Eastern Garter Snake	*Thamnophis sirtalis*

Reptiles and Amphibians (continued)

Eastern Gray Tree Frog	*Hyla chrysoscelis*
Eastern Kingsnake	*Lampropetis getulus*
Eastern Mud Salamander	*Pseudotriton montanus*
Eastern Mud Snake	*Farancia abacura*
Eastern Painted Turtle	*Chrysemys picta*
Eastern Ribbon Snake	*Thamnophis sauritus*
Green Treefrog	*Hyla cinerea*
Marbled Salamander	*Ambystoma opacum*
Northern Diamondback Terrapin	*Malaclemys terrapin*
Red-bellied Turtle*	*Chrysemys scripta rubriventer*
Red-bellied Water Snake	*Natrix erythrogaster*
Scarlet Snake	*Cemophora coccinea*
Slimy Salamander	*Plethodon glutinosus*
Southern Copperhead	*Agkistrodon contorix*
Southern Cricket Frog	*Acris gryllus*
Southern Dusty Salamander	*Desmognathus auriculatus*
Southern Water Snake	*Nerodia fascinata*
Yellow Spotted Turtle	*Clemmys guttata*

Note: * = Observed by Malcolm Pirnie during April 1996 field visits.

Sources: Horne Engineering and Environmental Services. *Draft Fort Story Integrated Natural Resources Management Plan*, June 28, 1995.

Field Surveys by Malcolm Pirnie, April 1996

APPENDIX M

ECOLOGICAL RISK ASSESSMENT EXPOSURE CALCULATIONS

EXPOSURE CALCULATIONS FOR KILLDEER
FTA SITE, FORT STORY, VIRGINIA

Chemical (mg/kg)	Concentration in Sediment/ Surface Soil (mg/kg)	Concentration in Terrestrial Invertebrates (mg/kg)	Concentration in Vegetation (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	Killdeer NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Acetone	3.43E-02	3.43E-02	3.43E-02	4.40E-05	3.98E-04	4.41E-05	4.87E-04	NA	NA
Toluene	1.80E-01	1.80E-01	1.69E-01	2.31E-04	2.09E-03	2.18E-04	2.54E-03	NA	NA
Fluoranthene	6.50E-01	4.55E-01	7.93E-03	8.34E-04	5.29E-03	1.02E-05	6.13E-03	NA	NA
Pyrene	7.20E-01	5.04E-01	8.78E-03	9.24E-04	5.85E-03	1.13E-05	6.79E-03	NA	NA
Aluminum	7.60E+03	7.60E+03	3.04E+01	9.75E+00	8.83E+01	3.91E-02	9.81E+01	1.31E+02	7.52E-01
Barium	1.10E+02	1.10E+02	1.65E+01	1.41E-01	1.28E+00	2.12E-02	1.44E+00	2.28E+01	6.32E-02
Chromium	5.80E+00	5.80E-01	4.35E-02	7.44E-03	6.74E-03	5.60E-05	1.42E-02	2.39E+00	5.96E-03
Cobalt	2.60E+00	2.60E+00	7.80E-02	3.34E-03	3.02E-02	1.00E-04	3.36E-02	NA	NA
Copper	1.30E+01	3.12E+01	5.20E+00	1.67E-02	3.62E-01	6.69E-03	3.86E-01	71.8	5.37E-03
Iron	1.70E+04	1.70E+04	6.80E+01	2.18E+01	1.97E+02	8.75E-02	2.19E+02	NA	NA
Lead	2.10E+02	2.00E+02	9.45E+00	2.70E-01	2.32E+00	1.22E-02	2.60E+00	4.21E+00	6.17E-01
Manganese	4.20E+01	4.20E+01	1.05E+01	5.39E-02	4.88E-01	1.35E-02	5.55E-01	1.21E+03	4.60E-04
Thallium	1.40E+00	1.40E+00	5.60E-03	1.80E-03	1.63E-02	7.20E-06	1.81E-02	NA	NA
Vanadium	1.80E+01	1.80E+01	9.90E-02	2.31E-02	2.09E-01	1.27E-04	2.32E-01	2.66E+01	8.73E-03
Zinc	2.20E+01	1.25E+02	3.30E+01	2.82E-02	1.46E+00	4.25E-02	1.53E+00	7.00E+00	2.18E-01

Cs	Ci = Cs x EUF	Cv = Cs X PUF	EEs=(CsxFSxIRxFR)/BW	EEi=CixFRxNIRi	EEv = CvxFRvxNIRv	EEt = EEs + EEi + EEv	HQ = EEt/NOAELr
			Cs = Conc. in sediment FS = 10% IR = 0.0123 kg/day FR = 0.145 x 0.66 FR = 0.096 BW = 0.092 kg	Ci = Conc. in invertebrates FR = 0.096 NIRi = NIRf x 90% NIRf = 0.134 g/g-day	Cv = Conc. in vegetation FR = 0.096 NIRv = NIRf X 10% NIRf = 0.134 g/g-day		

WHITE FOOTED MOUSE EXPOSURE CALCULATIONS
FTA SITE, FORT STORY, VIRGINIA

Chemical	Concentration in Sediment/ Surface Soil (mg/kg)	Concentration in Terrestrial Invertebrates (mg/kg)	Concentration in Vegetation (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	White-Footed Mouse NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Acetone	3.43E-02	3.43E-02	3.43E-02	9.15E-05	3.98E-03	2.88E-03	6.95E-03	2.50E+01	2.79E-04
Toluene	1.80E-01	1.80E-01	1.69E-01	4.80E-04	2.09E-02	1.42E-02	3.56E-02	2.88E+01	1.24E-03
Fluoranthene	6.50E-01	4.55E-01	7.93E-03	1.73E-03	5.28E-02	6.66E-04	5.52E-02	1.11E+00	4.98E-02
Pyrene	7.20E-01	5.04E-01	8.78E-03	1.92E-03	5.85E-02	7.38E-04	6.11E-02	1.11E+00	5.52E-02
Aluminum	7.60E+03	7.60E+03	3.04E+01	2.03E+01	8.82E+02	2.55E+00	9.04E+02	2.12E+00	4.27E+02
Barium	1.10E+02	1.10E+02	1.65E+01	2.93E-01	1.28E+01	1.39E+00	1.44E+01	1.27E+01	1.13E+00
Chromium	5.80E+00	5.80E-01	4.35E-02	1.55E-02	6.73E-02	3.65E-03	8.64E-02	6.83E+03	1.26E-05
Cobalt	2.60E+00	2.60E+00	7.80E-02	6.93E-03	3.02E-01	6.55E-03	3.15E-01	NA	NA
Copper	1.30E+01	3.12E+01	5.20E+00	3.47E-02	3.62E+00	4.37E-01	4.09E+00	4.15E+01	9.86E-02
Iron	1.70E+04	1.70E+04	6.80E+01	4.53E+01	1.97E+03	5.71E+00	2.02E+03	NA	NA
Lead	2.10E+02	2.00E+02	9.45E+00	5.60E-01	2.31E+01	7.94E-01	2.45E+01	1.99E+01	1.23E+00
Manganese	4.20E+01	4.20E+01	1.05E+01	1.12E-01	4.87E+00	8.82E-01	5.87E+00	2.20E+02	2.67E-02
Thallium	1.40E+00	1.40E+00	5.60E-03	3.73E-03	1.62E-01	4.70E-04	1.67E-01	1.80E-02	9.26E+00
Vanadium	1.80E+01	1.80E+01	9.90E-02	4.80E-02	2.09E+00	8.32E-03	2.14E+00	5.20E-01	4.12E+00
Zinc	2.20E+01	1.25E+02	3.30E+01	5.87E-02	1.45E+01	2.77E+00	1.74E+01	3.99E+02	4.35E-02

Cs	Ci = Cs x EUF	Cv = Cs x PUF	EEs=(CsxFSxIRxFR)/BW	EEi=CixFRxNIRi	EEv=CvxFRxNIRv	EEt = EEs + EEi + EEv	HQ = EEt/NOAELr
			Cs = Conc. in sediment	Ci = Conc. in inverts.	Cv = Conc. in vege.		
			FS = 2%	FR = 1	FR = 1		
			IR = 0.003 kg/day	NIRi = NIRf x 58%	NIRv = NIRf x 42%		
			FR = 1	NIRf = 0.20 g/g-day	NIRf = 0.20 g/g-day		
			BW = 0.0225 kg				

GRAY FOX EXPOSURE CALCULATIONS
FTA SITE, FORT STORY, VIRGINIA

Chemical	Concentration in Sediment/ Surface Soil (mg/kg)	Concentration in Vegetation Consumed by Prey (mg/kg)	Concentration in Invertebrates Consumed by Prey (mg/kg)	Concentration in Prey (mg/kg)	Concentration in Vegetation Consumed by Fox (mg/kg)	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)
Acetone	3.43E-02	3.43E-02	3.43E-02	3.43E-02	2.20E-01	8.20E-07	4.59E-05
Toluene	1.80E-01	1.69E-01	1.80E-01	1.75E-01	1.69E-01	4.30E-06	2.34E-04
Fluoranthene	6.50E-01	7.80E-03	4.55E-01	2.31E-01	7.80E-03	1.55E-05	3.10E-04
Pyrene	7.20E-01	8.64E-03	5.04E-01	2.56E-01	8.64E-03	1.72E-05	3.43E-04
Aluminum	7.60E+03	3.04E+01	7.60E+03	3.82E+03	3.04E+01	1.82E-01	5.11E+00
Barium	1.10E+02	1.65E+01	1.10E+02	6.33E+01	1.65E+01	2.63E-03	8.47E-02
Chromium	5.80E+00	4.35E-02	5.80E-01	3.12E-01	4.35E-02	1.39E-04	4.17E-04
Cobalt	2.60E+00	7.80E-02	2.60E+00	1.34E+00	7.80E-02	6.21E-05	1.79E-03
Copper	1.30E+01	5.20E+00	3.12E+01	1.82E+01	5.20E+00	3.11E-04	2.44E-02
Iron	1.70E+04	6.80E+01	1.70E+04	8.53E+03	6.80E+01	4.06E-01	1.14E+01
Lead	2.10E+02	9.45E+00	2.00E+02	1.04E+02	9.45E+00	5.02E-03	1.40E-01
Manganese	4.20E+01	1.05E+01	4.20E+01	2.63E+01	1.05E+01	1.00E-03	3.52E-02
Thallium	1.40E+00	5.60E-03	1.40E+00	7.03E-01	5.60E-03	3.35E-05	9.41E-04
Vanadium	1.80E+01	9.90E-02	1.80E+01	9.05E+00	9.90E-02	4.30E-04	1.21E-02
Zinc	2.20E+01	3.30E+01	1.25E+02	7.92E+01	1.14E+02	5.26E-04	1.06E-01

Cs

Cv = Cs x PUF

Ci = Cs x EUF

Cp = Cv/2 + Ci/2

EEs=(CsxFSxIRxFR)/BW

Cs = Conc. in sediment
FS = 2.8%
IR = 0.24 kg/day
FR = area/HR
FR = 0.016
BW = 4.5 kg

EEp = Cp x FR x NIRp

Cp = Conc. in prey
FR = 0.016
(NIRp = NIRf x 93%)
NIRp = 0.0837

GRAY FOX EXPOSURE CALCULATIONS
FTA SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	Gray Fox NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Acetone	2.22E-05	6.81E-05	6.89E-05	4.27E+00	1.61E-05
Toluene	1.71E-05	2.51E-04	2.55E-04	4.97E+00	5.13E-05
Fluoranthene	7.86E-07	3.11E-04	3.26E-04	1.91E-01	1.71E-03
Pyrene	8.71E-07	3.44E-04	3.61E-04	1.91E-01	1.89E-03
Aluminum	3.06E-03	5.11E+00	5.29E+00	3.63E-01	1.46E+01
Barium	1.66E-03	8.64E-02	8.90E-02	2.18E+00	4.08E-02
Chromium	4.38E-06	4.22E-04	5.60E-04	1.17E+03	4.80E-07
Cobalt	7.86E-06	1.80E-03	1.86E-03	NA	NA
Copper	5.24E-04	2.49E-02	2.52E-02	7.09E+00	3.56E-03
Iron	6.85E-03	1.14E+01	1.18E+01	NA	NA
Lead	9.53E-04	1.41E-01	1.46E-01	3.44E+00	4.24E-02
Manganese	1.06E-03	3.62E-02	3.72E-02	3.76E+01	9.90E-04
Thallium	5.64E-07	9.42E-04	9.75E-04	3.20E-03	3.05E-01
Vanadium	9.98E-06	1.21E-02	1.26E-02	9.00E-02	1.40E-01
Zinc	1.15E-02	1.18E-01	1.18E-01	6.83E+01	1.73E-03

EEv=CvxFRxNIRv EEd = EEv + EEp EEt = EEs+EEd HQ = EEt/NOAELr

Cv = Conc. in vege.
FR = 0.016
(NIRv = NIRf x 7%)
NIRv = 0.0063 g/g-day

NORTHERN BOBWHITE EXPOSURE CALCULATIONS
LARC SITE, FORT STORY, VIRGINIA

Chemical (mg/kg)	Concentration in Sediment/ Surface Soil (mg/kg)	Concentration in Terrestrial Invertebrates (mg/kg)	Concentration in Vegetation (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	Northern Bobwhite NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Aluminum	6.50E+02	6.50E+02	2.60E+00	7.29E+00	7.15E+00	1.74E-01	1.46E+01	1.07E+02	1.37E-01
Barium	2.70E+00	2.70E+00	4.05E-01	3.03E-02	2.97E-02	2.71E-02	8.71E-02	1.87E+01	4.66E-03
Copper	4.10E+01	9.84E+01	1.64E+01	4.60E-01	1.08E+00	1.10E+00	2.64E+00	5.89E+01	4.49E-02
Iron	9.40E+02	9.40E+02	3.76E+00	1.05E+01	1.03E+01	2.52E-01	2.11E+01	NA	NA
Lead	1.20E+01	1.14E+01	5.40E-01	1.35E-01	1.25E-01	3.62E-02	2.96E-01	3.45E+00	8.58E-02
Manganese	6.90E+00	6.90E+00	1.73E+00	7.73E-02	7.59E-02	1.16E-01	2.69E-01	9.90E+02	2.71E-04
Vanadium	2.70E+00	2.70E+00	1.49E-02	3.03E-02	2.97E-02	9.95E-04	6.10E-02	2.18E+01	2.80E-03
Zinc	3.30E+01	1.88E+02	4.95E+01	3.70E-01	2.07E+00	3.32E+00	5.76E+00	5.74E+00	1.00E+00

Ci = Cs x EUF

Cv = Cs X PUF

EEs=(CsxFSxIRxFR)/BW

Cs = Conc. in sediment
FS = 10.4%
IR = 0.018 kg/day
FR = 1
BW = 0.167 kg

EEi=CixFRxNIRi

Ci = Conc. in inverts.
FR = 1
NIRi = NIRf x 86%
NIRf = 0.078 g/g-day

EEv = CvxFRvxNIRv

Cv = Conc. in veg.
FR = 1
NIRv = NIRf X 14%
NIRf = 0.078 g/g-day

EEt = EEs + EEi + EEv

HQ = EEt/NOAELr

WHITE-FOOTED MOUSE EXPOSURE CALCULATIONS
LARC SITE, FORT STORY, VIRGINIA

Chemical	Concentration in Sediment/ Surface Soil (mg/kg)	Concentration in Terrestrial Invertebrates (mg/kg)	Concentration in Vegetation (mg/kg)	Estimated Exposure from Soil/Sediment (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	White-Footed Mouse NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Aluminum	6.50E+02	6.50E+02	2.60E+00	1.73E+00	7.54E+01	2.18E-01	7.74E+01	2.12E+00	3.65E+01
Barium	2.70E+00	2.70E+00	4.05E-01	7.20E-03	3.13E-01	3.40E-02	3.54E-01	1.27E+01	2.78E-02
Copper	4.10E+01	9.84E+01	1.64E+01	1.09E-01	1.14E+01	1.38E+00	1.29E+01	4.15E+01	3.11E-01
Iron	9.40E+02	9.40E+02	3.76E+00	2.51E+00	1.09E+02	3.16E-01	1.12E+02	NA	NA
Lead	1.20E+01	1.14E+01	5.40E-01	3.20E-02	1.32E+00	4.54E-02	1.40E+00	1.99E+01	7.02E-02
Manganese	6.90E+00	6.90E+00	1.73E+00	1.84E-02	8.00E-01	1.45E-01	9.64E-01	2.20E+02	4.39E-03
Vanadium	2.70E+00	2.70E+00	1.49E-02	7.20E-03	3.13E-01	1.25E-03	3.22E-01	5.20E-01	6.19E-01
Zinc	3.30E+01	1.88E+02	4.95E+01	8.80E-02	2.18E+01	4.16E+00	2.61E+01	3.99E+02	6.53E-02
	Cs	Ci = Cs x EUF	Cv = Cs x PUF	EEs=(CsxFSxIRxFR)/BW	EEi=CixFRxNIRi	EEv=CvxFRxNIRv	EEt = EEs + EEi + EEv		HQ = EEt/NOAELr
				Cs = Conc. in sediment FS = 2% IR = 0.003 kg/day FR = 1 BW = 0.0225 kg	Ci = Conc. in inverts. FR = 1 NIRi = NIRf x 58% NIRf = 0.20 g/g-day	Cv = Conc. in vege. FR = 1 NIRv = NIRf x 42% NIRf = 0.20 g/g-day			

GRAY FOX EXPOSURE CALCULATIONS
LARC SITE, FORT STORY, VIRGINIA

Chemical	Concentration in Sediment/ Surface Soil (mg/kg)	Concentration in Vegetation Consumed by Prey (mg/kg)	Concentration in Invertebrates Consumed by Prey (mg/kg)	Concentration in Prey (mg/kg)	Concentration in Vegetation Consumed by Fox (mg/kg)	Estimated Exposure from Surface Soil (mg/kg BW-day)
Aluminum	6.50E+02	6.50E+02	2.60E+00	3.26E+02	6.50E+02	4.27E-02
Barium	2.70E+00	2.70E+00	4.05E-01	1.55E+00	2.70E+00	1.77E-04
Copper	4.10E+01	9.84E+01	1.64E+01	5.74E+01	9.84E+01	2.69E-03
Iron	9.40E+02	9.40E+02	3.76E+00	4.72E+02	9.40E+02	6.18E-02
Lead	1.20E+01	1.14E+01	5.40E-01	5.97E+00	1.14E+01	7.88E-04
Manganese	6.90E+00	6.90E+00	1.73E+00	4.31E+00	6.90E+00	4.53E-04
Vanadium	2.70E+00	2.70E+00	1.49E-02	1.36E+00	2.70E+00	1.77E-04
Zinc	3.30E+01	1.88E+02	4.95E+01	1.19E+02	1.88E+02	2.17E-03
	Cs	Cv = Cs x PUF	Ci = Cs x EUF	Cp = Cv/2 + Ci/2		EEs=(CsxFSxIRxFR)/BW

Cs = Conc. in sediment
FS = 2.8%
IR = 0.24 kg/day
FR = area/HR
FR = 0.044
BW = 4.5 kg

GRAY FOX EXPOSURE CALCULATIONS
LARC SITE, FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Prey (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	Gray Fox NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Aluminum	1.20E+00	1.80E-01	1.38E+00	1.42E+00	3.63E-01	3.92E+00
Barium	5.72E-03	7.48E-04	6.47E-03	6.64E-03	2.18E+00	3.05E-03
Copper	2.11E-01	2.73E-02	2.39E-01	2.41E-01	7.09E+00	3.40E-02
Iron	1.74E+00	2.61E-01	2.00E+00	2.06E+00	NA	NA
Lead	2.20E-02	3.16E-03	2.51E-02	2.59E-02	3.44E+00	7.54E-03
Manganese	1.59E-02	1.91E-03	1.78E-02	1.82E-02	3.76E+01	4.86E-04
Vanadium	5.00E-03	7.48E-04	5.75E-03	5.92E-03	9.00E-02	6.58E-02
Zinc	4.38E-01	5.21E-02	4.90E-01	4.92E-01	6.83E+01	7.20E-03

EEp = Cp x FR x NIRp

Cp = Conc. in prey
FR = 0.044
NIRp = NIRf x 93%
NIRp = 0.0837

EEv=CvxFRxNIRv

Cv = Conc. in vege.
FR = 0.044
NIRv = NIRf x 7%
NIRv = 0.0063 g/g-day

EEd = EEv + EEp

EEt = EEs+EEd

HQ = EEt/NOAELr

KILLDEER EXPOSURE CALCULATIONS - AUTO CRAFT SITE
FORT STORY, VIRGINIA

Chemical (mg/kg)	Concentration in Surface Soil (mg/kg)	Concentration in Terrestrial Invertebrates (mg/kg)	Concentration in Vegetation (mg/kg)	Estimated Exposure from Soil (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	Killdeer NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Methyl ethyl ketone	3.75E-02	3.75E-02	3.75E-02	1.05E-05	9.53E-05	1.06E-05	1.16E-04	NA	NA
Acenaphthene	3.11E-01	2.18E-01	3.79E-03	8.73E-05	5.53E-04	1.07E-06	6.42E-04	NA	NA
Benz(a)anthracene	2.50E+00	1.75E+00	3.05E-02	7.02E-04	4.45E-03	8.58E-06	5.16E-03	NA	NA
Benzo(b)fluoranthene	4.10E+00	2.87E+00	5.00E-02	1.15E-03	7.29E-03	1.41E-05	8.46E-03	NA	NA
Benzo(k)fluoranthene	3.39E-01	2.37E-01	4.14E-03	9.52E-05	6.03E-04	1.16E-06	6.99E-04	NA	NA
Benzo(g,h,i)perylene	2.00E+00	1.40E+00	2.44E-02	5.62E-04	3.56E-03	6.87E-06	4.13E-03	NA	NA
Benzo(a)pyrene	3.40E+00	2.38E+00	4.15E-02	9.55E-04	6.05E-03	1.17E-05	7.01E-03	NA	NA
Butylbenzylphthalate	3.76E-01	2.63E-01	4.59E-03	1.06E-04	6.69E-04	1.29E-06	7.76E-04	NA	NA
Chrysene	2.00E+00	1.40E+00	2.44E-02	5.62E-04	3.56E-03	6.87E-06	4.13E-03	NA	NA
Fluoranthene	5.80E+00	4.06E+00	7.08E-02	1.63E-03	1.03E-02	1.99E-05	1.20E-02	NA	NA
Indeno(1,2,3-cd)pyrene	1.26E+00	8.82E-01	1.54E-02	3.54E-04	2.24E-03	4.33E-06	2.60E-03	NA	NA
Phenanthrene	1.02E+00	7.14E-01	1.24E-02	2.86E-04	1.81E-03	3.50E-06	2.10E-03	NA	NA
Pyrene	1.10E+01	7.70E+00	1.34E-01	3.09E-03	1.96E-02	3.78E-05	2.27E-02	NA	NA
Chromium	9.00E+00	9.00E-01	6.75E-02	2.53E-03	2.29E-03	1.90E-05	4.83E-03	2.39E+00	2.02E-03
Copper	1.80E+01	4.32E+01	7.20E+00	5.05E-03	1.10E-01	2.03E-03	1.17E-01	5.07E+01	2.30E-03
Iron	9.10E+03	9.10E+03	3.64E+01	2.55E+00	2.31E+01	1.02E-02	2.57E+01	NA	NA
Lead	9.50E+01	9.03E+01	4.28E+00	2.67E-02	2.29E-01	1.20E-03	2.57E-01	4.21E+00	6.11E-02
Nickel	4.80E+00	9.12E+00	2.88E+00	1.35E-03	2.32E-02	8.10E-04	2.53E-02	1.58E+02	1.60E-04
Zinc	6.40E+01	5.19E+04	9.60E+01	1.80E-02	1.32E+02	2.70E-02	1.32E+02	6.12E+00	2.15E+01

Cs

Ci = Cs x EUF

Cv = Cs X PUF

EEs=(CsxFSxIRxFR)/BW

Cs = Conc. in sediment
FS = 10%
IR = 0.0123 kg/day
FR = 0.032 x 0.66
FR = 0.021
BW = 0.092 kg

EEi=CixFRxNIRi

Ci = Conc. in invertebrates
FR = 0.021
NIRi = NIRf x 90%
NIRf = 0.134 g/g-day

EEv = CvxFRvxNIRv

Cv = Conc. in vegetation
FR = 0.021
NIRv = NIRf X 10%
NIRf = 0.134 g/g-day

EEt = EEs + EEi + EEv

HQ = EEt/NOAELr

WHITE FOOTED MOUSE EXPOSURE CALCULATIONS
AUTO CRAFT SITE, FORT STORY, VIRGINIA

Chemical	Concentration in Surface Soil (mg/kg)	Concentration in Terrestrial Invertebrates (mg/kg)	Concentration in Vegetation (mg/kg)	Estimated Exposure from Soil (mg/kg BW-day)	Estimated Exposure from Invertebrates (mg/kg BW-day)	Estimated Exposure from Vegetation (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	White-Footed Mouse NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Methyl ethyl ketone	3.75E-02	3.75E-02	3.75E-02	5.40E-05	2.35E-03	1.70E-03	4.10E-03	1.46E+01	2.81E-04
Acenaphthene	3.11E-01	2.18E-01	3.79E-03	4.48E-04	1.36E-02	1.72E-04	1.43E-02	1.11E+00	1.29E-02
Benz(a)anthracene	2.50E+00	1.75E+00	3.05E-02	3.60E-03	1.10E-01	1.38E-03	1.15E-01	1.11E+00	1.03E-01
Benzo(b)fluoranthene	4.10E+00	2.87E+00	5.00E-02	5.90E-03	1.80E-01	2.27E-03	1.88E-01	1.11E+00	1.70E-01
Benzo(k)fluoranthene	3.39E-01	2.37E-01	4.14E-03	4.88E-04	1.49E-02	1.88E-04	1.55E-02	1.11E+00	1.40E-02
Benzo(g,h,i)perylene	2.00E+00	1.40E+00	2.44E-02	2.88E-03	8.77E-02	1.11E-03	9.17E-02	1.11E+00	8.27E-02
Benzo(a)pyrene	3.40E+00	2.38E+00	4.15E-02	4.90E-03	1.49E-01	1.88E-03	1.56E-01	1.11E+00	1.41E-01
Butylbenzylphthalate	3.76E-01	2.63E-01	4.59E-03	5.41E-04	1.65E-02	2.08E-04	1.72E-02	1.11E+00	1.56E-02
Chrysene	2.00E+00	1.40E+00	2.44E-02	2.88E-03	8.77E-02	1.11E-03	9.17E-02	1.11E+00	8.27E-02
Fluoranthene	5.80E+00	4.06E+00	7.08E-02	8.35E-03	2.54E-01	3.21E-03	2.66E-01	1.11E+00	2.40E-01
Indeno(1,2,3-cd)pyrene	1.26E+00	8.82E-01	1.54E-02	1.81E-03	5.52E-02	6.97E-04	5.78E-02	1.11E+00	5.21E-02
Phenanthrene	1.02E+00	7.14E-01	1.24E-02	1.47E-03	4.47E-02	5.64E-04	4.68E-02	1.11E+00	4.22E-02
Pyrene	1.10E+01	7.70E+00	1.34E-01	1.58E-02	4.82E-01	6.09E-03	5.04E-01	1.11E+00	4.55E-01
Chromium	9.00E+00	9.00E-01	6.75E-02	1.30E-02	5.64E-02	3.06E-03	7.24E-02	6.83E+03	1.06E-05
Copper	1.80E+01	4.32E+01	7.20E+00	2.59E-02	2.71E+00	3.27E-01	3.06E+00	4.13E+01	7.41E-02
Iron	9.10E+03	9.10E+03	3.64E+01	1.31E+01	5.70E+02	1.65E+00	5.85E+02	NA	NA
Lead	9.50E+01	9.03E+01	4.28E+00	1.37E-01	5.65E+00	1.94E-01	5.98E+00	1.99E+01	3.00E-01
Nickel	4.80E+00	9.12E+00	2.88E+00	6.91E-03	5.71E-01	1.31E-01	7.09E-01	9.99E+01	7.10E-03
Zinc	6.40E+01	5.19E+04	9.60E+01	9.22E-02	3.25E+03	4.35E+00	3.25E+03	3.99E+02	8.16E+00
	Cs	Ci = Cs x EUF	Cv = Cs x PUF	EEs=(CsxFSxIRxFR)/BW	EEi=CixFRxNIRi	EEv=CvxFRxNIRv	EEt = EEs + EEi + EEv		HQ = EEt/NOAELr
				Cs = Conc. in sediment	Ci = Conc. in invertebrates	Cv = Conc. in vege.			
				FS = 2%	FR = 0.54	FR = 0.54			
				IR = 0.003 kg/day	NIRi = NIRf x 58%	NIRv = NIRf x 42%			
				FR = 0.54	NIRf = 0.20 g/g-day	NIRf = 0.20 g/g-day			
				BW = 0.0225 kg					

GRAY FOX EXPOSURE CALCULATIONS - AUTO CRAFT SITE
FORT STORY, VIRGINIA

Chemical	Concentration in Surface Soil (mg/kg)	Concentration in Vegetation Consumed by Prey (mg/kg)	Concentration in Invertebrates Consumed by Prey (mg/kg)	Concentration in Prey (mg/kg)	Concentration in Vegetation Consumed by Fox (mg/kg)	Estimated Exposure from Surface Soil (mg/kg BW-day)	Estimated Exposure from Prey (mg/kg BW-day)
Methyl ethyl ketone	3.75E-02	3.75E-02	3.75E-02	3.75E-02	3.75E-02	1.68E-07	9.42E-06
Acenaphthene	3.11E-01	3.79E-03	2.18E-01	1.11E-01	3.79E-03	1.39E-06	2.78E-05
Benz(a)anthracene	2.50E+00	3.05E-02	1.75E+00	8.90E-01	3.05E-02	1.12E-05	2.24E-04
Benzo(b)fluoranthene	4.10E+00	5.00E-02	2.87E+00	1.46E+00	5.00E-02	1.84E-05	3.67E-04
Benzo(k)fluoranthene	3.39E-01	4.14E-03	2.37E-01	1.21E-01	4.14E-03	1.52E-06	3.03E-05
Benzo(g,h,i)perylene	2.00E+00	2.44E-02	1.40E+00	7.12E-01	2.44E-02	8.96E-06	1.79E-04
Benzo(a)pyrene	3.40E+00	4.15E-02	2.38E+00	1.21E+00	4.15E-02	1.52E-05	3.04E-04
Butylbenzylphthalate	3.76E-01	4.59E-03	2.63E-01	1.34E-01	4.59E-03	1.68E-06	3.36E-05
Chrysene	2.00E+00	2.44E-02	1.40E+00	7.12E-01	2.44E-02	8.96E-06	1.79E-04
Fluoranthene	5.80E+00	7.08E-02	4.06E+00	2.07E+00	7.08E-02	2.60E-05	5.19E-04
Indeno(1,2,3-cd)pyrene	1.26E+00	1.54E-02	8.82E-01	4.49E-01	1.54E-02	5.64E-06	1.13E-04
Phenanthrene	1.02E+00	1.24E-02	7.14E-01	3.63E-01	1.24E-02	4.57E-06	9.12E-05
Pyrene	1.10E+01	1.34E-01	7.70E+00	3.92E+00	1.34E-01	4.93E-05	9.84E-04
Chromium	9.00E+00	6.75E-02	9.00E-01	4.84E-01	6.75E-02	4.03E-05	1.21E-04
Copper	1.80E+01	7.20E+00	4.32E+01	2.52E+01	7.20E+00	8.06E-05	6.33E-03
Iron	9.10E+03	1.11E+02	9.10E+03	4.61E+03	1.11E+02	4.08E-02	1.16E+00
Lead	9.50E+01	1.16E+00	9.03E+01	4.57E+01	1.16E+00	4.26E-04	1.15E-02
Nickel	4.80E+00	2.88E+00	9.12E+00	6.00E+00	2.88E+00	2.15E-05	1.51E-03
Zinc	6.40E+01	7.81E-01	5.19E+04	2.59E+04	7.81E-01	2.87E-04	6.51E+00

Cs

Cv = Cs x PUF

Ci = Cs x EUF

Cp = Cv/2 + Ci/2

EEs=(CsxFSxIRxFR)/BW

Cs = Conc. in sediment
FS = 2.8%
IR = 0.24 kg/day
FR = area/HR
FR = 0.003
BW = 4.5 kg

EEp = Cp x FR x NIRp

Cp = Conc. in prey
FR = 0.003
(NIRp = NIRf x 93%)
NIRp = 0.0837

GRAY FOX EXPOSURE CALCULATIONS - AUTO CRAFT SITE
FORT STORY, VIRGINIA

Chemical	Estimated Exposure from Vegetation (mg/kg BW-day)	Estimated Exposure from Diet (mg/kg BW-day)	Total Estimated Exposure (mg/kg BW-day)	Gray Fox NOAEL (mg/kg BW-day)	Hazard Quotents (unitless)
Methyl ethyl ketone	7.09E-07	1.01E-05	1.03E-05	2.50E+00	4.12E-06
Acenaphthene	7.17E-08	2.79E-05	2.93E-05	1.91E-01	1.53E-04
Benz(a)anthracene	5.76E-07	2.24E-04	2.35E-04	1.91E-01	1.23E-03
Benzo(b)fluoranthene	9.45E-07	3.68E-04	3.86E-04	1.91E-01	2.02E-03
Benzo(k)fluoranthene	7.82E-08	3.04E-05	3.19E-05	1.91E-01	1.67E-04
Benzo(g,h,i)perylene	4.61E-07	1.79E-04	1.88E-04	1.91E-01	9.86E-04
Benzo(a)pyrene	7.84E-07	3.05E-04	3.20E-04	1.91E-01	1.68E-03
Butylbenzylphthalate	8.67E-08	3.37E-05	3.54E-05	1.91E-01	1.85E-04
Chrysene	4.61E-07	1.79E-04	1.88E-04	1.91E-01	9.86E-04
Fluoranthene	1.34E-06	5.20E-04	5.46E-04	1.91E-01	2.86E-03
Indeno(1,2,3-cd)pyrene	2.91E-07	1.13E-04	1.19E-04	1.91E-01	6.21E-04
Phenanthrene	2.35E-07	9.14E-05	9.60E-05	1.91E-01	5.03E-04
Pyrene	2.54E-06	9.86E-04	1.04E-03	1.91E-01	5.42E-03
Chromium	1.28E-06	1.23E-04	1.63E-04	1.17E+03	1.40E-07
Copper	1.36E-04	6.46E-03	6.54E-03	7.13E+00	9.18E-04
Iron	2.10E-03	1.16E+00	1.20E+00	NA	NA
Lead	2.19E-05	1.15E-02	1.19E-02	3.44E+00	3.47E-03
Nickel	5.44E-05	1.56E-03	1.58E-03	1.71E+01	9.27E-05
Zinc	1.48E-05	6.51E+00	6.51E+00	6.89E+01	9.46E-02

EEv=CvxFRxNIRv EEd = EEv + EEp EEt = EEs+EEw+EEd HQ = EEt/NOAELr

Cv = Conc. in vege.
FR = 0.003
(NIRv = NIRf x 7%)
NIRv = 0.0063 g/g-day