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Draft

Remedial Investigation Report
Training Area T-5 Sites, Parcels 180(7), 182(7), 511(7), 512(7), 513(7), 514(7), and 516(7)

Fort McClellan
Calhoun County, Alabama

Volume I of III: Text, Tables, and Figures

Prepared for:

U.S. Army Corps of Engineers, Mobile District
109 St. Joseph Street
Mobile, Alabama 36602

Prepared by:

Shaw Environmental, Inc.
312 Directors Drive
Knoxville, Tennessee 37923

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Executive Summary

In accordance with Contract Number DACA21-96-D-0018, Task Order CK19, Shaw Environmental, Inc. (Shaw) completed site investigation (SI) and remedial investigation (RI) activities at the Training Area T-5 Sites, Parcels 180(7), 182(7), 511(7), 512(7), 513(7), 514(7), and 516(7), at Fort McClellan (FTMC) located in Calhoun County, Alabama. This report summarizes the SI/RI field activities, assesses the nature and extent of contamination at the site, presents information on contaminant fate and transport, and evaluates potential risks to human health and the environment.

As presented in this report, the Training Area T-5 Sites consist of the following seven parcels located in the western-central portion of the FTMC Main Post:

- Former Detection and Identification Area, Parcel 180(7)
- Training Area T-5, Parcel 182(7)
- Blacktop Training Area, Parcel 511(7)
- Fenced Yard in Blacktop Training Area, Parcel 512(7)
- Dog Training Area, Parcel 513(7)
- Old Burn Pit, Parcel 514(7)
- Dog Kennel Area, Parcel 516(7).

These sites were previously used for various chemical warfare material (CWM) training activities that may have involved chemical agent storage, detection, identification, and decontamination as well as CWM demonstration exercises.

A total of 48 surface and depositional soil samples, 32 subsurface soil samples, 102 groundwater samples, 5 surface water samples, and 5 sediment samples were collected for chemical analysis during the investigations. The samples were analyzed for metals, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and CWM breakdown products – except for 28 groundwater samples that were analyzed for VOCs only during the RI. Shaw also installed 48 permanent monitoring wells at the Training Area T-5 Sites, including 37 residuum wells and 11 bedrock wells, to facilitate groundwater sample collection and to provide site-specific geological and hydrogeological data.

The primary environmental concern at the Training Area T-5 Sites is the presence of chlorinated VOCs in groundwater. The source of contamination is believed to be decontamination solutions or certain chemical agents used in historical CWM training activities. Other contaminants of

concern included certain metals (cadmium, copper, and zinc) and polynuclear aromatic hydrocarbons (PAH) in surface soil at some of the parcels.

Based on the soil and groundwater data collected at the Training Area T-5 Sites, the most significant fate and transport pathway is within subsurface soil through the residuum and into the bedrock groundwater system. The low levels of VOCs in soil suggest that significant removal and/or subsequent leaching of organic contaminants to groundwater has occurred.

Two major plumes are present in the residuum at the Training Area T-5 Sites: one at Parcels 511(7) and 512(7), and one at Parcel 514(7). These plumes consist mainly of chlorinated ethane and ethene compounds, particularly 1,1,2,2-tetrachloroethane and trichloroethene with lesser amounts of cis/trans-1,2-dichloroethene, 1,1,2-trichloroethane, and chloroform. The chlorinated VOC plume within Parcels 511(7) and 512(7) is approximately 450 feet long by 150 feet wide and extends to the north. The chlorinated VOC plume at Parcel 514(7) is approximately 600 feet long by 150 feet wide and extends to the east-northeast. A third plume in the southern portion of Parcel 182(7), consisting mainly of carbon tetrachloride, 1,1,2,2-tetrachloroethane, and chloroform, is approximately 300 feet long by 200 feet wide and extends to the northeast. Total chlorinated VOCs present in bedrock wells are coincident and occur beneath similar contaminants present in the overlying residuum, except at Parcel 182(7) where the contaminants appear to be restricted to the residuum. Based on the data from monitoring wells installed during this investigation and on site topography and geology, the horizontal and vertical extent of groundwater contamination has been defined.

A streamlined human health risk assessment (SRA) was performed to evaluate potential risks to human receptors from exposure to environmental media at the Training Area T-5 Sites. Four plausible receptors were evaluated in the SRA: recreational site user, groundskeeper, construction worker, and resident. Surface water, sediment, and soil at the various Training Area T-5 Sites are uncontaminated or slightly contaminated and, therefore, do not pose a significant threat to human health. Groundwater, however, has been impacted by several solvents, particularly 1,1,2,2-tetrachloroethane, trichloroethene, carbon tetrachloride, and acetone. The Training Area T-5 Sites could be released for any purpose provided that groundwater is not developed as a potable source. Low levels of PAHs in surface soil at three of the sites contribute significantly to cancer risk only if exposure to groundwater developed as a potable source is included in the evaluation.

A screening-level ecological risk assessment (SLERA) was performed to evaluate potential risks to ecological receptors from exposure to environmental media at the Training Area T-5 Sites. Constituents of potential ecological concern (COPEC) were not identified for groundwater, surface water, or sediment. Exposures to subsurface soil are unlikely for potential ecological receptors at these sites. The predominant surface soil COPECs were three metals (cadmium, copper, and zinc) at Parcels 180(7), 182(7), and 511(7)/512(7) and several PAHs at Parcels 180(7) and 514(7). Two VOCs (1,1,2,2-tetrachloroethane and trichloroethene) were also identified as COPECs in surface soil at Parcel 514(7).

Based on the results of the RI, no further investigation is warranted to define the nature and extent of contamination at the Training Area T-5 Sites. Shaw recommends conducting a baseline ecological risk assessment (BERA) to complete the ecological risk assessment process. Following the BERA, a feasibility study should be performed to evaluate and select a remedial alternative for the protection of human health and the environment.

1.0 Introduction

The U.S. Army has selected Fort McClellan (FTMC), located in Calhoun County, Alabama, for closure by the Base Realignment and Closure (BRAC) Commission under Public Laws 100-526 and 101-510. The 1990 Base Closure Act, Public Law 101-510, established the process by which U.S. Department of Defense (DOD) installations would be closed or realigned. The BRAC Environmental Restoration Program requires investigation and cleanup of federal properties prior to transfer to the public domain. The U.S. Army is conducting environmental studies of the impact of suspected contaminants at parcels at FTMC under the management of the U.S. Army Corps of Engineers (USACE)-Mobile District.

FTMC is a U. S. Army facility under the control of the U. S. Army Training and Doctrine Command that was closed under the BRAC program in September 1999. Located in northeast Alabama, near the city of Anniston in Calhoun County, FTMC consisted of three tracts of land: the Main Post, Choccolocco Corridor, and Pelham Range (Figure 1-1). The majority of development at FTMC is in the northwest area of the Main Post. The City of Anniston is located to the south and west of the Main Post; adjoining the Main Post installation to the east are the Choccolocco Mountains of the Talladega National Forest.

The USACE contracted Shaw Environmental, Inc. (Shaw), formerly IT Corporation (IT), to conduct site investigations (SI) and remedial investigations (RI) at seven former chemical warfare material (CWM) training sites under Contract Number DACA21-96-D-0018, Task Order CK19. The seven sites are:

- Former Detection and Identification Area, Parcel 180(7)
- Training Area T-5, Parcel 182(7)
- Blacktop Training Area, Parcel 511(7)
- Fenced Yard in Blacktop Training Area, Parcel 512(7)
- Dog Training Area, Parcel 513(7)
- Old Burn Pit, Parcel 514(7)
- Dog Kennel Area, Parcel 516(7).

These sites are collectively referred to herein as the Training Area T-5 Sites. This report presents the results of the SI and RI activities conducted at the Training Area T-5 Sites, including field sampling and analysis, and monitoring well installation.

1.1 Scope and Objectives

An SI was initially conducted at several CWM training sites at FTMC, including the Training Area T-5 Sites, to determine the presence or absence of contamination. A site-specific work plan, comprised of a field sampling plan (SFSP), a safety and health plan, and an unexploded ordnance (UXO) safety plan, was prepared for SI field activities in October 2000 (IT, 2000a).

The SI results demonstrated the presence of contamination (primarily volatile organic compounds [VOC] in groundwater) and, thus, the need for an RI to determine the nature and extent of contamination. A site-specific work plan for RI activities was prepared in October 2002 (IT, 2002a). An additional site-specific work plan was prepared in February 2004 for supplemental RI activities at the Training Area T-5 Sites (Shaw, 2004). These work plans were used as attachments to the installation-wide work plan (IT, 1998; IT, 2002b) and the installation-wide sampling and analysis plan (SAP) (IT, 2000b; IT, 2002c). The SAP includes the installation-wide safety and health plan and quality assurance plan.

The objectives of this RI are to determine the nature and extent of contamination and to identify chemicals that pose an unacceptable risk to human health and the environment. Completion of these objectives under the Installation Restoration Program process enables the preparation of a feasibility study for the evaluation and selection of potential remedial measures.

1.2 Site Descriptions and History

The Training Area T-5 Sites are located in the eastern-central portion of the FTMC Main Post (Figure 1-2). The site descriptions are summarized below.

1.2.1 Former Detection and Identification Area, Parcel 180(7)

The Former Detection and Identification Area, Parcel 180(7), is an approximately 0.5-acre area located southwest of Building 3185 on the western side of Rucker Street (Figure 1-3). This site was used from the 1950s until 1973 for training in the detection and identification of CWM. CWM used at this location may have included simulated chemical agents (a.k.a. simulants), distilled mustard (HD), sarin (GB), phosgene (CG), cyanogen chloride (CK), phosgene oxime (CX), hydrogen cyanide (AC), and the decontaminants supertropical bleach (STB) and decontamination solution 2 (DS2) (Environmental Science and Engineering, Inc. [ESE], 1998). It is also believed that the U.S. Navy used the site in the late 1950s for the detection of HD. Agent simulants, CK, CG, CX, and AC may have been used in training exercises (Parsons Engineering Science, Inc. [Parsons], 2002).

Roy F. Weston, Inc. (Weston) reported that several types of CWM may have been used at this site and that STB and DS2 were used on surface soil, presumably during final decontamination before the U.S. Army Chemical School (USACMLS) transferred from FTMC to Aberdeen Proving Ground in 1973 (Weston, 1990). Before 1973, a pit was excavated at the site and all training aids from the site (e.g., structures), as well as a building from Area T-4, were incinerated twice and buried (Parsons, 2002). The burial pit was permanently marked with a concrete survey monument (Monument F).

Personnel interviewed during the environmental baseline survey (EBS) who had participated in operations at this site reported that no training materials (i.e., CWM) contacted the ground and that no disposal activities occurred at this location (ESE, 1998). Accounts of personnel interviewed during the EBS differ regarding the CWM used. Some sources indicated that only simulants were used at this location, while others recalled that dilute CWM mixtures were used during training. Vials of simulated CWM (diluted CWM according to some sources) were reportedly placed into containers atop 3-foot-high poles in the training area. Approximately 24 poles are visible on a 1964 aerial photograph. Simulant Chemical Agent Identification Training Set (SCAITS) kits were used at the Former Detection and Identification Area. Vials in old SCAITS kits of the 1950s reportedly contained a very low concentration of CWM. No spills were reported at this site (ESE, 1998).

FTMC personnel reported that other training activities, known as "G-shoots," were conducted at a nerve agent demonstration area that was located in the northern portion of the Former Detection and Identification Area (ESE, 1998). The operation involved placing one drop of GB on the nose of a goat, observing symptoms, and then reviving the animal with an intramuscular atropine injection. Reportedly, there was very little chance of a CWM release during this exercise because of the small quantities used.

1.2.2 Training Area T-5, Parcel 182(7)

Training Area T-5 is also known as the Former Toxic Hazards Detection and Decontamination Training Area. It is located between Sunset Hill and Howitzer Hill, south of Building 3174, at the southern end of Rucker Street (Figure 1-3). The site covers approximately 11.5 acres. Training Area T-5 was reportedly used from 1961 to 1973. The site is posted and partially fenced (the fence is missing along the northern boundary). Training activities reportedly involved detection and decontamination of CWM, including HD, O-ethyl-S-(di-isopropylaminoethyl)-methylphosphonothiolate (VX), GB, and the biological simulants *Bacillus globigii* (BG) and *Serratia marcescens* (SM) (Parsons, 2002). The decontaminants STB and

DS2 were also probably used. Training was likely confined to small areas within a fenced, controlled area.

Personnel interviewed during the EBS reported that explosive ordnance disposal (EOD) personnel conducted "render-safe" exercises on munitions (typically artillery shells) in this area (ESE, 1998). EOD personnel placed the munition on the ground and poured a vial of chemical agent over the munition. The EOD reaction team then identified the chemical agent, decontaminated the munition, and packaged it for transport. Exercises reportedly took place within 175 feet of the road. Some reports indicated that only simulated CWM rounds were used and that water was used as the decontaminant rather than STB or DS2 (ESE, 1998). Following completion of training at this site, all excavations were filled in accordance with standard operating procedures; training aids were decontaminated, incinerated twice, and sent to the landfill, or they were renovated and shipped to Redstone Arsenal (Parsons, 2002).

Previous reports speculated that this may be the location of a 110-gallon HD spill, which reportedly occurred in 1955 (Weston, 1990). None of the personnel interviewed during the EBS could recall a 110-gallon spill, nor could they imagine a scenario in which a spill of this magnitude could occur. However, the HD simulant molasses residuum was delivered in 55-gallon drums. Site soils were reportedly chemically decontaminated, excavated, and disposed at Range J on Pelham Range (ESE, 1998).

1.2.3 Blacktop Training Area, Parcel 511(7), and Fenced Yard in Blacktop Area, Parcel 512(7)

The Blacktop Training Area, Parcel 511(7), is addressed with the Fenced Yard in Blacktop Area, Parcel 512(7), as identified in the *Archives Search Report* (ASR) (USACE, 2001a). The approximately 3-acre site is primarily an "asphalt parking lot" located along the eastern side of Reggie Avenue, with viewing stands (bleachers) on both ends of the area and an inner fenced portion (Figure 1-3) (Parsons, 2002). The Fenced Yard in Blacktop Area is approximately 0.5 acre in area. The fence was removed at an unknown date.

The Blacktop Training Area was identified on the 1956 map of the Chemical Corps Training Areas and on the 1969 Chemical School Orientation Map (Parsons, 2002). Various demonstrations may have taken place at this site (e.g., decontamination training) but its actual use is unknown. The area was reportedly used for training in the use of flamethrowers, decontamination equipment, and smoke generators. The Fenced Yard was believed to have been used for chemical agent training or storage. However, it may be a more recent structure (Parsons, 2002).

Analysis of historical aerial photographs shows that the area was cleared in the early 1940s and paved sometime after 1954 (Parsons, 2002). Very few visible changes occurred after 1954. The Fenced Yard in Blacktop Area is evident on the 1982 aerial photograph (Parsons, 2002). Bleachers are visible near the northern and southern ends of the paved area, suggesting that training demonstrations took place here (Parsons, 2002).

Historical documents do not indicate what CWM, if any, was used at this site. Decontamination training may have taken place but it is not known if actual chemical agents were used (Parsons, 2002). The previously fenced area may have been used for storage or demonstrations of agent, but no documented evidence of such use was found. Training involving flame and smoke agents has also been reported for this site; however, these activities are no longer considered CWM-related (Parsons, 2002).

1.2.4 Dog Training Area, Parcel 513(7), and Dog Kennel Area, Parcel 516(7)

The Dog Training Area, Parcel 513(7), is located off of Reggie Avenue near the Dog Kennel Area, Parcel 516(7) (Figure 1-3). Both areas are approximate 1-acre sites. These sites were used to train dogs for the U.S. Army Military Police School; remnants of the training obstacles were still in existence in September 1998 but have since been removed (Parsons, 2002). A large, blistered/corroded concrete pad is located within the area and may have been used for chemical agent training or storage (USACE, 2001a).

Analysis of historical aerial photographs revealed that this area contained numerous small buildings in the 1940s, and that the concrete pad is one of many building foundations from that era. More recent aerial photographs showed several cleared areas that were likely used for dog training, but there are not any suspect CWM training areas (Parsons, 2002).

The ASR indicated that the Dog Kennel Area had an inner yard that possibly could have been used for chemical agent storage. The Dog Kennel Area is shown as part of Training Area T-5 on the 1969 Chemical School Orientation Map. Mustard confidence training, which used small amounts of mustard agent, may have taken place within the Quonset hut located inside the perimeter fence (USACE, 2001a). However, historical aerial photographs did not indicate the likelihood of disposal within these areas (Parsons, 2002). Small quantities of HD may have been used at this site. However, the reported use would likely have occurred within the confines of the structure in the fenced area. Parsons found no evidence of a burial pit at the site during a site visit (Parsons, 2002).

1.2.5 Old Burn Pit, Parcel 514(7)

The Old Burn Pit, Parcel 514(7), is located in a wooded area approximately 500 feet west of Rucker Street, across a dirt road and just southwest of the Former Motor Pool Area 3100 (Figure 1-3). This approximately 0.15-acre site was identified for consideration during the field visit to collect information for the ASR because it appeared to be a burn pit (USACE, 2001a). Although little is known about the site and this area is not specifically listed as a former chemical training site, it was selected for further investigation to ensure that CWM was not present (Parsons, 2002).

The aerial photograph analysis conducted by Parsons shows a well-defined cleared area in the 1961 aerial photograph that coincides with the location of the burn pit (Parsons, 2002). A site visit by Parsons in February 1999 revealed the remains of the pit. The pit was covered with wire mesh and contained some remnant metallic objects (Parsons, 2002).

1.3 Previous Investigations

An EBS was conducted by ESE to document the environmental condition of all FTMC properties (ESE, 1998). The objective of the study was to identify sites that based on available information, have no history of contamination and comply with DOD guidance for fast-track cleanup at closing installations. The EBS also provides a baseline picture of FTMC properties by identifying and categorizing the properties by the following seven criteria:

1. Areas where no storage, release, or disposal of hazardous substances or petroleum products has occurred (including no migration of these substances from adjacent areas).

2. Areas where only release or disposal of petroleum products has occurred.

3. Areas where release, disposal, and/or migration of hazardous substances has occurred, but at concentrations that do not require a removal or remedial response.

4. Areas where release, disposal, and/or migration of hazardous substances has occurred, and all removal or remedial actions to protect human health and the environment have been taken.

5. Areas where release, disposal, and/or migration of hazardous substances has occurred, and removal or remedial actions are underway, but all required remedial actions have not yet been taken.

6. Areas where release, disposal, and/or migration of hazardous substances has occurred, but required actions have not yet been implemented.

7. Areas that are not evaluated or require further evaluation.

For non-Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) environmental or safety issues, the parcel label includes the following components: a unique non-CERCLA issue number, the letter "Q" designating the parcel as a Community Environmental Response Facilitation Act (CERFA) Category 1 Qualified parcel, and the code for the specific non-CERCLA issue(s) present (ESE, 1998). The non-CERCLA issue codes used are:

- A = Asbestos (in buildings)
- L = Lead-based paint (in buildings)
- P = Polychlorinated biphenyls
- R = Radon (in buildings)
- RD = Radionuclides/radiological issues
- X = UXO
- CWM = Chemical warfare material.

The EBS was conducted in accordance with the CERFA protocols (CERFA-Public Law 102-426) and DOD policy regarding contamination assessment. Record searches and reviews were performed on all reasonably available documents from FTMC, the Alabama Department of Environmental Management (ADEM), EPA Region 4, and Calhoun County, as well as a database search of CERCLA-regulated substances, petroleum products, and Resource Conservation and Recovery Act-regulated facilities. Available maps and aerial photographs were reviewed to document historical land uses. Personal and telephone interviews of past and present FTMC employees and military personnel were conducted. In addition, visual site inspections were conducted to verify conditions of specific property parcels.

Parcels 180(7), 182(7), 511(7), 512(7), 513(7), 514(7), and 516(7) were categorized as CERFA Category 7 parcels in the EBS. Category 7 parcels are areas that have not been evaluated or that require further evaluation to determine their environmental condition. Previous investigations have been conducted at the Training Area T-5 Sites as discussed in the following sections.

1.3.1 Site Investigation (1993)

Between June 1991 and July 1993, SAIC conducted an SI to determine the presence or absence of contamination resulting from previous military training activities at the Former Detection and Identification Area, Parcel 180(7), and Training Area T-5, Parcel 182(7). These investigations focused exclusively on CWM.

The SI at Parcel 180(7) included the collection of four soil samples from two sample locations (DIA-S0101/02 and DIA-S0201/02), one within the burial pit, and the other from the area where the materials were burned (Figure 1-4). Samples were collected at depths of approximately 1 foot and 6 feet bgs. The soil samples were field screened for HD and GB agents by U.S. Army Technical Escort Unit (USATEU) using Miniature Continuous Air Monitoring System (MINICAMS) prior to shipment to the laboratory for analysis. The samples were analyzed for HD and GB breakdown products. All screening results were below background, and the analytical results did not indicate the presence of breakdown products in the soil samples (SAIC, 1993).

The SI at Parcel 182(7) included the collection of eight soil samples from four locations (T5-S0101/02, T5-S0201/02, T5-S0301/02, and T5-S0401/02) at depths of approximately 1 foot and 5 feet bgs and collection of a surface water/sediment sample (T5-W01/T5-D01) (Figure 1-5). The soil samples were field screened for GB, HD, and VX agents by USATEU using MINICAMS prior to shipping the samples to the laboratory. The soil samples were analyzed for GB, HD, and VX breakdown products. All screening results were below background, and the analytical results did not indicate the presence of breakdown products in the samples (SAIC, 1993).

1.3.2 Remedial Investigation (1995)

Based on the results of the SI, an RI was conducted by SAIC in 1994 and 1995 to determine the nature and extent of potential environmental contamination resulting from chemical agent training and chemical waste disposal activities at Parcels 180(7) and 182(7). The RI included a geophysical survey to delineate a former burn and burial pit located in the central portion of the parcel in the vicinity of Monument F (Figure 1-4). Data were recorded along four transects intersecting at Monument F. Four trenches were excavated within the former Detection and Identification Area based on the geophysical survey results (SAIC, 2000). Excavated materials included concrete rubble with rebar, wood, sand, and tar paper. Training-related materials that were excavated consisted of glass tube fragments (potentially from an M-18 test kit) and a rubber glove. Soil samples (DIA-S03, DIA-S04, DIA-S05, and DIA-S06) were collected from each of the trenches, screened by USATEU for HD, GB, and VX agents using MINICAMS, and sent to the laboratory for chemical agent breakdown product analysis. All screening results were below background, and the analytical results did not indicate the presence of breakdown products in the soil samples (SAIC, 2000).

The RI at Training Area T-5 included the collection of 44 surface soil screening samples, four surface soil samples (T5-S05, T5-S06, T5-S07, and T5-S08), and two surface water and

sediment samples (T5-W02/D02 and T5-W03/D03) (Figure 1-5). Sample locations were based on historical documentation, which included training location sketches and photographs of training activities. The samples were field-screened by USATEU for GB, HD, and VX using MINICAMS and were laboratory analyzed for their respective breakdown products. All screening results were below background, and the analytical results did not indicate the presence of breakdown products in the samples (SAIC, 2000).

1.3.3 CWM EE/CA (2002)

Parsons conducted an engineering evaluation/cost analysis (EE/CA) at 33 FTMC sites, including the Training Area T-5 Sites, to evaluate potential CWM contamination (Parsons, 2002).

The CWM EE/CA included the Former Detection and Identification Area, Parcel 180(7), and Training Area T-5, Parcel 182(7). Based on historical information and existing analytical data from the previous investigations, Parsons concluded that the risk of exposure to CWM at Parcels 180(7) and 182(7) was unlikely. Therefore, Parsons recommended a "no further action" response alternative related to CWM at the Former Detection and Identification Area, Parcel 180(7), and Training Area T-5, Parcel 182(7).

The EE/CA investigation at Parcels 511(7) and 512(7) consisted of soil sampling and qualitative risk evaluations (Parsons 2002). Thirty-six soil samples were collected from 18 borings advanced below the blacktop at Parcels 511(7) and 512(7). Soil sample locations were randomly selected over the sites (Figure 1-6). Soil samples were collected from each boring at depths of approximately 1 foot and 4 feet bgs. During soil sampling activities, continuous air monitoring was performed using MINICAMS, Open-Path Fourier Transform Infrared Spectroscopy (OPFTIR), and a photoionization detector (PID). The soil samples were field screened for GB and HD agents by Edgewood Chemical/Biological Command (ECBC) prior to shipment to its laboratory. The samples were analyzed for GB and HD breakdown products. All screening results were below background, and the analytical results did not indicate the presence of GB and HB breakdown products above reporting limits (Parsons, 2002).

The soil analytical results indicated that residual agents or breakdown products were not present in the sampled media. In addition, historical records did not indicate sources of CWM in the environment at Parcels 511(7) and 512(7). Therefore, the probability of current or future risk of human exposure to chemical agents was determined to be very small (Parsons, 2002). Hence, Parsons recommended a "no further action" response alternative related to CWM at the Blacktop Training Area, Parcel 511(7), and the Fenced Yard in Blacktop Area, Parcel 512(7).

The Dog Training Area, Parcel 513(7), was included as part of the EE/CA conducted by Parsons. Four soil samples were collected from two borings located adjacent to the concrete pads at Parcel 513(7) (Figure 1-7). Two soil samples were collected from each boring at depths of approximately 1 foot and 4 feet bgs. During soil sampling activities, continuous air monitoring was performed using MINICAMS, OPFTIR, and PID. The soil samples were field-screened for GB and HD agents by ECBC prior to shipment to ECBC's laboratory. The samples were analyzed for GB and HD breakdown products. All screening results were below background, and the analytical results did not indicate the presence of breakdown products above reporting limits (Parsons, 2002).

The soil analytical results indicated that residual agents or breakdown products were not present in the sampled media. In addition, historical records did not indicate sources of CWM in the environment at Parcel 513(7). Therefore, the probability of current or future risk to human exposure to chemical agents was judged to be very small (Parsons, 2002). Hence, Parsons recommended a "no further action" response alternative related to CWM at the Dog Training Area, Parcel 513(7).

The CWM EE/CA investigation at Parcel 514(7) consisted of an intrusive investigation and a qualitative risk evaluation. Three depressions near the Old Burn Pit were investigated using hand tools. During the excavation activities, continuous air monitoring was performed using MINICAMS, OPFTIR, and PID. The approximate locations of the three excavated areas (Areas 1, 2, and 3) are shown on Figure 1-8. Area 1 contained multiple inert and practice OE items in addition to metallic debris. Area 2 contained a steel box with cans, wire-wrapped cans, plate glass, and a dummy grenade. Area 3 contained flakes of rust and jar lids. No evidence was encountered to suggest that these pits were ever used for burning (Parsons, 2002).

Although some OE items were found in one of the excavated areas at the site, CWM was not encountered. Based on the results of the EE/CA, it was concluded that sources of CWM do not exist in the environment at the Old Burn Pit. Therefore, the probability of current or future risk of human exposure to chemical agents was determined to be very small (Parsons, 2002). Hence, Parsons recommended a "no further action" response alternative related to CWM at the Old Burn Pit, Parcel 514(7).

The Dog Kennel Area, Parcel 516(7), was also investigated during the CWM EE/CA (Figure 1-7). Based on historical information, small quantities of HD may have been used at this site. However, HD usage would have occurred within the confines of the structure in the fenced area (Parsons, 2002). A site visit by Parsons found no evidence of a burial pit at the site. The

likelihood of minute quantities of HD persisting in the environment for a long period is low. Therefore, the probability of current or future risk of human exposure to chemical agents was judged to be very small (Parsons, 2002). Hence, Parsons recommended a "no further action" response alternative related to CWM at the Dog Kennel Area, Parcel 516(7).

1.4 Report Organization

This RI report is organized as follows:

- ***Chapter 1.0 – Introduction.*** This chapter provides site description and history information for the Training Area T-5 Sites and describes the objectives of this RI. In addition, a brief summary of previous investigations at the Training Area T-5 Sites is provided.

- ***Chapter 2.0 – Study Area Investigation.*** This chapter summarizes the RI field activities conducted at the Training Area, T-5 Sites, including environmental sampling and analysis, and monitoring well installation.

- ***Chapter 3.0 – Physical Characteristics of Study Area.*** This chapter describes the physical characteristics of the Training Area, T-5 Sites, including demography and land reuse, meteorology, physiography, sensitive environments, soils, geology, and hydrogeology.

- ***Chapter 4.0 – Nature and Extent of Contamination.*** This chapter summarizes the analytical results and compares data with human health site-specific screening levels (SSSL), ecological screening values (ESV), and background screening values to assess the nature and extent of contamination and probable sources.

- ***Chapter 5.0 – Contaminant Fate and Transport.*** This chapter evaluates the chemical and physical properties of the site-related chemicals identified in Chapter 4.0. It also describes potential migration mechanisms, contaminant persistence, and contaminant migration.

- ***Chapter 6.0 – Streamlined Human Health Risk Assessment.*** This chapter presents the streamlined human health risk assessment (SRA), including the conceptual site exposure model (CSEM), data evaluation, chemicals of potential concern (COPC), exposure and toxicity assessments, risk characterization, and uncertainty analysis.

- ***Chapter 7.0 – Screening-Level Ecological Risk Assessment.*** This chapter presents the screening-level ecological risk assessment (SLERA), including the environmental setting, site conceptual model (SCM), screening-level risk estimation, constituents of potential ecological concern (COPEC), and uncertainty analysis.

- ***Chapter 8.0 – Summary, Conclusions, and Recommendations.*** This chapter summarizes the major conclusions of the RI report and provides recommendations for further action.

- ***Chapter 9.0 – References.*** This chapter lists the references cited in this RI report.

2.0 Study Area Investigation

This chapter summarizes SI and RI field activities conducted by Shaw at the Training Area T-5 Sites, including UXO avoidance, environmental sampling and analysis, and groundwater monitoring well installation.

2.1 UXO Avoidance

UXO avoidance was performed at the Training Area, T-5 Sites following methodology outlined in the SAP. Shaw UXO personnel used a low-sensitivity magnetometer to perform a surface sweep of the parcels prior to site access. After the sites were cleared for access, sample locations were monitored by UXO personnel following procedures outlined in the SAP.

2.2 Environmental Sampling

The environmental sampling performed during the field investigations at the Training Area T-5 Sites included the collection of surface and depositional soil samples, subsurface soil samples, groundwater samples, surface water samples, and sediment samples for chemical analysis. The sample locations were determined by observing physical characteristics during site reconnaissance, by reviewing historical documents and aerial photographs, and based on the results of previous investigations. The sampling locations, media, and rationale are summarized in Table 2-1 and the sampling locations are shown on Figure 2-1.

SI field activities were initiated in October 2001 and were completed in March 2002. SI field activities included the installation of 21 monitoring wells, and the collection and analysis of 29 surface and depositional soil samples, 21 subsurface soil samples, 28 groundwater samples, and 2 surface water/sediment samples.

Based on the SI analytical data, which showed chlorinated VOCs in groundwater, an RI was deemed necessary to determine the nature and extent of contamination. RI field activities were conducted from October 2002 through August 2004. RI field activities included the installation of 27 monitoring wells, and the collection and analysis of 19 surface and depositional soil samples, 11 subsurface soil samples, 76 groundwater samples, and 3 surface water/sediment samples. Five monitoring wells at adjacent Parcel 232Q-X were also sampled as part of the RI at the Training Area T-5 Sites.

2.2.1 Surface and Depositional Soil Sampling

A total of 32 surface soil samples and 16 depositional soil samples were collected at the Training Area T-5 Sites, as shown on Figure 2-1. Soil sample designations and analytical parameters are listed in Table 2-2. Sampling locations were determined in the field by the on-site geologist based on UXO avoidance activities, sampling rationale, site features, and topography.

Sample Collection. Surface soil samples were collected from 0 to 1 foot below ground surface (bgs) using either a direct-push technology (DPT) sampling system or a stainless-steel hand auger, following the methodology specified in the SAP. Depositional soil samples were collected from approximately the upper 6 inches of soil using either a stainless-steel spoon or hand auger. Prior to collecting the samples, surface debris (e.g., rocks, vegetation) was removed from the immediate sample area. The soil was then collected with the sampling device and screened with a photoionization detector (PID) in accordance with procedures outlined in the SAP. The sample fraction for volatile organic compound (VOC) analysis was collected directly from the sample device using three EnCore® samplers. The remaining soil was then transferred to a clean stainless-steel bowl, homogenized, and placed in the appropriate sample containers. Sample collection logs are included in Appendix A. The samples were analyzed for the parameters listed in Table 2-2 using methods outlined in Section 2.4.

2.2.2 Subsurface Soil Sampling

Subsurface soil samples were collected from 32 soil borings at the Training Area T-5 Sites, as shown on Figure 2-1. One subsurface soil sample was collected from each boring. Subsurface soil sampling locations and rationale are presented in Table 2-1. Sample designations, depths, and analytical parameters are listed in Table 2-2. Soil boring locations were determined in the field by the on-site geologist based on UXO avoidance activities, sampling rationale, site features, and topography.

Sample Collection. Subsurface soil samples were collected from soil borings at depths ranging from 1 to 12 feet bgs in the unsaturated zone. The soil borings were advanced and the samples were collected using a DPT sampling system, following procedures specified in the SAP. Sample collection logs are included in Appendix A. The samples were analyzed for the parameters listed in Table 2-2 using methods outlined in Section 2.4.

Subsurface soil samples were collected continuously to a maximum depth of 12 feet bgs or until DPT refusal was encountered. Samples were screened using a PID to measure volatile organic vapors. The sample displaying the highest reading was selected and sent to the laboratory for analysis; however, at those locations where PID readings were below background, the deepest

soil sample interval above the saturated zone was submitted for analysis. Samples for VOC analysis were collected directly from the sample device using three EnCore samplers. The remaining soil was then transferred to a clean stainless-steel bowl, homogenized, and placed in the appropriate sample containers. The on-site geologist constructed a detailed boring log for each soil boring (Appendix B).

At the completion of soil sampling, the boreholes were abandoned by filling with bentonite pellets and hydrating with potable water, following borehole abandonment procedures presented in the SAP.

2.2.3 Monitoring Well Installation

Shaw installed 48 permanent monitoring wells at the Training Area T-5 Sites, including 37 residuum wells and 11 bedrock wells, to provide site-specific geological and hydrogeological data and to collect groundwater samples for laboratory analysis. Monitoring wells CWM-182-MW07 and CWM-182-MW10 are considered deep residuum wells. The well locations are shown on Figure 2-1. Table 2-3 summarizes monitoring well construction details. The well construction logs are included in Appendix B. The monitoring wells were installed following procedures outlined in the SAP.

Residuum Monitoring Wells. The borehole at each residuum monitoring well location was advanced with a 4¼-inch inside diameter (ID) hollow-stem auger from ground surface to the top of bedrock, except at well location CWM-514-MW13 where rotosonic drilling techniques were used. In wells installed using hollow-stem augers, a 2-foot-long, 2-inch ID carbon steel split-spoon sampler was driven at 5-foot intervals to collect residuum for observing and describing lithology. Where split-spoon refusal was encountered, the auger was advanced until the first water-bearing zone was encountered. The on-site geologist logging the auger boreholes continued the lithological log for each borehole from the depth of split-spoon sampler refusal to the bottom of the auger borehole by logging the drill cuttings. The drill cuttings were logged to determine lithologic changes and the approximate depth of groundwater encountered during drilling. This information was used to determine the optimal placement of the monitoring well screen interval and to provide site-specific geological and hydrogeological information. Soil characteristics were described using the "Burmeister Identification System" described in Hunt (1986) and the Unified Soil Classification System (USCS) as outlined in the American Society for Testing and Materials (ASTM) Method D 2488 (ASTM, 2000). The boring logs are included in Appendix B.

Upon reaching the target depth in each borehole, a 10- to 20-foot-length of 2-inch ID, 0.010-inch continuous slot, Schedule 40 polyvinyl chloride (PVC) screen with a PVC end cap was placed through the auger to the bottom of the borehole. The screen and end cap were attached to 2-inch ID, flush-threaded Schedule 40 PVC riser. A sand pack consisting of Number 1 filter sand (environmentally safe, clean fine silica sand, sieve size 20 to 40) was tremied around the well screen to approximately 5 feet above the top of the well screen as the augers were removed. In some of the deeper residuum wells (CWM-182-MW01, CWM-514-MW01, CWM-514-MW02, and CWM-514-MW03), approximately 5 feet of Number 0 extra fine sand (sieve size 30 to 70) was tremied in place after the sand pack was installed. The well was surged using a solid PVC surge block for approximately 10 minutes, or until no more settling of the sand pack occurred inside the borehole. A bentonite seal, consisting of approximately 2 to 5 feet of bentonite pellets, was placed immediately on top of the sand pack and hydrated with potable water. In wells where the bentonite seal was installed below the water table surface, the bentonite pellets were allowed to hydrate in the groundwater. Bentonite seal placement and hydration followed procedures in the SAP.

Bentonite-cement grout (described below) was tremied into the remaining annular space of the well. The surface completion consisted of placing a locking protective steel casing around the top of the PVC well casing, and installing a concrete pad around the wellhead. At well locations where the PVC casing extended above the ground surface, four protective steel posts were installed around the well pad.

Bedrock Monitoring Wells. With the exception of monitoring wells CWM-514-MW12 and CWM-514-MW15, which were installed using rotosonic drilling methods (see below), the bedrock wells and two deep residuum wells were installed using an air-rotary drill rig equipped with a 7⅞-inch or 12¼-inch tri-cone roller bit or an 8-inch ODEX® bit. The borehole at each well location was advanced from ground surface to approximately 5 feet into competent bedrock or 5 feet below the bottom of the adjacent residuum monitoring well. Eight-inch ID carbon steel International Pipe Standard (IPS) outer casing was installed from ground surface to the bottom of the borehole. A minimum of 2 inches of annular space was maintained between the outer casing and the borehole wall. The outer casing was grouted in place using a tremie pipe suspended in the annulus outside the casing. Bentonite-cement grout was mixed using approximately 6.5 to 7 gallons of water and 5 pounds of bentonite per 94-pound bag of Type II Portland cement. After the grout cured for a minimum of 48 hours, the borehole was advanced with a PQ wireline triple-tube core barrel with a longitudinally split inner tube to collect core samples from the bottom of the outer steel casing to the completion depth of the borehole. Bedrock cores were described according to the methodology outlined in USACE manual DM 1110-1-1 (USACE, 1983). After

completion of core sample collection, a 7⅞-inch air percussion or rotary bit was used to ream the hole to the total depth of the boring. Water was the only lubricant used during drilling operations.

At well locations CWM-514-MW12 and CWM-514-MW15, the borehole was initially advanced using a rotosonic drill rig equipped with 4-inch and 6-inch sonic bits. The borehole was extended approximately 5 feet into competent bedrock. The borehole was then reamed with a 10-inch sonic bit attached to temporary 10-inch steel casing. Permanent 6¼-inch or 8-inch ID carbon steel IPS outer casing was installed through the temporary casing from ground surface to the bottom of the borehole. A minimum of 2 inches of annular space was maintained between the inner permanent casing and the outer temporary casing. The permanent casing was then grouted in place as the temporary casing was removed from the borehole. After the grout cured for a minimum of 48 hours, the borehole was advanced with a bulk sample 4-inch core barrel and core samples were collected from the bottom of the outer steel casing to the completion depth of the borehole. Bedrock cores were described according to the methodology outlined in USACE manual DM 1110-1-1 (USACE, 1983).

Upon reaching the target depth in each borehole, a 2-inch monitoring well was installed through the outer casing, except at two locations (CWM-514-MW08 and CWM-514-MW10) where a 4-inch well was installed. The 2-inch well casing consisted of threaded, flush-joint, Schedule 40 PVC pipe. A 10- to 20-foot length of threaded, flush-joint, 0.010-inch continuous wrap PVC well screen was attached to the bottom of the 4-inch well casing. The 4-inch well casing for wells CWM-514-MW08 and CWM-514-MW10 consisted of threaded, flush-joint, Schedule 80 PVC pipe and 0.010-inch continuous wrap PVC well screen. A pre-packed well screen was installed in five wells (CWM-180-MW05, CWM-180-MW07, CWM-511-MW05, CWM-512-MW02, and CWM-514-MW04) because voids were encountered within the screened interval of the well. The pre-packed screen consisted of an outer Schedule 40 PVC factory slot screen and an inner Schedule 40 PVC continuous wrap well screen. A sand pack consisting of 20/40 silica sand was installed between the two well screens.

After the casing and screen materials were lowered into the boring, a sand pack consisting of Number 1 filter sand (environmentally safe, clean fine silica sand, sieve size 20 to 40) was tremied around the well screen to approximately 5 feet above the top of the well screen. A bentonite seal, consisting of a minimum of 5 feet of bentonite pellets, was placed on top of the filter pack and hydrated with potable water. In wells where the bentonite seal was installed below the water table surface, the bentonite pellets were allowed to hydrate in the groundwater. A bentonite-cement mixture (described above) was tremied into the remaining annular space. A

locking protective steel casing was placed around the top of the PVC well casing, and a concrete pad was constructed around the wellhead. At well locations where the PVC casing extended above the ground surface, four protective steel posts were installed around the well pad.

2.2.4 Well Development

The wells were developed by surging and pumping with a submersible pump in accordance with methodology outlined in the SAP. The submersible pump used for well development was moved in an up-and-down fashion to encourage any residual well installation materials to enter the well. These materials were then pumped out of the well to re-establish the natural hydraulic flow conditions. Development continued until the water turbidity was equal to or less than 20 nephelometric turbidity units (NTU), for a maximum of 8 hours (residuum wells) or 12 hours (bedrock wells), or until the well was repeatedly pumped dry and allowed to recharge. The well development logs are included in Appendix C.

2.2.5 Groundwater Sampling

A total of 102 groundwater samples were collected during SI/RI activities at the Training Area T-5 Sites. Eighty-eight samples were collected from the 48 monitoring wells installed during the investigations and an additional 14 samples were collected from five existing monitoring wells at adjacent Parcel 232Q-X. All monitoring wells were sampled at least once. The well/groundwater sample locations are shown on Figure 2-1. The groundwater sampling locations and rationale are listed in Table 2-1.

Sample Collection. Groundwater sampling was performed following procedures outlined in the SAP. Groundwater was sampled after purging a minimum of three well volumes and after field parameters (i.e., temperature, pH, dissolved oxygen, specific conductivity, oxidation-reduction potential, and turbidity) stabilized. Purging and sampling were performed with a mechanical pump (i.e., peristaltic, submersible, or bladder pump) equipped with Teflon™ tubing and/or using a Teflon bailer. In instances where a peristaltic pump was used for sampling, the samples for VOC analysis were collected via the "tube evacuation" method described in the SAP (IT, 2002c). Field parameters were measured using a calibrated water-quality meter, as summarized in Table 2-4. Sample collection logs are included in Appendix A. The samples were analyzed for the parameters listed in Table 2-5 using methods outlined in Section 2.4.

2.2.6 Water Level Measurements

The depth to groundwater was measured in the monitoring wells at the Training Area T-5 Sites and in select wells at adjacent Parcel 232Q-X in April and June 2003, and in May and September

2004, following procedures outlined in the SAP. Depth to groundwater was measured with an electronic water-level meter. The meter probe and cable were cleaned before use at each well, following decontamination methodology presented in the SAP. Measurements were referenced to the top of the PVC well casing, as summarized in Tables 2-6 and 2-7 for residuum wells and bedrock wells, respectively.

2.2.7 Surface Water Sampling

A total of five surface water samples were collected at the Training Area T-5 Sites from the locations shown on Figure 2-1. The sampling locations were determined in the field, based on the sampling rationale and actual field conditions.

Sample Collection. Surface water samples were collected in accordance with procedures specified in the SAP. The samples were collected by dipping a stainless-steel pitcher in the water and pouring the water into the sample containers or by dipping the sample containers directly in the water and allowing the water to fill the sample containers. The samples were collected after field parameters had been measured using a calibrated water quality meter. Surface water field parameters are summarized in Table 2-8. The sample collection logs are included in Appendix A. The samples were analyzed for the parameters listed in Table 2-9 using methods outlined in Section 2.4.

2.2.8 Sediment Sampling

Five sediment samples were collected at the same locations as the surface water samples at the Training Area T-5 Sites, as shown on Figure 2-1. Sampling locations were determined in the field, based on the sampling rationale and actual field conditions.

Sample Collection. Samples were collected from the upper 6 inches of sediment using either a stainless-steel spoon or hand auger and placed in a stainless-steel bowl, following procedures outlined in the SAP. The sample fraction for VOC analysis was then immediately collected from the bowl using three EnCore samplers. The remaining sample was then homogenized and placed in the appropriate sample containers. Sample collection logs are included in Appendix A. The samples were analyzed for the parameters listed in Table 2-9 using methods outlined in Section 2.4.

2.3 Surveying of Sample Locations

Monitoring well and sample locations were surveyed using global positioning system survey techniques and conventional civil survey techniques described in the SAP. Horizontal coordinates were referenced to the U.S. State Plane Coordinate System, Alabama East Zone,

North American Datum of 1983. Elevations were referenced to the North American Vertical Datum of 1988. Horizontal coordinates and elevations are included in Appendix D.

2.4 Analytical Program

Samples collected during the field investigations at the Training Area T-5 Sites were analyzed for various chemical parameters based on the potential site-specific chemicals and on EPA, ADEM, FTMC, and USACE requirements. Target analyses included the following parameters using EPA SW-846 methods, including Update III methods where applicable:

- Target compound list (TCL) VOCs – EPA Method 8260B
- TCL semivolatile organic compounds (SVOC) – EPA Method 8270C
- Target analyte list (TAL) metals – EPA Method 6010B/7000
- CWM breakdown products (including orthosulfur compounds) – EPA Methods 8321 and 8270 (modified).
- Nitroaromatic/nitramine explosives – EPA Method 8330 (Parcel 232Q-X samples only).
- Perchlorate – EPA Method 314.0 (Parcel 232Q-X samples only).
- Total organic carbon (TOC) – Walkley Black Method (sediment samples only).
- Grain size – ASTM Method D422 (sediment samples only).

2.5 Sample Preservation, Packaging, and Shipping

Sample preservation, packaging, and shipping followed requirements specified in the SAP. Sample containers, sample volumes, preservatives, and holding times for the analyses performed for this investigation are listed in the SAP. Sample documentation and chain-of-custody records (Appendix A) were completed as specified in the SAP.

Completed analysis request and chain-of-custody records were included with each shipment of samples to either EMAX Laboratories, Inc. in Torrance, California or to Severn Trent Laboratories in Knoxville, Tennessee.

2.6 Investigation-Derived Waste Management and Disposal

Investigation-derived waste (IDW) was managed and disposed as outlined in the SAP. IDW generated during the field investigations at the Training Area T-5 Sites was segregated as follows:

- Drill cuttings
- Purge water from well development, sampling activities, and decontamination fluids
- Spent well materials and personal protective equipment.

Solid IDW was stored in lined roll-off bins in the fenced area surrounding the Shaw field office prior to characterization and disposal. Solid IDW was characterized using toxicity characteristic leaching procedure analysis (EPA Method 1311) using the procedures described in the IDW Management Plan in the SAP. Based on the results, drill cuttings, spent well materials, and personal protective equipment generated prior to January 2002 were disposed as nonhazardous waste at the Industrial Waste Landfill on the Main Post of FTMC. Solid IDW generated after January 2002 was disposed as nonhazardous waste at the Three Corners Landfill located in Piedmont, Alabama.

Liquid IDW was contained in a sump located within the fenced area surrounding the Shaw field office and/or in portable tanks. Liquid IDW was characterized by VOC, SVOC, and metals analyses using the ADEM-approved procedure described in the IDW Management Plan in the SAP. Based on the analytical results, liquid IDW was discharged on the ground surface as nonhazardous, nonregulated waste or sent to the City of Anniston wastewater treatment plant for disposal.

2.7 Variances/Nonconformances

Four variances to the site-specific work plans were recorded during completion of field activities at the Training Area T-5 Sites. These variances did not alter the intent of the investigation or the sampling rationale presented in the work plans. The variances are summarized in Table 2-10 and copies of the variance reports are included in Appendix E.

No nonconformances were recorded during completion of the field investigations at the Training Area T-5 Sites.

2.8 Data Quality

The field sample analytical data are presented in tabular form in Appendix F. The field samples were collected, documented, handled, analyzed, and reported in a manner consistent with the site-specific work plans; the FTMC SAP and quality assurance plan; and standard, accepted methods and procedures. Data were reported and evaluated in accordance with Corps of

Engineers South Atlantic Savannah Level B criteria (USACE, 2001b) and the stipulated requirements for the generation of definitive data as described in the SAP. Chemical data were reported via hard-copy data packages by the laboratory using Contract Laboratory Program-like forms.

Data Validation. The reported analytical data were validated in accordance with EPA National Functional Guidelines by Level III criteria. The results of the data validation are summarized in data validation summary reports included in Appendix G. Selected results were rejected or otherwise qualified based on the implementation of accepted data validation procedures and practices. These qualified parameters are highlighted in the reports. The validation-assigned qualifiers were added to the ShawView™ database for tracking and reporting. The data presented in this report, except where qualified, meet the principle data quality objective for this investigation.

3.0 Physical Characteristics of Study Area

The physical characteristics of the Training Area T-5 Sites are important to understanding the current nature and extent of contamination and the future transport of contaminants. These characteristics can be described in terms of demography and land reuse, meteorology, physiography, sensitive environments, soils, geology, hydrology, and hydrogeology.

3.1 Demography and Land Reuse

FTMC includes 45,679 acres of government-owned and formerly leased land situated in the foothills of the Appalachian Mountains of northeast Alabama. The post is located in Calhoun County (population 112,249), approximately 60 miles northeast of Birmingham (population 242,820), approximately 75 miles northwest of Auburn (population 42,987), and approximately 90 miles west of Atlanta, Georgia (population 416,474). The city of Anniston (population 24,276) adjoins the Main Post on the south and west. The city of Weaver (population 2,619) is located approximately 1 mile northwest of the Main Post, and the city of Oxford (population 14,592) is approximately 5 miles south of Anniston. In Calhoun County, 0.2 percent of the total labor force is in the armed forces. Of the civilian labor force, the top five industries in which people are employed are: manufacturing (21.7 percent); educational, health, and social services (18.4 percent); retail trade (12.8 percent); public administration (8.0 percent); and construction (6.7 percent) (U.S. Census Bureau, 2000).

According to the *Fort McClellan Comprehensive Reuse Plan* (EDAW, Inc., 1997), the projected land use for the Training Area T-5 Sites includes mixed business use, passive recreation, and development reserve as follows:

- Parcel 180(7) – Mixed business use
- Parcel 182(7) – Primarily development reserve but also passive recreation.
- Parcel 511(7) – Mixed business use and passive recreation
- Parcel 512(7) – Mixed business use
- Parcel 513(7) – Primarily passive recreation but also development reserve
- Parcel 514(7) – Mixed business use and passive recreation
- Parcel 516(7) – Primarily passive recreation but also development reserve.

3.2 Meteorology

FTMC is situated in a temperate, humid climate. Summers are long and hot, and winters are usually short and mild to moderately cold. The climate is influenced by frontal systems moving from northwest to southeast, and temperatures change rapidly from warm to cool due to the inflow of northern air. The average annual temperature is 63 degrees Fahrenheit (°F). Summer

temperatures usually reach 90°F or higher about 70 days per year, but temperatures above 100°F are rare. Freezing temperatures are common in winter but are usually of short duration. The first frost may arrive by late October. Snowfall averages 0.5 to 1 inch. On rare occasions, several inches of snow accumulate from a single storm. At Anniston, the average date of the first 32°F temperature is November 6, and the last is March 30. This provides a growing season of 221 days (ESE, 1998).

The average annual rainfall is approximately 53 inches and is well distributed throughout the year. The more intense rains usually occur during the warmer months, and some flooding occurs nearly every year. Drought conditions are rare. Approximately 80 percent of the flood-producing storms are of the frontal type and occur in the winter and spring, lasting from 2 to 4 days each. Summer storms are usually thunderstorms with intense precipitation over small areas, sometimes resulting in local flooding. Occasionally, several wet years or dry years occur in series. Annual rainfall records indicate no characteristic order or pattern.

Winds in the FTMC area are seldom strong and frequently blow from the northwest. However, there is no truly persistent wind direction. Normally, only light breezes or calm prevail, except during passages of cyclonic disturbances, when destructive local wind storms develop, some into tornadoes, with winds of 100 miles per hour or more.

3.3 Physiography

All of FTMC except for the easternmost portion of the Choccolocco Corridor lies within the Valley and Ridge Physiographic Province. The easternmost portion of the Choccolocco Corridor lies within the Piedmont Physiographic Province. Local relief on the Main Post of FTMC is in excess of 1,320 feet. The lower elevations (700 feet amsl) occur along Cane Creek, near Baltzell Gate Road, while the maximum elevations (2,063 feet amsl) occur on Choccolocco Mountain, with the steep easterly slopes grading abruptly into Choccolocco Valley. The western slopes are more continuous, with the southern extension near the western reservation boundary maintaining elevations up to 900 feet amsl. The northern extension decreases in elevation in the vicinity of Reilly Airfield. The central portion of FTMC is characterized by flat to gently sloping land (SAIC, 2000).

All of the Training Area T-5 Sites except Parcel 182(7) are located within the valley area of the Fort McClellan geologic window, between Sunset Hill and Howitzer Hill. Parcel 182(7) straddles the window and the eastern edge of Sunset Hill. As shown on Figure 1-3, elevation across the sites ranges from a maximum of approximately 925 feet amsl at Parcel 182(7) to approximately 800 feet amsl at Parcel 511(7).

3.4 Sensitive Environments

3.4.1 Wetlands

A study conducted by Foster Wheeler in 1996 estimated over 3,000 acres of wetlands within FTMC. Major wetland communities were originally characterized and mapped in 1984. However, regulatory criteria for identifying wetlands have significantly changed since this original study was performed. Consequently, the USACE performed a supplementary study in 1992 to identify larger wetland complexes (Reisz Engineering [Reisz], 1998). The following are recognized wetland communities located within FTMC (Reisz, 1998): Bottomland Hardwoods, Depressions, Mixed Shrub Communities, Shrub Depression, and Herbaceous Wetlands.

Wetland habitats at FTMC are generally located in various topographical depressions, near stream seepage, and in valleys along creek floodplains (Weston, 1990; SAIC 1993). The indicator plant species that assist in defining a wetland include water oaks, sweet gum, bulrush, needlerush, and cattail. The Main Post, Pelham Range, and Choccolocco Corridor have an abundance of wetlands representing important habitats for a wide variety of plants and animals. The major wetland communities found on the Main Post are the Marcheta Hill Orchid Seep, Cane Creek Seep, South Branch of Cane Creek, and approximately 200 acres that comprise the tributary to Victoria Creek near Reilly Airfield (Garland, 1996; USACE, 1992). The major Pelham Range wetland communities occur along the banks of Cane Creek, Willett Spring, and Cabin Creek Spring (Alabama Department of Conservation and Natural Resources [ADCNR], 1994a and 1994b). Additionally, wetland habitat potentially exists around the installation's lakes, namely, Reilly Lake, Lake Contreras, Yahou Lake, and Lake Willett, and along the nearly 10 miles of creeks, namely, Cane Creek and Cave Creek (Weston, 1990).

No designated wetland areas are present within the Training Area T-5 Sites. The closest designated wetland area is located approximately 1 mile northwest of the site (IT, 2002b).

3.4.2 Sensitive Habitats

FTMC operated under the guidelines of the Endangered Species Act of 1973, the regulations of the U.S. Fish and Wildlife Service (USFWS), Army Regulation 200-3, *Natural Resources - Land, Forest and Wildlife Management,* and the Endangered Species Management Plan (ESMP) (Garland, 1996). The overall objectives of the ESMP are to sustain the existing habitat that supports populations of species identified in the ESMP and to promote the augmentation of these species into unoccupied land that has similar habitats.

The ESMP identifies 11 special interest natural areas (SINA) on the Main Post. SINAs are locations where the habitat fosters one or more rare, threatened, or endangered species. Because these species are sensitive to environmental degradation, SINAs require management practices that promote the continued well being of these ecosystems. According to the ESMP, the 11 SINAs located on the Main Post include:

- Mountain Longleaf Community Complex
- Cave Creek Seep
- Moorman Hill Mountain Juniper
- Frederick Hill Aster Site
- Baby Bains Gap Seep
- Marcheta Hill Crow-Poison Seep
- Marcheta Hill Orchid Seep
- South Branch of Cane Creek Seep
- Stanley Hill Chestnut Oak Forest
- Reynolds Hill Turkey Oak
- Davis Hill Honeysuckle.

No SINAs are present within the Training Area T-5 Sites. The closest SINA is located approximately 1.4 miles southwest of the site (IT, 2002b).

3.4.3 Threatened and Endangered Species

Rare species deserving unofficial protection and management measures in the State of Alabama are inventoried and ranked by the Alabama Natural Heritage Program. The sensitivity of these rare species to environmental degradation is used to gauge the well-being of the habitat as a whole. Four species listed as threatened or endangered by the USFWS have been recorded at FTMC:

- Gray bat (*Myotis grisescens*)
- Blue shiner (*Cyprinella caerules*)
- Mohr's barbara buttons (*Marshallia mohrii*)
- Tennessee yellow-eyed grass (*Xyris tennesseensis*).

An additional endangered species, the red-cockaded woodpecker (*Picoides borealis*), historically inhabited the installation but no longer exists at FTMC. The only federally listed species with the potential to occur in the vicinity of the Training Area T-5 Sites is the gray bat. However, this species roosts in caves and requires major surface water bodies for foraging. The closest major surface water body capable of providing gray bat foraging habitat is South Branch of Cane Creek, which is located approximately 1,600 feet northeast of the nearest Training Area T-5 parcel. Therefore, potential impacts to this species, if present, are considered unlikely.

Additional information on threatened and endangered species is presented in Chapter 7.0.

3.5 Soils

The soil associations found on the FTMC Main Post include (U.S. Department of Agriculture [USDA], 1961):

- ***Anniston-Allen, Decatur-Cumberland.*** Alluvium, resulting from weathering of older residual soils developed from sandstone, shale, and quartzite; deep, well-drained, level to moderately steep soils in valleys underlain by limestone and shale. Subsoil is dark red sandy clay loam. Cumberland and Decatur soils are dark reddish brown gravelly loam developed from weathered limestone.

- ***Rarden-Montevallo-Lehew.*** Moderately deep or shallow soils on ridgetops and steep slopes and in local alluvium in draws. Soils are developed from the residuum of shale and fine-grained, micaceous sandstone; reddish brown to dark gray-brown to yellow-brown silt loam, clay, or silty clay.

- ***Stony Rough Land.*** Shallow, steep, and stony soils formed from the weathering of sandstone, limestone, and Talladega Slate. Infiltration is slow; the soils contain many boulders and fragments with clayey residuum. This association underlies a large portion of the Main Post at FTMC.

In general, the soils are acidic to very strongly acidic (SAIC, 2000).

3.5.1 Site-Specific Soils

Soils at the Training Area T-5 Site fall primarily in the followings soil series:

- Anniston and Allen series
- Jefferson series.

The soils at Parcels 180(7), 182(7), 513(7), and 516(7) are mapped as the Anniston and Allen gravelly loam, 2 to 6 percent slopes, eroded (AcB2). The Anniston and Allen series of soils consist of strongly acid, deep, well-drained soils that have developed in old local alluvium. The parent material washed from the adjacent higher lying Linker, Muskingum, Enders, and Montevallo soils, which developed from weathered sandstone, shale, and quartzite. The surface sandstone and quartzite gravel and cobbles, as large as 8 inches in diameter, are on the surface and throughout the soil. The typical soil description is 2 to 10 feet of well-drained stony loam to clay loam over stratified local alluvium, limestone or shale bedrock. This mapping unit consists of friable soils that have developed in old alluvium on foot slopes and along the base of mountains. The color of the surface soil ranges from very dark brown and dark brown to reddish brown and dark reddish brown. The texture of subsoil ranges from light clay loam to clay or

silty clay loam. The alluvium ranges in thickness from 2 to more than 8 feet. Infiltration and runoff are medium, permeability is moderate, and the capacity for available moisture is high. Organic matter is moderately low (USDA, 1961).

Soils at Parcel 514(7) fall into the Anniston and Allen gravelly loams, 15 to 25 percent slopes, eroded (USDA, 1961). The general Anniston and Allen series is described above.

Soils at Parcels 511(7) and 512(7) are mapped as the Jefferson gravelly fine sandy loam, 2 to 6 percent slopes, eroded (USDA, 1961). The soils typically consist of 1.5 to 4 feet of well-drained, strongly acid soils that occur in small areas on fans and on foot slopes in the Choccolocco, Colvin and Coldwater Mountains (USDA, 1961). These soils typically have developed from old local alluviums that washed or sloughed from ridges of sandstone, shale, and Weisner quartzite. This mapping unit is friable soil developed from old local alluvium on foot slopes and fans along ridges and mountains. The surface soil is dark-grayish-brown fine sandy loam, and the subsoil is yellowish-brown, light fine sandy clay. Fragments as large as 8 inches in diameter are on the surface and throughout the soil.

3.6 Geology

The regional geology in the vicinity of FTMC and site-specific geology at the Training Area T-5 Sites are discussed in the following sections.

3.6.1 Regional Geology

Calhoun County includes parts of two physiographic provinces, the Piedmont Upland Province and the Valley and Ridge Province. The Piedmont Upland Province occupies the extreme eastern and southeastern portions of the county and is characterized by metamorphosed sedimentary rocks. The generally accepted range in age of these metamorphics is Cambrian to Devonian.

The majority of Calhoun County, including the Main Post of FTMC, lies within the Appalachian fold-and-thrust structural belt (Valley and Ridge Province), where southeastward-dipping thrust faults with associated minor folding are the predominant structural features. The fold-and-thrust belt consists of Paleozoic sedimentary rocks that have been asymmetrically folded and thrust-faulted, with major structures and faults striking in a northeast-southwest direction.

Northwestward transport of the Paleozoic rock sequence along the thrust faults has resulted in the imbricate stacking of large slabs of rock referred to as thrust sheets. Within an individual thrust sheet, smaller faults may splay off the larger thrust fault, resulting in imbricate stacking of

rock units within the individual thrust sheet (Osborne and Szabo, 1984). Geologic contacts in this region generally strike parallel to the faults, and repetition of lithologic units is common in vertical sequences. Geologic formations within the Valley and Ridge Province portion of Calhoun County have been mapped by Warman and Causey (1962), Osborne and Szabo (1984), and Moser and DeJarnette (1992) and vary in age from Lower Cambrian to Pennsylvanian.

The basal unit of the sedimentary sequence in Calhoun County is the Cambrian Chilhowee Group. The Chilhowee Group consists of the Cochran, Nichols, Wilson Ridge, and Weisner Formations (Osborne and Szabo, 1984) but in Calhoun County is either undifferentiated or divided into the Cochran and Nichols Formations and an upper, undifferentiated Wilson Ridge and Weisner Formation. The Cochran is composed of poorly sorted arkosic sandstone and conglomerate with interbeds of greenish gray siltstone and mudstone. Massive to laminated greenish gray and black mudstone makes up the Nichols Formation, with thin interbeds of siltstone and very fine-grained sandstone (Osborne et al., 1988). These two formations are mapped only in the eastern part of the county.

The Wilson Ridge and Weisner Formations are undifferentiated in Calhoun County and consist of both coarse-grained and fine-grained clastics. The coarse-grained facies appears to dominate the unit and consists primarily of coarse-grained, vitreous quartzite and friable, fine- to coarse-grained, orthoquartzitic sandstone, both of which locally contain conglomerate. The fine-grained facies consists of sandy and micaceous shale and silty, micaceous mudstone, which are locally interbedded with the coarse clastic rocks. The abundance of orthoquartzitic sandstone and quartzite suggests that most of the Chilhowee Group bedrock in the vicinity of FTMC belongs to the Weisner Formation (Osborne and Szabo, 1984).

The Cambrian Shady Dolomite overlies the Weisner Formation northeast, east, and southwest of the Main Post and consists of interlayered bluish gray or pale yellowish gray sandy dolomitic limestone and siliceous dolomite with coarsely crystalline, porous chert (Osborne et al., 1989). A variegated shale and clayey silt have been included within the lower part of the Shady Dolomite (Cloud, 1966). Material similar to this lower shale unit was noted in coreholes drilled by the Geologic Survey of Alabama (GSA) on FTMC (Osborne and Szabo, 1984). The character of the Shady Dolomite in the FTMC vicinity and the true assignment of the shale at this stratigraphic interval are still uncertain (Osborne, 1999).

The Rome Formation overlies the Shady Dolomite and locally occurs to the northwest and southeast of the Main Post, as mapped by Warman and Causey (1962) and Osborne and Szabo (1984), and immediately to the west of Reilly Airfield (Osborne and Szabo, 1984). The Rome

Formation consists of variegated, thinly interbedded grayish-red-purple mudstone, shale, and siltstone and greenish red and light gray sandstone, with locally occurring limestone and dolomite. The Conasauga Formation overlies the Rome Formation and occurs along anticlinal axes in the northeastern portion of Pelham Range (Warman and Causey, 1962; Osborne and Szabo, 1984) and the northern portion of the Main Post (Osborne et al., 1997). The Conasauga Formation is composed of dark gray, finely to coarsely crystalline, medium- to thick-bedded dolomite with minor shale and chert (Osborne et al., 1989).

Overlying the Conasauga Formation is the Knox Group, which is composed of the Copper Ridge and Chepultepec dolomites of Cambro-Ordovician age. The Knox Group is undifferentiated in Calhoun County and consists of light medium gray, fine to medium crystalline, variably bedded to laminated, siliceous dolomite and dolomitic limestone that weather to a chert residuum (Osborne and Szabo, 1984). The Knox Group underlies a large portion of the Pelham Range area.

The Ordovician Newala and Little Oak Limestones overlie the Knox Group. The Newala Limestone consists of light to dark gray, micritic, thick-bedded limestone with minor dolomite. The Little Oak Limestone consists of dark gray, medium- to thick-bedded, fossiliferous, argillaceous to silty limestone with chert nodules. These limestone units are mapped as undifferentiated at FTMC and in other parts of Calhoun County. The Athens Shale overlies the Ordovician limestone units. The Athens Shale consists of dark gray to black shale and graptolitic shale with localized interbedded dark gray limestone (Osborne et al., 1989). These units occur within an eroded "window" in the Jacksonville Thrust Sheet at FTMC and underlie much of the developed area of the Main Post.

Other Ordovician-aged bedrock units mapped in Calhoun County include the Greensport Formation, Colvin Mountain Sandstone, and Sequatchie Formation. These units consist of various siltstones, sandstones, shales, dolomites, and limestones and are mapped as one undifferentiated unit in some areas of Calhoun County. The only Silurian-age sedimentary formation mapped in Calhoun County is the Red Mountain Formation. This unit consists of interbedded red sandstone, siltstone, and shale with greenish gray to red silty and sandy limestone.

The Devonian Frog Mountain Sandstone consists of sandstone and quartzitic sandstone with shale interbeds, dolomudstone, and glauconitic limestone (Osborne et al., 1988). This unit locally occurs in the western portion of Pelham Range.

The Mississippian Fort Payne Chert and the Maury Formation overlie the Frog Mountain Sandstone and are composed of dark to light gray limestone with abundant chert nodules and greenish gray to grayish red phosphatic shale, with increasing amounts of calcareous chert toward the upper portion of the formation (Osborne and Szabo, 1984). These units occur in the northwestern portion of Pelham Range. Overlying the Fort Payne Chert is the Floyd Shale, also of Mississippian age, which consists of thin-bedded, fissile, brown to black shale with thin intercalated limestone layers and interbedded sandstone. Osborne and Szabo (1984) reassigned the Floyd Shale, which was mapped by Warman and Causey (1962) on the Main Post of FTMC, to the Ordovician Athens Shale based on fossil data.

The Pennsylvanian Parkwood Formation overlies the Floyd Shale and consists of medium to dark gray, silty clay shale and mudstone with interbedded light to medium gray, very fine to fine grained, argillaceous, micaceous sandstone. Locally the Parkwood Formation also contains beds of medium to dark gray argillaceous, bioclastic to cherty limestone and beds of clayey coal up to a few inches thick (Raymond et al., 1988). In Calhoun County, the Parkwood Formation is generally found within a structurally complex area known as the Coosa deformed belt. In the deformed belt, the Parkwood Formation and Floyd Shale are mapped as undifferentiated because their lithologic similarity and significant deformation make it impractical to map the contact (Thomas and Drahovzal, 1974; Osborne et al., 1988). The undifferentiated Parkwood Formation and Floyd Shale are found throughout the western quarter of Pelham Range.

The Jacksonville thrust fault is the most significant structural geologic feature in the vicinity of the Main Post of FTMC, both for its role in determining the stratigraphic relationships in the area and for its contribution to regional water supplies. The trace of the fault extends northeastward for approximately 39 miles between Bynum, Alabama, and Piedmont, Alabama. The fault is interpreted as a major splay of the Pell City fault (Osborne and Szabo, 1984). The Ordovician sequence that makes up the Eden thrust sheet is exposed at FTMC through an eroded window, or fenster, in the overlying thrust sheet. Rocks within the window display complex folding, with the folds being overturned and tight to isoclinal. The carbonates and shales locally exhibit well-developed cleavage (Osborne and Szabo, 1984). The FTMC window is framed on the northwest by the Rome Formation, north by the Conasauga Formation, northeast, east, and southwest by the Shady Dolomite, and southeast and southwest by the Chilhowee Group (Osborne et al., 1997). Two small klippen of the Shady Dolomite, bounded by the Jacksonville fault, have been recognized adjacent to the Pell City fault at the FTMC window (Osborne et al., 1997).

The Pell City fault serves as a fault contact between the bedrock within the FTMC window and the Rome and Conasauga Formations. The trace of the Pell City fault is also exposed

approximately nine miles west of the FTMC window on Pelham Range, where it traverses northeast to southwest across the western quarter of Pelham Range. The trace of the Pell City fault marks the boundary between the Pell City thrust sheet and the Coosa deformed belt.

The eastern three-quarters of Pelham Range is located within the Pell City thrust sheet, while the remaining western quarter of Pelham Range is located within the Coosa deformed belt. The Pell City thrust sheet is a large-scale thrust sheet containing Cambrian and Ordovician rocks. It is relatively less structurally complex than the Coosa deformed belt (Thomas and Neathery, 1982). The Pell City thrust sheet is exposed between the traces of the Jacksonville and Pell City faults along the western boundary of the FTMC window, and along the trace of the Pell City fault on Pelham Range (Thomas and Neathery, 1982; Osborne et al., 1988). The Coosa deformed belt is a narrow (approximately 5 to 20 miles wide) northeast-to-southwest-trending linear zone of complex structure (approximately 90 miles in length) consisting mainly of thin imbricate thrust slices. The structure within these imbricate thrust slices is often internally complicated by small-scale folding and additional thrust faults (Thomas and Drahovzal, 1974).

3.6.2 Site-Specific Geology

The Training Area T-5 Sites are located along the southwestern portion of the FTMC geologic window. All of the parcels are located within the window except for the southwestern portion of Parcel 182(7), which is located within the Jacksonville thrust sheet. As shown on Figure 3-1, the Jacksonville thrust fault cuts northwest-southeast across the central portion of Parcel 182(7), marking the fault contact between the undifferentiated Cambrian Chilhowee Group and younger Mississippian- and Ordovician-age formations (Osborne et al., 1997). Figure 3-1 reflects a revised geologic model of the area based on site-specific information obtained during the field investigations.

Site-specific geologic conditions were assessed using bedrock cores and lithologic logs prepared by Shaw. Cross sections showing site geology are presented on Figures 3-2 and 3-3. The cross section locations are shown on Figure 3-1. Lithologic logs constructed during drilling activities at the Training Area T-5 Sites are included in Appendix B.

In general, residuum at the Training Area T-5 Sites consists predominantly of light brown to brown to reddish brown to yellowish orange clay with lesser amounts of sand, silt, and gravel. The thickness of residuum along cross-section A-A' (Figure 3-2) increases from east to west, from approximately 20 feet to 75 feet. As shown on cross-section B-B', sand, sandstone, and chert gravel dominate the sequence in the southwestern part of Parcel 182(7) where over 90 feet of residuum is developed from the Chilhowee Group. The soil descriptions noted on the boring

logs are consistent with the mapped Anniston and Allen gravelly loam and the Jefferson gravelly fine sandy loam.

Bedrock shown on Figure 3-1 and on cross-sections A-A' and B-B' includes undifferentiated Mississippian/Ordovician Floyd and Athens Shale and undifferentiated Ordovician Little Oak and Newala Limestones. The limestone lithology is present beneath residuum along the axis of an east-west trending, westward-plunging anticline (Figure 3-2). The limestone is moderately hard, slightly to highly weathered, highly fractured, locally interbedded with gray to black shale and consistent with the undifferentiated Little Oak and Newala Limestone. Voids, some filled with clay or limestone gravel, are present in the limestone. The shale lithology occurs in a syncline to the south, and in the northern part of the area on the north limb of the anticline (Figure 3-3). The shale is slightly to highly weathered, soft to moderately hard, highly fractured, dark gray to black with contorted calcite veins and is typical of the undifferentiated Floyd and Athens Shale. A structure contour map on the top of bedrock is presented as Figure 3-4. The map shows the general axis of the anticline shown on Figure 3-1. In addition, a structural low is evident in the area between Parcels 514(7) and 180(7). This low may represent a collapse feature developed in the limestone lithology.

3.7 Surface Water Hydrology

The regional surface water hydrology in the vicinity of FTMC and site-specific surface water hydrology at the Training Area T-5 Sites are discussed in the following sections.

3.7.1 Regional Surface Water Hydrology

Portions of three drainage basins (Cane Creek, Choccolocco Creek, and Tallasseehatchee Creek) are found within the Main Post of FTMC. All three of these drainage basins eventually empty into the Coosa River, approximately 16 miles west of the Main Post. Figure 3-5 shows the surface water hydrology and drainage basins of the Main Post and Choccolocco Corridor.

The Choccolocco Mountains located in the eastern portion and the Skeleton Mountains located in the southern portion of the Main Post form a major surface water divide. East of the Choccolocco Mountains, FTMC consists of a narrow strip called Choccolocco Corridor, which extends approximately 3.5 to 4 miles from the mountains across the floodplain of Choccolocco Creek to the base of Rattlesnake Mountain. Choccolocco Creek and its tributaries drain all of Choccolocco Corridor and the eastern and southernmost portions of the Main Post (Figure 3-5). The Choccolocco Creek drainage basin covers approximately 7.5 square miles of the Main Post.

On the western side of the Choccolocco Mountains are the Cane Creek and Tallasseehatchee Creek drainage basins (Figure 3-5). The headwaters of the Cane Creek drainage basin originate in the Choccolocco Mountains and flow west through the Main Post. Cane Creek has four named tributaries within the Main Post: Cave Creek, Remount Creek, South Branch of Cane Creek, and Ingram Creek. Although Cave Creek is a tributary to Cane Creek, it occurs as a separate drainage basin within the confines of the Main Post. Cave Creek eventually joins Cane Creek off-post east of the unincorporated development of Sherman Heights, near McMinn Airfield. Cane Creek and its tributaries receive surface runoff from the central portion of the Main Post and exit the reservation at Baltzell Gate. Cave Creek and its unnamed tributaries drain the north-central portion of the Main Post. Cave Creek exits the Main Post near the unincorporated development of Sherman Heights. The on-post drainage area of the Cane Creek basin covers approximately 19.6 square miles.

The Tallasseehatchee Creek drainage basin drains the northernmost portion of the Main Post (Figure 3-5). Most of the surface runoff from this portion of the Main Post collects in unnamed tributaries to Reilly Lake. Reilly Lake empties into Dothard Creek, a tributary to Tallasseehatchee Creek, and exits the Main Post northwest of Reilly Airfield. The Tallasseehatchee drainage basin covers approximately 2.5 square miles of the Main Post.

Most surface water bodies are fed, at least in part, by freshwater springs. Freshwater springs occur abundantly on installation lands, often appearing along the trace of thrust faults. Karst features, including developed caves and sinkholes, have been identified in the FTMC area (SAIC, 2000).

Freshwater marshes are located along Cane Creek; most are limited to the cumulatively larger downstream watershed of Pelham Range. Only one major marsh area, the 25-acre marsh near Reilly Lake, occurs on the Main Post (SAIC, 2000).

3.7.2 Site-Specific Surface Water Hydrology

Surface water drainage at the Training Area T-5 Sites follows the general topography and flows to the northeast, eventually emptying into South Branch of Cane Creek approximately 1,600 feet northeast of Parcel 511(7). Overland flow occurs westward off Howitzer Hill towards Parcels 511(7) and 512(7) and two small intermittent streams drain eastward off Sunset Hill across the northern end of Parcel 182(7). A larger intermittent stream flows northward parallel to the eastern boundary of Parcels 182(7) and 513(7) and the western boundary of Parcels 511(7) and 512(7). Several drainage ditches are also present and additionally assist in the discharge of surface water from the sites and transport to South Branch of Cane Creek.

3.8 Hydrogeology

The regional hydrogeology in the vicinity of FTMC and site-specific hydrogeology at the Training Area T-5 Sites are discussed in the following sections.

3.8.1 Regional Hydrogeology

The hydrogeology of Calhoun County has been investigated by the GSA (Moser and DeJarnette, 1992) and by the U.S. Geological Survey (USGS) in cooperation with the GSA (Warman and Causey, 1962) and ADEM (Planert and Pritchette, 1989). Groundwater near FTMC occurs in residuum derived from bedrock decomposition along fault zones within fractured bedrock and from the development of karst frameworks. Groundwater flow may be estimated to be toward major surface water features. Areas with well-developed residuum horizons may subtly reflect the surface topography, but the groundwater flow direction also may exhibit the influence of existing structural fabrics or the presence of perched water horizons on unweathered ledges or impermeable clay lenses.

Precipitation and subsequent infiltration provide recharge to the groundwater flow system in the region. The main recharge areas for the aquifers in Calhoun County are located in the valleys. The ridges generally consist of sandstone, quartzite, and slate, which are resistant to weathering, relatively unaffected by faulting and, therefore, relatively impermeable. The ridges have steep slopes and thin to no soil cover, which enhances runoff to the edges of the valleys (Planert and Pritchette, 1989).

The thrust fault zones typical of the county form large storage reservoirs for groundwater. Points of discharge occur as springs, effluent streams, and lakes. Coldwater Spring is one of the largest springs in the State of Alabama, with a discharge of approximately 32 million gallons per day. This spring is the main source of water for the Anniston Water Department, from which FTMC purchases its water. The spring is located approximately 5 miles southwest of Anniston and discharges from the brecciated zone of the Jacksonville Fault (Warman and Causey, 1962).

Shallow groundwater on FTMC occurs principally in the residuum developed from Cambrian sedimentary and carbonate bedrock units of the Weisner Formation and the Shady Dolomite and locally in Lower Ordovician carbonates. The residuum may yield adequate groundwater for domestic and livestock needs but may go dry during prolonged dry weather. Groundwater within the residuum serves as a recharge reservoir for the underlying bedrock aquifers. Bedrock permeability is locally enhanced by fracture zones associated with thrust faults and by the development of solution (karst) features.

Two major aquifers were identified by Planert and Pritchette (1989), the Knox-Shady and Tuscumbia-Fort Payne aquifers. The continuity of the aquifers has been disrupted by the complex geologic structure of the region, such that each major aquifer occurs repeatedly in different areas. The Knox-Shady aquifer group occurs over most of Calhoun County and is the main source of groundwater in the county. It consists of Cambrian- and Ordovician-aged quartzite and carbonates. The Conasauga Formation is the most utilized unit of the Knox-Shady aquifer, with twice as many wells drilled as any other unit (Moser and DeJarnette, 1992). There are no potable water supply wells within a 1-mile radius of the Training Area T-5 Sites.

The Tuscumbia-Fort Payne aquifer occurs in the extreme northwestern portion of the county. This aquifer consists of Mississippian-age carbonates and shales. Because of its limited outcrops in the recharge area and the rugged terrain of the outcrop area, the Tuscumbia-Fort Payne aquifer is not considered a major groundwater supply in Calhoun County (Moser and DeJarnette, 1992). However, it is an important source of groundwater in counties to the west (Planert and Pritchette, 1989).

Regional groundwater flow in the bedrock was approximated for the FTMC vicinity by the USGS (Scott et al., 1987). Regional groundwater elevation ranged from 800 feet amsl on the Main Post to approximately 600 feet amsl to the west on Pelham Range, based on water depths in wells completed across multiple formations. Groundwater elevation contours suggest that regional groundwater flow is from the Main Post to the northwest. There is not enough groundwater data to support this interpretation. Scott et al. (1987) concluded that the groundwater surface broadly coincides with the surface topography and that the regional aquifers are hydraulically connected. Groundwater flow on a local scale may be more complex and may be affected by geological structures such as the shallow thrust faults, rock fracture systems, and karst development in soluble formations.

Shallow groundwater occurs in weathered residuum derived from the bedrock and thin sediment deposits that are very similar to the decomposed rock. The shallow groundwater more closely follows the local topography.

3.8.2 Site-Specific Hydrogeology

Groundwater elevations were measured in monitoring wells at the Training Area T-5 Sites in May and September 2004, as summarized in Tables 2-6 and 2-7. Groundwater elevations were calculated by measuring the depth to groundwater relative to the top-of-casing elevations in the wells. Groundwater elevation maps for both the residuum and bedrock aquifers are provided on

Figures 3-6 through 3-9. The two water level measurement events were intended to capture data from a generally above-average period of precipitation (May 2004) and from a typically below-average period of precipitation (September 2004).

Based on the groundwater elevation data presented on Figures 3-6 and 3-7, groundwater flow within the residuum generally conforms to surface topography. Both the May 2004 and September 2004 data sets show an overall northerly to northeasterly flow direction. A broad groundwater low is present between Parcels 514(8) and 180(7). The bedrock data (Figures 3-8 and 3-9) also support a northerly flow direction within the underlying shale and limestone interval. The bedrock flow is also influenced by a generalized groundwater low between Parcels 514(7) and 180(7). The lows in groundwater flow in the residuum and bedrock coincide with the top-of-bedrock structural low discussed previously (Figure 3-4).

Aquifer Characteristics. Over most of the Training Area T-5 Sites, the average horizontal hydraulic gradient in both the residuum and bedrock aquifers is moderate. The head difference across the area is approximately 103 feet in residuum and approximately 35 feet in bedrock. Horizontal hydraulic gradients were calculated using both the May 2004 and September 2004 water level data. Within the residuum, hydraulic gradients are higher in the western part of the Training Area T-5 Sites and diminish with decreasing topography towards the east and north. Hydraulic gradients in the bedrock are somewhat higher. Average hydraulic gradients of 0.031 feet per foot (ft/ft) for residuum and 0.065 ft/ft for bedrock were calculated (Table 3-1).

Vertical hydraulic gradients between residuum and bedrock were calculated for seven well clusters, as presented in Table 3-2. The gradients were calculated from hydraulic head differences for groundwater elevations for May 2004 and September 2004. Five of the well clusters compare vertical gradients in monitoring wells where contaminants were detected in both the residuum and underlying limestone bedrock. For two of the well clusters (CWM-514-MW05/CWM-514-MW06 and CWM-514-MW07/CWM-514-MW08) comparison is between residuum and shale bedrock. Vertical hydraulic gradients in the well clusters where contaminants were detected in both wells exhibit strong to weak downward gradients (positive values). The downward gradients support connectivity between the two aquifer zones. Vertical hydraulic gradients between the two sets of residuum and shale bedrock wells exhibit either a weak downward gradient (at CWM-514-MW05/CWM-514-MW06) or a moderate upward gradient (at CWM-514-MW07/CWM-514-MW08). This supports general confined aquifer conditions.

Slug tests were not conducted during the RI field activities. Therefore, hydraulic conductivity values could not be calculated for rising or falling head tests.

4.0 Nature and Extent of Contamination

This chapter summarizes the sample analytical results to evaluate the nature and extent of contamination at the Training Area T-5 Sites. In addition, information is provided on potential sources of contamination.

4.1 Summary of Analytical Results

The results of the chemical analysis of samples collected indicate that metals, VOCs, and SVOCs were detected in the various site media. In addition, one CWM breakdown product was detected in four soil samples. To evaluate the nature and extent of contamination, the analytical results were compared to human health site-specific screening levels (SSSL), ecological screening values (ESV), and background screening values for FTMC. Site metals data were further evaluated using statistical and geochemical methods to determine if the metals detected in site media are naturally occurring (Shaw, 2003). The statistical and geochemical evaluation is presented in Appendix H.

The SSSLs and ESVs were developed by Shaw as part of human health and ecological risk evaluations associated with investigations performed under the BRAC Environmental Restoration Program at FTMC. The SSSLs and ESVs are presented in the *Final Human Health and Ecological Screening Values and PAH Background Summary Report* (IT, 2000c). Background metals screening values are presented in the *Final Background Metals Survey Report, Fort McClellan, Alabama* (SAIC, 1998). Complete human health and ecological risk assessments are provided in Chapters 6.0 and 7.0, respectively, of this report.

The following sections and Tables 4-1 through 4-5 summarize the results of the comparison of detected constituents to the SSSLs, ESVs, and background screening values. Complete analytical results are presented in Appendix F.

4.1.1 Surface and Depositional Soil Analytical Results

Forty-eight surface soil and depositional soil samples were collected for chemical analysis during the SI and RI at the Training Area T-5 Sites. The surface and depositional soil samples were collected from the uppermost foot of soil at the locations shown on Figure 2-1. Analytical results were compared to residential human health SSSLs, ESVs, and background screening values as presented in Table 4-1.

Metals. All of the surface and depositional soil samples were analyzed for metals. A total of 23 metals were detected in the samples. The concentrations of eight metals (aluminum, antimony, arsenic, chromium, iron, manganese, thallium, and vanadium) exceeded SSSLs. Of these metals, the following seven metals exceeded their respective background concentrations in one or more samples each:

- Aluminum (16,500 to 28,400 mg/kg) exceeded its SSSL (7,803 mg/kg) and background (16,306 mg/kg) at 17 sample locations.

- Antimony (5.68 mg/kg) exceeded its SSSL (3.11 mg/kg) and background (1.99 mg/kg) at one sample location (CWM-514-MW01). The analytical result was flagged with a "B" data qualifier indicating that antimony was also detected in an associated laboratory or field blank sample.

- Arsenic (15.5 to 38.3 mg/kg) exceeded its SSSL (0.4 mg/kg) and background (13.7 mg/kg) at four sample locations (CWM-180-MW01, CWM-180-MW03, CWM-180-MW04, and CWM-513-MW01).

- Chromium (41 to 63.6 mg/kg) exceeded its SSSL (23.2 mg/kg) and background (37 mg/kg) at three sample locations (CWM-180-MW03, CWM-180-MW08, and CWM-183-DEP10).

- Iron (34,400 to 132,000 mg/kg) exceeded its SSSL (2,345 mg/kg) and background (34,154 mg/kg) at seven sample locations.

- Manganese (1,710 to 5,040 mg/kg) exceeded its SSSL (363 mg/kg) and background (1,579 mg/kg) at three sample locations (CWM-182-DEP04, CWM-182-DEP09, and CWM-182-DEP10).

- Vanadium (59.4 and 95.1 mg/kg) exceeded its SSSL (53.1 mg/kg) and background (58.8 mg/kg) at two sample locations (CWM-180-MW03 and CWM-514-MW09).

Seventeen metals were detected at concentrations exceeding ESVs and background concentrations in one or more samples:

- Aluminum (16,500 to 28,400 mg/kg) exceeded its ESV (50 mg/kg) and background (16,306 mg/kg) at 17 sample locations.

- Antimony (5.68 mg/kg) exceeded its ESV (3.5 mg/kg) and background (1.99 mg/kg) at one sample location (CWM-514-MW01). The analytical result was flagged with a "B" data qualifier indicating that antimony was also detected in an associated laboratory or field blank sample.

- Arsenic (15.5 to 38.3 mg/kg) exceeded its ESV (10 mg/kg) and background (13.7 mg/kg) at four sample locations (CWM-180-MW01, CWM-180-MW03, CWM-180-MW04, and CWM-513-MW01).

- Barium (192 to 374 mg/kg) exceeded its ESV (165 mg/kg) and background (124 mg/kg) at three sample locations (CWM-182-DEP04, CWM-182-DEP09, and CWM-516-MW02).

- Beryllium (1.12 to 2.41 mg/kg) exceeded its ESV (1.1 mg/kg) and background (0.8 mg/kg) at seven sample locations.

- Cadmium (1.77 to 2.72 mg/kg) exceeded its ESV (1.6 mg/kg) and background (0.29 mg/kg) at four sample locations (CWM-180-DEP01, CWM-511-DEP01, CWM-511-DEP02, and CWM-513-DEP01).

- Chromium (41 to 63.6 mg/kg) exceeded its ESV (0.4 mg/kg) and background (37 mg/kg) at three sample locations (CWM-180-MW03, CWM-180-MW08, and CWM-182-DEP10).

- Cobalt (20.1 and 30 mg/kg) exceeded its ESV (20 mg/kg) and background (15.2 mg/kg) at two sample locations (CWM-180-MW03 and CWM-182-DEP08).

- Copper (43.5 to 199 mg/kg) exceeded its ESV (40 mg/kg) and background (12.7 mg/kg) at five sample locations.

- Iron (34,400 to 132,000 mg/kg) exceeded its ESV (200 mg/kg) and background (34,154 mg/kg) at seven sample locations.

- Lead (51.5 and 66.2 mg/kg) exceeded its ESV (50 mg/kg) and background (40 mg/kg) at two sample locations (CWM-182-DEP04 and CWM-514-MW07).

- Manganese (1,710 to 5,040 mg/kg) exceeded its ESV (100 mg/kg) and background (1,579 mg/kg) at three sample locations (CWM-182-DEP04, CWM-182-DEP09, and CWM-182-DEP10).

- Mercury (0.11 mg/kg) exceeded its ESV (0.1 mg/kg) and background (0.08 mg/kg) at one sample location (CWM-182-DEP08).

- Nickel (30.6 to 36.9 mg/kg) exceeded its ESV (30 mg/kg) and background (10.3 mg/kg) at two sample locations (CWM-182-MW04 and CWM-514-MW07).

- Selenium (0.81 to 3.4 mg/kg) exceeded its ESV (0.81 mg/kg) and background (0.48 mg/kg) at 16 sample locations. Four of the 16 results were flagged with a "B" data qualifier indicating that selenium was also detected in an associated laboratory or field blank sample.

- Vanadium (59.4 and 95.1 mg/kg) exceeded its ESV (2 mg/kg) and background (58.8 mg/kg) at two sample locations (CWM-180-MW03 and CWM-514-MW09).

- Zinc (56.8 to 1,170 mg/kg) exceeded its ESV (50 mg/kg) and background (40.6 mg/kg) at 14 sample locations.

The statistical and geochemical evaluation concluded that concentrations of barium (at sample location CWM-516-MW02), cadmium (CWM-180-DEP01, CWM-511-DEP01, CWM-511-DEP02, CWM-511-MW06, and CWM-513-DEP01), copper (CWM-182-DEP03, CWM-182-DEP04, and CWM-511-DEP01), and zinc (CWM-182-DEP03) were anomalously high and may be indicative of contamination. As noted above, these metals results exceeded ESVs but were below SSSLs.

Volatile Organic Compounds. All of the surface and depositional soil samples were analyzed for VOCs. A total of 15 VOCs were detected in the samples (Table 4-1). VOC concentrations in surface soils ranged from 0.00096 to 0.88 mg/kg and all results were below SSSLs. The concentrations of two VOCs exceeded their ESVs:

- Trichloroethene (0.0021 and 0.051 mg/kg) exceeded its ESV (0.001 mg/kg) at two sample locations (CWM-182-DEP07 and CWM-514-MW09).

- 1,1,2,2-Tetrachloroethane (0.11 mg/kg) exceeded its ESV (0.1 mg/kg) at sample location CWM-514-MW09.

Semivolatile Organic Compounds. All of the surface soil samples were analyzed for SVOCs. A total of 15 SVOCs, including 13 PAH compounds, were detected in the samples (Table 4-1). The concentrations of five PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene) exceeded SSSLs. Of these PAHs, all except dibenz(a,h)anthracene also exceeded their respective background concentrations at sample location CWM-180-MW06:

- Benzo(a)anthracene, 3.3 mg/kg (SSSL=0.85 mg/kg; background=1.2 mg/kg).
- Benzo(a)pyrene, 2.8 mg/kg (SSSL=0.085 mg/kg; background=1.42 mg/kg).
- Benzo(b)fluoranthene, 4.5 mg/kg (SSSL=0.85 mg/kg; background=1.66 mg/kg).
- Indeno(1,2,3-cd)pyrene, 1.8 mg/kg (SSSL=0.85 mg/kg; background=0.94 mg/kg).

The concentrations of five PAHs exceeded ESVs: anthracene, benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene. Of these PAHs, all except anthracene exceeded their respective background concentrations at sample location CWM-180-MW06:

- Benzo(a)pyrene, 2.8 mg/kg (ESV=0.1 mg/kg; background=1.42 mg/kg).
- Fluoranthene, 7.7 mg/kg (ESV=0.1 mg/kg; background=2.0 mg/kg).
- Phenanthrene, 1.5 mg/kg (ESV=0.1 mg/kg; background=1.1 mg/kg).
- Pyrene, 5.5 mg/kg (ESV=0.1 mg/kg; background=1.6 mg/kg).

CWM Breakdown Products. All of the surface and depositional samples were analyzed for CWM breakdown products. Methylphosphonic acid was detected at one sample location (CWM-180-MW08) at a concentration (0.06 mg/kg) below its SSSL (621 mg/kg). An ESV for methylphosphonic acid was not available.

4.1.2 Subsurface Soil Analytical Results

Thirty-two subsurface soil samples were collected for chemical analysis during the SI and RI at the Training Area T-5 Sites. Subsurface soil samples were collected at depths ranging from 1 to 12 feet bgs at the locations shown on Figure 2-1. Analytical results were compared to residential human health SSSLs and background screening values as presented in Table 4-2.

Metals. All of the subsurface soil samples were analyzed for metals. A total of 22 metals were detected in the samples. The concentrations of nine metals exceeded their respective SSSLs and background concentrations:

- Aluminum (15,200 to 41,000 mg/kg) exceeded its SSSL (7,803 mg/kg) and background (13,591 mg/kg) at 23 sample locations.

- Antimony (5.18 and 5.82 mg/kg) exceeded its SSSL (3.11 mg/kg) and background (1.31 mg/kg) in two sample locations (CWM-180-MW01 and CWM-180-MW03).

- Arsenic (22.2 to 30.7 mg/kg) exceeded its SSSL (0.43 mg/kg) and background (18.3 mg/kg) at five sample locations.

- Barium (1,400 mg/kg) exceeded its SSSL (547 mg/kg) and background (234 mg/kg) at sample location CWM-180-MW05.

- Chromium (38.6 and 51 mg/kg) exceeded its SSSL (23.2 mg/kg) and background (38.3 mg/kg) at two sample locations (CWM-180-MW08 and CWM-513-MW01).

- Iron (47,300 to 57,400 mg/kg) exceeded its SSSL (2,345 mg/kg) and background (44,817) at six sample locations.

- Manganese (2,490 to 9,290 mg/kg) exceeded its SSSL (363 mg/kg) and background (1,355 mg/kg) at four sample locations.

- Thallium (1.65 to 2.13 mg/kg) exceeded its SSSL (0.51 mg/kg) and background (1.4 mg/kg) at three sample locations (CWM-180-MW08, CWM-514-MW05, and CWM-514-MW07).

- Vanadium (65.5 mg/kg) exceeded its SSSL (53.1 mg/kg) and background (64.9 mg/kg) at sample location CWM-514-MW02.

The statistical and geochemical evaluation determined that all of the metals detected in subsurface soil are naturally occurring.

Volatile Organic Compounds. All of the subsurface soil samples were analyzed for VOCs. A total of 11 VOCs were detected in the samples (Table 4-2). The majority of the VOC results were flagged with either a "J" or "B" data qualifier, indicating that the concentrations were estimated or that the compounds were detected in a laboratory or field blank sample. VOC concentrations in subsurface soils ranged from 0.0012 to 0.23 mg/kg and all results were below SSSLs.

Semivolatile Organic Compounds. All of the subsurface soil samples were analyzed for SVOCs. A total of 11 SVOCs, including 10 PAH compounds, were detected in five of the samples (Table 4-2). Only one compound (benzo[a]pyrene) was detected at concentrations exceeding its SSSL. Benzo(a)pyrene concentrations (0.17 to 0.22 mg/kg) exceeded its SSSL (0.085 mg/kg) at three sample locations (CWM-180-MW06, CWM-511-MW01 and CWM-511-MW03).

CWM Breakdown Products. All of the subsurface soil samples were analyzed for CWM breakdown products. One compound (methylphosphonic acid) was detected at three sample locations (CWM-180-MW06, CWM-180-MW08, and CWM-514-MW11) at estimated concentrations (0.05 to 0.058 mg/kg) below its SSSL (621 mg/kg).

4.1.3 Groundwater Analytical Results

A total of 102 groundwater samples were collected for chemical analysis from the 48 monitoring wells installed at the Training Area T-5 Sites and from five peripheral monitoring wells located at Parcel 232Q-X. The sample locations are shown on Figure 2-1. Analytical results were compared to residential human health SSSLs and metals background screening values, as presented in Table 4-3.

Dissolved Metals. One groundwater sample collected from CWM-180-MW05 was analyzed for dissolved metals top provide data on the degree of metals adsorption to particulates in

groundwater. A total of 14 metals were detected in the sample. The concentrations of four metals (aluminum, arsenic, chromium, and iron) exceeded SSSLs but were below their respective background concentrations (note: a background value for chromium was not available).

Total Metals. Seventy-four groundwater samples were analyzed for total metals. A total of 21 metals were detected in the samples. The concentrations of 12 metals exceeded SSSLs: aluminum, arsenic, barium, beryllium, cadmium, chromium, iron, lead, manganese, nickel, thallium, and vanadium. Of these, the following ten metals also exceeded their respective background concentrations in one or more samples:

- Aluminum (2.68 to 26.1 mg/L) exceeded its SSSL (1.56 mg/L) and background (2.34 mg/L) in five samples from five wells.

- Arsenic (0.028 mg/L) exceeded its SSSL (0.00004 mg/L) and background (0.018 mg/L) in one sample from CWM-180-MW05.

- Barium (0.13 to 1.05 mg/L) exceeded its SSSL (0.11 mg/L) and background (0.13 mg/L) in 12 samples from 8 wells.

- Beryllium (0.0064 mg/L) exceeded its SSSL (0.0031 mg/L) and background (0.0013 mg/L) in the sample collected from CWM-180-MW05.

- Cadmium (0.0066 and 0.0077 mg/L) exceeded its SSSL (0.0008 mg/L) and background (0.0025 mg/L) in the samples collected from wells CWM-514-MW05 and HR-232QX-MW10. The cadmium result at sample location HR-232QX-MW10 was flagged with a "B" data qualifier indicating that the metal was also detected in an associated laboratory or field blank sample.

- Iron (7.68 to 59.6 mg/L) exceeded its SSSL (0.47 mg/L) and background (7.04 mg/L) in six samples from five wells.

- Lead (0.057 mg/L) exceeded its SSSL (0.015 mg/L) and background (0.008 mg/L) in one sample from CWM-180-MW05.

- Manganese (0.63 to 7.07 mg/L) exceeded its SSSL (0.07 mg/L) and background (0.58 mg/L) in 25 samples from 19 wells.

- Thallium (0.005 to 0.007 mg/L) exceeded its SSSL (0.0001 mg/L) and background (0.0015) in four samples from four wells. Three of the four thallium results were flagged with a "B" data qualifier indicating that the metal was also detected in an associated laboratory or field blank sample.

- Vanadium (0.048 mg/L) exceeded its SSSL (0.011 mg/L) and background (0.017 mg/L) in one sample from CWM-180-MW05.

It should be noted that background values were not available for chromium and nickel, which exceeded their SSSLs in five samples and three samples, respectively. The statistical and geochemical evaluation concluded that all of the metals detected in groundwater are naturally occurring.

Volatile Organic Compounds. All of the groundwater samples were analyzed for VOCs. A total of 21 VOCs were detected in the samples at concentrations ranging from 0.00014 to 20 mg/L. The concentrations of ten VOCs exceeded their respective SSSLs:

- 1,1,2,2-Tetrachlorethane (0.00031 to 0.29 mg/L) exceeded its SSSL (0.0002 mg/L) in 17 samples from 10 wells.

- 1,1,2-Trichloroethane (0.00079 to 0.0023 mg/L) exceeded its SSSL (0.0007 mg/L) in four samples from two wells (CWM-514-MW03 and CWM-514-MW09).

- 1,1-Dichloroethene (0.00065 mg/L) exceeded its SSSL (0.00009 mg/L) in one sample from CWM-514-MW04.

- 1,2-Dichloroethane (0.00066 mg/L) exceeded its SSSL (0.00045 mg/L) in one sample from CWM-512-MW01.

- Acetone (0.2 to 20 mg/L) exceeded its SSSL (0.16 mg/L) in ten samples from eight wells.

- Bromodichloromethane (0.0015 mg/L) exceeded its SSSL (0.0011 mg/L) in one sample from CWM-514-MW15.

- Carbon tetrachloride (0.00087 to 0.059 mg/L) exceeded its SSSL (0.00041 mg/L) in seven samples from six wells.

- Chloroform (0.0012 to 0.014 mg/L) exceeded its SSSL (0.0011 mg/L) in 28 samples from 18 wells. One of the chloroform results was flagged with a "B" data qualifier indicating that the compound was also detected in an associated laboratory or field blank sample.

- Tetrachloroethene (0.0015 to 0.0018 mg/L) exceeded its SSSL (0.0013 mg/L) in four samples from two wells (CWM-512-MW02 and CWM-514-MW03).

- Trichloroethene (0.0055 to 0.11 mg/L) exceeded its SSSL (0.0045 mg/L) in 17 samples from 11 wells.

Figure 4-1 shows VOCs detected at concentrations exceeding SSSLs in groundwater for all sampling events at the Training Area T-5 Sites. Figure 4-2 presents VOCs detected in groundwater during the 2004 sampling events.

Of the VOCs that exceeded SSSLs in groundwater, chloroform was the most frequently detected compound at the Training Area T-5 Sites. It was detected in 27 samples from 18 wells (excluding "B"-flagged data). Chloroform is a degradation product of carbon tetrachloride. As shown on Figure 4-1, the occurrence of the two chemicals together is common for monitoring wells located at Parcel 182(7). Carbon tetrachloride was not detected in groundwater at the other six parcels (Figures 4-1 and 4-2). Trichloroethene and 1,1,2,2-tetrachloroethane were the next most frequently detected chlorinated VOCs exceeding SSSLs; these compounds were detected in 17 samples from 11 and 10 wells, respectively.

Isopleth maps of total chlorinated VOCs were constructed for residuum and bedrock wells sampled during 2003 (Figures 4-3 and 4-4) and 2004 (Figures 4-5 and 4-6). Plumes developed in the residuum (Figure 4-3) at Parcels 511(7) and 512(7), and at Parcel 514(7) consist mainly of chlorinated ethane and ethene compounds. Total chlorinated VOC plumes and contaminants present in bedrock wells (Figure 4-4) are coincident and occur beneath similar contaminants present in overlying residuum wells. This distribution supports connectivity between the two aquifer zones.

The plume shown in the weathered Chilhowee residuum in the southern part of Parcel 182(7) (Figure 4-3) consists mainly of carbon tetrachloride and chloroform. The downgradient extent of the plume is defined by wells and the Jacksonville fault. The source of contaminants may be within the parcel boundary or the higher elevations of Sunset Hill.

Analysis of groundwater data from 2004 shows a generally similar development of plumes in the residuum (Figure 4-5) and bedrock (Figure 4-6) as the 2003 data. Groundwater data from residuum well CWM-514-MW12, which was installed in April 2004, extended the plume at Parcel 514(7) farther to the east-northeast. Two additional residuum wells (CWM-514-MW14 and CWM-514-MW16) defined the plume's upgradient and downgradient extent. In bedrock, the concentration of total chlorinated VOCs in monitoring well CWM-514-MW04 (Figure 4-6) increased four-fold over it's concentration in 2003. However, the eastern extent of the plume (at CWM-514-MW10) was approximately 20 times lower in 2004. Figures 4-7 through 4-9 are isopleth maps showing chlorinated ethanes, chlorinated ethenes, and chloroform concentrations in residuum using the 2004 analytical data. Figures 4-10 through 4-12 show chlorinated ethanes, chlorinated ethenes, and chloroform concentrations in bedrock in 2004. The predominant ethane

constituents are 1,1,2,2-tetrachloroethane and 1,1,2-trichloroethane. The primary ethene constituents are trichloroethene and tetrachloroethene. Ethane compounds in the bedrock in CWM-514-MW15 are restricted to bromodichloromethane and dibromochloromethane.

As noted above, acetone exceeded its SSSL in ten samples from eight wells, primarily at Parcels 180(7) and 514(7). Acetone was also evaluated in the fate and transport section of this report (Chapter 5.0) and was selected as a site-related COPC in the SRA (Chapter 6.0). However, the chemical is a common sample contaminant and is not known to have been used in historical site operations. Based on this and given the significant chlorinated VOC contamination detected and mapped, isopleth maps for acetone are not presented herein.

Semivolatile Organic Compounds. Sixty-nine groundwater samples were analyzed for SVOCs. A total of four SVOCs (4-methylphenol, bis[2-ethylhexyl]phthalate, diethyl phthalate, and phenol) were detected in seven of the samples. The SVOC results were below SSSLs except for bis(2-ethylhexyl)phthalate (0.045 to 0.12 mg/L), which exceeded its SSSL (0.0043 mg/L) in four samples. Bis(2-ethylhexyl)phthalate, however, is a common sample contaminant.

CWM Breakdown Products. Sixty-nine groundwater samples were analyzed for CWM breakdown products. CWM breakdown products were not detected in the samples.

Explosives. Five groundwater samples from the Parcel 232Q-X wells were analyzed for explosive compounds. Explosives were not detected in the samples.

Perchlorate. Five groundwater samples from the Parcel 232Q-X wells were analyzed for perchlorate. Perchlorate was not detected in the samples.

4.1.4 Surface Water Analytical Results

Five surface water samples were collected for chemical analysis at the Training Area T-5 Sites at the locations shown on Figure 2-1. Analytical results were compared to recreational site user SSSLs, ESVs, and metals background screening values as presented in Table 4-4. It should be noted that the assumptions for recreational site user and residential exposure to surface water are identical.

Metals. All of the surface water samples were analyzed for metals. A total of 10 metals were detected in the samples at concentrations below SSSLs. Five metals (aluminum, barium, chromium, manganese, and mercury) exceeded ESVs but were below their respective background concentrations except for chromium in one sample (note: a background value for

mercury was not available). Chromium (0.014 mg/L) exceeded its ESV (0.011 mg/L) and background (0.011 mg/L) at sample location CWM-511-SW/SD04.

The statistical and geochemical evaluation concluded that all of the metals detected in surface water are naturally occurring.

Volatile Organic Compounds. All of the surface water samples were analyzed for VOCs. A total of three VOCs (acetone, methylene chloride, and toluene) were detected in the samples at concentrations ranging from 0.00022 to 0.009 mg/L. The methylene chloride and toluene results were flagged with a "B" data qualifier, signifying that these compounds were also detected in an associated laboratory or field blank sample. All results were below SSSLs and ESVs.

Semivolatile Organic Compounds. All of the surface water samples were analyzed for SVOCs. SVOCs were not detected in the samples.

CWM. Breakdown Products. All of the surface water samples were analyzed for CWM breakdown products. CWM breakdown products were not detected in the samples.

4.1.5 Sediment Analytical Results

Five sediment samples were collected for chemical analysis at the Training Area T-5 Sites at the locations shown on Figure 2-1. Analytical results were compared to recreational site user SSSLs, ESVs, and metals background screening values as presented in Table 4-5. It should be noted that the assumptions for recreational site user and residential exposure to sediment are identical.

Metals. All of the sediment samples were analyzed for metals. A total of 18 metals were detected in the samples at concentrations below SSSLs. The concentrations of three metals exceeded their respective ESVs and background values:

- Cadmium (1.04 and 2.57 mg/kg) exceeded its ESV (1 mg/kg) and background (0.43 mg/kg) at sample locations CWM-511-SW/SD04 and CWM-512-SW/SD01.

- Chromium (61.8 mg/kg) exceeded its ESV (52.3 mg/kg) and background (31.2 mg/kg) at sample location CWM-182-SW/SD02.

- Copper (20.1 and 28.4 mg/kg) exceeded its ESV (18.7 mg/kg) and background (17.1 mg/kg) at sample locations CWM-182-SW/SD01 and CWM-512-SW/SD01.

The statistical and geochemical evaluation concluded that all of the metals detected in sediment are naturally occurring except for the aforementioned chromium result at sample location CWM-182-SW/SD02.

Volatile Organic Compounds. All of the sediment samples were analyzed for VOCs. A total of three VOCs were detected in the samples at concentrations ranging from 0.0016 to 0.16 mg/kg. All results were below SSSLs and ESVs.

Semivolatile Organic Compounds. All of the sediment samples were analyzed for SVOCs. A total of nine SVOCs, all of which were PAH compounds, were detected at estimated concentrations ranging from 0.079 to 0.23 mg/kg. With the exception of fluoranthene, which was detected at two locations, the PAHs were only detected at sample location CWM-511-SW/SD03. All results were below SSSLs and ESVs.

CWM Breakdown Products. All of the surface water samples were analyzed for CWM breakdown products. CWM breakdown products were not detected in the samples.

4.2 Sources of Contamination

As summarized in the preceding sections, the predominant contamination at the Training Area T-5 Sites is VOCs in groundwater. Specifically, several chlorinated VOCs were detected at concentrations exceeding SSSLs in monitoring wells at the site. The probable source of chlorinated VOCs is decontaminants and chemical agents, which were directly discharged to the ground surface during CWM training activities. The most likely culprit is decontamination agent noncorrosive (DANC), which is a solution of RH-195 (1,3-dichloro-5,5-dimethylhydantoin) in 1,1,2,2-tetrachloroethane (U.S. Departments of the Army and the Air Force, 1963). However, the available historical information does not specifically indicate that DANC was used at these sites. Nonetheless, DANC was known to have been used at other CWM training areas at FTMC and it is possible it was used at the Training Area T-5 Sites. Similarly, certain chemical agents (e.g., CNC, CNS, CNB), which contained mixtures of agent and chlorinated solvents (e.g., chloroform, carbon tetrachloride), may have been the source of the chlorinated VOC contamination. Again, however, historical information does not indicate that these agents were specifically used at the sites. Thus, while it is generally believed that decontaminants and/or chemical agents caused site groundwater contamination, the specific chemicals responsible remain less certain.

5.0 Contaminant Fate and Transport

This chapter discusses factors related to the fate and transport of contaminants identified at the Training Area T-5 Sites.

5.1 Introduction

Two major factors affecting the fate and transport of a chemical when released to the environment are its mobility and its persistence. Mobility is a measure of the tendency for a chemical to migrate through the environment and is affected by the physical/chemical characteristics of the chemical. The major processes at work in the natural environment include aqueous solubility, volatilization, sorption, hydrolysis, photolysis, and oxidation rates. Persistence, a measure of the time a chemical remains in the environment, is influenced by many of the same factors affecting chemical mobility (e.g., photolysis, hydrolysis, and oxidation rates). Persistence is also a function of chemical-biological interactions in the environment, such as biodegradation and/or bioaccumulation.

Potential routes of transport and transport mechanisms that may be applicable to the contaminants at the Training Area T-5 Sites are presented and evaluated in Section 5.2. The persistence of chemicals detected at the site and factors affecting the environmental fate process are discussed in Section 5.3. Table 5-1 lists the physical and chemical properties of the organic chemicals detected above SSSLs/ESVs and background at Training Area T-5 Sites. Table 5-2 provides data on the distribution coefficient for metals. Section 5.4 evaluates the direction and rate of contaminant migration at the Training Area T-5 Sites and includes Table 5-3, which summarizes estimated migration rates and distances for organic chemicals cited in Table 5-1. Also included in Section 5.4 are geologic cross sections of the Training Area T-5 Sites showing the vertical distribution of total chlorinated VOCs.

For the purposes of this RI report, only a qualitative evaluation of potential routes of migration, contaminant persistence, and contaminant migration is presented. Fate and transport modeling were not included in the scope of work.

5.2 Potential Routes of Migration

Contaminants can be transported from their source(s) to other areas as a result of several potential transport mechanisms and migration pathways. The migration of contaminants at a site is dependent on factors that include 1) site characteristics such as soil and bedrock conditions, groundwater and surface water conditions, and climatic conditions; and 2) contaminant

characteristics. As part of the evaluation process for the Training Area T-5 Sites, potential migration pathways considered are:

- Fugitive dust emissions and volatilization from soil
- Erosion and surface water runoff
- Surface water and sediment transport
- Infiltration and leaching from surface soils to subsurface soils to groundwater
- Transport within the groundwater flow system
- Discharge of groundwater to the surface
- Bioaccumulation.

5.2.1 Dust Emission and Volatilization

Contaminants adsorbed to surface soils could be transported from source areas by fugitive dust generation and entrainment by wind. Subsequent atmospheric mixing could transport contaminant-associated particulates to other parts of the Training Area T-5 Sites or to off-site locations. Contaminant-adsorbed dust could also be released to the atmosphere through construction activities.

The surface area at the Training Area T-5 Sites is characterized by relatively immature mixed deciduous/coniferous woods (Parcels 180[7] and 182[7]) with an understory and a well-developed litter layer of mostly pine needles; cleared, grassy areas (Parcel 514[7]) some with concrete pads (Parcels 513[7] and 516[7]); or asphalt covered (Parcels 511[7] and 512[7]). No major construction activities have occurred at any of the sites. In view of the above, the generation of fugitive dust and subsequent transfer by wind is not anticipated to be a significant transport mechanism.

Site-related contamination could be released through volatilization into the air. This migration path would be limited primarily to VOCs in surface soil. The inorganic elements detected are not expected to volatilize to any great extent. They are expected to remain in the soil relatively unchanged by physical and chemical processes for long periods of time. The statistical and geochemical evaluation (Appendix H) concluded that the metals detected in surface soil are naturally occurring except for barium, cadmium, copper, and zinc in a limited number of samples. These metals results exceeded their ESVs but were below SSSLs.

VOCs concentrations in surface and depositional soils were below SSSLs and ESVs except for 1,1,2,2-tetrachloroethane and trichloroethene, which were detected above ESVs in one sample and two samples, respectively. Because of its relatively high vapor pressure, trichloroethene will readily volatilize to the atmosphere; 1,1,2,2-tetrachloroethane has a moderate vapor pressure and

its volatilization would be less rapid. Five SVOCs (PAHs) exceeded ESVs in one surface soil sample; four were above background values. PAHs, particularly the low molecular weight compounds, may volatilize from soils. The concentrations of PAHs and VOCs detected at the Training Area T-5 Sites are low; therefore, this transport mechanism is expected to be insignificant.

5.2.2 Erosion and Surface Water Runoff

Erosion and surface water runoff have the potential to transfer contaminants either in a dissolved state or adsorbed to soil particulates or organic matter. Transport routes follow local topography and any site-established drainage systems. The potential for surface water runoff exists at the Training Area T-5 Sites.

The Training Area T-5 Sites are located in between and downslope of Howitzer and Sunset Hills. Parcel 182(7) is located on the eastern flank of Sunset Hill. Maximum topographic relief across the parcel is approximately 75 feet. A small ephemeral stream drains across the northern part of the parcel. A larger intermittent stream flows northward parallel to the east boundary of Parcels 182(7) and 513(7) and continues on past the west boundary of Parcels 511(7) and 512(7). Elsewhere, several drainage ditches are present and additionally assist in the discharge of surface water from the sites and transport to South Branch of Cane Creek. Stream flow is only present during periods of appreciable precipitation.

Surface soil contaminants could be solubilized by rainwater and subsequently transported by surface runoff to the ephemeral drainage features. The solubility of inorganics in rainwater is largely dependent upon the pH of the rainwater. Because the rainwater in this region is most likely slightly acidic, inorganic constituents in surface soils may solubilize to some degree and be subject to transport via runoff. However, the statistical and geochemical evaluation concluded that the metals detected in surface soil are naturally occurring except for barium, cadmium, copper, and zinc metals in a limited number of samples.

As mentioned previously, two VOCs (1,1,2,2-tetrachloroethane and trichloroethene) and five PAHs were detected above ESVs in a limited number of surface and depositional soil samples. Trichloroethene is moderately soluble in water; however, during surface water transport it would be expected to volatilize to the atmosphere. 1,1,2,2-Tetrachloroethane is also fairly soluble in water, but has a significantly lower Henry's Law constant and is not as volatile. The partitioning of 1,1,2,2-tetrachloroethane to soil is low. PAHs have a low solubility and have soil adsorption coefficients (K_{oc}) in the range that indicate a moderate to strong tendency to be adsorbed to organic carbon. These chemicals would be strongly bound to particulate matter and may be

entrained in surface water runoff and transported to ephemeral drainage features. However, it is not anticipated that erosion and surface water runoff will be a significant transport mechanism at the Training Area T-5 Sites.

5.2.3 Surface Water and Sediment Transport

Surface water and sediment samples were collected from the northerly flowing ephemeral stream that separates Parcels 182(7), 513(7), 516(7) to its west from Parcels 511(7), 512(7) to its east. The substrate is mostly cobbles and gravel with small depositional areas of sand and leaf litter, interspersed throughout.

Metals were detected in both surface water and sediment samples but all results were below SSSLs. Three metals were detected at concentrations above ESVs and background concentrations. However, the statistical and geochemical evaluation concluded that the metals detected in surface water and sediment are naturally occurring.

VOCs were detected in surface water and sediment samples but all concentrations were below SSSLs and ESVs. The compounds were common laboratory and field contaminants and the results were either "B" or "J" qualified. VOCs in surface water would be expected to rapidly volatilize from the water-air interface and be dispersed to the atmosphere. Based on the low levels of VOCs detected and the fact that these compounds would be expected to volatilize, the transport of VOCs in surface water is expected to be insignificant.

Contaminant transfer to sediments represents another potential transport mechanism, especially where constituents are in the form of suspended solids or are hydrophobic compounds (e.g., PAHs) that can become adsorbed to organic matter in the sediment. The only SVOCs detected were nine PAHs at levels below SSSLs and ESVs in one sediment sample located farthest downstream. The substrate of the intermittent stream is not characterized as being organic rich. Therefore, the adsorption capacity of the bottom sediment would be low and the potential for creek sediments to adsorb and subsequently release contaminants over time would be low.

5.2.4 Leaching from Surface and Subsurface Soils to Groundwater

VOC concentrations in surface soils at the Training Area T-5 Sites were below SSSLs and only two compounds (1,1,2,2-tetrachloroethane and trichloroethene) were detected at concentrations above ESVs. Although VOCs were detected in subsurface soil, they were present at concentrations below SSSLs. The presence of VOCs at reduced concentrations may be taken as an indication of either an original limited release of VOCs or that leaching of contaminants from surface and subsurface soils has occurred. The calculated soil organic carbon adsorption

coefficients (K_{oc}) for trichloroethene (166 milliliters per gram [mL/g]) and 1,1,2,2-tetrachloroethane (93.3 mL/g) are indicative of medium to high mobility. Precipitation percolating through the soil in the unsaturated zone would have partitioned contaminants from the soil matrix into the leachate. The absence of significant VOC concentrations in the upper soil profile and residuum is a qualitative indication of the relative ease with which VOCs may partition. Four SVOCs (PAHs) were detected above ESVs and background values in one surface soil sample. Benzo(a)pyrene was the only PAH detected in subsurface soil (three samples) at concentrations above its SSSL. In general, PAHs are considered to have low solubilities in water. Benzo(a)pyrene is considered a high-molecular-weight PAH with an organic carbon partition coefficient in the range of 10^5 to10^6, indicating a strong tendency to adsorb to organic carbon. It is not likely to be mobile in the subsurface. Therefore, migration of soil contamination through percolation of rainwater and movement of the leachate into groundwater is considered the most significant route of contaminant migration at the Training Area T-5 Sites.

5.2.5 Groundwater Transport

Contaminants in groundwater can be transported in either a dissolved phase or a soil-adsorbed phase. Soluble chemical constituents will be transported in the direction of groundwater flow. Based on the water level data collected, groundwater at the Training Area T-5 Sites appears to have an overall flow direction to the north in both residuum and bedrock. Over much of the area, the average horizontal hydraulic gradient in both the residuum and bedrock aquifers is moderate. The head difference across the area is approximately 103 feet in residuum and 35 feet in bedrock. In the residuum, hydraulic gradients are higher in the western part of the Training Area T-5 Sites and decrease with the decreasing topography towards the east and north. Hydraulic gradients in the bedrock are lower and more consistent. Average hydraulic gradients of 0.031 ft/ft and 0.065 ft/ft (Table 3-1) were calculated for the residuum and bedrock aquifers, respectively.

Vertical hydraulic gradients between residuum and bedrock in well clusters where contaminants were detected in both wells (Table 3-2), exhibit strong to weak downward gradients. The downward gradients and the similarity of chemical constituents between the residuum and bedrock support connectivity between the two aquifer zones. Vertical hydraulic gradients between residuum and shale bedrock wells exhibit weak downward and moderate upward gradients. This supports general confined aquifer conditions.

Soluble chemical constituents entering the groundwater system in either residuum or bedrock would flow in the direction of groundwater movement. The rate of transport of these chemical constituents in the residuum is determined, in part, by equilibrium partitioning between the

mobile aqueous phase and the soil particles of the residuum. The degree of partitioning in the residuum is governed mainly by the organic matter content. In bedrock, the degree of partitioning is substantially less. Release and transport to the groundwater system is the principal migration pathway and mechanism of on-site contaminant migration and potential off-site contaminant transport of both dissolved organic and inorganic compounds detected at the Training Area T-5 Sites.

5.2.6 Discharge of Groundwater to the Surface

There are no known surface water discharges (e.g., springs or wetlands) at the Training Area T-5 Sites. No standing bodies of water (e.g., ponds) or flowing surface waters are present where hydraulic connectivity to the residuum or bedrock aquifers occurs. Groundwater from the Training Area T-5 Sites could discharge to the northerly flowing ephemeral stream located along the western boundary of Parcels 511(7) and 512(7). This event would occur if the potentiometric surface rose above the stream bed during periods of high precipitation. This transport mechanism would only be occasionally active. Therefore, discharge of contaminated groundwater to the surface is not considered as a transport mechanism.

5.2.7 Bioaccumulation

Many organic and inorganic chemicals have the potential to bioconcentrate and bioaccumulate in plants and/or animals. This may occur through direct bioconcentration from an aqueous medium, root uptake from soils to plants, ingestion of water, incidental ingestion of soils and sediments, and ingestion of contaminated plants or animal prey as food sources. These pathways are discussed in detail in Chapter 7.0.

5.3 Contaminant Persistence

Factors affecting environmental persistence and mobility processes are defined in this section. These factors deal with the chemical and physical reactions that take place in the environment and their effect on contaminant transport. In the discussion following, chemicals are divided into two groups: organic and inorganic. Table 5-1 presents parameters governing the environmental fate of organic chemicals detected at levels above SSSLs or ESVs at the Training Area T-5 Sites.

5.3.1 Chemical and Physical Processes Affecting Fate and Transport

The most important fate and transport process for organic constituents detected at the Training Area T-5 Sites is likely to be aqueous solubility. The greater the solubility of an organic constituent, the greater the potential for migration via groundwater transport. For inorganic constituents, the ability to enter the groundwater transport system is largely determined by the distribution coefficient of the metal.

A number of measurable chemical parameters are used to determine the rate and extent of a chemical process. The parameters include aqueous solubility, Henry's Law constant, diffusion coefficient, vapor pressure, adsorption/partitioning coefficient, and degradation rate. These parameters can be used to estimate the quantity of contaminants that will go into solution; rates of volatilization; rates of diffusion; quantity of contaminants adsorbed or desorbed onto, or released from, soil particles; and rates of degradation.

5.3.1.1 Aqueous Solubility

Aqueous solubility is the maximum amount of a chemical that will dissolve in pure water at a specified temperature. The solubility of most organic compounds ranges from approximately 1 to 10,000 mg/L at ambient temperatures. Aqueous solubility is an important determinant of chemical concentration and residence time in water. Highly soluble chemicals readily dissolve in water and remain in solution; chemicals with low solubility tend to adsorb to solids or form nonpolar phases.

5.3.1.2 Volatilization

Volatilization is the movement of a chemical from the surface of a liquid or solid to a gas or vapor phase. Volatilization losses to the air are related to the chemical concentration, molecular weight, solubility, vapor pressure, and ambient temperature. The tendency for a chemical to volatilize from water can be estimated from its Henry's Law constant, H (atmospheres per cubic meter per mole [atm-m^3/mol]). This measure relates the equilibrium concentrations of a compound in the dissolved and vapor phases and is a constant at a given temperature. H relates the partial pressure of a gas above a liquid and a mole fraction of the gas dissolved in the liquid and affects the rate and extent of volatilization. Lyman et al. (1982) classified compounds based on their H value, as readily (>10^{-3} atm-m^3/mol), significantly (10^{-3} to 10^{-5} atm-m^3/mol), or limitedly (< 10^{-5} atm-m^3/mol) tending to volatilize.

5.3.1.3 Diffusion

A diffusion coefficient is a measure of the diffusive mobility of a contaminant in solution. As the diffusion coefficient increases, so does the rate of diffusion. Diffusion coefficients are temperature dependent and increase with temperature. The diffusion coefficient is important in determining vapor-phase diffusion. By definition, vapor pressure is the pressure exerted by a chemical vapor in equilibrium with its solid or liquid form at any given temperature. It is used to calculate the rate of volatilization of a pure substance or in estimating a Henry's Law constant for chemicals with low water solubility. The higher the vapor pressure, the more likely a chemical is to exist in a gaseous state.

5.3.1.4 Adsorption/Desorption

Adsorption/desorption is the binding of a chemical to (adsorption) or its release from (desorption) a solid matrix (e.g., soils, sediments, and suspended solids). Partition coefficients are important measures of sorptive characteristics and help define the relative concentrations of a given chemical in two phases or matrices. Partition coefficients are expressed as concentration ratios between two phases and include:

- Organic Partitioning or Adsorption Coefficient, K_{oc} – Provides a measure of the extent of chemical partitioning between organic carbon and water at equilibrium. The greater the K_{oc} of a chemical, the more likely that chemical is to adsorb to soil or sediment rather than remain dissolved in water.

- Soil Adsorption or Distribution Coefficient, K_d – Provides a measure of the extent of chemical partitioning between soil or sediment and water, unadjusted for dependence on organic carbon. Adsorption coefficients are site specific and specific to soil types. K_d can be normalized for organic carbon content by the soil adsorption coefficient (K_{oc}) times the soil organic carbon content (f_{oc}) (mg of organic carbon/mg soil). If site-specific values cannot be obtained, values can be estimated from the organic carbon content, carbon content, and the octanol-water coefficient. The higher the K_d value, the more likely a chemical is to bind to soil or sediment rather than to remain dissolved in water.

- Octanol-Water Partition Coefficient, K_{ow} – Provides a measure of the extent of chemical partitioning between water and octanol at equilibrium. The greater the K_{ow} value, the more likely a chemical is to partition to octanol rather than to remain in water. K_{ow} can be used to estimate K_{oc} and to predict bioconcentration in living organisms. Chemicals with a log $K_{ow} < 2.5$ rarely bioaccumulate significantly in plants or animals and have a high water solubility.

5.3.1.5 Degradation Rate

Degradation rate is a measure of the rate at which a contaminant breaks down into other, simpler compounds. Types of degradation rates can be broken into four categories: hydrolysis rates, photolysis rates, oxidation/reduction rates, and biodegradation rates.

- Hydrolysis is the reaction of a chemical with hydrogen ions or the hydroxyl radicals, resulting in the degradation or structural modification of the chemical. The extent of a chemical's hydrolytic reaction is a function of the molecular structure of the chemical and the pH of the environment.

- Photolysis is a chemical degradation process caused by sunlight. The rate of degradation from photochemical reactions depends on the chemical's molecular

structure, the proximity and character of the radiant energy (light source), and the presence of other reactive compounds.

- Oxidation/Reduction is a chemical reaction in which a chemical either loses an electron (oxidation) or adds an electron (reduction). Oxidation/reduction rates of chemicals are significant, in that they influence both the environmental mobility and fate of a chemical.

- Biodegradation of organic compounds can transform them through various reactions. The chemical processes that remove or transform compounds can involve oxidation or reduction, depending on whether aerobic or anaerobic conditions exist. The rate of biodegradation is influenced by numerous parameters, including but not limited to groundwater temperature, pH, dissolved oxygen, organic matter content, phosphate, sulfate, and nitrate concentrations.

5.3.2 Contaminant Fate and Transport

Contaminant fate and transport of VOCs, SVOCs, and inorganic compounds are discussed in the following sections.

5.3.2.1 Volatile Organic Compounds

VOCs were detected in all media at the Training Area T-5 Sites, as summarized in Chapter 4.0. None of the VOCs detected in soil, surface water, or sediment exceeded SSSLs or ESVs except for trichloroethene and 1,1,2,2-tetrachloroethane, which exceeded ESVs in one or two surface soil samples each. Eighteen VOCs were detected in groundwater, of which ten (including chloroform, trichloroethene, and 1,1,2,2-tetrachloroethane) exceeded their SSSLs. Table 5-1 presents the physical and chemical parameters governing the environmental fate and transport of the VOCs that exceeded SSSLs in groundwater and the two VOCs that exceeded ESVs in surface soil. These VOCs are divided into two primary groups of organic constituents: ketones and chlorinated aliphatic hydrocarbons.

Ketones. Acetone was the only ketone detected above its SSSL in groundwater. The compound was detected in 10 samples from 8 monitoring wells. In soils, volatilization to the atmosphere and leaching into groundwater constitute the most important transport mechanisms for acetone. The most important fate determining process in water is biodegradation (Agency for Toxic Substances and Disease Registry [ATSDR], 1994). Acetone's high miscibility in water suggests that it does not adsorb appreciably to soil or suspended solids in water. Its tendency for limited adsorption is further supported by its low K_{oc} value.

Chlorinated Aliphatic Hydrocarbons. Chlorinated ethanes and ethenes, chloroform, and carbon tetrachloride were detected at concentrations above SSSLs in groundwater at the Training

Area T-5 Sites. In addition, the chlorinated hydrocarbons trichloroethene and 1,1,2,2-tetrachloroethane exceeded ESVs in surface soil. Chlorinated hydrocarbons are synthetic solvents. They can occur in the environment directly through product usage or as a breakdown by-product from the degradation of other solvents. Chlorinated hydrocarbons tend to have high solubilities in water. The high solubilities are, in part, due to their relatively low molecular weights and high polarity. The constituents tend to have a low affinity for soils and are generally highly mobile through the soil column and most aquifers. Low K_{oc} values would suggest that sorption to soils would be expected to be relatively minor; thus, transport in groundwater is expected to be the dominant transport pathway.

The main degradation process acting to reduce chlorinated aliphatic hydrocarbons concentrations in the environment is biodegradation. Under conditions simulating those at a landfill, 1,1,2,2-tetrachloroethane was transformed into products such as 1,1,2-trichloroethane, trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, 1,1-dichloroethene, and vinyl chloride (ATSDR, 1996). The transformations were largely attributed to anaerobic degradation. The most important process for natural biodegradation is reductive dechlorination. This process occurs by sequential dechlorination (e.g., from tetrachloroethene to trichloroethene to dichloroethene to vinyl chloride to ethane). The contaminant suites observed at the site indicate that reductive chlorination by microbial degradation under anaerobic conditions is likely occurring in groundwater at the site. The compound 1,1,2,2-tetrachloroethane is a likely precursor solvent. The decontaminant DANC, which may have been used at the Training Area T-5 Sites, is a solution of RH-195 dissolved in 1,1,2,2-tetrachloroethane. Photolysis and hydrolysis are not expected to be significant removal mechanisms.

Chloroform was the chlorinated hydrocarbon most frequently detected above its SSSL in groundwater at the Training Area T-5 Sites. The compound was detected above its SSSL in 27 samples from 18 wells. The chlorinated solvent carbon tetrachloride is also present above SSSLs in groundwater. It was present in groundwater sampled from six monitoring wells in the southeast part of Parcel 182(7). Four of the six wells in this area also had chloroform at levels above SSSLs. Chloroform is a degradation product of carbon tetrachloride. Both compounds were major constituents in certain CWM tear agents: chloroform in CNC and CNS and carbon tetrachloride in CNB. Photolysis and hydrolysis are not expected to be significant removal mechanisms of either chloroform or carbon tetrachloride. In the absence of toxicity from other chlorinated hydrocarbons in groundwater and where chloroform concentrations are low (< 0.001 mg/L), slow but substantial aerobic and/or anaerobic biodegradation of chloroform can occur (ATSDR, 1997). Carbon tetrachloride may undergo reductive dechlorination in groundwater in

the presence of free sulfide and ferrous ions, or naturally occurring minerals providing these ions (ATSDR, 2003).

5.3.2.2 Semivolatile Organic Compounds

SVOCs were detected in soils, groundwater, and sediments at the Training Area T-5 Sites. At one surface soil location, the concentration of five SVOCS (PAHs) detected exceeded their ESVs. Four of these PAHs also exceeded background concentrations. In the subsurface soil sample at this location, and at two other subsurface soil sample locations, one of the four PAHs (benzo[a]pyrene) exceeded its SSSL. In groundwater, bis(2-ethylhexyl)phthalate was the only SVOC detected above its SSSL. It was detected in four wells and, although none of the results were "B" qualified, phthalates are common field and laboratory sample contaminants. Table 5-1 presents the physical and chemical parameters governing the environmental fate and transport of bis(2-ethylhexyl)phthalate and the PAHs that exceeded ESVs and background in surface soil. The SVOCs are divided into two primary groups of organic constituents: phthalate esters and PAHs.

Phthalate Esters. Although it is a common sample contaminant, the presence of bis(2-ethyhexyl)phthalate above its SSSL in four groundwater sample requires consideration of its environmental fate. Phthalate esters are considered to be fairly soluble, although their solubility is low compared to the VOCs detected at the site. Because of this generally low solubility, runoff and ground water transport will not be an important environmental process. Some phthalate esters readily adsorb to organic matter and soil particles. The tendency to adsorb is reflected by high K_{oc} and K_{ow} partition coefficients. Biodegradation is a significant fate process. Phthalate esters are degraded under most aerobic and anaerobic conditions by microbial populations. Due to their low volatilization rate, indicated by their Henry's Law constants and vapor pressures, volatilization will not be a significant environmental fate process. Photolysis/hydrolysis will also be limited and of little importance.

Polycyclic Aromatic Hydrocarbons. Potential routes of transport likely to affect the transport of PAHs detected above ESVs and background in soils were presented previously in Section 5.2. Benzo(a)pyrene was the only PAH detected above its SSSL in both surface and subsurface soils. Benzo(a)pyrene can be chemically oxidized in groundwater. Significant biodegradation will occur under oxygenated conditions.

5.3.2.3 Inorganics

Many of the chemical and physical processes governing fate and transport of organic constituents also influence inorganic constituents. In addition to those processes, complexation,

precipitation/co-precipitation, and cationic exchange are significant factors unique in influencing the persistence and movement of inorganic chemicals (Alloway, 1990). A brief discussion of these factors is presented in this section. The distribution coefficient (K_d) values for inorganic constituents are also discussed for metals. For inorganic chemicals, the simple relationship between soil organic carbon content and sorption observed for organic chemicals does not apply; K_d is essentially independent of K_{oc} or K_{ow}.

- Complexation is the ability of metals to form numerous organic and inorganic complexes with inorganic ligands such as carbonate, chloride, hydroxide, and sulfate in the natural environment. Complexation is influenced by many factors, of which pH, and the availability of complexing compounds are significant.

- Precipitation and co-precipitation are important removal mechanisms of dissolved aqueous species. Precipitation depends upon the ionic concentration/aqueous solubility, pH and other physical/chemical considerations of the aqueous media.

- Cationic Exchange – Many metals are capable of undergoing substitution with cations present in the crystal lattice of minerals within soils and sediments. This process is commonly influenced by the type of clay minerals present in the media and factors such as pH and organic content.

The potential for inorganic constituents to migrate in groundwater is related to their distribution coefficient (K_d). The soil-water distribution coefficient for metals is affected by many geochemical parameters including, but not restricted to, pH, adsorption to clays, oxidation/reduction conditions, ion chemistry of the water, and chemical form of the metal. K_d values for commonly evaluated metals range from less than 1 to over 10,000 mL/g.

Inorganic solutes in groundwater are considered essentially immobile, with K_d values exceeding 100 mL/g. K_d values between 0.1 and 50 mL/g suggest moderate mobility, and K_d values below 0.1 mL/g suggest high mobility (Dragun, 1988). Trace metals in general tend to be very immobile. Cations are moderately mobile in groundwater, and anions are the most mobile. Because of the number of varying geochemical parameters in the field influencing organic distribution coefficients and differences in experimental methods, a wide range of K_d values are obtained (Table 5-2).

Unlike organic compounds, metals are not degradable through biological or chemical actions and are typically considered to be persistent in the environment. The fate of metals depends primarily on partitioning between soluble and particulate solid phases. Some metals can be oxidized or reduced through the actions of microorganisms that can change their chemical and physical properties. Among the mechanisms discussed in the preceding sections,

solubility/aqueous chemical speciation, adsorption/desorption, complexation, precipitation/co-precipitation, and cationic exchange have the potential to significantly influence fate and transport of the metals detected.

Various metals were detected in site media at concentrations exceeding SSSLs/ESVs and background. The statistical and geochemical evaluation (Appendix H) concluded that the metals detected in site media are naturally occurring except for four metals (barium, cadmium, copper, and zinc) in a limited number of surface soil samples and chromium in one sediment sample. Of these, cadmium, copper, and zinc were identified as COPECs but not human health COPCs.

5.4 Contaminant Migration

The chemical and physical processes that are involved in the solute transport of contaminants at the Training Area T-5 Sites include advection, dispersion, diffusion, and retardation. The response of these factors to the local hydrogeological conditions will control the horizontal and vertical migration of VOCs. These processes are briefly discussed in Section 5.4.1. In Section 5.4.2, the horizontal, vertical, and downgradient migration of contaminants is discussed.

5.4.1 Processes Involved in Solute Transport

The mechanisms that govern contaminant transport in the groundwater flow system include various physical and chemical processes. These transport processes include advection, dispersion, diffusion, and retardation, which are briefly discussed below.

5.4.1.1 Advection

Advection is the process of contaminant (solute) migration due to the average linear velocity of groundwater. Advection is typically the most important factor governing solute movement. Contaminants that are moving under advection are traveling at the same rate as the average linear flow velocity of the groundwater. The advective transport term is computed using velocities determined from Darcy's Law. The governing chemical parameter in advection is solubility; the effect of advection increases with increasing solubility.

5.4.1.2 Dispersion

Hydrodynamic dispersion is the spread or mixing of contaminants around an average groundwater flow path. Dispersion can occur both longitudinally and transversely. The mixing that occurs along or parallel to the flow path in the horizontal plane is called longitudinal dispersion and that occurring perpendicular to the pathway of fluid flow is called transverse dispersion.

5.4.1.3 Diffusion

Diffusion is the movement of contaminants as a consequence of a concentration gradient. Contaminants diffuse from an area of higher concentration to an area of lower concentration; diffusion will occur until equilibrium in concentration exists. The rate of diffusion increases with temperature and decreases as the porosity of the medium increases. The chemical parameter governing diffusion is the diffusion coefficient; as the diffusion coefficient increases, so does the extent of contamination movement by diffusion.

5.4.1.4 Retardation

Dissolved contaminants moving through an aquifer may interact with solid constituents encountered along its flow path. This interaction may include adsorption, partitioning, ion exchange reactions, and other chemical and physical processes which remove the dissolved constituent(s) from groundwater. The greater the fraction of contaminant sorbed, the more its transport is retarded. Because of these various processes (primarily adsorption), a solute may move at a slower velocity than the groundwater mass itself. One of several accepted equations for estimating the migration rate of a chemical in a soil-groundwater system is the retardation equation (Fetter, 1988):

$$V_c = V\left[1 + K_d\left(D_b/n\right)\right]^{-1} = Rd$$

where:

- V_c = Velocity of the chemical at the point where the solute concentration is one-half of the original value
- V = Average linear velocity of groundwater
- K_d = Adsorption coefficient
- D_b = Soil bulk density
- n = Total porosity
- Rd = Retardation factor.

The adsorption or distribution coefficient is a function of the soil's and contaminant's chemistry and, therefore, can be compound-specific. For VOCs, the amount of organic carbon present in the aquifer matrix is an important factor. Generally, the larger the value of K_d, the greater the compound's affinity for the solid matrix (Dragun, 1988). For compounds with very low K_d values, the contaminant mass moves at virtually the same rate as the average linear groundwater velocity. The distribution coefficient is defined by:

$$K_d = C_s / C_w = f_{oc} \bullet K_{oc}$$

where:

C_s = Concentration by weight in soil
C_w = Concentration by volume in water
f_{oc} = Fraction of organic carbon
K_{oc} = Organic partitioning coefficient.

5.4.2 Migration of Contaminants

Based on the soil and groundwater data collected at the Training Area T-5 Sites, the most significant fate and transport pathway is the leaching of organic contaminants within subsurface soils and movement through the residuum and into the bedrock groundwater system. The low levels of VOCs in surface and subsurface soils suggest that significant removal and/or subsequent leaching of organic contaminants to groundwater has occurred. Four SVOCs (PAHs) were detected in surface soils above ESVs and background values. Benzo(a)pyrene was the only PAH detected above its SSSL in subsurface soil. Because of its high K_{oc} it is not likely to be mobile in the subsurface.

The mobility of inorganic constituents is primarily related to their retardation factor (Table 5-2). Depending on how the metals enter site media, some may persist near the source area longer than others. For example, some metals may enter shallow aquifers in a reduced state. It would be expected that these metals would migrate in the groundwater until pH and Eh conditions were such that precipitation might occur. If dissolved metals entered limestone bedrock, they would likely migrate significant distances through fractures or solution-enhanced pathways. This migration would be relatively unhindered, due to a chemically more reducing environment and a lower percentage of naturally present organic matter. Shale bedrock would have a higher percentage of organic matter and likely be less permeable to groundwater flow.

The groundwater regime for the Training Area T-5 Sites is separated into residuum and bedrock flow systems. Groundwater flow maps are presented on Figures 3-6 through 3-9 and, as discussed in Section 3.8.2, support an overall northerly to northeasterly flow direction in both systems. Vertical hydraulic gradients were calculated for seven well clusters and are presented in Table 3-2. In well clusters where contaminants were detected in both the residuum and underlying limestone bedrock, weak to strong downward groundwater flow direction is shown. The downward gradients support connectivity between the two aquifer zones.

Isopleth maps constructed using the 2003 groundwater analytical data (Figures 4-3 and 4-4) and the 2004 data (Figures 4-5 and 4-6) show the distribution of total chlorinated VOCs in the residuum and bedrock aquifers. For the 2003 data, five plumes are defined in the residuum: three plumes in the northern parcels (i.e., Parcels 180, 511/512, and 514) and two plumes at Parcel 182(7) to the south. Contaminant flow distribution parallels groundwater flow direction in both residuum and bedrock. The northern plumes consist mainly of chlorinated ethane and ethene compounds. The plumes are coincident with bedrock plumes and verify vertical connectivity between the aquifers. The southern plume is restricted to the residuum and is dominated by carbon tetrachloride and its daughter product, chloroform.

Calculated vertical hydraulic gradients indicate that downward flow of groundwater seasonally dominates. Specific gravity values are presented in Table 5-1 for the VOCs that exceeded SSSLs in groundwater. If present as a free-phase product, or at concentrations approaching the contaminant's solubility limit, these compounds might be expected to sink within the residuum. However, the concentrations of dissolved VOCs presently detected are too low for density to be a factor in vertical migration.

Contaminant migration rates and distances in groundwater were estimated for both residuum and bedrock (Table 5-3). Solute transport rates for VOCs in residuum ranged from approximately 33.1 feet per year (ft/yr) for tetrachloroethene to 154.2 ft/yr for acetone. The distance for solute migration in groundwater calculated for a 50-year period considerably exceeds the 600-foot length of the well-defined plume that extends northeast from Parcel 514(7). Assumptions for bulk density, porosity, and percent total organic carbon of the aquifer material used to calculate the soil adsorption coefficient (K_d) and retardation coefficient (R_d), however, are within ranges commonly specified in the literature. Contaminant velocities in bedrock are low; calculated rates are all less than 25 ft/yr. The degree of influence of fracture flow or solution porosity within the limestone bedrock present cannot be assessed from the present data.

Figures 5-1 though 5-4 present cross-sectional views of the distribution of total chlorinated VOCs in residuum and bedrock in relation to the subsurface geology.

6.0 Streamlined Human Health Risk Assessment

Due to the large size and complexity of the FTMC installation, a streamlined human health risk assessment (SRA) protocol has been developed to standardize risk assessments across sites and to simplify their presentation, resulting in a considerable economy of scale. The heart of the SRA protocol is the development of SSSLs, which are medium-specific and receptor-specific, risk-based screening concentrations. The SSSLs are used to quickly and efficiently screen the site for potential cancer risk and noncancer hazard from residual chemicals in environmental media. They address all significant exposure pathways and are sufficiently site-specific regarding exposure assumptions that they are used to estimate risk with as much precision as a typical CERCLA baseline risk assessment. The exposure assumptions and SSSL methodology are described in detail in the ADEM- and EPA-approved *Installation-Wide Work Plan* (IT, 2002b), hereafter referred to as the IWWP. It is assumed that the reader is familiar with the FTMC facility, with risk assessment in general, and with the IWWP.

The SSSLs were recently updated with the most current toxicity values, and the SSSLs, toxicity values and chemical-specific physical properties used to generate the SSSLs are compiled in the *Human Health and Ecological Screening Values and PAH Background Summary Report* (IT, 2000c). IT (2000c) also presents toxicity profiles, which are brief descriptions of the physical and toxicological properties of the chemicals that may be identified as contaminants at FTMC sites. The toxicity values for all chemicals detected at the Training Area T-5 Sites were examined for currency before the SRA was performed.

The SSSLs are based on the most highly exposed receptor or receptor scenario for each of several uses to which an individual site on FTMC may be subject. For example, it was determined that current or future land-use of most FTMC sites may be categorized broadly as follows:

- Residential: restricted to living areas, such as single- or multiple-dwelling homes and retirement centers.

- Commercial/Industrial: including schools, parks, playgrounds, golf courses, employment areas, office buildings, stores, malls, medical facilities, research facilities, motor pools and garages, transportation facilities, military facilities, training fields, landfills, dumps, disposal sites, and all other areas and activities other than residential.

- Open space: including "unused" land or buffer space, wetlands, wooded or meadow areas, and all other areas not used for residential or industrial activities. Hiking, hunting, fishing or other recreational use may occur.

The most highly exposed receptor for each land-use category was selected and SSSLs were developed for that receptor alone, rather than for each receptor that might be included in a land-use category. For example, an exposure scenario for an on-site resident consisting of a family with children was developed as a surrogate for all who may be exposed in a residential setting, and separate SSSLs were not developed for residents in a children's home, boarding school, retirement or assisted living home, etc. The on-site resident would be more highly and frequently exposed to site media, such as soil and groundwater and would represent the upper bound on residential risk. Most sites are evaluated with the residential scenario even if the site is not slated for residential development, because the resident generally represents the upper bound on long-term risk, and the information provided by this evaluation is useful to site managers. Sites that "pass" the residential evaluation generally can be released for unrestricted use with no further action. Sites that "fail" the residential evaluation do not necessarily require remediation, but the information may be useful for determining future site use, site-use restrictions, or other site management decisions.

An exposure scenario for an on-site groundskeeper was developed as a surrogate for all site workers. The groundskeeper would be more intensely exposed to site media than an indoor worker, delivery person or part-time maintenance personnel, and would represent the upper bound on worker risk. Similarly, an exposure scenario was developed for a recreational site user as a surrogate for all recreational site use. The original EDAW (1997) *Fort McClellan Comprehensive Reuse Plan, Implementation Strategy* distinguished active recreation (e.g., parks, playgrounds) from passive recreation (e.g., open space, hiking or camping facilities), but the distinctions were insufficient for developing separate exposure assumptions with confidence. Therefore, the exposure assumptions for the recreational site user are intended to be sufficiently protective for either active or passive recreation.

Please refer to the IWWP for more detail regarding the rationale and protocol for development of the SSSLs.

It should be noted that the IWWP has been updated from the 1998 version, improving the manner in which source-term concentrations (STC) are estimated for soil, surface water and sediment. Also, the protocol for comparing site and background data for the identification of site-related chemicals has been revised since the updated IWWP (Shaw, 2003). Changes in

protocol are discussed in more detail in their appropriate sections in the remainder of this chapter. The reuse plan for the FTMC facility as a whole also has been updated (EDAW, 1997).

6.1 Streamlined Risk Assessment Protocol

An SRA consists of the following steps:

- Develop a conceptual site exposure model (CSEM)
- Evaluate data
- Assess exposure
- Assess toxicity
- Characterize risk
- Discuss sources of uncertainty.

The SRA protocol is briefly described below. The results for the individual Training Area T-5 sites are discussed in Section 6.2.

6.1.1 Conceptual Site Exposure Model

The physical characteristics of the Training Area T-5 Sites are discussed in greater detail in Chapter 1.0 of this document. The seven Training Area T-5 sites included in this evaluation, the order in which they are discussed, and salient features pertinent to risk assessment are as follows:

- ***Former Detection and Identification Area, Parcel 180(7).*** This approximately 0.5-acre roughly rectangular site located to the west of Rucker St. is not contiguous with other Training Area T-5 Sites. The historical evidence suggests that significant contamination with CWM is unlikely. Perhaps the most significant characteristic is a pit in which CWM training aids were twice burned and buried.

- ***Training Area T-5, Parcel 182(7).*** This approximately 10.5-acre roughly rectangular site is the largest of the Training Area T-5 Sites. It is also known as the Former Area T-5, and the Former Toxic Hazards Detection and Decontamination Training Area. Various decontamination solvents and solutions may have been used on this site. A former report states that site soils were chemically decontaminated, excavated and disposed at another location. The site is contiguous with the Dog Kennel Area, Parcel 516(7) (see below).

- ***Blacktop Training Area, Parcel 511(7), and Fenced Yard in Blacktop Area, Parcel 512(7).*** This approximately 3.5-acre, roughly rectangular site is located to the northeast of the Dog Training Area, Parcel 513(7), but is not contiguous with it. Contained entirely within the Blacktop Training Area, Parcel 511(7) is the Fenced Yard in Blacktop Area, Parcel 512(7), which is an approximately 0.5-acre rectangle. Training performed in this area may have included flame and smoke agents. The Fenced Yard, at one time surrounded by a high fence, may have been

used to store agents or for toxic agent training. Soil samples were taken adjacent to or from the paved area proper (Figure 2-1). Since PAHs are an integral constituent of asphalt, the IT (2000c) background screening criteria (BSC) for PAHs in soil beneath asphalt will be used in the selection of site-related chemicals in soil. The Fenced Yard is sufficiently small and the former use of both parcels appears to be sufficiently similar that the two parcels are combined as one for evaluation in the SRA.

- ***Dog Training Area, Parcel 513(7).*** This approximately 1-acre roughly rectangular site is located just to the north and contiguous along part of its southern border with the Dog Kennel Area, Parcel 516(7). It was used for training dogs for the Military Police. The most salient feature is a large concrete pad showing severe degeneration. The Dog Training Area, Parcel 513(7) is evaluated separately from the Dog Kennel Area, Parcel 516(7) in the SRA because the potential for contamination of the two areas appears to be somewhat different.

- ***Dog Kennel Area, Parcel 516(7).*** This approximately 1-acre rectangular site is located largely within Training Area T-5, Parcel 182(7). It is evaluated separately from the Dog Kennel Area, Parcel 516(7) largely because the potential for contamination of the two parcels appears to be different and because both parcels are of reasonable size for a residential exposure unit (EU).

- ***Old Burn Pit, Parcel 514(7).*** This approximately 0.15-acre roughly triangular site is located in the woods about 300 ft west-northwest of the Former Detection and Identification Area, Parcel 180(7). The site apparently was used as a burn pit, but details of its former use are lacking. Although very small, the site is evaluated separately in the SRA because it is not contiguous with any other site.

6.1.1.1 Contaminant Sources, Release, and Transport

The CSEM identifies the potential contaminant sources and release mechanisms, the originally contaminated environmental media ("source" media), and contaminant migration pathways for the Training Area T-5 Sites (Figure 6-1). The sites are sufficiently similar that they can be described as one for the purposes of the CSEM.

Briefly, the storage of toxic substances, their use in training, and decontamination activities may have resulted in release, discharge or spills of various CWM and decontamination agents. In addition, burning of training aids and other potentially contaminated items may have resulted in release of metals and release of PAHs, which form ubiquitously as products of incomplete combustion.

Chemicals in soil may leach to groundwater and remain in the groundwater beneath the Training Area T-5 Sites, or migrate by groundwater flow to downgradient and possibly off site locations. Seeps may discharge groundwater to the surface, particularly in the drainage feature to the

northeast of the Old Burn Pit, Parcel 514(7), which often has a small area of standing water. The wet area is too small to be considered a significant exposure point. Chemicals in surface soil may enter surface water and sediment via runoff and erosion, and migrate downgradient through various drainage features. Chemicals in surface soil also may volatilize into the air, enter the air in the form of dust, or accumulate in vegetation browsed by deer. Contaminants may enter the human food chain when the deer are hunted and the venison is consumed. Although hunting is not currently permitted, it was in the past and is slated to be permitted in the future.

Contaminant sources and their release and transport mechanisms are displayed graphically in Figure 6-1.

6.1.1.2 Receptors, Exposure Media, and Exposure Routes

Human receptors may come into contact with the chemicals in soil, groundwater, surface water, and sediment.

The Training Area T-5 Sites are currently unused except that the Dog Kennel Area, Parcel 516(7) is being used to kennel dogs. Future site use is projected to be mixed business, passive recreation and developmental reserve. Therefore, it is accurate to conclude, for the purposes of CSEM development, that the future site use of the Training Area T-5 Sites is projected to be recreational or commercial.

Five receptor scenarios were chosen from the IWWP to evaluate potential human exposure to the environmental media at the Training Area T-5 Sites. The receptor scenarios shown on Figure 6-1 are explained more fully in Table 6-1.

The recreational site user is included as the only plausible receptor for all but one of the Training Area T-5 Sites under the current site-use scenario. The exception is the Dog Kennel Area, Parcel 516(7), which is currently being used to kennel dogs, and for which the groundskeeper is evaluated as the upper bound on risk for long-term commercial or industrial site use under the current site-use scenario. As indicated in Table 6-1, receptors under the current site-use scenarios are assumed to be exposed to surface soil (i.e., it is assumed that construction, excavation or grading that would bring subsurface soil to the surface is not currently underway). In addition, the recreational site user is assumed to play in the drainage features with exposure to surface water and sediment.

The groundskeeper is included under the future site-use scenario as the upper bound on risk for long-term commercial or industrial site use. The construction worker is evaluated as the upper

bound on risk for intense, short-term exposure. Presumably, construction activity would be required should the sites be developed for any use other than passive recreation. The on-site resident is included for the additional information provided by the theoretical upper-bound on long-term risk. Residential development is very unlikely for the Training Area T-5 Sites.

Receptors under the future site-use scenarios are assumed to be exposed to total soil to reflect the potential for construction or development to bring subsurface soil to the surface. In addition, the recreational site user is assumed to play in the drainage features with exposure to surface water and sediment as described under the current site-use scenarios. The groundskeeper, construction worker and on-site resident are also assumed to be exposed to groundwater developed as a potable source.

Another plausible exposure pathway involves consumption of game animals harvested from the sites. Hunting is not currently allowed on the Training Area T-5 Sites, but it has been allowed in the past and is slated to be allowed in the future. The game is assumed to be venison because deer are the game species most widely hunted and most likely to contribute significantly to the diet. Game consumption is evaluated only for the recreational site user under both the current and future site-use scenarios. Game consumption is considered a plausible exposure scenario at all sites except the Blacktop Training Area, Parcel 511(7) including the Fenced Yard in Blacktop Area, Parcel 512(7), which are paved and provide no browse for deer, and Dog Kennel Area, Parcel 516(7), which is currently used to kennel dogs. Consumption of sport-caught fish was also considered, but the drainage features are ephemeral and are not sufficient to support sport fishing. Therefore, consumption of sport-caught fish is not evaluated.

6.1.2 Data Evaluation

Data evaluation consists of the following steps as described in the IWWP.

6.1.2.1 Establish Data Sets

The exposure unit (EU) concept must be introduced at this point. An EU is the area over which exposure is assumed to be random. The concept applies to soil, surface water, and sediment. For example, a reasonable EU for soil for an on-site resident or a construction worker may be as small as 0.5 acre or possibly smaller (i.e., the size of a building lot, or a small area on which a construction project is performed). An EU for a groundskeeper or recreational site user, on the other hand, may be much greater, perhaps the size of an entire site, because these receptors are expected to work or play over a larger area.

Two of the Training Area T-5 Sites are larger than a reasonable EU for construction worker or residential exposure. Future site use, however, is not known in sufficient detail to identify realistic EUs. Therefore, the approach taken herein is to simplify by initially treating each of the Training Area T-5 sites as a single EU. Following the initial evaluation, chemicals of potential concern (COPC) in soil are re-evaluated using their maximum detected concentrations (MDC). The risk estimates from the initial evaluation and the reevaluation are compared to determine whether an EU evaluation would lead to different conclusions regarding management of the site.

The EU concept applies also to surface water and sediment. All five surface water and sediment samples were taken from the only significant drainage feature at the Training Area T-5 Sites, which is the ephemeral ditch that flows northward near the eastern border of Training Area T-5, Parcel 182(7), the Dog Kennel Area, Parcel 516(7), the Dog Training Area, Parcel 513(7), and near the western border of the Blacktop Training Area, Parcel 511(7). The data from all five samples will be combined to form single surface water and sediment data sets assuming that the recreational site user would be randomly exposed across the entire drainage feature while playing in water.

Separate data sets for each parcel were established for surface soil, subsurface soil and total soil. (See Section 6.1.2.3 for an explanation of total soil.) The surface water and sediment data were combined into single data sets as explained above. The groundwater data were also compiled into a single data set because production wells can be installed at any location and potable water can be piped to any location at one or several sites.

6.1.2.2 Select Site-Related Chemicals

Recently the procedure for comparing site and background metals data sets and for selecting site-related chemicals has changed, making better use of background and site data, applying more precise statistical comparisons, and employing geochemical analysis to help resolve the site-related question as necessary (Shaw, 2003; Appendix H). Briefly, the new procedure consists of the following three-tiered process:

- ***Tier 1.*** The MDC of the metal is compared with the Background Screening Criterion (BSC), which is two-times the mean background concentration as estimated by SAIC (1998). If the MDC does not exceed the BSC, concentrations of that metal at all points within the geographic area represented by the data set are considered to be comparable to background and that metal is not evaluated further. Metals whose MDCs exceed their BSCs are carried to Tier 2.

- ***Tier 2.*** Two different statistical tests described in detail in Appendix H are used to determine whether the site concentrations are comparable to background

concentrations. One test is the slippage test, which is used as a test of upper tails. The other is the Wilcoxon Rank Sum Test (WRST), which evaluates the likelihood that the site and background data sets are drawn from different populations. Metals that pass statistical testing are ordinarily not evaluated further, unless knowledge about site activities or the nature of the data set suggest that the metal could be site related. Such chemicals, as well as those that fail their statistical tests are carried to Tier 3.

- ***Tier 3.*** Geochemical analysis is based on the natural association between the metal of interest and one or more specific soil-forming minerals that concentrate that metal. The correlation of the metal of interest with a major element representing the abundance of the specific mineral that concentrates the trace element is evaluated. Metals that pass the geochemical evaluation are not evaluated further in the SRA. Metals that fail are selected as site-related chemicals and are subjected to COPC selection as described below.

Metals eliminated from COPC selection by the three-tiered system described above are termed "background metals" to differentiate them from "site-related metals," which are subjected to COPC selection as described below. Data for each medium were combined across all seven parcels to produce the largest and most robust data sets for the statistical (Tier 2) evaluation.

6.1.2.3 Identify Chemicals of Potential Concern

The MDCs of the site-related chemicals were compared with their respective SSSLs to identify COPCs, as explained in the IWWP. Cancer-based SSSLs correspond to an incremental lifetime cancer risk (ILCR) of 1E-6, and noncancer-based SSSLs correspond to a hazard index (HI) of 0.1 to provide additional protection for simultaneous exposure to multiple chemicals. The COPCs identified in this manner are receptor- and medium-specific risk-based concentrations.

An important clarification of the IT (2002b) IWWP involves how COPCs are identified and STCs are estimated for total soil, which is a hypothetical soil data set designed to address the potential for exposure to both surface and subsurface soil as a result of excavation and grading. A former commonly used approach involves combining the surface and subsurface soil data sets into one data set for COPC identification. This approach implies that perfect blending of surface and subsurface soil over the entire site occurs during construction activities. More realistically, soil at the surface to which a receptor may be exposed is likely to be predominantly surface soil or predominately subsurface soil from one place to another within an EU. Therefore, the surface and subsurface soil data sets are not combined in this manner for the total soil evaluation. Instead, COPCs are selected separately for surface and subsurface soil. Any chemical selected as a COPC for either surface or subsurface soil is selected as a COPC for total soil. The STC selected for a given COPC in total soil is the larger of the STCs estimated for surface or

subsurface soil. This revision is somewhat more health-protective than the earlier protocol, because data from the more lightly contaminated soil level do not "dilute" the data from the more heavily contaminated soil level. Furthermore, maintaining separate data sets for surface and subsurface soil facilitates identifying the depth at which contamination is present at unacceptable concentrations, which permits more efficient and cost-effective cleanup.

6.1.2.4 Estimate Source-Term Concentrations

Ideally, the STC of a given COPC in soil, sediment and surface water is a single value that reflects a conservative estimate of average over the area represented by the entire data set. The 95th upper confidence limit (UCL) on the arithmetic mean is usually estimated for this purpose. The first step in UCL estimation is application of the Shapiro-Wilks test to characterize the nature of the data distribution for each COPC. Distribution testing is limited to data sets with five or more samples. The Student's *t* test was used to estimate UCLs for COPCs with normal distributions, and the Chebyshev Inequality method was used to estimate UCLs for COPCs with lognormal and nonparametric distributions as explained in the IWWP and recommended by EPA (2002a). A minor change from previous SRAs for other sites is use of one-half the method detection limit (MDL) rather than one-half the reporting limit (RL) as a surrogate concentration for non-detects in the data sets of detected chemicals. Use of one-half the MDL yields a more reasonable UCL because the region between the MDL and RL is not double-counted in estimating a surrogate concentration.

The MDC is selected as the STC when it is lower than the UCL on the mean, or when a UCL is not estimated (e.g., if the data set contains fewer than five samples). The arithmetic mean is selected as the STC for lead as explained in Section 6.1.5.2.

EPA (2002b) recommends that the arithmetic mean of the most concentrated part of the plume should be selected as the STC for COPCs in groundwater. The groundwater data are evaluated in detail and the selection of COPCs and STCs is explained in Section 6.2.1.2, the description of the groundwater evaluation for the Former Detection and Identification Area, Parcel 180(7).

6.1.3 Exposure Assessment

The exposure assessment involves developing the receptor scenarios, estimating exposure-point concentrations, and estimating exposure route-specific intake or uptake rates for all receptors. The receptor scenarios included in this evaluation were identified in the CSEM and previously developed in the IWWP. The SSSLs incorporate the models and variable values that relate exposure-media concentrations to STCs, as well as the models and variable values for COPC

intake and uptake, which obviates estimating exposure route-specific intake or uptake rates as a separate task in the risk assessment.

The EU concept was introduced in Section 6.1.2.1. Underestimating the size of a reasonable EU may impart a conservative bias to a risk assessment, largely because the size of the data set is reduced, which usually results in increased STC estimates. Overestimating the size of the EU, on the other hand, may impart a non-conservative bias to the risk assessment. This could occur because the analytical results from smaller, more heavily contaminated areas may be diluted by analytical data from larger, less heavily contaminated areas. In other words, the STC estimated from the entire data set may be less than the STC estimated from the data for a smaller area. It is generally impractical to divide the area of a site into reasonable EUs for the risk assessment, in part because the future site use is not that precisely known. The usual approach, therefore, is to include all of the soil data into a single data set, or, as was done herein, treat each of the seven parcels as a single EU. It is acknowledged, however, that two of the parcels constitute an unrealistically large EU for receptors such as the construction worker and on-site resident. The implications to the risk assessment are discussed in the results sections below for each of the seven parcels.

6.1.4 Toxicity Assessment

The toxicity assessment involves identifying the nature of the adverse health effects and quantifying the dose-response relationship for the chemicals selected as COPCs. The dose-response relationship is generally quantified by the development of toxicity values according to EPA-prescribed protocol. Toxicity values for cancer risk include a cancer slope factor (SF) expressed as risk per unit dose $[(mg/kg\text{-}day)^{-1}]$ or unit risk factor (URF) expressed as risk per unit concentration in air $[(\mu g/m^3)^{-1}]$. Toxicity values for noncancer effects include an RfD or threshold level based on dose expressed as mg/kg-day, or reference concentration (RfC) or threshold level based on concentration in air expressed as mg/m^3.

Toxicity values are usually found in various EPA sources, or they may be developed from the primary literature or by analogy to more completely studied chemicals that behave similarly. The EPA protocol is assumed to impart sufficient conservatism to the toxicity values so that they are protective for even the most sensitive members of the population. However, there is uncertainty regarding the development of toxicity factors, depending largely on the adequacy and completeness of the toxicity data base for each chemical. Therefore, it is possible, although unlikely, that the toxicity value for a given chemical may not be sufficiently protective for all members of the population.

The toxicity values are incorporated into the SSSLs. They are not developed or presented separately herein; rather, they are located or developed in the IT (2000c) report. However, the toxicity values of all detected chemicals were checked to ensure they were current before the SRA was initiated.

6.1.5 Risk Characterization

6.1.5.1 Protocol and Policy: Chemicals Other than Lead

Up to this point, the terms "risk" or "risk assessment" have been used generically to refer to the association of adverse human health effects with exposure to hazardous chemicals. In the risk characterization discussion, however, it is often helpful to distinguish cancer risk and noncancer hazard, because the two are estimated separately and the estimates are not combined. Cancer risk is more precisely called ILCR to reflect the assumption that risk above background levels is directly and linearly correlated with cumulative dose averaged over the receptor's lifetime. Cancer is generally evaluated as a non-threshold phenomenon; i.e., exposure to a potential carcinogen in any amount, however small, leads to some measurable risk.

The non-threshold assumption requires the application of policy to interpretation of ILCR estimates. EPA (1990) considers a cancer risk of 1E-6 to be a point of departure below which risks are generally considered to be insignificant. Therefore, chemicals that yield ILCR estimates less than 1E-6 are not considered in ILCR sums across COPCs or media. An ILCR between 1E-6 and 1E-4 is considered to fall within the risk management range, and is interpreted herein as not posing an unacceptable cancer risk. The regulators may exercise their prerogative to order further action, but they are not required to do so, particularly if further action is impractical. ILCR estimates that exceed 1E-4 are generally considered to be unacceptable.

The potential for the occurrence of noncancer effects is termed noncancer hazard, and is measured as an HI. Noncancer effects are generally considered to be threshold phenomena; therefore, the HI is the ratio of the ambient concentration of the COPC to the threshold level at which adverse effects are not expected to occur. This elevates interpretation to a science rather than policy. By definition, an HI less than or equal to 1 is interpreted to mean that noncancer adverse health effects are unlikely. An HI greater than 1 is interpreted to mean that the threshold has been exceeded, raising concern that adverse effects might occur.

Generally the first step in characterizing the total noncancer hazard for a given receptor is to sum the HI values across all the chemicals in the media to which the receptor may be exposed. Total HI values that do not exceed the threshold level of 1 indicate that adverse noncancer health

effects are unlikely, and noncancer effects are not investigated further. Total HI values that exceed the threshold level of 1 are subject to further refinement.

EPA (1989) acknowledges that adding all HI values may overestimate hazard, because the assumption of additivity is probably appropriate only for those chemicals that exert their toxicity by the same mechanism. However, sufficient data describing mechanisms of toxicity for use in predicting additivity with a high level of confidence are available for very few chemicals or chemical mixtures. In the absence of such data, EPA (1989) assumes that chemicals that act on the same target organ or that exert the same critical effect may do so by the same mechanism of toxicity. In other words, target organ or critical effect serves as a surrogate for mechanism of toxicity. When the sum of HI values for a receptor exceeds 1 due to the contributions of several chemicals, it may be appropriate to refine the HI estimate by segregating the chemicals by mechanism of toxicity (i.e., target organ or critical effect) and estimating separate HI values for each.

As a practical matter, since human environmental exposures are likely to involve near- or sub-threshold dose rates, the target organ(s) chosen for a given chemical are those associated with dose rates at or near the critical effect. The target organ selected is also based on duration of exposure (i.e., the target organ for chronic or subchronic exposure to low or moderate dose rates is selected rather than the target organ for acute exposure to high dose rates).

Risk characterization involves combining the results of the exposure assessment and toxicity assessment to estimate cancer risk and noncancer hazard. As noted above, both the exposure assumptions and toxicity assessment are included in the SSSLs. Therefore, all that remains for risk estimation in the SRA is to divide the STC by the appropriate cancer or noncancer SSSL and adjust for the basis of the SSSL. Specifically, ILCR for a given receptor exposed to a given COPC in a given medium is estimated as:

$$ILCR = \frac{STC \bullet TR}{SSSLc} \qquad \text{Eq. 6.1}$$

where:

ILCR	=	incremental lifetime cancer risk (unitless, calculated)
STC	=	source-term concentration (mg/kg for solid media, mg/L for water)
TR	=	target cancer risk on which SSSLc is based (unitless, 1E-6)
SSSLc	=	site-specific screening level based on cancer risk (same units as STC).

Similarly, the HI for a given receptor exposed to a given COPC in a given medium is estimated as:

$$HI = \frac{STC \bullet THI}{SSSLnc} \qquad \text{Eq. 6.2}$$

where:

HI	=	hazard index (unitless, calculated)
STC	=	source-term concentration (mg/kg for solid media, mg/L for water)
THI	=	target HI on which SSSLnc is based (unitless, 1E-1)
SSSLnc	=	site-specific screening level based on noncancer hazard (same units as STC).

EPA (1989, 2002b) suggests rounding risk and hazard estimates to one significant figure to reflect the uncertainty inherent in their estimation. Numerical estimates in the tables and text are presented in scientific notation with one integer and two digits to the right of the decimal. This presentation facilitates document review and replication of the calculations. Rounding of risk estimates was done only in the text, and only when it was helpful for interpretation. For example, an HI of 1.49E+0 would be rounded to 1 and interpreted as equal to, but not exceeding, the threshold level of 1. An ILCR of 9.50E-7 would be rounded to 1E-6 and interpreted as falling at the lower end of the risk management range.

6.1.5.2 Protocol and Policy: Lead

Lead is not evaluated in the same manner as other chemicals for two reasons. One reason is that health effects appear to occur at levels so low as to have no practical threshold. The second reason is that lead is ubiquitous so that exposure simultaneously involves multiple routes and sources. This means that toxicity values (reference doses and cancer slope factors), which generally apply only to one exposure route and source, may not be sufficiently protective. Therefore, neither a cancer SF nor noncancer RfD are available or developed. Instead, the EPA (2003a) Integrated Exposure Uptake Biokinetic model (IEUBK) was developed to estimate blood lead levels of very young children (0 to 7 years old) exposed to lead from multiple sources. The unborn or very young child is the human receptor most sensitive to exposure to lead, and delayed or impaired neurological development is the critical endpoint. The EPA (1996a) adult blood lead model (ABLM) was developed to estimate blood lead levels of women of child-bearing age, assuming that the unborn child is the most sensitive receptor in an adult exposure context. The ABLM was designed primarily to address exposure to lead in soil, but can be applied to other media as well.

The most appropriate way to evaluate lead is to compare the *average* ambient concentration with receptor- and medium-specific cleanup levels. Average concentration is used as the STC instead of the more conservative UCL on the mean because the blood lead models contain modules that statistically adjust for variation in exposure. Application of the EU concept, however, is important to ensure that data from relatively clean areas do not dilute the data from the more heavily contaminated areas.

EPA (1998) recommends using the IEUBK to back-calculate site-specific cleanup levels for lead in soil to which children might be regularly exposed. This recommendation was followed to develop the SSSL for residential soil of 400 mg/kg. A soil lead concentration of 350 mg/kg (calculations not shown) was found to comply with EPA (1998) standards. The concentration of 350 mg/kg, rounded to one significant figure to reflect the uncertainty about the estimation, is 400 mg/kg. The SSSL of 400 mg/kg is accepted as the cleanup level for lead in soil for residential exposure scenarios that may include children. The net effect of this exercise is to elevate the status of the 400 mg/kg soil lead concentration from an SSSL to a cleanup level. The new designation of 400 mg/kg in residential soil as a cleanup level is consistent with the recent EPA (1998, 2001) evaluation that describes 400 mg/kg as a "level of public health concern (that) may pose a health risk to children through elevated blood lead levels." The ABLM was used in a similar manner to estimate the SSSL of 880 mg/kg for groundskeeper and construction worker exposure to soil. The SSSL of 880 mg/kg is adopted as the cleanup level for soil for these receptors.

The SSSL for residential soil of 400 mg/kg was adopted as the SSSL for lead in soil for the recreational site user. This approach is very conservative because recreational site use is expected to result in far less intense exposure to soil than residential use, so a more realistic cleanup level for lead in soil was developed for this scenario. Unsupervised young children are unlikely to roam repeatedly and predictably over the Training Area T-5 Sites used for passive recreation; therefore, a woman of child-bearing age was selected as the most sensitive receptor for lead in soil. The recreational site user is visualized as a woman – perhaps an avid wildlife/birdwatcher/hiker – who visits the site regularly for two days on each weekend of the year. (The site-specific exposure parameters for the recreational site user scenario were developed and defended in the IWWP). A cleanup level for lead in soil of 7.60E+3 mg/kg was derived for areas designated for passive recreation by applying the site-specific exposure variables developed in the IWWP to the EPA (1996a) ABLM. The details of the calculation are presented in Appendix I.

The SSSL for residential soil of 400 mg/kg was adopted as the SSSL for lead in soil for the indirect exposure venison consumption pathway. The intention of this extremely conservative approach is to cause lead to be selected as a COPC if its MDC in soil exceeds its residential screening level. Selection as a COPC generally means that further investigation is in order. Further investigation consists of clarifying the potential for lead to significantly affect human health through food-chain pathways. The biotransfer of lead has been studied extensively. Although minimal biotransfer occurs, biomagnification does not (ATSDR, 1999). Furthermore, lead in terrestrial animals (such as deer and other game animals) partitions largely to the bones, which are generally considered to be inedible. It is concluded that lead in soil is unlikely to participate significantly in terrestrial food-chain pathways and further evaluation is not required.

The residential soil SSSL of 400 mg/kg was adopted as the SSSL for lead in sediment for the recreational site user. This approach is very conservative because exposure to sediment in a recreational site-use scenario would be far less than exposure to soil in a residential scenario. A somewhat more realistic approach, adopted herein, is to adopt the cleanup level for lead in soil of 7.60E+3 mg/kg for the recreational site user described above as the cleanup level for lead in sediment for the recreational site user.

The EPA (2004a) action level for lead in tap water of 1.50E-2 mg/L was adopted as the SSSL for lead in groundwater for residential use. The same value was also adopted as the SSSL for lead in surface water for recreational site-user exposure, to cover for the plausible but infrequent intentional consumption of surface water (1 liter/day) by a thirsty individual playing far from a potable water source. A more realistic approach, however, would be to adjust the SSSL by the differences in drinking water consumption and exposure frequency between a resident and a recreational site user. The adult resident is assumed to consume 2 liters of drinking water from the site on 350 days/year; the recreational site user is assumed to consume 1 liter of surface water on the site on 104 days/year. In other words, exposure is expected to be 0.15 times as great for the recreational site user as for the on-site resident. Therefore, the EPA (2004a) action level for lead of 1.5E-2 mg/L is divided by 0.15 to yield a cleanup level of 1.0E-1 mg/L for lead in surface water for recreational site user exposure.

An additional consideration for lead in soil at residential sites is the potential for harm from acute exposure. EPA (2003b) developed an acute criterion for lead in soil of 6.50E-3 mg/kg, intended to be protective of a two-year-old child ingesting 10 grams of soil as a one-time event. The acute criterion of 6.50E-3 mg/kg should be applied as a not-to-exceed value for lead in residential soil.

6.1.6 Uncertainty Evaluation

This section discusses some of the more significant uncertainties inherent in the risk assessment for the Training Area T-5 Sites as a whole that may affect the results or their interpretation. Uncertainty is a factor in each step of the SRA. Uncertainties associated with the earlier stages of the SRA become magnified when they are concatenated with uncertainties in the latter stages of the process. It is not possible to eliminate all uncertainty; however, a recognition of the more significant uncertainties is fundamental to the understanding and reasonable use of risk assessment results. Significant sources of uncertainty specific to a given parcel are addressed in the discussion for that parcel.

Generally, risk assessments carry two types of uncertainty. Measurement uncertainty refers to the usual variance that accompanies the scientific measurements (e.g., instrument uncertainty [accuracy and precision] associated with contaminant concentrations). A different kind of uncertainty stems from data gaps (i.e., additional information needed to complete the database for the assessment). Often the data gap is significant, such as the absence of information on the effects of human exposure to a chemical (e.g., 1,1,2,2-tetrachloroethane) or the frequency with which a certain receptor (e.g., recreational site user) may visit the site.

Adequacy of the sampling program to identify the areas of greatest contamination is a source of uncertainty in any risk assessment. However, the former use and layout of the parcels under investigation is fairly well known, facilitating identification of areas most likely to be contaminated. Also, investigation of the Training Area T-5 Sites has undergone several iterations. Therefore, uncertainty about the adequacy of the sampling program is considered to be minimal for these sites.

Variations in sampling and laboratory analytical procedures introduce uncertainty; it is unclear whether this imparts a positive or negative bias to the risk assessment. Along with this is the MDL achieved by the laboratory. For example, cadmium was detected in 1 of 7 soil samples at the Former Detection and Identification Area, Parcel 180(7). The MDL for cadmium ranged from 0.495 to 4.92 mg/kg. Therefore, 86 percent of the samples were nondetects, for which one-half the MDL was used as a surrogate concentration. However, the value of one-half the MDL is very likely to exceed the background screening criterion of 0.29 mg/kg, which suggests that its use as a surrogate concentration for nondetects artificially increases the mean concentration of cadmium as a site-related metal in surface soil.

Another source of uncertainty is the manner in which the data sets for soil are compiled for the various receptors. It is reasonable to assume that a groundskeeper or recreational site user may

be exposed randomly over an entire parcel in the course of his activities, in which case estimating a single STC for a given COPC from the entire data set for that parcel is appropriate. However, a construction project or a residential site may be restricted to an EU as small as 0.25 acre, in which case estimating a single STC from the entire data set for some of the parcels (e.g., Training Area T-5, Parcel 182[7]; Blacktop Training Area, Parcel 511[7]) may underestimate risk. Conversely, assuming that a groundskeeper or recreational site user would spend all of his time at the smaller sites (e.g., Old Burn Pit, Parcel 514[7]; Former Detection and Identification Area, Parcel 180[7]; Fenced Yard in Blacktop Area, Parcel 512[7]) may overestimate risk. Inability at this time to identify actual future EUs adds to the uncertainty. However, very little contamination of significance was found in the soil, so this imparts no significant uncertainty to this particular evaluation.

Uncertainty arises by excluding background metals from the quantitative risk assessment. A non-conservative bias could have been imparted to the results and interpretation if these chemicals had been excluded in error (i.e., if in fact their ambient concentrations reflect site-related releases rather than background conditions). The likelihood of error, however, is less for CWM training sites than for other kinds of sites (e.g., landfills) because the activities that took place at these sites and the chemicals that may have been released are fairly well known. Metals, with the possible exception of arsenic are unlikely to result from CWM testing and decontamination.

As noted above, the exclusion of background metals is performed as a 3-tiered process. Tier 1 – comparison of the MDC with the BSC – is generally considered to be sufficiently conservative so that the uncertainty associated with metals excluded at this tier is minimal. Also, only metals present at concentrations greater than their SSSL are considered to potentially contribute significant risk. Therefore, only metals excluded at Tier 2 or Tier 3, *and* that have MDCs that exceed their SSSLs are considered to impart significant uncertainty. These metals are addressed in the uncertainty discussions for the individual parcels.

Iron was designated a background metal at several sites. The toxicity evaluation for iron, however, is controversial and is probably overly conservative for environmental exposures in the United States, and generally is not used in risk assessments (see toxicity profile for iron in IT, 2000c). Therefore, the exclusion of iron as a COPC in total soil is judged to contribute minimal uncertainty to the SRA.

The purpose of the uncertainty discussion is not to disparage the results of the risk assessment, but to provide perspective to risk managers who may use this evaluation to make decisions regarding future use or management of the Training Area T-5 Sites.

6.2 Site-Specific Results

6.2.1 Former Detection and Identification Area, Parcel 180(7)

6.2.1.1 Data Sets

The five surface water and sediment samples were taken from the only significant drainage feature in the Training Area T-5 Sites, which is the ephemeral ditch described in Section 6.1.2.1. Therefore, the surface water and sediment data were combined to form single data sets rather than individual data sets for each of the Training Area T-5 Sites. This approach reflects the only plausible scenario for exposure to surface water and sediment – there is only one location in the entire Training Area T-5 Area where receptors may engage in water play. The surface water (Table 6-2) and sediment (Table 6-3) data sets consist of co-located samples analyzed for CWM degradation products (including orthosulfur compounds), metals, SVOCs, and VOCs.

The groundwater data set consists of 102 samples taken from 53 monitoring wells associated with each of the Training Area T-5 Sites, including 5 wells associated with Parcel 232Q-X (Ranges West of Iron Mountain Road) (Table 6-4). Various samples were analyzed for various parameters as indicated in Table 6-4. The analytical data from all samples were combined and evaluated as a single data set instead of segregated by individual parcel. This conservative approach reflects a realistic exposure scenario: production wells can be installed essentially anywhere and the water can be piped to receptor locations at any of the individual Training Area T-5 Sites.

The surface soil data set for the Former Detection and Identification Area, Parcel 180(7) consists of seven samples taken from seven locations analyzed for the parameters listed in Table 6-5. The samples include a depositional soil sample taken approximately 180 feet north of the site border, and surface samples from well installations within the boundaries of the site (3 samples) and north (downgradient) of the site (3 samples) (Figure 2-1). The subsurface soil data set consists of six samples taken from the six well installation locations described above analyzed for the same parameters (Table 6-6).

6.2.1.2 Chemicals of Potential Concern

Chemicals detected in site surface water are limited to metals and low concentrations of acetone (Table 6-7). The metals were essential nutrients or judged to be present at background concentrations and were not selected as site-related chemicals. The MDC of acetone was more than two orders of magnitude below its SSSL; therefore, acetone was not selected as a COPC (Table 6-8). In summary, no chemicals in surface water were identified as COPCs. Surface water is judged to be essentially uncontaminated for purposes of the SRA and is not considered further in any of the site-specific evaluations.

Chemicals detected in sediment include metals, several PAHs, and low concentrations of a few VOCs (Table 6-9). All the metals except chromium were essential nutrients or judged to be present at background concentrations and were not selected as site-related chemicals. Examination of the raw data (Appendix F) reveals that all the PAHs (except one low detection of fluoranthene) were identified only at sample location CWM-511-SW/SD03, which is immediately downgradient of the Blacktop Training Area, Parcel 511(7). It appears that the PAHs at this location reflect runoff from the blacktop, which is known to be an anthropogenic background source of these chemicals. Chromium, the PAHs, and the VOCs were subjected to COPC selection by comparison of their MDCs with their respective SSSLs (Table 6-10). None were identified as COPCs. Sediment is judged to be only lightly contaminated and very unlikely to contribute significantly to risk. Therefore, sediment is not considered further in any of the site-specific evaluations.

The groundwater picture at the Training Area T-5 Sites is very complicated. As stated above, 102 samples were taken from 53 wells (Table 6-4) spread over a very large area (Figure 2-1). Isopleth maps presented in Chapter 4.0 clearly show that multiple plumes exist, at least regarding the chlorinated solvents, each likely reflecting a separate source area independent of the others. The identification of COPCs and estimation of STCs is described for each of the classes of chemicals identified in the groundwater.

Metals. The usual long list of metals was identified in groundwater, but all metals were essential nutrients or judged to be present at background concentrations (Table 6-11); therefore, none were subjected to COPC selection.

Semivolatile Organic Compounds. Four SVOCs were detected in groundwater (Table 6-11). Only bis(2-ethylhexyl)phthalate would have been selected as a COPC because its MDC exceeded one or more SSSLs. Bis(2-ethylhexyl)phthalate was reported in 4 (of 69) samples as follows:

Sample Location	Detection Sample Date/ Result (mg/L)[a]	Other Sample Date/ Result (mg/L)
HR-232QX-MW18	1 April 2003/ 0.074	NA
CWM-182-MW04	19 December 2001/ 0.12	18 March 2003/ ND
CWM-514-MW01	5 February 2002/ 0.077	9 April 2003/ ND
CWM-514-MW03	7 February 2002/ 0.045	7 February 2002 FD[b]/ ND 14 April 2003/ ND 14 April 2003 FD[b]/ ND

[a] From the data summarized in Table 6-11.
[b] FD = field duplicate.
NA = not analyzed; ND = not detected.

It is noted that bis(2-ethylhexyl)phthalate was not identified in more recent samples (including field duplicates) from 3 of the 4 wells in which it was reported, casting doubt upon the original reports. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant and a widely used plasticizer that leaches readily from plasticware and is frequently reported in environmental samples, particularly samples of aqueous media. External contamination with the compound is not always revealed in the field and laboratory blanks that accompany the samples. Also, examination of the raw data (Appendix F) and sample locations (Figure 2-1) shows no evidence of a release or a resulting plume. It is concluded that bis(2-ethylhexyl)phthalate is not a site-related chemical in groundwater at the Training Area T-5 Sites. An STC is not estimated and the compound in groundwater is not evaluated further.

Volatile Organic Compounds. A total of 21 VOCs were detected in groundwater samples from the Training Area T-5 Sites (Table 6-11). Several were reported at concentrations below their respective SSSLs and are considered no further. The others are addressed individually.

1,1,2,2-Tetrachloroethane (1,1,2,2-TCA). 1,1,2,2-TCA is identified as a COPC because its MDC exceeds at least one SSSL for each of three receptors (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 indicates that the compound was identified in four general areas. Three of these appear to be isolated reports that do not define a plume, including: (1) the southern part of Training Area T-5, Parcel 182(7) (CWM-182-MW07), (2) the northern part of Training Area T-5, Parcel 182(7) or more accurately within the Dog Kennel Area, Parcel 516(7) (CWM-516-MW02), and (3) the Fenced Yard in Blacktop Area, Parcel 512(7) (CWM-512-MW01 [residuum well] and CWM-512-MW02 [bedrock well]). A plume, however, is clearly

seen in residuum groundwater including the Old Burn Pit, Parcel 514(7) and the area to the east and northeast (Figure 2-1), consistent with the direction of groundwater flow (Figures 3-6 and 3-7). The most highly contaminated part of the plume appears to involve CWM-514-MW03 and CWM-514-MW09. Concentrations in these wells appear to be unusually consistent, ranging from 0.14 to 0.29 mg/L, with little change between February 2002 and April 2004. The analytical results from three samples from CWM-514-MW03 yield an average concentration for CWM-514-MW03 of 0.24 mg/L. The analytical results from two samples from CWM-514-MW09 yield an average concentration for CWM-514-MW09 of 0.155 mg/L. A concentration of 0.20 mg/L, which is adopted as the STC for 1,1,2,2-TCA, is estimated from the averages of these two wells.

1,1,2-Trichloroethane (1,1,2-TCA). 1,1,2-TCA is identified as a COPC because its MDC exceeds the cancer-based SSSL for residential exposure (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 indicates that the compound was identified in three general areas, similar to those observed for 1,1,2,2-TCA. Two of these appear to be isolated reports that do not define a plume, including: the southern part of Training Area T-5, Parcel 182(7) (CWM-182-MW07), and the Fenced Yard in Blacktop Area, Parcel 512(7) (CWM-512-MW02 [bedrock well]). Generally higher concentrations, however, appear to define a plume in residuum groundwater including the Old Burn Pit, Parcel 514(7) and the area to the east (Figure 2-1). The most highly contaminated part of the plume appears to involve CWM-514-MW03 and CWM-514-MW09. Concentrations in these wells ranged from 6.4E-4 mg/L to 2.3E-3 mg/L. It is unclear if the concentrations in either well are trending upward or downward. The analytical results from three samples from CWM-514-MW03 and two samples from CWM-514-MW09 were averaged to obtain a concentration of 1.2E-3 mg/L, which is adopted as the STC for 1,1,2-TCA for this evaluation.

1,1-Dichloroethene (1,1-DCE). 1,1-DCE is identified as a COPC because its single reported concentration exceeds the cancer-based SSSL for 2 receptors (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 shows that the single detection occurred in Sample Number TKC3005 taken on April 19, 2004, from CWM-514-MW04, which is a bedrock well in the area of greatest chlorinated solvent contamination. 1,1-DCE is a known degradation product of chlorinated solvents and this sample also had the MDC of trichloroethene (TCE). A sample taken from the same well a year earlier (April 11, 2003) was nondetect for 1,1-DCE. It is possible that the concentration of 1,1-DCE at this location may be increasing as the chlorinated solvent plume ages and TCE degradation occurs. Largely for this reason it is deemed prudent to select the compound as a COPC and adopt the detected concentration of 6.50E-4 mg/L as the STC.

1,2-Dichloroethane (1,2-DCA). 1,2-DCA is identified as a COPC because its single reported concentration exceeds the cancer-based SSSL for residential exposure (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 indicates that the compound was reported at an estimated concentration (J-validation qualifier) only in CWM-512-MW01 (April 3, 2003), but in no other wells in the Blacktop Training Area, Parcel 511(7) or the Fenced Yard in Blacktop Area, Parcel 512(7), or in any of the other Training Area T-5 Sites. The compound is not a known degradation product of chlorinated solvents and there is no evidence that it was used at the Training Area T-5 Sites. Furthermore, a previous sample (November 28, 2001) from CWM-512-MW01 was nondetect for the compound. For these reasons the single report of 1,2-DCA is considered a spurious finding, no STC is estimated, and the compound is not evaluated further in the SRA.

Acetone. Acetone is identified as a COPC because its MDC exceeds the noncancer-based SSSL for all receptors assumed to be exposed to groundwater developed as a potable source (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 indicates that the compound was identified predominantly in two general areas: (1) the Former Detection and Identification Area, Parcel 180(7), and (2) the Old Burn Pit, Parcel 514(7). In addition, a single detection was reported at the Blacktop Training Area, Parcel 511(7). Although acetone is a common sample contaminant and is not a constituent of the decontamination solutions or CWM likely used at the Training Area T-5 Sites, it is possible that acetone or alcohols that may degrade to acetone may have been used at these sites. Furthermore, the detected concentrations were sufficiently high (up to 20 mg/L) to suggest that acetone was a site-related chemical requiring further evaluation rather than a common sample contaminant in this case. Therefore, the compound is selected as a COPC. It is noted that all detections were J-qualified during data validation, reflecting the well-known difficulty in quantifying acetone concentrations by EPA Method 8260. The highest concentrations reported were associated with the Former Detection and Identification Area, Parcel 180(7). A total of six reported detections ranged from 0.066 to 20 mg/L. The next highest concentrations, associated with the Old Burn Pit, Parcel 514(7), ranged from 0.0042 to 2.4 mg/L. The six detections at Parcel 180(7) were averaged to obtain a concentration of 5.4 mg/L, which is adopted as the STC for this evaluation.

Bromodichloromethane. Bromodichloromethane is identified as a COPC because its single reported concentration exceeds the cancer-based SSSL for residential exposure (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 indicates that the compound was reported only in CWM-514-MW15 (August 4, 2004), but in no other wells in or near the Old Burn Pit, Parcel 514(7), or in any of the other Training Area T-5 Sites. The compound is not a known

degradation product of chlorinated solvents and there is no evidence that it was used at the Training Area T-5 Sites. For these reasons the single report of bromodichloromethane is considered a spurious finding; no STC is estimated and the compound is not evaluated further in the SRA.

Carbon Tetrachloride. Carbon tetrachloride is identified as a COPC because its MDC exceeds the SSSLs for all receptors evaluated for exposure to groundwater (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 indicates that the compound was reported in eight samples from five wells associated with the southern third of Training Area T-5, Parcel 182(7). It appears that carbon tetrachloride may have been used as a solvent or decontamination agent restricted largely to this area. Reported concentrations ranged from 2.2E-4 mg/L to 5.9E-2 mg/L with an average of 2.2E-2 mg/L, which is adopted as the STC.

Tetrachloroethene (Perchloroethene or PERC). PERC is identified as a COPC because its MDC exceeds the cancer-based SSSL for the resident (Table 6-12). Review of the raw data (Appendix F) and Figure 2-1 indicates that the compound was detected in detected samples from four wells associated with the Old Burn Pit, Parcel 514(7) at concentrations ranging from 2.1E-4 mg/L to 1.8E-3 mg/L, which is the MDC. A single detect was reported also at the Fenced Yard in Blacktop Area, Parcel 512(7), and two detections from one well was reported in the southern third of Training Area T-5, Parcel 182(7). It appears that PERC may have been used or disposed primarily at the Old Burn Pit, Parcel 514(7). Reported concentrations in the seven samples from this area ranged from 2.1E-4 mg/L to 1.8E-3 mg/L with an average of 9.7E-4 mg/L, which is adopted as the STC.

Trichloroethene (TCE). TCE was identified as a COPC because its MDC exceeded SSSLs for each of the three receptors evaluated for exposure to groundwater (Table 6-12). The compound was identified in 46 of 102 samples. Review of the raw data (Appendix F) and Figure 2-1 indicates that TCE occurrence in groundwater is widespread, generally consistent with isopleth maps in Chapter 4.0, suggesting it was the solvent or decontamination agent of choice and was widely used. TCE detections in groundwater were associated with four major areas: (1) The Old Burn Pit, Parcel 514(7), extending as far northeast as CWM-514-MW16. The highest concentrations were found in this area. (2) The Former Detection and Identification Area, Parcel 180(7), (3) The Blacktop Training Area, Parcel 511(7), including the Fenced Yard in Blacktop Area, Parcel 512(7), and (4) Training Area T-5, Parcel 182(7). The data are sufficient to generalize that TCE concentrations at Training Area T-5, Parcel 182(7), are generally holding steady, and that concentrations at the Former Detection and Identification Area, Parcel 180(7), are generally decreasing. The situation at the Old Burn Pit, Parcel 514(7), and the Blacktop

Training Area, Parcel 511(7), is not as clear because data for multiple samples from given wells are insufficient to reveal trends.

As noted above, the highest TCE concentrations were associated with the Old Burn Pit, Parcel 514(7). In a total of 17 samples from 10 wells, concentrations ranged from 1.7E-4 mg/L to 1.1E-1 mg/L. Concentrations for any given well appeared to be holding fairly steady or decreasing slightly, except that concentrations at CWM-514-MW04 increased from 0.035 mg/L on April 11, 2003, to 0.11 mg/L on April 19, 2004. The average concentration was calculated as the most representative concentration for each of the 10 wells associated with the Old Burn Pit, Parcel 514(7). The representative concentrations for each of the 10 wells were averaged to estimate a concentration of 2.6E-2 mg/L, which is adopted as the STC for TCE.

As noted in Sections 6.1.2.1 and 6.2.1.1, wells for the production of potable water may be installed essentially at any location and the water may be piped to receptors at any location. Therefore, the groundwater data are compiled into a single data set and the COPCs and STCs described above will be applied to all receptors theoretically exposed to groundwater developed as a potable source for each of the site-specific evaluations.

Chemicals detected in Former Detection and Identification Area, Parcel 180(7) surface soil (Table 6-13) and subsurface soil (Table 6-14) include metals, several PAHs, a few VOCs and the CWM degradation product methylphosphonic acid (MPA). All metals in surface and subsurface soil were identified as essential nutrients or determined to be present at concentrations comparable to background except cadmium in surface soil (Table 6-13). All the organic chemicals were selected as site-related.

COPCs in surface soil were limited to five PAHs (Table 6-15), probably associated with the burn pit located on this site. Benzo(a)pyrene, one of the PAHs identified as a COPC in surface soil was selected as the only COPC for subsurface soil (Table 6-16). STCs selected for total soil reflect those of the COPCs identified in surface soil (Table 6-17).

6.2.1.3 Risk Characterization: Chemicals Other than Lead

ILCR and HI estimates for all receptors under current and future site-use scenarios are compiled for each medium and summed across media in Table 6-18. Documentation is provided in the form of receptor- and medium-specific risk tables, including Tables 6-19 and 6-20 for exposure to total soil, and Tables 6-21, 6-22, and 6-23 for exposure to groundwater that detail the risk from exposure to each COPC. The numerical results and their interpretation are discussed by receptor and site-use scenario.

Recreational Site User, Current Site Use. The recreational site user is evaluated as the only plausible receptor under the current site use scenario. The recreational site user is assumed to be exposed to surface soil, surface water, and sediment. In addition, he is assumed to consume venison, representing an indirect or food-chain pathway for exposure to surface soil, from an annual successful deer-hunting expedition. Neither ILCR nor HI were estimated for the current recreational site user (Table 6-18) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to surface soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the current recreational site user.

Recreational Site User, Future Site Use. The future site-use scenario for the recreational site user is identical to the current site-use scenario, except that he is assumed to be exposed to total soil to reflect the possibility that construction or development for future use may bring subsurface soil to the surface. Neither ILCR nor HI were estimated for the future recreational site user (Table 6-18) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to total soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the future recreational site user.

Groundskeeper, Future Site Use. The groundskeeper is not evaluated as a plausible receptor for current site use because the Former Detection and Identification Area, Parcel 180(7), is not currently used for any purpose. The groundskeeper is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 1.69E-4 (Table 6-18) slightly exceeds the risk management range and is considered unacceptable. Major contributors include several potentially carcinogenic VOCs in groundwater (Table 6-21) and two PAHs in total soil (Table 6-19). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 1.47E-4 was estimated (Table 6-21). The total HI does not exceed the threshold level of 1 (Table 6-18). It is concluded that exposure to groundwater developed as a potable source, or groundwater in combination with total soil may result in unacceptable cancer risk. However, exposure to total soil and groundwater is unlikely to induce adverse noncancer health effects for the future groundskeeper. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Construction Worker, Future Site Use. The construction worker is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 6.33E-6 (Table 6-18) falls within the risk management range. The total HI does not exceed the threshold level of 1 (Table 6-18). It is concluded that exposure to total soil and groundwater developed as a potable source is unlikely to induce adverse health effects for the future construction worker.

Construction sites, however, may involve smaller EUs than represented by the data set for all of the Former Detection and Identification Area, Parcel 180(7). However, COPCs for the construction worker were not identified in soil, obviating the need to explore the EU issue further for this receptor.

On-Site Resident, Future Site Use. The on-site resident is assumed to be exposed to total soil, groundwater developed as a potable source, surface water, and sediment under the future site-use scenario. The assumptions for exposure to surface water and sediment are identical to those for the recreational site user; therefore, the risk estimates for recreational site user exposure to these media, had they been calculated, would be applied also to the on-site resident.

The total ILCR summed across all relevant media of 1.09E-3 (Table 6-18) exceeds the risk management range and is considered unacceptable. Major contributors include several potentially carcinogenic VOCs in groundwater (Table 6-23) and five PAHs in total soil (Table 6-20). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 9.81E-4 was estimated (Table 6-23).

The total HI of 6.05E+0 exceeds the threshold level of 1 (Table 6-18) due largely to acetone and carbon tetrachloride in groundwater (Table 6-23). It is concluded that exposure to groundwater developed as a potable source, or groundwater in combination with total soil may result in unacceptable cancer risk. Exposure to groundwater alone also raises concern for adverse noncancer health effects for the future on-site resident. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Home sites, however, may involve smaller EUs than represented by the data set for all of the Former Detection and Identification Area, Parcel 180(7). COPCs identified in soil for the on-site resident were limited to five PAHs. For all COPCs the UCL on the mean was adopted as the STC (Tables 6-13, 6-15, and 6-17). The MDCs, however, exceeded their respective UCLs by a

factor of only 1.2 to 1.3. Therefore, an approximation of the maximum total ILCR associated with the PAHs can be made by multiplying the sum of the ILCR values for the PAHs based on their STCs by the factor of 1.3 described above. The sum of the ILCR values for the PAHs based on their STCs (ILCR = 4.05E-5, Table 6-20) multiplied by the factor of 1.3 yields a maximum total ILCR of 5.27E-5. The ILCR of 5.27E-5 falls within the risk management range, as does the ILCR of 4.04E-5 based on the STCs of the PAHs. In other words, dividing the site into smaller EUs or rearranging the EUs would have no impact on the interpretation of the risk results. Therefore, there is no need to explore the EU issue further for this receptor.

6.2.1.4 Risk Characterization: Lead

Lead was not identified as a COPC in any of the media associated with the Former Detection and Identification Area, Parcel 180(7). It is concluded that exposure to the media at the Former Detection and Identification Area, Parcel 180(7), is unlikely to result in adverse health effects induced by lead.

6.2.1.5 Uncertainty Analysis

Probably the most important source of uncertainty regarding the Former Detection and Identification Area, Parcel 180(7) is the exclusion of background metals from the quantitative risk assessment. The background metals are discussed by medium.

Soil. Several metals in soil were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Tables 6-13 and 6-14). Several had MDCs exceeding their residential soil SSSLs, including aluminum, arsenic, chromium, iron, and vanadium in surface soil, and aluminum, antimony, arsenic, chromium, iron, and thallium in subsurface soil (comparisons of MDCs and SSSLs not shown). Among these, arsenic is the only metal that might have been selected as a cancer-based COPC, imparting some uncertainty to the cancer evaluation of exposure to soil. In all cases except arsenic, chromium (in surface soil only), and iron, the exceedance of noncancer SSSLs was less than a factor of 10, indicating that HI values calculated for these chemicals would fall below the threshold level of 1. As noted above, the oral RfD for iron is controversial and most likely unnecessarily conservative, and its selection as a background chemical is judged not to impart significant uncertainty to the assessment. However, some level of uncertainty remains about the other metals that may impart a non-conservative bias to the assessment.

Surface Water. Only chromium and mercury in surface water were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Table 6-7). Neither metal had an MDC that exceeded its recreational site user (or residential) SSSL (SSSL comparison not shown).

Excluding background metals in surface water imparts no uncertainty to the risk estimates for the recreational site user or resident.

Sediment. Metals in sediment excluded at the Tier 2 or Tier 3 stage are limited to cadmium, copper, and zinc (Table 6-9). However, none had MDCs exceeding their recreational site user SSSLs (SSSL comparison not shown). The exclusion of background metals is judged to impart no significant uncertainty to the SRA.

Groundwater. All metals in groundwater were excluded from COPC selection and quantitative evaluation in the SRA at the Tier 2 or Tier 3 stage (except for those few that were accepted as essential nutrients) (Table 6-11). Most had MDCs that exceeded their residential SSSLs (SSSL comparison not shown). The exclusion of these metals represents a source of uncertainty that may impart a non-conservative bias to the assessment. Concern is reduced, however, because it is unlikely that groundwater at the Training Area T-5 Sites would be developed as a potable source.

Background Metals in All Media. Largely the same metals in soil and groundwater were excluded from COPC selection and quantitative evaluation in the SRA because they were determined to be present at levels comparable to background. As noted above, excluding background metals in surface water and sediment imparted no significant uncertainty to the SRA. Excluding background metals in soil and groundwater, however, would result in understating risk if they were excluded in error (i.e., if they were in fact present at their ambient concentrations as a result of site-related activities). The activities performed at the Former Detection and Identification Area, Parcel 180(7) (and indeed on all of the Training Area T-5 Sites) are sufficiently well known to conclude that metals are unlikely to have been released or disposed during site-related activities. The possible exception would be arsenic, which is a component of certain CWM. Given the fact that erroneously excluding metals as background is unlikely, and that development of the groundwater as a potable source is also unlikely, it is concluded that the exclusion of background metals imparts only a small source of uncertainty to evaluation of the Former Detection and Identification Area, Parcel 180(7).

6.2.1.6 Conclusions, Former Detection and Identification Area, Parcel 180(7)

The Training Area T-5 Sites are projected to be used in the future for mixed business, passive recreation, and developmental reserve. Therefore, the recreational site user, groundskeeper, and construction worker are the relevant receptor scenarios that were evaluated herein. The recreational site user is assumed to be exposed to surface soil or total soil, surface water, and sediment at Parcel 180(7). The groundskeeper and construction worker are assumed to be

exposed to total soil and to groundwater developed as a potable source – an unlikely possibility. The on-site resident, included only for the additional information provided by generally the most conservative receptor scenario, is assumed to be exposed to total soil, groundwater developed as a potable source, and to surface water and sediment in the same manner as the recreational site user.

COPCs at Parcel 180(7) include five PAHs in soil and several solvents in groundwater. COPC concentrations in soil are sufficiently low so that the recreational site user is not expected to experience adverse health effects from exposure to the site in its current condition. The future groundskeeper, construction worker, and on-site resident may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only when exposure to groundwater as a potable source – a very unlikely scenario – is included in the estimations. Concentrations of PAHs in soil alone are not sufficient to yield unacceptable risk estimates for any receptor. It is clear that the VOCs in groundwater hypothetically developed as a potable source represent the only significant threat to human health. Therefore, further action to evaluate or remediate soil would have no effect on suitability of the site for any future use. Furthermore, the site currently can be considered suitable for any future use so long as groundwater in its current condition is not developed as a potable source.

6.2.2 Training Area T-5, Parcel 182(7)

6.2.2.1 Data Sets

The surface water, sediment, and groundwater data sets described in Section 6.2.1.1 for the Former Detection and Identification Area, Parcel 180(7), apply to all the Training Area T-5 Sites including Training Area T-5, Parcel 182(7).

The surface soil data set for Training Area T-5, Parcel 182(7), consists of 17 samples taken from 17 locations analyzed for the parameters listed in Table 6-24. The samples include nine depositional soil samples taken from generally dry drainage features within and surrounding the site, and eight surface samples from well installations within or on the boundaries of the site (Figure 2-1). The subsurface soil data set consists of eight samples taken from the eight well installation locations mentioned above, analyzed for the same parameters (Table 6-25).

6.2.2.2 Chemicals of Potential Concern

No chemicals were identified as COPCs in surface water or sediment, as described in Section 6.2.1.2. Several VOCs were identified as COPCs in groundwater, as described in Section 6.2.1.2.

Chemicals detected in Parcel 182(7) surface soil (Table 6-26) and subsurface soil (Table 6-27) include metals, one SVOC (bis[2-ethylhexyl]phthalate), and several VOCs. All metals in surface and subsurface soil were identified as essential nutrients or determined to be present at concentrations comparable to background except copper in surface soil (Table 6-26). All the organic chemicals were selected as site-related. Concentrations of copper in surface soil and the organic compounds in surface and subsurface soil were sufficiently low that none were identified as COPCs (Tables 6-28, 6-29).

6.2.2.3 Risk Characterization: Chemicals Other than Lead

ILCR and HI estimates for all receptors under current and future site-use scenarios are compiled for each medium and summed across media in Table 6-30. As noted above, COPCs were identified only in groundwater. Documentation for the risks associated with exposure to groundwater is provided in Tables 6-21, 6-22, and 6-23. The numerical results and their interpretation are discussed by receptor and site-use scenario.

Recreational Site User, Current Site Use. The recreational site user is evaluated as the only plausible receptor under the current site use scenario. The recreational site user is assumed to be exposed to surface soil, surface water, and sediment. In addition, he is assumed to consume venison, representing an indirect or food-chain pathway for exposure to surface soil, from an annual successful deer-hunting expedition. Neither ILCR nor HI were estimated for the current recreational site user (Table 6-30) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to surface soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the current recreational site user.

Recreational Site User, Future Site Use. The future site-use scenario for the recreational site user is identical to the current site-use scenario, except that he is assumed to be exposed to total soil to reflect the possibility that construction or development for future use may bring subsurface soil to the surface. Neither ILCR nor HI were estimated for the future recreational site user (Table 6-30) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to total soil, surface water, and sediment does not pose an unacceptable

cancer risk and is unlikely to induce adverse noncancer health effects for the future recreational site user.

Groundskeeper, Future Site Use. The groundskeeper is not evaluated as a plausible receptor for current site use because Parcel 182(7) is not currently used for any purpose. The groundskeeper is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 1.61E-4 (Table 6-30) slightly exceeds the risk management range and is considered unacceptable. Major contributors are limited to several potentially carcinogenic VOCs in groundwater (Table 6-21). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 1.47E-4 was estimated. The total HI does not exceed the threshold level of 1 (Table 6-30). It is concluded that exposure to groundwater developed as a potable source, or groundwater in combination with total soil may result in unacceptable cancer risk. However, exposure to total soil and groundwater is unlikely to induce adverse noncancer health effects for the future groundskeeper. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Construction Worker, Future Site Use. The construction worker is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 6.33E-6 (Table 6-30) falls within the risk management range. The total HI does not exceed the threshold level of 1 (Table 6-30). It is concluded that exposure to total soil and groundwater developed as a potable source is unlikely to induce adverse health effects for the future construction worker.

Construction sites may involve smaller EUs than represented by the data set for all of Parcel 182(7). However, no chemicals in soil were identified as COPCs for the construction worker. Therefore, no smaller area or rearrangement of EU could generate risks in soil higher than those discussed above, obviating the need to explore the EU issue further for this receptor.

On-Site Resident, Future Site Use. The on-site resident is assumed to be exposed to total soil, groundwater developed as a potable source, surface water, and sediment under the future site-use scenario. The assumptions for exposure to surface water and sediment are identical to those for the recreational site user; therefore, the risk estimates for recreational site user exposure to these media, had they been calculated, would be applied also to the on-site resident.

The total ILCR summed across all relevant media of 1.05E-3 (Table 6-30) exceeds the risk management range and is considered unacceptable. Major contributors include several potentially carcinogenic VOCs in groundwater (Table 6-23). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 9.81E-4 was estimated.

The total HI of 6.05E+0 exceeds the threshold level of 1 (Table 6-30) due largely to acetone and carbon tetrachloride in groundwater (Table 6-23). It is concluded that exposure to groundwater developed as a potable source may result in unacceptable cancer risk. Exposure to groundwater also raises concern for adverse noncancer health effects for the future on-site resident. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Home sites, however, may involve smaller EUs than represented by the data set for all of Parcel 182(7). However, COPCs for the on-site resident were not identified in soil, obviating the need to explore the EU issue further for this receptor.

6.2.2.4 Risk Characterization: Lead

Lead was not identified as a COPC in any of the media associated with Parcel 182(7). It is concluded that exposure to the media at Parcel 182(7) is unlikely to result in adverse health effects induced by lead.

6.2.2.5 Uncertainty Analysis

Probably the most important source of uncertainty regarding Parcel 182(7) is the exclusion of background metals from the quantitative risk assessment. The background metals are discussed by medium. Background metals in surface water, sediment, and groundwater were discussed in Section 6.2.1.5.

Soil. Several metals in soil were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Tables 6-26 and 6-27). Several had MDCs exceeding their residential soil SSSLs, including aluminum, chromium, and manganese in surface soil, and aluminum, arsenic, barium, and manganese in subsurface soil (comparisons of MDCs and SSSLs not shown). Among these, arsenic is the only metal that might have been selected as a cancer-based COPC, imparting some uncertainty to the cancer evaluation of exposure to soil. In all cases except manganese in surface soil, and arsenic and manganese in subsurface soil, the exceedance of noncancer SSSLs was less than a factor of 10, indicating that HI values calculated for these chemicals would fall below the threshold level of 1.

Background Metals in All Media. As noted in Section 6.2.1.5, excluding background metals in soil and groundwater would result in understating risk if they were excluded in error. The activities performed at Training Area T-5, Parcel 182(7) (and indeed on all of the Training Area T-5 Sites) are sufficiently well known to conclude that metals are unlikely to have been released or disposed during site-related activities. The possible exception would be arsenic, which is a component of certain CWM. Given the fact that erroneously excluding metals as background is unlikely, and that development of the groundwater as a potable source is also unlikely, it is concluded that the exclusion of background metals imparts only a small source of uncertainty to evaluation of Training Area T-5, Parcel 182(7).

6.2.2.6 Conclusions, Training Area T-5, Parcel 182(7)

The Training Area T-5 Sites are projected to be used in the future for mixed business, passive recreation, and developmental reserve. Therefore, the recreational site user, groundskeeper, and construction worker are the relevant receptor scenarios that were evaluated herein. The recreational site user is assumed to be exposed to surface soil or total soil, surface water, and sediment at Training Area T-5, Parcel 182(7). The groundskeeper and construction worker are assumed to be exposed to total soil and to groundwater developed as a potable source – an unlikely possibility. The on-site resident, included only for the additional information provided by generally the most conservative receptor scenario, is assumed to be exposed to total soil, groundwater developed as a potable source, and to surface water and sediment in the same manner as the recreational site user.

COPCs at Parcel 182(7) are limited to several solvents in groundwater. No COPCs were identified in soil; therefore, it is concluded that the recreational site user is not expected to experience adverse health effects from exposure to the site in its current condition. Also, the future construction worker is not expected to experience adverse health effects from exposure to the site in its current condition. The future groundskeeper and on-site resident may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only when exposure to groundwater as a potable source – a very unlikely scenario – is included in the estimations. Since COPCs were not identified in soil, it is clear that the VOCs in groundwater hypothetically developed as a potable source represent the only significant threat to human health. Therefore, further action to evaluate or remediate soil would have no effect on suitability of the site for any future use. Furthermore, the site currently can be considered suitable for any future use so long as groundwater in its current condition is not developed as a potable source.

6.2.3 Blacktop Training Area, Parcels 511(7) and 512(7)

As explained in Section 6.1.1, the Blacktop Training Area, Parcel 511(7), and the Fenced Yard in Blacktop Training Area, Parcel 512(7), are combined under the designation Blacktop Training Area, Parcels 511(7) and 512(7) and evaluated as a single site in the SRA.

6.2.3.1 Data Sets

The surface water, sediment, and groundwater data sets described in Section 6.2.1.1 for the Former Detection and Identification Area, Parcel 180(7), apply to all the Training Area T-5 Sites including the Blacktop Training Area, Parcels 511(7) and 512 (7).

The surface soil data set for the Blacktop Training Area, Parcels 511(7) and 512(7), consists of nine samples taken from nine locations analyzed for the parameters listed in Table 6-31. The samples include two depositional soil samples taken from generally dry drainage features on the western boundary of the site, and seven surface samples from well installations within or just west of the boundaries of the site (Figure 2-1). The subsurface soil data set consists of seven samples taken from the seven well installation locations mentioned above, analyzed for the same parameters (Table 6-32).

6.2.3.2 Chemicals of Potential Concern

No chemicals were identified as COPCs in surface water or sediment, as described in Section 6.2.1.2. Several VOCs were identified as COPCs in groundwater, as described in Section 6.2.1.2.

Chemicals detected in the Blacktop Training Area, Parcels 511(7) and 512(7) surface soil (Table 6-33) and subsurface soil (Table 6-34) include metals, several PAHs, one SVOC (bis[2-ethylhexyl]phthalate) in surface soil only, and several VOCs. All metals in surface and subsurface soil were identified as essential nutrients or determined to be present at concentrations comparable to background except cadmium, copper, and zinc in surface soil (Table 6-33). The PAHs in surface and subsurface soil were subjected to background screening in a manner identical to the Tier 1 evaluation for metals described in Section 6.1.2.2. The PAH BSCs for soil beneath asphalt from Table 4-1 of IT (2000c) were used in the screening process. It was shown that the PAH concentrations in surface and subsurface soil did not exceed their BSCs; therefore, the PAHs were considered to be present as anthropogenic background and were not selected as site-related chemicals. All other organic chemicals were selected as site-related. Concentrations of all site-related metals and organic compounds in surface and subsurface soil were sufficiently low that none were identified as COPCs (Tables 6-35 and 6-36).

6.2.3.3 Risk Characterization: Chemicals Other than Lead

ILCR and HI estimates for all receptors under current and future site-use scenarios are compiled for each medium and summed across media in Table 6-37. As noted above, COPCs were identified only in groundwater. Documentation for the risks associated with exposure to groundwater is provided in Tables 6-21, 6-22, and 6-23. The numerical results and their interpretation are discussed by receptor and site-use scenario.

Recreational Site User, Current Site Use. The recreational site user is evaluated as the only plausible receptor under the current site use scenario. The recreational site user is assumed to be exposed to surface soil, surface water, and sediment. Venison consumption, which was considered as an indirect exposure pathway for most of the other Training Area T-5 Sites, was not considered for Parcels 511(7) and 512(7) because the site does not represent habitat suitable for game animals. Neither ILCR nor HI were estimated for the current recreational site user (Table 6-37) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to surface soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the current recreational site user.

Recreational Site User, Future Site Use. The future site-use scenario for the recreational site user is identical to the current site-use scenario, except that he is assumed to be exposed to total soil to reflect the possibility that construction or development for future use may bring subsurface soil to the surface. Neither ILCR nor HI were estimated for the future recreational site user (Table 6-37) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to total soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the future recreational site user.

Groundskeeper, Future Site Use. The groundskeeper is not evaluated as a plausible receptor for current site use because Parcels 511(7) and 512(7) are not currently used for any purpose. The groundskeeper is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 1.61E-4 (Table 6-37) slightly exceeds the risk management range and is considered unacceptable. Major contributors are limited to several potentially carcinogenic VOCs in groundwater (Table 6-21). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 1.47E-4 was estimated. The total HI does not exceed the threshold level of 1 (Table 6-37). It is concluded that exposure to groundwater

developed as a potable source, or groundwater in combination with total soil may result in unacceptable cancer risk. However, exposure to total soil and groundwater is unlikely to induce adverse noncancer health effects for the future groundskeeper. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Construction Worker, Future Site Use. The construction worker is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 6.33E-6 (Table 6-37) falls within the risk management range. The total HI does not exceed the threshold level of 1 (Table 6-37). It is concluded that exposure to total soil and groundwater developed as a potable source is unlikely to induce adverse health effects for the future construction worker.

Construction sites may involve smaller EUs than represented by the data set for all of Parcels 511(7) and 512(7). However, no chemicals in soil were identified as COPCs for the construction worker. Therefore, no smaller area or rearrangement of EU could generate risks in soil higher than those discussed above, obviating the need to explore the EU issue further for this receptor.

On-Site Resident, Future Site Use. The on-site resident is assumed to be exposed to total soil, groundwater developed as a potable source, surface water, and sediment under the future site-use scenario. The assumptions for exposure to surface water and sediment are identical to those for the recreational site user; therefore, the risk estimates for recreational site user exposure to these media, had they been calculated, would be applied also to the on-site resident.

The total ILCR summed across all relevant media of 1.05E-3 (Table 6-37) exceeds the risk management range and is considered unacceptable. Major contributors include several potentially carcinogenic VOCs in groundwater (Table 6-23). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 9.81E-4 was estimated.

The total HI of 6.05E+0 exceeds the threshold level of 1 (Table 6-37) due largely to acetone and carbon tetrachloride in groundwater (Table 6-23). It is concluded that exposure to groundwater developed as a potable source may result in unacceptable cancer risk. Exposure to groundwater also raises concern for adverse noncancer health effects for the future on-site resident. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Home sites, however, may involve smaller EUs than represented by the data set for all of Parcels 511(7) and 512(7). However, COPCs for the on-site resident were not identified in soil, obviating the need to explore the EU issue further for this receptor.

6.2.3.4 Risk Characterization: Lead

Lead was not identified as a COPC in any of the media associated with Parcels 511(7) and 512(7). It is concluded that exposure to the media at the Blacktop Training Area, Parcels 511(7) and 512(7) is unlikely to result in adverse health effects induced by lead.

6.2.3.5 Uncertainty Analysis

Probably the most important source of uncertainty regarding the Blacktop Training Area, Parcels 511(7) and 512(7) is the exclusion of background metals from the quantitative risk assessment. The background metals are discussed by medium. Background metals in surface water, sediment, and groundwater were discussed in Section 6.2.1.5.

Soil. Aluminum and selenium in surface soil, and aluminum, beryllium, cobalt, iron, nickel, selenium, and zinc in subsurface soil were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Tables 6-33 and 6-34). A few had MDCs exceeding their residential soil SSSLs, including aluminum in surface soil, and aluminum and iron in subsurface soil (comparisons of MDCs and SSSLs not shown). In all cases except iron in subsurface soil the exceedance of noncancer SSSLs was less than a factor of 10, indicating that HI values calculated for these chemicals would fall below the threshold level of 1. As noted above, the oral RfD for iron is controversial and most likely unnecessarily conservative, and its selection as a background chemical is judged not to impart significant uncertainty to the assessment.

Background Metals in All Media. As noted in Section 6.2.1.5, excluding background metals in soil and groundwater would result in understating risk if they were excluded in error. The activities performed at the Blacktop Training Area, Parcels 511(7) and 512(7) (and indeed on all of the Training Area T-5 Sites) are sufficiently well known to conclude that metals are unlikely to have been released or disposed during site-related activities. Given the fact that erroneously excluding metals as background is unlikely, and that development of the groundwater as a potable source is also unlikely, it is concluded that the exclusion of background metals imparts only a small source of uncertainty to evaluation of Parcels 511(7) and 512(7).

6.2.3.6 Conclusions, Blacktop Training Area, Parcels 511(7) and 512(7)

The Training Area T-5 Sites are projected to be used in the future for mixed business, passive recreation, and developmental reserve. Therefore, the recreational site user, groundskeeper, and

construction worker are the relevant receptor scenarios that were evaluated herein. The recreational site user is assumed to be exposed to surface soil or total soil, surface water, and sediment at Parcels 511(7) and 512(7). The groundskeeper and construction worker are assumed to be exposed to total soil and to groundwater developed as a potable source – an unlikely possibility. The on-site resident, included only for the additional information provided by generally the most conservative receptor scenario, is assumed to be exposed to total soil, groundwater developed as a potable source, and to surface water and sediment in the same manner as the recreational site user.

COPCs at Parcels 511(7) and 512(7) are limited to several solvents in groundwater. No COPCs were identified in soil; therefore, it is concluded that the recreational site user is not expected to experience adverse health effects from exposure to the site in its current condition. Also, the future construction worker is not expected to experience adverse health effects from exposure to the site in its current condition. The future groundskeeper and on-site resident may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only when exposure to groundwater as a potable source – a very unlikely scenario – is included in the estimations. Since COPCs were not identified in soil, it is clear that the VOCs in groundwater hypothetically developed as a potable source represent the only significant threat to human health. Therefore, further action to evaluate or remediate soil would have no effect on suitability of the site for any future use. Furthermore, the site currently can be considered suitable for any future use so long as groundwater in its current condition is not developed as a potable source.

6.2.4 Dog Training Area, Parcel 513(7)

6.2.4.1 Data Sets

The surface water, sediment, and groundwater data sets described in Section 6.2.1.1 for the Former Detection and Identification Area, Parcel 180(7), apply to all the Training Area T-5 Sites including the Dog Training Area, Parcel 513(7).

The surface soil data set for the Dog Training Area, Parcel 513(7) consists of three samples taken from three sample locations analyzed for the parameters listed in Table 6-38. The samples include a single depositional soil sample taken from the generally dry drainage feature immediately to the east of the site, and two surface samples from well locations within the boundaries of the site (Figure 2-1). The subsurface soil data set consists of two samples taken from the well locations mentioned above, analyzed for the same parameters (Table 6-39).

6.2.4.2 Chemicals of Potential Concern

No chemicals were identified as COPCs in surface water or sediment, as described in Section 6.2.1.2. Several VOCs were identified as COPCs in groundwater, as described in Section 6.2.1.2.

Chemicals detected in Parcel 513(7) surface soil include metals, several PAHs, and a few VOCs (Table 6-40). Chemicals detected in subsurface soil are limited to metals and a single VOC (Table 6-41). All metals in surface and subsurface soil were identified as essential nutrients or determined to be present at concentrations comparable to background except cadmium in surface soil (Table 6-40). All the organic chemicals were selected as site-related. Concentrations of cadmium in surface soil and the organic compounds in surface and subsurface soil were sufficiently low that none were identified as COPCs except for benzo(a)pyrene in surface soil, which was selected as a COPC only for the on-site resident (Tables 6-42 and 6-43). The STC selected for benzo(a)pyrene in total soil reflects its concentration in surface soil (Table 6-44).

6.2.4.3 Risk Characterization: Chemicals Other than Lead

ILCR and HI estimates for all receptors under current and future site-use scenarios are compiled for each medium and summed across media in Table 6-45. Documentation is provided in the form of receptor- and medium-specific risk tables, including Table 6-46 for exposure to total soil, and Tables 6-21, 6-22, and 6-23 for exposure to groundwater that detail the risk from exposure to each COPC. The numerical results and their interpretation are discussed by receptor and site-use scenario.

Recreational Site User, Current Site Use. The recreational site user is evaluated as the only plausible receptor under the current site use scenario. The recreational site user is assumed to be exposed to surface soil, surface water, and sediment. In addition, he is assumed to consume venison, representing an indirect or food-chain pathway for exposure to surface soil, from an annual successful deer-hunting expedition. Neither ILCR nor HI were estimated for the current recreational site user (Table 6-45) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to surface soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the current recreational site user.

Recreational Site User, Future Site Use. The future site-use scenario for the recreational site user is identical to the current site-use scenario, except that he is assumed to be exposed to total soil to reflect the possibility that construction or development for future use may bring subsurface soil to the surface. Neither ILCR nor HI were estimated for the future recreational

site user (Table 6-45) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to total soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the future recreational site user.

Groundskeeper, Future Site Use. The groundskeeper is not evaluated as a plausible receptor for current site use because Parcel 513(7) is not currently used for any purpose. The groundskeeper is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 1.61E-4 (Table 6-45) slightly exceeds the risk management range and is considered unacceptable. Major contributors are limited to several potentially carcinogenic VOCs in groundwater (Table 6-21). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater , for which an ILCR of 1.47E-4 was estimated. The total HI does not exceed the threshold level of 1 (Table 6-45). It is concluded that exposure to groundwater developed as a potable source, or groundwater in combination with total soil may result in unacceptable cancer risk. However, exposure to total soil and groundwater is unlikely to induce adverse noncancer health effects for the future groundskeeper. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Construction Worker, Future Site Use. The construction worker is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 6.33E-6 (Table 6-45) falls within the risk management range. The total HI does not exceed the threshold level of 1 (Table 6-45). It is concluded that exposure to total soil and groundwater developed as a potable source is unlikely to induce adverse health effects for the future construction worker.

Construction sites may involve smaller EUs than represented by the data set for all of Parcel 513(7). However, no chemicals in soil were identified as COPCs for the construction worker. Therefore, no smaller area or rearrangement of EU could generate risks in soil higher than those discussed above, obviating the need to explore the EU issue further for this receptor.

On-Site Resident, Future Site Use. The on-site resident is assumed to be exposed to total soil, groundwater developed as a potable source, surface water, and sediment under the future site-use scenario. The assumptions for exposure to surface water and sediment are identical to

those for the recreational site user; therefore, the risk estimates for recreational site user exposure to these media, had they been calculated, would be applied also to the on-site resident.

The total ILCR summed across all relevant media of 1.05E-3 (Table 6-45) exceeds the risk management range and is considered unacceptable. Major contributors include several potentially carcinogenic VOCs in groundwater (Table 6-23). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 9.81E-4 was estimated. The contribution from benzo(a)pyrene in total soil is very small (Table 6-46), at the lower end of the risk management range.

The total HI of 6.05E+0 exceeds the threshold level of 1 (Table 6-45) due largely to acetone and carbon tetrachloride in groundwater (Table 6-23). It is concluded that exposure to groundwater developed as a potable source may result in unacceptable cancer risk. Exposure to groundwater also raises concern for adverse noncancer health effects for the future on-site resident. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Home sites may involve smaller EUs than represented by the data set for all of Parcel 513(7). However, COPCs in soil for the on-site resident were limited to benzo(a)pyrene, and the MDC was adopted as the STC. Therefore, no smaller area or rearrangement of EU could generate risks in soil higher than those discussed above, obviating the need to explore the EU issue further for this receptor.

6.2.4.4 Risk Characterization: Lead

Lead was not identified as a COPC in any of the media associated with Parcel 513(7). It is concluded that exposure to the media at the Dog Training Area, Parcel 513(7), is unlikely to result in adverse health effects induced by lead.

6.2.4.5 Uncertainty Analysis

Probably the most important source of uncertainty regarding Parcel 513(7) is the exclusion of background metals from the quantitative risk assessment. The background metals are discussed by medium. Background metals in surface water, sediment, and groundwater were discussed in Section 6.2.1.5.

Soil. Several metals in soil were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Tables 6-40 and 6-41). Some had MDCs exceeding their residential soil SSSLs, including arsenic in surface soil, and aluminum and chromium in subsurface soil (comparisons of

MDCs and SSSLs not shown). Among these, arsenic is the only metal that might have been selected as a cancer-based COPC, imparting some uncertainty to the cancer evaluation of exposure to soil. In all cases except arsenic in surface soil, the exceedance of noncancer SSSLs was less than a factor of 10, indicating that HI values calculated for these chemicals would fall below the threshold level of 1.

Background Metals in All Media. As noted in Section 6.2.1.5, excluding background metals in soil and groundwater would result in understating risk if they were excluded in error. The activities performed at the Dog Training Area, Parcel 513(7) (and indeed on all of the Training Area T-5 Sites) are sufficiently well known to conclude that metals are unlikely to have been released or disposed during site-related activities. The possible exception would be arsenic, which is a component of certain CWM. Given the fact that erroneously excluding metals as background is unlikely, and that development of the groundwater as a potable source is also unlikely, it is concluded that the exclusion of background metals imparts only a small source of uncertainty to evaluation of Parcel 513(7).

6.2.4.6 Conclusions, Dog Training Area, Parcel 513(7)

The Training Area T-5 Sites are projected to be used in the future for mixed business, passive recreation, and developmental reserve. Therefore, the recreational site user, groundskeeper, and construction worker are the relevant receptor scenarios that were evaluated herein. The recreational site user is assumed to be exposed to surface soil or total soil, surface water, and sediment at the Dog Training Area, Parcel 513(7). The groundskeeper and construction worker are assumed to be exposed to total soil and to groundwater developed as a potable source – an unlikely possibility. The on-site resident, included only for the additional information provided by generally the most conservative receptor scenario, is assumed to be exposed to total soil, groundwater developed as a potable source, and to surface water and sediment in the same manner as the recreational site user.

COPCs at Parcel 513(7) are limited to several solvents in groundwater and benzo(a)pyrene in total soil for the on-site resident. Therefore, it is concluded that the recreational site user is not expected to experience adverse health effects from exposure to the site in its current condition. Also, the future construction worker is not expected to experience adverse health effects from exposure to the site in its current condition. The future groundskeeper and on-site resident may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only when exposure to groundwater as a potable source – a very unlikely scenario – is included in the estimations. It is clear that the VOCs in groundwater hypothetically developed as a potable source represent the only significant threat to human health. Therefore,

further action to evaluate or remediate soil would have no effect on suitability of the site for any future use. Furthermore, the site currently can be considered suitable for any future use so long as groundwater in its current condition is not developed as a potable source.

6.2.5 Dog Kennel Area, Parcel 516(7)

6.2.5.1 Data Sets

The surface water, sediment, and groundwater data sets described in Section 6.2.1.1 for the Former Detection and Identification Area, Parcel 180(7), apply to all the Training Area T-5 Sites including the Dog Kennel Area, Parcel 516(7).

The surface soil data set for Parcel 516(7) consists of three samples taken from three locations analyzed for the parameters listed in Table 6-47. The samples include a single depositional soil sample taken near the northern boundary of the site, and two surface samples from well locations within the boundaries of the site (Figure 2-1). The subsurface soil data set consists of two samples taken from the two well locations mentioned above, analyzed for the same parameters (Table 6-48).

6.2.5.2 Chemicals of Potential Concern

No chemicals were identified as COPCs in surface water or sediment, as described in Section 6.2.1.2. Several VOCs were identified as COPCs in groundwater, as described in Section 6.2.1.2.

Chemicals detected in Parcel 516(7) surface and subsurface soil include metals and VOCs (Tables 6-49 and 6-50). All metals in surface and subsurface soil were identified as essential nutrients or determined to be present at concentrations comparable to background except barium in surface soil (Table 6-49). All the organic chemicals were selected as site-related. Concentrations of barium in surface soil and the organic compounds in surface and subsurface soil were sufficiently low that none were identified as COPCs except for barium in surface soil, which was selected as a COPC only for the construction worker (Tables 6-51 and 6-52). The STC selected for barium in total soil reflects its concentration in surface soil (Table 6-53).

6.2.5.3 Risk Characterization: Chemicals Other than Lead

ILCR and HI estimates for all receptors under current and future site-use scenarios are compiled for each medium and summed across media in Table 6-54. Documentation is provided in the form of receptor- and medium-specific risk tables, including Table 6-55 for exposure to total soil, and Tables 6-21, 6-22, and 6-23 for exposure to groundwater that detail the risk from

exposure to each COPC. The numerical results and their interpretation are discussed by receptor and site-use scenario.

Recreational Site User, Current Site Use. The recreational site user was evaluated as the only plausible receptor under the current site use scenario for most of the Training Area T-5 Sites. The Dog Kennel Area, Parcel 516(7), however, is currently used to kennel dogs; therefore, the recreational site user is not considered to be a plausible receptor for this site under current site use. Also, venison consumption, which was considered as an indirect exposure pathway for most of the other Training Area T-5 Sites, was not considered for Parcel 516(7) because the site does not represent habitat suitable for game animals.

Recreational Site User, Future Site Use. The future site-use scenario for the recreational site user is identical to the current site-use scenario described for the other Training Area T-5 Sites, except that the receptor is assumed to be exposed to total soil instead of surface soil to reflect the possibility that construction or development for future use may bring subsurface soil to the surface. Neither ILCR nor HI were estimated for the future recreational site user (Table 6-54) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to total soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the future recreational site user.

Groundskeeper, Current Site Use. The Dog Kennel Area, Parcel 516(7) is currently used to kennel dogs. An exposure scenario specific for a canine careperson has not been developed. However, the exposure assumptions for the groundskeeper, generally considered to be the upper bound on commercial or industrial exposure, are judged to be sufficiently conservative for the canine careperson. Therefore, the groundskeeper is adopted as a surrogate for the canine careperson and is evaluated as the only plausible receptor for current site use. Under the current site-use scenario, the groundskeeper is assumed to be exposed to surface soil. Neither ILCR nor HI were estimated for the current groundskeeper (Table 6-54) because no chemicals in the relevant medium (surface soil) were selected as COPCs. It is concluded that exposure to surface soil does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the current groundskeeper.

Groundskeeper, Future Site Use. The groundskeeper is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario. The total ILCR summed across media of 1.61E-4 (Table 6-54) slightly exceeds the risk management range and is considered unacceptable. Major contributors are limited to several potentially carcinogenic VOCs in groundwater (Table 6-21). The "risk driver" in this scenario is 1,1,2,2-

TCA in groundwater , for which an ILCR of 1.47E-4 was estimated. The total HI does not exceed the threshold level of 1 (Table 6-54). It is concluded that exposure to groundwater developed as a potable source, or groundwater in combination with total soil may result in unacceptable cancer risk. However, exposure to total soil and groundwater is unlikely to induce adverse noncancer health effects for the future groundskeeper. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Construction Worker, Future Site Use. The construction worker is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 6.33E-6 (Table 6-54) falls within the risk management range. The total HI rounded to one significant figure does not exceed the threshold level of 1 (Table 6-54). It is concluded that exposure to total soil and groundwater developed as a potable source is unlikely to induce adverse health effects for the future construction worker.

Construction sites may involve smaller EUs than represented by the data set for all of Parcel 516(7). Barium was identified as the only COPC in soil for the construction worker. However, the MDC was adopted as the STC and used in the HI estimate. Therefore, no smaller area or rearrangement of EU could generate risks in soil higher than those discussed above, obviating the need to explore the EU issue further for this receptor.

On-Site Resident, Future Site Use. The on-site resident is assumed to be exposed to total soil, groundwater developed as a potable source, surface water, and sediment under the future site-use scenario. The assumptions for exposure to surface water and sediment are identical to those for the recreational site user; therefore, the risk estimates for recreational site user exposure to these media, had they been calculated, would be applied also to the on-site resident.

The total ILCR summed across all relevant media of 1.05E-3 (Table 6-54) exceeds the risk management range and is considered unacceptable. Major contributors include several potentially carcinogenic VOCs in groundwater (Table 6-23). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 9.81E-4 was estimated.

The total HI of 6.05E+0 exceeds the threshold level of 1 (Table 6-54) due largely to acetone and carbon tetrachloride in groundwater (Table 6-23). It is concluded that exposure to groundwater developed as a potable source may result in unacceptable cancer risk. Exposure to groundwater also raises concern for adverse noncancer health effects for the future on-site resident. Exposure

to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Home sites may involve smaller EUs than represented by the data set for all of Parcel 516(7). However, no chemicals in soil were selected as COPCs for the on-site resident. Therefore, no smaller area or rearrangement of EU could generate risks in soil higher than those discussed above, obviating the need to explore the EU issue further for this receptor.

6.2.5.4 Risk Characterization: Lead

Lead was not identified as a COPC in any of the media associated with Parcel 516(7). It is concluded that exposure to the media at the Dog Kennel Area, Parcel 516(7), is unlikely to result in adverse health effects induced by lead.

6.2.5.5 Uncertainty Analysis

Probably the most important source of uncertainty regarding Parcel 516(7) is the exclusion of background metals from the quantitative risk assessment. The background metals are discussed by medium. Background metals in surface water, sediment and groundwater were discussed in Section 6.2.1.5.

Soil. Several metals in soil were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Tables 6-49 and 6-50). Some had MDCs exceeding their residential soil SSSLs, including arsenic in surface soil, and aluminum and chromium in subsurface soil (comparisons of MDCs and SSSLs not shown). Among these, arsenic is the only metal that might have been selected as a cancer-based COPC, imparting some uncertainty to the cancer evaluation of exposure to soil. In all cases except arsenic in surface soil, the exceedance of noncancer SSSLs was less than a factor of 10, indicating that HI values calculated for these chemicals would fall below the threshold level of 1.

Background Metals in All Media. As noted in Section 6.2.1.5, excluding background metals in soil and groundwater would result in understating risk if they were excluded in error. The activities performed at the Dog Kennel Area, Parcel 516(7) (and indeed on all of the Training Area T-5 Sites) are sufficiently well known to conclude that metals are unlikely to have been released or disposed during site-related activities. The possible exception would be arsenic, which is a component of certain CWM. Given the fact that erroneously excluding metals as background is unlikely, and that development of the groundwater as a potable source is also unlikely, it is concluded that the exclusion of background metals imparts only a small source of uncertainty to evaluation of Parcel 516(7).

6.2.5.6 Conclusions, Dog Kennel Area, Parcel 516(7)

The Training Area T-5 Sites are projected to be used in the future for mixed business, passive recreation, and developmental reserve. Therefore, the recreational site user, groundskeeper, and construction worker are the relevant receptor scenarios that were evaluated herein. The recreational site user is assumed to be exposed to total soil, surface water, and sediment at the Dog Kennel Area, Parcel 516(7). The groundskeeper is assumed to be exposed to surface soil, or total soil and groundwater developed as a potable source – an unlikely possibility. The construction worker is assumed to be exposed to total soil and to groundwater developed as a potable source. The on-site resident, included only for the additional information provided by generally the most conservative receptor scenario, is assumed to be exposed to total soil, groundwater developed as a potable source, and to surface water and sediment in the same manner as the recreational site user.

COPCs at Parcel 516(7) are limited to several solvents in groundwater and barium in total soil for the construction worker. Therefore, it is concluded that the recreational site user is not expected to experience adverse health effects from exposure to the site in its current condition. Also, the future construction worker is not expected to experience adverse health effects from exposure to the site in its current condition. The future groundskeeper and on-site resident may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only when exposure to groundwater as a potable source – a very unlikely scenario – is included in the estimations. It is clear that the VOCs in groundwater hypothetically developed as a potable source represent the only significant threat to human health. Therefore, further action to evaluate or remediate soil would have no effect on suitability of the site for any future use. Furthermore, the site currently can be considered suitable for any future use so long as groundwater in its current condition is not developed as a potable source.

6.2.6 Old Burn Pit, Parcel 514(7)

6.2.6.1 Data Sets

The surface water, sediment, and groundwater data sets described in Section 6.2.1.1 for the Former Detection and Identification Area, Parcel 180(7), apply to all the Training Area T-5 Sites including the Old Burn Pit, Parcel 514(7).

The surface soil data set for the Old Burn Pit, Parcel 514(7) consists of nine samples taken from nine locations analyzed for the parameters listed in Table 6-56. The samples include two depositional soil samples taken from the generally dry drainage feature northeast and north of the

site, and seven surface samples from well installations within or hydrogeologically lateral or downgradient of the site (Figure 2-1). The subsurface soil data set consists of seven samples taken from the seven well locations mentioned above, analyzed for the same parameters (Table 6-57).

6.2.6.2 Chemicals of Potential Concern

No chemicals were identified as COPCs in surface water or sediment, as described in Section 6.2.1.2. Several VOCs were identified as COPCs in groundwater, as described in Section 6.2.1.2.

Chemicals detected in Parcel 514(7) surface soil include metals, several PAHs, and several VOCs (Table 6-58). Chemicals detected in subsurface soil include metals, low concentrations of two VOCs, and a single detection of MPA (Table 6-59). All metals in surface and subsurface soil were identified as essential nutrients or determined to be present at concentrations comparable to background and were not subjected to COPC screening. Concentrations of organic compounds in surface and subsurface soil were sufficiently low that none were identified as COPCs except for benzo(a)pyrene in surface soil, which was selected as a COPC only for the on-site resident (Tables 6-60 and 6-61). The STC selected for benzo(a)pyrene in total soil reflects its concentration in surface soil (Table 6-62).

6.2.6.3 Risk Characterization: Chemicals Other than Lead

ILCR and HI estimates for all receptors under current and future site-use scenarios are compiled for each medium and summed across media in Table 6-63. Documentation is provided in the form of receptor- and medium-specific risk tables, including Table 6-64 for exposure to total soil, and Tables 6-21, 6-22, and 6-23 for exposure to groundwater that detail the risk from exposure to each COPC. The numerical results and their interpretation are discussed by receptor and site-use scenario.

Recreational Site User, Current Site Use. The recreational site user is evaluated as the only plausible receptor under the current site use scenario. The recreational site user is assumed to be exposed to surface soil, surface water, and sediment. In addition, he is assumed to consume venison, representing an indirect or food-chain pathway for exposure to surface soil, from an annual successful deer-hunting expedition. Neither ILCR nor HI were estimated for the current recreational site user (Table 6-63) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to surface soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the current recreational site user.

Recreational Site User, Future Site Use. The future site-use scenario for the recreational site user is identical to the current site-use scenario, except that he is assumed to be exposed to total soil to reflect the possibility that construction or development for future use may bring subsurface soil to the surface. Neither ILCR nor HI were estimated for the future recreational site user (Table 6-63) because no chemicals in the relevant media were selected as COPCs. It is concluded that exposure to total soil, surface water, and sediment does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the future recreational site user.

Groundskeeper, Future Site Use. The groundskeeper is not evaluated as a plausible receptor for current site use because Parcel 514(7) is not currently used for any purpose. The groundskeeper is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 1.61E-4 (Table 6-63) slightly exceeds the risk management range and is considered unacceptable. Major contributors are limited to several potentially carcinogenic VOCs in groundwater (Table 6-21). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater , for which an ILCR of 1.47E-4 was estimated. The total HI does not exceed the threshold level of 1 (Table 6-63). It is concluded that exposure to groundwater developed as a potable source, or groundwater in combination with total soil may result in unacceptable cancer risk. However, exposure to total soil and groundwater is unlikely to induce adverse noncancer health effects for the future groundskeeper. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Construction Worker, Future Site Use. The construction worker is assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

The total ILCR summed across media of 6.33E-6 (Table 6-63) falls within the risk management range. The total HI does not exceed the threshold level of 1 (Table 6-63). It is concluded that exposure to total soil and groundwater developed as a potable source is unlikely to induce adverse health effects for the future construction worker.

Construction sites may involve smaller EUs than represented by the data set for all of Parcel 514(7). However, no chemicals in soil were identified as COPCs for the construction worker.

Therefore, no smaller area or rearrangement of EU could generate risks in soil higher than those discussed above, obviating the need to explore the EU issue further for this receptor.

On-Site Resident, Future Site Use. The on-site resident is assumed to be exposed to total soil, groundwater developed as a potable source, surface water, and sediment under the future site-use scenario. The assumptions for exposure to surface water and sediment are identical to those for the recreational site user; therefore, the risk estimates for recreational site user exposure to these media, had they been calculated, would be applied also to the on-site resident.

The total ILCR summed across all relevant media of 1.05E-3 (Table 6-63) exceeds the risk management range and is considered unacceptable. Major contributors include several potentially carcinogenic VOCs in groundwater (Table 6-23). The "risk driver" in this scenario is 1,1,2,2-TCA in groundwater, for which an ILCR of 9.81E-4 was estimated. The contribution from benzo(a)pyrene in total soil is small (Table 6-64), near the lower end of the risk management range.

The total HI of 6.05E+0 exceeds the threshold level of 1 (Table 6-63) due largely to acetone and carbon tetrachloride in groundwater (Table 6-23). It is concluded that exposure to groundwater developed as a potable source may result in unacceptable cancer risk. Exposure to groundwater also raises concern for adverse noncancer health effects for the future on-site resident. Exposure to total soil without concurrent exposure to groundwater developed as a potable source is unlikely to yield an unacceptable cancer risk or adverse noncancer health effects.

Home sites may involve smaller EUs than represented by the data set for all of Parcel 514(7). COPCs in soil for the on-site resident were limited to benzo(a)pyrene, for which the UCL on the mean was adopted as the STC. The MDC, however, exceeded the UCL by a factor of only 1.2. Therefore, an approximation of the maximum total ILCR associated with exposure to soil can be made by multiplying the ILCR for benzo(a)pyrene of 3.68E-6 (Table 6-64) by the factor of 1.2 described above. An ILCR of 4.42E-6 is estimated in this manner. The ILCR of 4.42E-6 falls within the risk management range, as does the ILCR of 3.68E-6 based on adopting the UCL as the STC. In other words, dividing the site into smaller EUs or rearranging the EUs would have no impact on the interpretation of the risk results. Therefore, there is no need to explore the EU issue further for this receptor.

6.2.6.4 Risk Characterization: Lead

Lead was not identified as a COPC in any of the media associated with Parcel 514(7). It is concluded that exposure to the media at the Old Burn Pit, Parcel 514(7), is unlikely to result in adverse health effects induced by lead.

6.2.6.5 Uncertainty Analysis

Probably the most important source of uncertainty regarding Parcel 514(7) is the exclusion of background metals from the quantitative risk assessment. The background metals are discussed by medium. Background metals in surface water, sediment and groundwater were discussed in Section 6.2.1.5.

Soil. Several metals in soil were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Tables 6-58 and 6-59). Some had MDCs exceeding their residential soil SSSLs, including aluminum and vanadium in surface soil, and aluminum, iron and thallium in subsurface soil (comparisons of MDCs and SSSLs not shown). In all cases except iron in subsurface soil, the exceedance of noncancer SSSLs was less than a factor of 10, indicating that HI values calculated for these chemicals would fall below the threshold level of 1. As noted above, the oral RfD for iron is controversial and most likely unnecessarily conservative, and its selection as a background chemical is judged not to impart significant uncertainty to the assessment.

Background Metals in All Media. As noted in Section 6.2.1.5, excluding background metals in soil and groundwater would result in understating risk if they were excluded in error. The activities performed at the Old Burn Pit, Parcel 514(7) (and indeed on all of the Training Area T-5 Sites) are sufficiently well known to conclude that metals are unlikely to have been released or disposed during site-related activities. Given the fact that erroneously excluding metals as background is unlikely, and that development of the groundwater as a potable source is also unlikely, it is concluded that the exclusion of background metals imparts only a small source of uncertainty to evaluation of Parcel 514(7).

6.2.6.6 Conclusions, Old Burn Pit, Parcel 514(7)

The Training Area T-5 Sites are projected to be used in the future for mixed business, passive recreation, and developmental reserve. Therefore, the recreational site user, groundskeeper, and construction worker are the relevant receptor scenarios that were evaluated herein. The recreational site user is assumed to be exposed to surface soil or total soil, surface water, and sediment at the Old Burn Pit, Parcel 514(7). The groundskeeper and construction worker are assumed to be exposed to total soil and to groundwater developed as a potable source – an

unlikely possibility. The on-site resident, included only for the additional information provided by generally the most conservative receptor scenario, is assumed to be exposed to total soil, groundwater developed as a potable source, and to surface water and sediment in the same manner as the recreational site user.

COPCs at Parcel 514(7) are limited to several solvents in groundwater and benzo(a)pyrene in total soil for the on-site resident. Therefore, it is concluded that the recreational site user is not expected to experience adverse health effects from exposure to the site in its current condition. Also, the future groundskeeper and construction worker are not expected to experience adverse health effects from exposure to the site in its current condition. The on-site resident may experience unacceptable cancer risk and adverse noncancer health effects, but only when exposure to groundwater as a potable source – a very unlikely scenario – is included in the estimations. It is clear that the VOCs in groundwater hypothetically developed as a potable source represent the only significant threat to human health. Therefore, further action to evaluate or remediate soil would have no effect on suitability of the site for any future use. Furthermore, the site currently can be considered suitable for any future use so long as groundwater in its current condition is not developed as a potable source.

6.3 Final SRA Summary and Conclusions

The parcels of the Training Area T-5 Sites were evaluated individually because all the parcels are not contiguous, the size of some of them approximates a reasonable size for an EU, and the analytical data for soil lend themselves to parcel-specific evaluation. The surface water and sediment data were obtained from the only significant drainage feature in the area, and receptors at all sites are assumed to have equal access to this drainage feature. Therefore, the surface water and sediment data were compiled into single medium-specific data sets for evaluation. Similarly, groundwater samples were taken from a huge area. Since production wells may be installed at any location and potable water may be piped to any location, the groundwater data from all parcels were combined for COPC identification and STC estimation.

The Training Area T-5 Sites with one exception are currently unused; therefore, the recreational site user or groundskeeper are the most relevant exposure scenarios. Future use is expected to include mixed business, passive recreation, and developmental reserve. The groundskeeper, construction worker, and on-site resident were included in the evaluation in the event that the sites would be developed for these or other purposes in the future.

The recreational site user is assumed to be exposed randomly to surface soil, surface water, and sediment over the entire area of any given site. The groundskeeper is assumed to be randomly

exposed to surface soil under the current site-use scenario, and to total soil and groundwater developed as a potable source – an unlikely possibility – under the future site-use scenario. The groundskeeper is assumed to be exposed uniformly over the whole of any given parcel.

The construction worker is assumed to be exposed to total soil and groundwater developed as a potable source. Construction projects, however, are expected to involve exposure to soil in an area smaller than any entire parcel area. Lacking definitive EU information, COPC concentrations at one or more soil sample locations that would yield a total ILCR that exceeds 1E-4 or a target organ HI that exceeds the threshold level of 1 for the construction worker, had they been identified, would have been interpreted as posing a health threat.

The on-site resident is assumed to be exposed to total soil, groundwater developed as a potable source, and to surface water and sediment in the same manner as the recreational site user. Home sites are expected to be smaller than any entire parcel. Lacking definitive EU information, COPC concentrations at one or more soil sample locations that would yield a total ILCR that exceeds 1E-4 or a target organ HI that exceeds the threshold level of 1 for the on-site resident must be interpreted as posing a health threat. Exposure to surface water and sediment, however, is expected to occur randomly over the entire drainage feature associated with the Training Area T-5 Sites.

COPCs were not identified in surface water or sediment; therefore, exposure to surface water and sediment (relevant to the recreational site user and on-site resident) was not evaluated further.

COPCs in groundwater, assuming that groundwater is developed as a potable source in the future, included several solvents with concentrations sufficient to yield cancer risk estimates above the risk management range for the groundskeeper and on-site resident, and noncancer hazard estimates for the on-site resident above the threshold level of 1. COPCs in soil and site-specific risk results and their interpretation are discussed below.

6.3.1 Former Detection and Identification Area, Parcel 180(7)

COPCs in soil at the Former Detection and Identification Area, Parcel 180(7), are limited to several PAHs in surface soil and benzo(a)pyrene in subsurface soil. COPC concentrations are sufficiently low so that the recreational site user and construction worker are not expected to experience adverse health effects from exposure to the site in its current condition. The groundskeeper and on-site resident, on the other hand, may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only if

groundwater is developed as a potable source in the future, a very unlikely scenario. The interpretation of the risk results is summarized in Table 6-65.

6.3.2 Training Area T-5, Parcel 182(7)

COPCs were not identified in soil at Training Area T-5, Parcel 182(7). The recreational site user and construction worker are not expected to experience adverse health effects from exposure to the site in its current condition. The groundskeeper and on-site resident, on the other hand, may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only if groundwater is developed as a potable source in the future, a very unlikely scenario. The interpretation of the risk results is summarized in Table 6-65.

6.3.3 Blacktop Training Area, Parcels 511(7) and 512(7)

COPCs were not identified in soil at the Blacktop Training Area, Parcels 511(7) and 512(7). The recreational site user and construction worker are not expected to experience adverse health effects from exposure to the site in its current condition. The groundskeeper and on-site resident, on the other hand, may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only if groundwater is developed as a potable source in the future, a very unlikely scenario. The interpretation of the risk results is summarized in Table 6-65.

6.3.4 Dog Training Area, Parcel 513(7)

COPCs in soil at the Dog Training Area, Parcel 513(7), are limited to benzo(a)pyrene in surface soil. COPC concentrations are sufficiently low so that the recreational site user and construction worker are not expected to experience adverse health effects from exposure to the site in its current condition. The groundskeeper and on-site resident, on the other hand, may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only if groundwater is developed as a potable source in the future, a very unlikely scenario. The interpretation of the risk results is summarized in Table 6-65.

6.3.5 Dog Kennel Area, Parcel 516(7)

COPCs in soil at the Dog Kennel Area, Parcel 516(7), are limited to barium in surface soil for the construction worker only. COPC concentrations are sufficiently low so that the recreational site user and construction worker are not expected to experience adverse health effects from exposure to the site in its current condition. The groundskeeper and on-site resident, on the other hand, may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only if groundwater is developed as a potable source in the future, a very unlikely scenario. The interpretation of the risk results is summarized in Table 6-65.

6.3.6 Old Burn Pit, Parcel 514(7)

COPCs in soil at the Old Burn Pit, Parcel 514(7), are limited to benzo(a)pyrene in surface soil for the on-site resident only. COPC concentrations are sufficiently low so that the recreational site user and construction worker are not expected to experience adverse health effects from exposure to the site in its current condition. The groundskeeper and on-site resident, on the other hand, may experience unacceptable cancer risk, and the on-site resident may experience adverse noncancer health effects, but only if groundwater is developed as a potable source in the future, a very unlikely scenario. The interpretation of the risk results is summarized in Table 6-65.

6.3.7 Conclusion

Surface water, sediment, and soil at the various Training Area T-5 Sites are uncontaminated or so lightly contaminated that these media pose no significant threat to human health. Groundwater, on the other hand, has been seriously impacted by several solvents, particularly 1,1,2,2-TCA, TCE, carbon tetrachloride, and acetone. The Training Area T-5 Sites could be released for any purpose so long as the groundwater is not developed as a potable source. Low levels of PAHs in surface soil at three of the sites contribute significantly to cancer risk only if exposure to groundwater developed as a potable source is included in the evaluation.

7.0 Screening-Level Ecological Risk Assessment

7.1 Introduction

In order to determine the potential for ecological risks posed by site-related chemicals at the Training Area T-5 Sites, a screening-level ecological risk assessment (SLERA) was conducted. This SLERA consists of a description of the habitat(s) in and around the Training Area T-5 Sites, a discussion of the constituents detected in samples collected from environmental media at the training areas, a discussion of the conceptual site model, an estimation of the screening-level risk, the identification of the constituents of potential ecological concern, an uncertainty analysis, a discussion of the different lines of evidence, and a summary of the results and conclusions.

7.2 Environmental Setting

The Training Area T-5 Sites consist of several individual parcels including the Former Detection and Identification Area, Parcel 180(7), The Training Area T-5, Parcel 182(7), the Blacktop Training Area, Parcel 511(7) and Fenced Yard in Blacktop Area, Parcel 512(7), the Dog Training Area, Parcel 513(7), Dog Kennel Area, Parcel 516(7), and the Old Burn Pit, Parcel 514(7). The Training Area T-5 Sites are located in the west-central portion of the Main Post. Parcel 180(7) is located southwest of Building 3185 and encompasses approximately 0.5 acre on the west side of Rucker Street. Training Area T-5, Parcel 182(7), is located between Sunset Hill and Howitzer Hill, south of Building 3174, at the end of Rucker Street, and encompasses approximately 10.5 acres. Parcel 511(7) and 512(7) are combined a little over 3 acres in size and are primarily an asphalt parking lot. These two parcels are located along the east side of Reggie Avenue. Parcels 513(7) and 516(7) are located at the south end of Reggie Avenue and are each approximately one acre in size. Parcel 514(7) is located in the woods behind Former Motor Pool Area 3100 on Rucker Street and encompasses an area of approximately 0.15 acres.

Six of the Training Area T-5 Sites, Parcels 180(7), 511(7), 512(7), 513(7), 514(7), and 516(7), are located within the valley area of Fort McClellan, between Sunset Hill and Howitzer Hill. The seventh parcel (Parcel 182[7]) straddles the eastern edge of Sunset Hill. The elevation across the sites ranges from a maximum of approximately 925 feet amsl in Parcel 182(7) to approximately 800 feet amsl in Parcel 511(7).

Surface water drainage at the Training Area T-5 Sites follows the general topography and eventually flows into South Branch of Cane Creek. Surface runoff flows westward off Howitzer Hill towards Parcels 511(7) and 512(7) and two small ephemeral streams drain eastward off Sunset Hill across the north end of Parcel 182(7). A larger intermittent stream flows northward

parallel to the eastern boundary of Parcel 182(7) and Parcel 513(7) and the western boundary of Parcels 511(7) and 512(7).

The environmental setting of the Training Area T-5 Sites is varied. The study areas of the Blacktop Training Area, Parcel 511(7), and Fenced Yard in Blacktop Area, Parcel 512(7), are entirely paved with asphalt and provide no viable ecological habitat. The habitat at the Dog Training Area, Parcel 513(7), consists of mixed deciduous/coniferous forest with significant underbrush. A portion of this site can be characterized as being in a relatively early successional stage, with pioneer species and numerous loblolly pine saplings dominating and more mature tees around the perimeter of the site. The Dog Kennel Area, Parcel 516(7), is characterized by maintained lawn with mature pine and hardwood trees interspersed. Training Area T-5, Parcel 182(7), is characterized by relatively mature mixed deciduous/coniferous forest with very little understory. Significant leaf litter and pine needles inhibits the growth of herbaceous species in this habitat. The Former Detection and Identification Area, Parcel 180(7), is a combination of oldfield and mixed deciduous/coniferous forest habitat. The forested portion of the site is relatively immature with significant underbrush present. The habitat at the Old Burn Pit, Parcel 514(7), consists of relatively mature mixed deciduous/coniferous forest with very little herbaceous growth due to the thick leaf litter and pine needle cover.

Other than the Blacktop Training Area, Parcel 511(7) and Fenced Yard in Blacktop Area, Parcel 512(7), which are entirely paved, the terrestrial habitat at the Training Area T-5 Sites consists of oldfield and mixed deciduous/ coniferous forest. The oldfield habitats were formerly maintained as lawns or mowed fields. Since maintenance activities have ceased in these areas, pioneer species are now colonizing these areas. Typically, the species most likely to colonize these types of areas are the "weed" species that tend to be vigorous pioneer plants that grow and spread rapidly. The first of the pioneer species to invade these abandoned areas are the grasses and other herbaceous species. These formerly maintained grassy areas are classified as being in an early oldfield successional state. Over time, the grass and other herbaceous species will be followed by shrubs and small trees. The early oldfield successional areas at the Training Area T-5 sites are dominated by various grasses and herbs, including *Rumex spp.* (dock), *Trifolium spp.* (clover), *Astragalus spp.* (vetch), *Ascelepias spp.* (milkweed), *Galium spp.* (bed straw), *Chrysanthemum leucanthemum* (ox-eye daisy), and *Sorghum halepense* (Johnson grass). Other oldfield herbaceous species occurring at the Training Area T-5 sites are *Rubus occidentalis* (black raspberry), *Toxicodendron radicans* (poison ivy), *Rubus glabra* (smooth sumac), *Smilax rotundiflora* (green brier), *Lonicera japonica* (Japanese honeysuckle), *Vitus labrusca* (fox grape), and *Rosa multiflora* (multiflora rose). Scrub pine (*Pinus virginiana*) and loblolly pine (*Pinus taeda*) saplings have also begun to encroach on these cleared areas.

Portions of the Training Area T-5 Sites that were not maintained lawns are characteristic of the surrounding forest type which is a mixed deciduous/coniferous forest. The canopy species typically found in this forest type at FTMC include shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), longleaf pine (*Pinus palustris*), yellow poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), white oak (*Quercus alba*), and northern red oak (*Quercus rubra*). The dominant understory species of this forest type are red maple (*Acer rubrum*), flowering dogwood (*Cornus florida*), witch hazel (*Hamamelis virginia*), sweetgum (*Liquidambar styraciflua*), wild black cherry (*Prunus serotina*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), and sourwood (*Oxydendrum arboreum*). The shrub layer is dominated by chokeberry (*Aronia arbutifolia*), mountain laurel (*Kalmia latifolia*), Piedmont azalea (*Rhododendron canescens*), southern low blueberry (*Vaccinium pallidum*), southern wild raisin (*Viburnum nudum*), Virginia creeper (*Parthenocissus quinquefolia*), and poison ivy (*Toxicodendron radicans*). The herbaceous layer consists mainly of foxglove (*Aureolaria pectinata*), little bluestem (*Schizachyrium scoparium*), narrow-leaved sensitive brier (*Schrankia microphylla*), poison oak (*Toxicodendron toxicarium*), goat's rue (*Tephrosia virginiana*), and pencil flower (*Stylosanthes biflora*).

Typical terrestrial species that may inhabit the Training Area T-5 Sites include opossum, short-tailed shrew, raccoon, white-tail deer, red fox, coyote, gray squirrel, striped skunk, a number of species of mice and rats (e.g., white-footed mouse, eastern harvest mouse, cotton mouse, eastern woodrat, and hispid cotton rat), and eastern cottontail. Approximately 200 avian species reside at FTMC at least part of the year (USACE, 1998). Common species expected to occur in the vicinity of the Training Area T-5 sites include northern cardinal (*Cardinalis cardinalis*), northern mockingbird (*Mimus polyglottus*), warblers (*Dendroica spp.*), indigo bunting (*Passerina cyanea*), red-eyed vireo (*Vireo olivaceus*), American crow (*Corvus brachyrhynchos*), bluejay (*Cyanocitta cristata*), several species of woodpeckers (*Melanerpes spp., Picoices spp.*), and Carolina chickadee (*Parus carolinensis*). Game birds present in the vicinity of the Training Area T-5 sites may include northern bobwhite (*Colinus virginianus*), mourning dove (*Zenaida macroura*), and eastern wild turkey (*Meleagris gallopavo*). A variety of woodland hawks (e.g., sharp-shinned hawk) and other raptors (e.g., red-tailed hawk, barred owl, and great horned owl) are expected to use this area for hunting and/or nesting.

As stated previously, several small, ephemeral drainage features conduct surface runoff from the Training Area T-5 Sites to South Branch of Cane Creek, which is located north of the sites. There are no permanent water bodies or wetlands present within the Training Area T-5 Sites. When water is present in the small ephemeral drainage features, they are narrow (2 to 3 feet

wide) and shallow (3 to 6 inches deep). The substrate is mostly cobbles and gravel with small depositional areas of sand and leaf litter, interspersed throughout. The small size and ephemeral nature of these drainage features preclude the presence of most fish species and other animals that might prey on fish (piscivores); however, semi-aquatic species (amphibians) could occur in these drainage features and drought-tolerant fish species could occur during periods of high precipitation.

7.3 Constituents Detected On Site

The sampling and analysis programs conducted at the Training Area T-5 Sites were designed based on a number of factors, including:

- Site history
- Results of the EBS
- Results of previous sampling and analysis programs.

The sampling and analysis programs at the Training Area T-5 Sites are described in Chapter 2.0 of this report. Constituents detected in soil, surface water, sediment, and groundwater at the sites are presented in Chapter 4.0 of this report.

Surface soil is described for each site independently, whereas surface water, sediment, and groundwater are discussed for the Training Area T-5 sites as a whole. Surface soil samples from the Former Detection and Identification Area, Parcel 180(7), exhibited maximum concentrations of the following constituents that exceeded ESVs and naturally occurring levels:

- Cadmium
- Copper
- Zinc
- Anthracene
- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene.

Training Area T-5, Parcel 182(7), exhibited concentrations of the following constituents that exceeded the ESVs and naturally occurring levels:

- Copper
- Zinc.

Surface soil samples from the Blacktop Training Area, Parcel 511(7), and the Fenced Yard in the Blacktop Area, Parcel 512(7), exhibited maximum concentrations of the following constituents that exceeded ESVs and naturally occurring levels:

- Cadmium
- Copper
- Zinc.

Surface soil samples from the Dog Training Area [Parcel 513(7)} exhibited maximum concentrations of the following constituents that exceeded ESVs and naturally occurring levels:

- Cadmium
- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene.

Surface soil samples from the Dog Kennel Area [Parcel 516(7)] exhibited maximum concentrations of the following constituents that exceeded ESVs and naturally occurring levels:

- Barium
- Trichloroethene.

Surface soil samples from the Old Burn Pit [Parcel 514(7)] exhibited maximum concentrations of the following constituents that exceeded ESVs and naturally occurring levels:

- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene
- 1,1,2,2-Tetrachloroethane
- Trichloroethene.

None of the constituents detected in surface water at the Training Area T-5 Sites exceeded ESVs or naturally occurring levels. One sediment sample exhibited chromium at a concentration exceeding its ESV.

Bis(2-ethylhexyl)phthalate and 1,1,2,2-tetrachloroethane were detected in groundwater at the Training Area T-5 Sites at concentrations exceeding ESVs.

7.4 Site Conceptual Model

The ecological site conceptual model (SCM) is a simplified, schematic diagram of possible exposure pathways and the means by which contaminants are transported from the primary contaminant source(s) to ecological receptors (Figure 7-1). The exposure scenarios include the sources, environmental transport, partitioning of the contaminants amongst various environmental media, potential chemical/biological transformation processes, and identification of potential routes of exposure for the ecological receptors. In this chapter the SCM will be described in relation to constituent fate and transport properties, the ecotoxicity of the various constituents, potential ecological receptors at the Training Area T-5 sites, and the complete exposure pathways expected to exist at the sites.

7.4.1 Constituent Fate and Transport

The environmental fate and transport of contaminants in surface soil, sediment, and groundwater at the Training Area T-5 Sites will govern the potential for exposures to ecological receptors. In general, contaminants in environmental media may be available for direct exposure (e.g., plants exposed to surface soil), and they may also have the potential to migrate to other environmental media or areas of the site. This section discusses the mechanisms by which contaminants can be transported and the chemical properties that determine their transport.

7.4.1.1 Fate and Transport in Soil

Contaminants in surface soil at the Training Area T-5 Sites have the potential to be transported from their source areas to off-site locations by a number of mechanisms, including volatilization, dust entrainment, surface runoff, and infiltration to subsurface soil/groundwater.

The inorganic constituents detected in surface soil are generally closely associated with the soil particles themselves and are not expected to be transported great distances from their source. Volatilization of inorganic constituents is expected to be insignificant. Fugitive dust generation and entrainment by the wind with subsequent dispersion by atmospheric mixing could transport particulate-associated contaminants to other parts of the study area and to off-site locations. However, due to the fact that two of the parcels are entirely covered with asphalt and the other parcels are covered by vegetation and/or a thick layer of leaf litter, fugitive dust generation is expected to be minimal. Several VOCs were identified in the surface soil at the Training Area T-5 Sites. These constituents have varying degrees of volatilization potential with subsequent off-site transportation via air movement. However, VOCs were infrequently detected and at relatively low concentrations; therefore, volatilization and subsequent transport of these compounds is expected to be insignificant with respect to other transport mechanisms potentially active at these sites.

The transport of surface soil-associated contaminants by surface runoff is another potential transport mechanism. Although there are no permanent surface water bodies at the Training Area T-5 Sites, several small ephemeral drainage features drain these sites and eventually discharge into South Branch of Cane Creek north of the sites. These drainage features collect surface runoff from the sites and transport it off-site to the north. As such, surface runoff via the ephemeral drainage features has the potential for significant constituent transport off-site during periods of significant precipitation.

Contaminants in surface soil may be transported vertically to subsurface soils and groundwater via solubilization in rainwater and infiltration. Migration in this manner is dependent upon contaminant solubility and frequency of rainfall. The soil type (Stony Rough Land) in the vicinity of the sites does not promote rapid infiltration, but rather is more conducive to the promotion of surface runoff. Based on the constituents detected in surface soil and the soil type found at these sites, vertical migration of surface soil constituents is expected to be minimal at the Training Area T-5 Sites.

The transfer of contaminants in surface soil to terrestrial plants through root uptake and to terrestrial animals through ingestion and other pathways are potentially significant transfer mechanisms. Many metals are readily absorbed from soil by plants, but they are not biomagnified to a great extent through the food web. VOCs and SVOCs do not bioaccumulate to any significant extent (Shugart et al., 1990); therefore, food web transfer of these constituents is expected to be minimal.

VOCs in the surface soil at the Training Area T-5 Sites are expected to volatilize and/or photolyze relatively rapidly when exposed to sunlight (half-lives of 3 hours to 5 days) (Burrows et al., 1989).

7.4.1.2 Fate and Transport in Surface Water

Although the drainage features at the Training Area T-5 sites are ephemeral, they represent a potentially significant transport mechanism during periods of significant precipitation. Constituents transported to these ephemeral drainage features via surface runoff could be transported off-site via surface water flow through these drainage features. Groundwater from the Training Area T-5 Sites is unlikely to infiltrate the ephemeral drainage features since the depth to groundwater is greater than 20 feet bgs.

7.4.1.3 Fate and Transport in Sediment

As is the case with surface water, the transport of sediment in the ephemeral drainage features at these sites could represent a transport pathway for soil-related constituents to off-site areas during periods of significant precipitation. Sediment in the ephemeral drainage features could become entrained in the runoff conducted in these drainage features and could potentially be transported off-site.

7.4.1.4 Fate and Transport in Groundwater

Ecologically relevant transport processes involving groundwater at the Training Area T-5 Sites are not present. As stated previously, groundwater at the sites is greater than 20 feet bgs. As such, groundwater discharge to surface water bodies (e.g., the ephemeral drainage features) is unlikely. Without groundwater discharge to a surface water body, ecological exposures are not complete. Therefore, the fate and transport of groundwater at the Training Area T-5 Sites are not relevant with respect to ecological risks.

7.4.2 Ecotoxicity

The ecotoxicological properties of the constituents detected at concentrations that exceeded their respective ESVs and naturally occurring levels in surface soil, sediment, and groundwater at the Training Area T-5 Sites are discussed in the following sections. No COPECs have been identified in surface water at the Training Area T-5 sites.

7.4.2.1 Barium

Barium, a silvery-white metal, is used in various alloys, in paints, soap, paper and rubber and in the manufacture of ceramics and glass. Two forms of barium, barium sulfate and barium carbonate, are often found in nature as underground ore deposits. Barium is relatively abundant in nature and is found in plants and animal tissue. Plants can accumulate barium from the soil.

Most of the barium that enters an animal's body is removed within a few days and almost all of it is gone within 1 to 2 weeks. Most of the barium that stays in the body goes into the bones and teeth. Rats exposed to barium in their diet at lower doses, but for longer time periods, showed increased blood pressure and changes in the function and chemistry of the heart (ATSDR, 1992).

Plants. Background concentrations of barium in various food and feed plants are reported to range from 1 to 198 mg/kg (dry weight) (Kabata-Pendias and Pendias, 1992). Concentrations are often highest in the leaves of cereals and legumes and lowest in grains and fruits (Kabata-Pendias and Pendias, 1992). The availability of barium to plants is greatly influenced by the pH of the soil, with barium more available under acidic soil conditions (Kabata-Pendias and Pendias,

1992). The concentration of barium in leaf tissue that has been reported as excessive or toxic to various plant species is 500 mg/kg (Kabata-Pendias and Pendias, 1992). A soil concentration of 500 mg/kg has been proposed by Efroymson et al. (1997a) as a benchmark screening value for barium phytotoxicity.

Terrestrial Invertebrates. No information was found regarding the toxicity of barium to terrestrial invertebrates.

Mammals. Barium administered to rats via their drinking water at doses of 1, 10, and 100 mg/L had no effect on food or water consumption, or growth. Because the highest dose tested (100 mg/L) did not elicit any adverse effects, it was considered the no-observed-adverse-effects level (NOAEL) (5.1 mg/kg/day) (EPA, 2003c). Laboratory rat toxicity data for barium chloride in drinking water was used to calculate a NOAEL value of 5.1 mg/kg/day (Perry et al., 1983). Growth and hypertension were the test endpoints. Rats administered barium through oral gavage showed no adverse effects at dosages up to 300 mg/kg/day. These data were used to derive a NOAEL value of 19.8 mg/kg/day (Borzelleca et al., 1988). Mortality was the endpoint for this study.

Birds. A study of 1-day old chicks fed barium in their diet was used to determine the amount of barium to cause mortality. While barium exposures up to 2,000 parts per million (ppm) produced no mortality, chicks in the 4,000 to 32,000 ppm exposure groups experienced 5 to 100 percent mortality. Because 2,000 ppm was the highest non-lethal dose, this dose was considered to be the subchronic NOAEL (Johnson et al., 1960). A NOAEL value of 20.8 mg/kg/day was derived from these data.

Aquatic Life. The chronic value for daphnids is from a 21-day test on *Daphnia magna* by Biesinger and Christensen (1972) which resulted in 16 percent reproductive impairment. The Tier II secondary acute water quality value and secondary chronic water quality value for barium, as calculated by the method described in the EPA's *Final Water Quality Guidance for the Great Lakes System* (EPA, 1995), are 110 and 4.0 micrograms per liter (□g/L), respectively.

7.4.2.2 Cadmium

Cadmium is a silver-white, blue-tinged, lustrous metal. It is insoluble in water, although its chloride and sulfate salts are freely soluble (Windholz et al., 1976). Cadmium compounds in soil are stable and are not subject to degradation (ATSDR, 1993a).

Plants. Cadmium is a non-essential element for plant growth that can be absorbed from air or soil. The availability of cadmium is soil is influenced by organic content, clay content, pH, and reduction-oxidation potential (Sharma, 1980). The distribution of accumulated cadmium within plants is generally roots>stem and leaves>fruits, grains, seeds, or nutrient storage organs (Eisler, 1985). Concentrations from 10 to 20 mg/kg in plant tissue are expected to result in 10 percent loss in crop yield. Concentrations in leaf tissue that are excessive or toxic to various plant species range from 5 to 30 mg/kg. General symptoms of cadmium poisoning in plants include growth retardation, root damage, chlorosis of leaves, and red-brown coloration of leaf margins or veins (Kabata-Pendias and Pendias, 1992).

Terrestrial Invertebrates. A number of studies have been conducted to assess the potential adverse effects on terrestrial invertebrates. Van Gestel et al. (1992) evaluated the effects of cadmium, added to the soil as cadmium chloride, on growth and reproduction of *Eisenia andrei* after 21 days. A concentration of 18 mg/kg cadmium was required to reduce the number of cocoons produced per week and the number of juveniles per worm. Growth and reproduction were not affected at 10 mg/kg cadmium.

The effects of cadmium added to horse manure (as cadmium acetate) on *Eisenia fetida* was investigated by Malecki et al. (1982). Two growth periods were studied, 8 and 20 weeks, and survival, weight gain, and cocoon production were measured. The most sensitive parameter was cocoon production. In the 8-week test, the lowest concentration tested, 25 mg/kg cadmium, caused a 52 percent decrease in cocoon production. In the 20-week test, the lowest concentration tested, 50 mg/kg cadmium, caused a 24 percent decrease in cocoon production.

Using the results of the above tests and a number of other studies, Efroymson et al. (1997b) computed an earthworm benchmark concentration of 20 mg/kg.

Mammals. Cadmium uptake by most animals is relatively low. Absorption and retention of cadmium decreases with prolonged exposure. Cadmium tends to accumulate in the viscera, especially in liver and kidney tissues. The biological half-life of cadmium in muscle, kidney, and liver tissues ranges from 10 to 30 years. About 5 percent of ingested cadmium is absorbed, whereas between 10 and 50 percent of inhaled cadmium is absorbed (Friberg et al., 1986).

Mammals are relatively resistant to cadmium toxicity. The production of metallothioneins helps to protect mammals from cadmium toxicosis. The lowest published toxic dose of cadmium for mammals is 21.5 mg/kg, which was reported to induce adverse effects on fertility of rats (Registry of Toxic Effects of Chemical Substances [RTECS], 1996). Sutou et al. (1980) studied

the effects of cadmium on rats exposed through oral gavage. While no adverse effects were observed at the 1 mg/kg/day dose level, fetal implantations were reduced by 28 percent, fetal survivorship was reduced by 50 percent, and fetal resorptions increased by 400 percent amongst the 10 mg/kg/day exposure group. Because this study considered oral exposures during reproduction, the 1 and 10 mg/kg/day doses were considered to be chronic NOAELs and lowest-observed-adverse-effects levels (LOAEL), respectively.

Exposure to cadmium has been shown to induce teratogenic effects in laboratory animals. The teratogenic effects of cadmium can be synergized by lead and mercury salts and antagonized by selenium (Ferm and Layton, 1981).

Birds. Birds, like mammals, are relatively resistant to cadmium toxicity. Sublethal effects in birds are similar to those in other species and include growth retardation, anemia, and testicular damage (Hammons et al., 1978). In one experiment, drake mallards were fed up to 200 mg/kg cadmium chloride in their diet for 90 days, and all survived with no loss in body weight. Egg production was, however, suppressed in mallard hens fed 200 mg/kg cadmium chloride in their diet (White and Finley, 1978). As in mammals, metallothionein binds to cadmium and thus aids in the reduction of a toxic response. Japanese quail that were fed 75 mg/kg cadmium in their diets developed signs of bone marrow hyperplasia, anemia, and hypertrophy of both heart ventricles after six weeks of exposure (Richardson et al., 1974). White and Finley (1978) studied the effects on reproduction of mallard ducks fed cadmium in their diets. Based on the results of this study, a NOAEL value of 1.45 mg/kg/day has been derived.

Aquatic Life. Freshwater organisms are more sensitive to elevated cadmium concentrations than are wildlife or plant species (Eisler, 1985). Among all species of freshwater biota examined, cadmium concentrations of 0.47 to 5.0 µg/L were associated with decreases in standing crop, decreases in growth, inhibition of reproduction, immobilization, and population alterations (Eisler, 1985). EPA's National Recommended Water Quality Criteria are 2.0 µg/L for acute exposure and 0.25 µg/L for chronic exposure of freshwater aquatic life to cadmium (based on a water hardness of 100 mg/L) (EPA, 2002c). The test EC_{20} (the concentration that will result in a specified effect on 20 percent of the test population) for fish can be used as a benchmark indicative of production within a population. The EC_{20} value for cadmium is 1.8 µg/L (Suter and Tsao, 1996). The EC_{20} value for cadmium with respect to daphnids is 0.75 µg/L (Suter and Tsao, 1996).

Concentrations of cadmium in freshwater biota from uncontaminated areas are usually less than 1 mg/kg in fish and less than 5 mg/kg in mollusks, annelids, and macrophytes (Eisler, 1985). Bioconcentration factors of 2,000 have been reported in insects, fish, and algae.

7.4.2.3 Chromium

Chromium exists in soil primarily in the form of insoluble oxides with very limited mobility. In soil, chromium (+3) is readily hydrolyzed and precipitated as chromium hydroxide. In the aquatic phase, chromium may be in the soluble state or attached to clay-like or organic suspended solids.

Plants. Chromium does not play an essential role in plant metabolism. The concentration of chromium in terrestrial plants is controlled primarily by soluble chromium in the soil (Kabata-Pendias and Pendias, 1992). Chromium concentrations in plants are usually higher in roots than in leaves or shoots. Concentrations of chromium in leaf tissue that are excessive or toxic to various plant species range from 5 to 30 mg/kg soil (Kabata-Pendias and Pendias, 1992). General symptoms of chromium toxicity in plants include chlorosis of new leaves, necrotic spots and purpling tissues, and injured root growth (Kabata-Pendias and Pendias, 1992).

Terrestrial Invertebrates. Abbasi and Soni (1983) exposed the earthworm *Octochaetus pattoni* to chromium (as $K_2Cr_2O_7$) in soil for 60 days to assess the effects on survival and reproduction. Survival was the most sensitive endpoint with a 75 percent decrease resulting from exposure to 2.0 ppm chromium, the lowest concentration tested. The number of cocoons produced was not reduced until the concentration reached 20 ppm chromium (the highest concentration tested). The number of juveniles produced was not affected.

It is difficult to establish a benchmark concentration for chromium based on earthworm toxicity because the relative toxicity of Cr^{+3} and Cr^{+6} is not clear from the available data. Cr^{+6} ions can pass through cell membranes with much greater ease than Cr^{+3} ions. However, it is thought that Cr^{+6} is reduced to Cr^{+3} inside the cell (Molnar et al., 1989). Without a better understanding of chromium transformations in the soil, transport across earthworm cell membranes, and reactions within the cell, it is difficult to separate the effects of the two different forms of chromium. These difficulties not withstanding, a soil benchmark value of 0.4 mg/kg has been suggested by Efroymson, et al. (1997b), based on the work of Abbasi and Soni (1983).

Mammals. Chromium is a required element in animal nutrition. In general, hexavalent chromium compounds are more toxic than the trivalent chromium compounds. Adverse effects on blood and serum chemistry and morphological changes in liver have been reported in rabbits

and rats exposed to chromium concentrations of 1.7 mg/kg/day for six weeks. Rats exposed to hexavalent chromium concentrations of 134 mg/L in drinking water over a two-to-three-month period were found to develop lesions in kidney and liver tissues (Eisler, 1986).

Laboratory data based on rats exposed to chromium (as Cr_2O_3) in their diets were used to derive a NOAEL value for trivalent chromium of 2,737 mg/kg/day (Ivankovic and Preussmann, 1975). Reproduction and longevity were the endpoints in this study. Laboratory data based on rats exposed to chromium (as $K_2Cr_2O_4$) in their drinking water were used to derive a NOAEL value for hexavalent chromium of 3.28 mg/kg/day (MacKenzie et al., 1958). Body weight and food consumption were the endpoints in this study. Mammalian laboratory studies have shown chromium to be mutagenic, carcinogenic and teratogenic (Eisler, 1986).

Birds. Data on the effects of chromium to avian species are limited. No adverse effects were found in chickens exposed to 100 mg/kg dietary hexavalent chromium in a 32-day study (Rosomer et al., 1961). Haseltine et al. (1985) did not observe changes in survival, reproduction or blood chemistry following exposure of adult black ducks (*Anas rubripes*) to diets containing between 10 and 50 mg/kg chromium III (as $CrK[SO_4]_2$). Ducklings from this group that were fed the same chromium diet as the parent ducks experienced alterations in growth patterns and a reduction in survival. Based on these data, a NOAEL value of 1 mg/kg/day has been derived.

Aquatic Life. In freshwater systems, hexavalent chromium appears to be more toxic than the trivalent form. The National Recommended Water Quality Criteria for trivalent chromium are 570 µg/L for acute exposures and 74 µg/L for chronic exposures. The National Recommended Water Quality Criteria for hexavalent chromium are 16 µg/L for acute exposures and 11 µg/L for chronic exposures (EPA, 2002c). These values are based on a water hardness of 100 mg/L.

The test EC_{20} for fish can be used as a benchmark indicative of production within a population. It is the highest tested concentration causing less than 20 percent reduction in either the weight of young fish per initial female fish in a life-cycle or partial life-cycle test, or the weight of young per egg in an early life-stage test. The EC_{20} value for trivalent chromium is 89 µg/L and for hexavalent chromium is 51 µg/L (Suter and Tsao, 1996). A similar value can be determined for daphnids, which represents the highest tested concentration causing less than 20 percent reduction in the product of growth, fecundity, and survivorship in a chronic test with a daphnid species. The EC_{20} benchmark for daphnids has been determined to be 0.5 µg/L for hexavalent chromium (Suter and Tsao, 1996).

7.4.2.4 Copper

Copper is ubiquitously distributed in nature in the free state and in sulfides, arsenides, chlorides, and carbonates. Several copper containing proteins have been identified in biological systems as oxygen binding hemomcyanin, cytochrome oxidase, tyrosinase, and laccase. Copper has also been identified with the development of metalloproteins employed in the sequestering and cellular detoxification of metals.

Copper has been known to sorb rapidly to sediment. The rate of sorption is of course dependent upon factors such as the sediment grain size, organic fraction, pH, competing cations, and the presence of ligands. In industrialized freshwater environments around the world total copper levels within sediments can range from 7 to 2,350 ppm (Moore and Ramamoorthy, 1984).

Plants. Copper is an essential nutrient for the growth of plants. Background concentrations of copper in grasses and clovers collected in the United States averaged 9.6 mg/kg and 16.2 mg/kg (dry weight), respectively (Kabata-Pendias and Pendias, 1992). Copper is one of the least mobile heavy metals in soil, and its availability to plants is highly dependent on the molecular weight of soluble copper complexes (Kabata-Pendias and Pendias, 1992).

According to Rhodes et al. (1989), copper concentrations in plant tissues do not serve as conclusive evidence of copper toxicity in species of plants such as tomatoes, because some species are able to tolerate higher concentrations of copper than others. The pH of soil may also influence the availability and toxicity of copper in soils to plants (Rhodes et al., 1989). In a study with tomato plants, Rhodes et al. (1989) found a reduction in plant growth when plants were grown in soils containing greater than 150 mg/kg of copper at a pH of less than 6.5. At pH values greater than 6.5, soil copper concentrations of greater than 330 mg/kg were required to reduce plant growth.

Concentrations of copper in leaf tissue that are excessive or toxic to various plant species range from 20 to 100 mg/kg (dry weight) (Kabata-Pendias and Pendias, 1992). A soil concentration of 100 mg/kg has been proposed by Efroymson et al., (1997a) as a benchmark screening value for copper phytotoxicity in soil. General symptoms of copper toxicity in plants include the presence of dark green leaves followed by induced iron chlorosis; thick, short, or barbed-wire roots; and depressed tillering (Kabata-Pendias and Pendias, 1992).

Terrestrial Invertebrates. A number of studies have been conducted to study earthworm toxicity with exposure to copper. The work of Streit and Jaggy (1983) and others shows that the organic carbon content of the soil is a strong determinant of the bioavailability and toxicity of

copper. It appears that low pH has a compounding effect, with an increase in copper bioavailability resulting from more acid conditions. Overall, reproduction is more sensitive than mortality, and there is no consistent evidence that one genus of earthworms is any less tolerant to copper under a given set of conditions than another genus.

Neuhauser et al. (1984) evaluated the effects of soluble forms of copper on growth and reproduction in *Eisenia fetida*. After 6 weeks, both growth (weight) and cocoon production were decreased (75 and 85 percent) by 2,000 ppm copper, while 1,000 ppm had no effect. Using OECD artificial soil (pH = 6) and a 21-day test procedure, van Gestel et al. (1989) looked at the effects of copper (as $CuCl_2$) on reproductive parameters of adult *Eisenia andrei*. After 21 days, cocoon production was decreased by 36 percent by the addition of 180 ppm copper to the substrate, while 120 ppm had no effect.

The sublethal effects of copper on *L. rubellus* were investigated with respect to mortality, growth, cocoon production, and litter breakdown activity (Ma, 1984). Loamy sand field soil (5.7 percent organic matter, pH = 4.8) with copper added as $CuCl_2$, was placed in bags with leaf litter added to the top. In an experiment lasting 6 weeks, the number of cocoons produced was decreased 42 percent by 131 ppm copper, while 54 ppm copper had no effect.

Efroymson, et al. (1997b) have proposed a soil screening level of 60 ppm based on earthworm toxicity.

Mammals. Copper is an essential trace element to plants and animals (Callahan et al., 1979), but becomes toxic at concentrations only slightly higher than essential levels (EPA, 1985). Copper is an essential element for hemoglobin synthesis and oxidative enzymes in animals. Copper is absorbed by mammals following ingestion, inhalation, and dermal exposure. Once absorbed, copper is distributed to the liver. Copper is not metabolized (Marceau et al., 1970). No evidence of bioaccumulation was obtained in a study of pollutant concentrations in the muscles and livers of 10 species of herbivorous, omnivorous, and carnivorous animals in Donana National Park in Spain (Hernandez et al., 1985). Copper concentrations in small mammals collected from various uncontaminated sites ranged from 8.3 to 13.4 mg/kg (whole-body concentrations) (Talmage and Walton, 1991). Highest concentrations of copper tend to be in hair, followed in decreasing concentration by liver, kidney, and whole body (Hunter and Johnson, 1982). Among the small mammals collected, Hunter and Johnson (1982) found shrews (*Sorex araneus*) to contain the highest concentrations of copper. Mice were found to contain the lowest copper concentrations. Increased fetal mortality was observed in fetuses of mice fed

more than 104 mg/kg-day of copper as copper sulfate (Lecyk, 1980). Increased mortality rates in mink offspring have been observed at levels above 3.21 mg/kg-day (Aulerich et al., 1982).

Laboratory toxicity data for mink exposed to copper sulfate in their diet were used to estimate a NOAEL value of 11.7 mg/kg/day (Aulerich et al., 1982). Reproduction was the endpoint studied. Symptoms of acute copper poisoning in mammals include vomiting, hypotension, melena, coma, jaundice, and death (Klaassen et al., 1991). Selenium can act as an antidote for copper poisoning.

Birds. Laboratory toxicity data for one-day old chicks exposed to copper oxide in their diets were used to estimate a NOAEL value of 47 mg/kg/day (Mehring et al., 1960). Growth and mortality were the endpoints studied. Reduced growth and mortality were seen at copper concentrations as low as 749 ppm over the 10-week exposure period.

Aquatic Life. Invertebrates inhabiting "polluted" freshwaters worldwide have been known to have tissue residues of copper ranging from 5 to 200 ppm (Moore and Ramamoorthy, 1984). Field studies have shown that there is virtually no accumulation of this metal through the food chain (Fuller and Averett, 1975). Studies by Kosalwat and Knight (1987) indicated that copper present in the substrate or sediment was significantly less toxic to chironomid species than overlying water column levels. The substrate copper concentration that chironomid larval growth was reduced 50 percent (EC_{50}) was 1,602 mg/kg. These researchers found that deformities in larval mouth parts were observed in elevated concentrations, and adult emergence was inhibited when the sediment concentration exceeded 1,800 mg/kg. Carins et al. (1984) reported copper toxicity in sediment for several chironomus midges and cladocerans with LC_{50} values ranging from 681 to 2,296 mg/kg.

7.4.2.5 Zinc

Zinc is a naturally occurring element which may be found in both organic and inorganic forms and, as such, is commonly found in the environment. In general, zinc is concentrated in the sediments of water bodies. The National Academy of Sciences (NAS) (1977) has reported that zinc will probably be detected in 75 percent of all water bodies examined for the compound at various locations. The fate of zinc in soils appears to have a pH basis. Studies have shown that a pH of less than 7 often favors zinc desorption (EPA, 1984).

Plants. Background concentrations of zinc in terrestrial plants range from 25 to 150 mg/kg (dry weight) (NAS, 1979). The deficiency content of zinc in plants is between 10 and 20 ppm (dry

weight). Roots often contain the highest concentrations of zinc (Kabata-Pendias and Pendias, 1992).

Certain species of plants, particularly those from the families *Caryophyllaceae*, *Cyperaceae*, and *Plumbaginaceae*, and some tree species are extremely tolerant to elevated zinc concentrations (Kabata-Pendias and Pendias, 1992). Concentrations of zinc in these plants may reach 1 percent (dry weight) in the plant. Concentrations in leaf tissue that are excessive or toxic to various plant species range from 100 to 400 mg/kg. Concentrations of 100 to 500 mg/kg are expected to result in a 10 percent loss in crop yield (Kabata-Pendias and Pendias, 1992). General symptoms of zinc toxicity in plants include the presence of chlorotic and necrotic leaf tips, interveinal chlorosis in new leaves, retarded growth of the entire plant, and injured roots that resemble barbed wire (Kabata-Pendias and Pendias, 1992).

Terrestrial Invertebrates. Spurgeon and Hopkin (1996) exposed the earthworm *Eisenia fetida* to zinc in soils with differing organic matter content and soil pH. The EC_{50} concentrations for cocoon production in soils with a pH of 7.0 and 5 percent, 10 percent, and 15 percent organic matter were 136, 462, and 592 mg/kg, respectively. The EC_{50} concentrations for cocoon production in soils of pH 6.0 and 5 percent, 10 percent, and 15 percent organic matter were 199, 343, and 548 mg/kg, respectively. The EC_{50} concentrations for cocoon production in soils of pH 5.0 and 5 percent, 10 percent, and 15 percent organic matter were 142, 189, and 230 mg/kg, respectively. Mortality was observed at higher zinc concentrations. A decrease in pH and/or organic matter content in soil led to a lower toxic concentration of zinc.

Neuhauser et al., (1985) determined an LC_{50} for zinc in soil using adult *Eisenia fetida* exposed for 14 days. The calculated LC_{50} was 662 mg/kg. Data from the preceding studies were used to derive a soil benchmark value for zinc in soil of 100 mg/kg (Efroymson et al., 1997b).

Mammals. Zinc is an essential trace element for normal fetal growth and development. However, exposure to high levels of zinc in the diet has been associated with reduced fetal weights, altered concentrations of fetal iron and copper, and reduced growth in offspring (Cox et al., 1969). Poisoning has been observed in ferrets and mink from chewing corroded galvanized cages (Clark et al., 1981). Symptoms of zinc toxicity are lassitude, slower tendon reflexes, bloody enteritis, diarrhea, lowered leukocyte count, depression of the central nervous system, and paralysis of the extremities (Venugopal and Luckey, 1978). A study by Kinnamon (1963) showed a NOAEL for oral exposure to a zinc compound over a period of 73 days to be 250 mg/kg body weight, and mice given 500 mg/L of zinc, as zinc sulfate, in drinking water have

shown hypertrophy of the adrenal cortex and pancreas. Young animals are much more susceptible to poisoning by zinc than are mature animals (Clark et al., 1981).

Animals are quite tolerant to high concentrations of zinc in the diet. Levels 100-times that required in the diet usually do not cause detectable symptoms of toxicosis (NAS, 1979). Laboratory data for rats exposed to zinc oxide in their diet were used to estimate a NOAEL value of 160 mg/kg/day (Schlicker and Cox, 1968). Reproduction was the endpoint studied. Symptoms of zinc poisoning in mammals include lameness, acute diarrhea, and vomiting (Eisler, 1993).

Birds. Dietary zinc concentrations of greater than 2,000 mg/kg diet are known to result in reduced growth of domestic poultry and wild birds (Eisler, 1993). Reduced survival has been documented at zinc concentrations greater than 3,000 mg/kg diet or at a single dose of greater than 742 mg/kg body weight (Eisler, 1993). Laboratory data for white leghorn hens exposed to zinc sulfate in their diet for 44 weeks were used to estimate a NOAEL value of 14.5 mg/kg/day (Stahl et al., 1990). Reproduction was the endpoint for this study. A value of 51 mg/L has been calculated as the NOAEL for chronic exposure of birds to zinc carbonate in drinking water (Sample et al., 1996).

Aquatic Life. Zinc residues in freshwater and marine fish are generally much lower than those found in algae and invertebrates. Thus there is little evidence for accumulation (Moore and Ramamoorthy, 1984). Rainbow trout (*Oncorhyncus mykiss*) have the ability to detect and avoid areas of water containing 5.6 ppb zinc (Sprague, 1968). Cairns and Scheier (1968) reported 96-hour LC_{50}s ranging from 10.13 to 12.5 ppm in hard water for bluegills (*Lepomis macrochirus*), and 96-hour LC_{50}s ranging from 2.86 to 3.78 ppm in soft water. These results demonstrate that water hardness affects the toxicity of zinc to fish. Chronic toxicity tests have been conducted with five species of freshwater fish. Chronic values ranged from 47 µg/L for flagfish (*Jordanella floridae*) to 852 µg/L for brook trout (*Salvenius fontinallis*) (EPA, 1980).

Acute toxicity to freshwater invertebrates is relatively low, and as with other metals, increasing water hardness decreases the toxicity of zinc (Moore and Ramamoorthy, 1984). As reported by Baudouin and Scoppa (1974), the 48-hour LC_{50} for the cladaceran *Daphnia hyalina* was 0.055 mg/L, and 5.5 mg/L for the copepod *Cyclops abyssorum*. Four chronic toxicity tests are reported for *Daphnia magna*, with chronic values ranging from 47 to 136 µg/L (EPA, 1980). Chronic testing with the saltwater species *Mysidopsis bahia* resulted in a chronic value of 166 µg/L (EPA, 1980).

7.4.2.6 Phthalates

Phthalates are a class of predominantly man-made compounds which do not naturally occur in nature. They are manufactured and commonly used to produce flexible plastics, wetting agents, insecticidal sprays, paints, and glues (Hazardous Substance Data Bank [HSDB], 1996; ATSDR, 1993b). Because of their many uses, phthalates are widespread in the environment and have been identified at low levels in the air, water and soil. In air, phthalates may be adsorbed to particulate matter, and can be transferred to water by wet or dry deposition. In water and soil phthalates are subject to microbial degradation. Both aerobic and anaerobic degradation have been reported. Inman et al. (1984) demonstrated that di-n-butyl phthalate in soil was completely degraded within 100 days. Di-n-butyl phthalate and di-n-octyl phthalate have strong ultraviolet absorption bands at 274 nanometers extending beyond 290 nanometers and are therefore strong candidates for photolysis. However, the estimated photolysis half-life in natural waters is 144 days for both compounds (Callahan et al., 1979). There is some evidence that phthalate esters might be biosynthesized and occur naturally in some plants and organisms (Callahan et al., 1979).

Plants. No information was found regarding the toxicity of phthalates to plants.

Terrestrial Invertebrates. No information was found regarding the potential toxicity of phthalates to terrestrial invertebrates.

Mammals. No studies were located on the effects of phthalate exposure to wildlife. Effects of phthalate esters in laboratory animals were seen at only very high doses (one to two percent di-n-butyl phthalate in the diet in oral studies). The male reproductive system appears to be the most sensitive target organ for acute-duration oral exposure to di-n-butyl phthalate in animals. A LOAEL of 1,000 mg/kg-day was established for decreased testis weight in rats (Oishi and Hiraga, 1980). The mechanism of testicular damage by di-n-butyl phthalate may involve interference with zinc metabolism (Foster et al., 1980). After oral administration, butyl benzyl phthalate was rapidly excreted. Rats and mice exposed to high concentrations of butyl benzyl phthalate lost weight, had testicular atrophy, hemorrhages, and hepatomegaly. LD_{50} values for these experiments were 2.3 g/kg for rats and 4.2 to 6.2 g/kg for mice (DIALOG, 1996).

Mice fed bis(2-ethylhexyl)phthalate in their diets for 105 days were studied for effects on reproduction. While significant reproductive effects were observed among mice on diets containing 0.1 and 0.3 percent bis(2-ethylhexyl)phthalate, no adverse effects were observed

among the 0.01 percent dose group. These data were used to derive a NOAEL value of 18.3 mg/kg/day (Lamb et al., 1987).

Birds. Ringed doves were fed bis(2-ethylhexyl)phthalate in their diets for 4 weeks during a critical lifestage and studied for reproductive effects (Peakall, 1974). No significant reproductive effects were observed in the maximally exposed doves (10 ppm). These data were used to derive a NOAEL value of 1.1 mg/kg/day based on reproductive effects.

Aquatic Life. Studies by Sasaki (1978) indicate that both di-n-butyl phthalate and di-n-octyl phthalate are non- or low-bioaccumulative in fishes. Studies by Streufert et al. (1981) showed the acute 48-hour LC_{50}s of di-2-ethylhexyl phthalate and di-n-butyl phthalate to the midge larvae *Chironomus plumosus* to be 18 mg/L and 0.76 mg/L, respectively. Chronic life cycle toxicity tests showed no effect up to 0.36 mg/L di-2-ethylhexyl phthalate on midge emergence, egg production, or egg hatchability.

7.4.2.7 Polycyclic Aromatic Hydrocarbons

PAHs are a diverse group of organic chemicals consisting of substituted and unsubstituted polycyclic and heterocyclic aromatic rings in which interlinked rings have at least two carbon atoms in common (Zander, 1983). They are formed as a result of incomplete combustion of organic materials such as wood, coal, and oil and exist in the environment in quantity, both from anthropogenic and natural sources. Activities associated with large releases of PAHs include coke production, petroleum refining, the manufacture of carbon black, coal tar pitch and asphalt, heating and power generation, and emissions from internal combustion engines. It is estimated that approximately 270,000 metric tons of PAHs reach the environment yearly (Eisler, 1987).

Plants. Some PAHs are synthesized by plants at very low concentrations (Sims and Overcash, 1983). Background concentrations of specific PAH compounds usually range from 22 to 88 μg/kg in tree leaves, 48 to 66 μg/kg in cereal crop plants, 0.05 to 50 μg/kg in leafy vegetables, 0.01 to 6 μg/kg in underground vegetables, and 0.02 to 0.04 μg/kg in fruits (Sims and Overcash, 1983). In general, PAH concentrations are usually greater in above-ground plant parts than in below-ground parts, and are greater on plant surfaces than within internal tissues (Eisler, 1987).

Lower molecular weight PAHs are taken up from soil by plants more readily than higher molecular weight PAHs (Eisler, 1987). Soil-to-plant concentration ratios for total PAHs have been reported to range from 0.001 to 0.183 (Talmage and Walton, 1990). Atmospheric

deposition is believed to be the usual source of PAHs in plants, not uptake from soil (Sims and Overcash, 1983).

Limited data exist on the phytotoxicity of PAHs to plants. Benzo(b)fluoranthene concentrations of 6,254 μg/kg in soil were reported to reduce stem growth in wheat but did not affect rye plants. Benzo(a)pyrene and benzo(b)fluoranthene soil concentrations of up to 18,000 μg/kg do not appear to be severely toxic to higher plants. There is some evidence that low concentrations of some PAHs may actually stimulate plant growth (Sims and Overcash, 1983).

Terrestrial Invertebrates. Earthworms (*Eisenia fetida*) exposed to benzo(a)pyrene (up to 500 mg/kg) in soil for 28 days did not exhibit DNA strand breaks (Honeycutt and Roberts, 1995), indicating the lack of genotoxicity at the exposure concentrations. PAH compounds were determined to be relatively non-toxic to the earthworm *Eisenia fetida* (Roberts and Dorough, 1984).

Mammals. Most of the PAHs taken into the body are not accumulated but are oxidized, and the metabolites excreted (National Library of Medicine [NLM], 1996). In fact, most PAH compounds are detoxified and excreted from the body (Klaassen et al., 1991). PAHs are metabolized in vertebrates by a group of enzymes known as mixed-function oxidases in the liver. A few laboratory studies on rodents have revealed acute oral toxicities of PAHs are greatest for benzo(a)pyrene, followed in decreasing order of toxicity by phenanthrene, naphthalene, and fluoranthene (Sims and Overcash (1983). Data from a study of mice fed benzo(a)pyrene in their diets were used to derive a NOAEL value of 1.0 mg/kg/day (MacKenzie and Angevine, 1981). The critical endpoint in this study was reproduction.

Sims and Overcash (1983) have reported LC_{50} values for rodents (*Rattus* spp. and *Mus* spp.) as 50 mg/kg-day benzo(a)pyrene, 700 mg/kg-day phenanthrene, and 2,000 mg/kg-day fluoranthene. Sublethal effects manifested as decreased pup weight in mice have been reported at 10 mg/kg-day benzo(a)pyrene (MacKenzie and Angevine, 1981). Subchronic and chronic effects of exposure to PAHs in rats include liver and kidney damage, unspecified changes in peripheral blood pattern, body weight loss, genetic aberrations, and increased serum aminotransferase activity (Knobloch et al., 1969).

Birds. Hoffman and Gay (1981) measured embryotoxicity of various PAHs applied externally to the surface of mallard duck eggs. Approximately 0.002 μg/egg of 7,12-dimethylbenz(a)anthracene (DMBA) caused 26 percent mortality in 18 days, and among the

survivors, produced significant reduction in embryonic growth and a significant increase in the percent of abnormalities (e.g., incomplete skeletal ossification, defects in eye, brain liver, feathers, and bill). At 0.1 μg DMBA/egg, only 10 percent survived to day 18.

Aquatic Life. In general, PAHs as a group are not appreciably acutely toxic (Eisler, 1987; Neff, 1985). The toxicity of PAH compounds to fish is related to the solubility of the compound in water. The toxicity of PAHs to aquatic organisms is very species-specific and related to the organisms' ability to metabolize and excrete the compound (Eisler, 1987). For aquatic organisms, only PAHs in the molecular weight range from naphthalene to pyrene are considered acutely toxic. Toxicity in this group increases with increasing molecular weight. There is some evidence to suggest that PAHs are responsible for the production of reproductive and teratogenic effects in eggs of the sand sole (*Psettichthys melanostictus*) exposed to 0.1 μg benzo(a)pyrene/L for five days showed reduced and delayed hatch and, when compared to controls, produced larvae with high accumulations (2.1 mg/kg fresh weight) and gross abnormalities, such as tissue overgrowths, in 50 percent of the test larvae (Hose et al., 1982).

Inhibited reproduction of daphnids and the delayed emergence of larval midges by fluorene was reported by Finger et al. (1985). When sediment PAH levels are elevated, benthic organisms obtain a majority of their PAHs from sediments through their ability to mobilize PAHs from the sediment/pore water matrix. The elevated levels in the tissues of these organisms could provide a significant source of PAHs to predatory fish. However, fish do have the ability to efficiently metabolize and degrade PAHs.

7.4.2.8 1,1,2,2-Tetrachloroethane

1,1,2,2-Tetrachloroethane is a man-made, colorless, dense liquid that does not burn easily. It is volatile and has a penetrating, sweet odor similar to chloroform. Most 1,1,2,2-tetrachloroethane released into the environment eventually moves into the air or groundwater. If released on the land, it does not tend to attach to soil particles. When released to surface water, much of the chemical will evaporate while the remainder may undergo degradation through hydrolysis. Similar reactions can take place in soils and sediments. Breakdown of 1,1,2,2-tetrachloroethane in both the air and groundwater is slow. In groundwater, the major degradation processes involve anaerobic biodegradation and chemical hydrolysis. Bioaccumulation of tetrachloroethane in fish or other aquatic organisms is expected to be minimal (ATSDR, 1996).

Plants. No information was found regarding the potential toxicity of 1,1,2,2-tetrachloroethane to plants.

Terrestrial Invertebrates. No information was found regarding the potential toxicity of 1,1,2,2-tetrachloroethane to terrestrial invertebrates.

Mammals. The liver appears to be the target organ most likely to be affected from low-level 1,1,2,2-tetrachloroethane exposure. However, reliable studies which demonstrate the hepatotoxicity of 1,1,2,2-tetrachloroethane are few in number. 1,1,2,2-Tetrachloroethane is converted by the liver to reactive intermediates, and hepatic hyperplasia and necrosis are most often noted in animal exposures. Common to all volatile chlorohydrocarbons, 1,1,2,2-tetrachloroethane causes pronounced depression of the central nervous system and respiratory depression is a frequent cause of death after acute exposures to high doses (ATSDR, 1996).

In rats treated with 300 mg/kg/day by gavage for 3-4 days, body weights were depressed by 16 percent. No depression in body weight was observed at an exposure level of 150 mg/kg/day. The available data show that oral administration of 1,1,2,2-tetrachloroethane to rats for 16 weeks caused no histopathological changes in the spleen or lymph nodes (ATSDR, 1996).

There is limited information available on the effects of 1,1,2,2-tetrachloroethane on reproduction. One report indicated necrosis of the testes, disturbed spermatogenesis, and clumping of the sperm in rats after 120 days of oral exposure to 1,1,2,2-tetrachloroethane. However, in another study, no histological changes in the reproductive organs of rats or mice were observed after receiving high doses of the chemical for 78 weeks (ATSDR, 1996).

Birds. No information was found regarding the potential toxicity of 1,1,2,2-tetrachloroethane to birds.

Aquatic Life. The Tier II Secondary Acute and Secondary Chronic Values derived using the methodologies presented in the *Final Water Quality Guidance for the Great Lakes System* (EPA, 1995) are 2,100 and 610 µg/L, respectively. The lowest chronic toxicity values for fish, daphnids, and aquatic plants are reported as 2,400, 9,900, and 136,000 µg/L, respectively (Suter and Tsao, 1996). The test EC_{20} for fish can be used as a benchmark indicative of production within a population. It is the highest tested concentration causing less than 20 percent reduction in either the weight of young fish per initial female fish in a life-cycle or partial life-cycle test, or the weight of young per egg in an early life-stage test (Suter and Tsao, 1996). The value for 1,1,2,2-tetrachloroethane has been determined to be 1,400 µg/L (Suter and Tsao, 1996). The test EC_{20} for daphnids is < 420 µg/L (Suter and Tsao, 1996).

The EPA Region 5 ecological screening level (ESL) for 1,1,2,2-tetrachloroethane is 380 µg/L (EPA, 2003d).

7.4.2.9 Trichloroethene

Trichloroethene, or trichloroethylene, is not known to occur as a natural product (Howard, 1991). This chlorinated organic compound is primarily used as a degreaser of metals (Howard, 1991). Photooxidation is the primary mode by which trichloroethene is removed from the atmosphere (NLM, 1996). The compound is fairly stable in soil; however, it can leach to groundwater. The primary removal process in aquatic systems is evaporation. Biodegradation is expected to be significant only under anaerobic conditions (NLM, 1996).

Plants. Data on measured concentrations of trichloroethene in plants are limited to concentrations reported in grain-based foods, which ranged from 0.77 to 2.7 µg/kg (Heikes and Hopper, 1986). Phytotoxicity data for trichloroethene could not be found in the literature.

Terrestrial Invertebrates. No information was found regarding the potential toxicity of trichloroethene to terrestrial invertebrates.

Mammals. Concentrations of trichloroethene in wildlife are not reported in the literature. Trichloroethene is a hepatotoxin and central nervous system toxin (NLM, 1996). The oral LD_{50} value for mice exposed to trichloroethene is 2.402 g/kg (RTECS, 1996). The inhalation LC_{50} value for mice exposed to trichloroethene is 8,450 ppm for a four-hour exposure period (RTECS, 1996). The LD_{50} for dermal exposure of rabbits to trichloroethene is greater than 20 g/kg (RTECS, 1996). Fetotoxic and teratogenic effects have been reported in the offspring of pregnant rats exposed to trichloroethene (RTECS, 1996). Symptoms of chronic poisoning in dogs from inhalation of trichloroethene include lethargy, anorexia, nausea, vomiting, and weight loss (American Conference of Governmental Industrial Hygienists [ACGIH], 1971). There is a limited amount of evidence that suggests trichloroethene is carcinogenic in mammals (RTECS, 1996).

Mice exposed to trichloroethene through oral gavage for 6 weeks at dosage levels that ranged from 100 to 3,200 mg/kg/day were used to derive a chronic NOAEL value of 0.7 mg/kg/day (Buben and O'Flaherty, 1985). The critical endpoint in this study was hepatotoxicity.

Birds. No information was found regarding the potential toxicity of trichloroethene to birds.

Aquatic Life. Very little data exist on concentrations of trichloroethene in aquatic biota. Bioconcentration factors of between 17 and 39 have been reported for bluegill sunfish and rainbow trout exposed to trichloroethene (Burrows et al., 1989). LC_{50} values for fathead minnows (*Pimephales promelas*) and bluegill sunfish (*Lepomis macrochirus*) exposed to trichloroethene for 96 hours have been reported as 20 and 44.7 mg/L (Borthwick, 1977).

The Tier II Secondary Acute and Secondary Chronic Values derived using the methodologies presented in the *Final Water Quality Guidance for the Great Lakes System* (EPA, 1995) are 440 and 47 µg/L, respectively. The lowest chronic toxicity values for fish and daphnids are reported as 11,100 and 7,257 µg/L, respectively (Suter and Tsao, 1996). The test EC_{20} for fish can be used as a benchmark indicative of production within a population. It is the highest tested concentration causing less than 20 percent reduction in either the weight of young fish per initial female fish in a life-cycle or partial life-cycle test, or the weight of young per egg in an early life-stage test (Suter and Tsao, 1996). The value for trichloroethene has been determined to be 5,758 µg/L (Suter and Tsao, 1996).

7.4.3 Potential Receptors

Potential ecological receptors in the vicinity of the Training Area T-5 Sites fall into two general categories: terrestrial and semi-aquatic. Within these two general categories there are several major feeding guilds that could be expected to occur in the vicinity of the sites: herbivores, invertivores, omnivores, and carnivores. All of these feeding guilds have the potential to be directly exposed to site-related constituents in soil, surface water, and sediment via various activities (e.g., feeding, grooming, bathing). These feeding guilds may also be exposed to site-related chemicals via food web interactions.

Ingestion of soil-related constituents either through direct ingestion of soil or through food web interactions is expected to be the dominant exposure pathway for most organisms at the Training Area T-5 Sites. Dermal absorption of constituents from soil is a potential pathway for all feeding guilds at the Training Area T-5 Sites; however, birds and mammals are less susceptible to dermal exposures because their feathers or fur prevents skin from coming into direct contact with the soil (EPA, 1993). Dermal absorption of inorganic compounds from direct contact with soil is expected to be minimal due to the low dermal permeability of these constituents; however, dermal absorption of VOCs or SVOCs from soil is more likely. Because VOCs were only detected in very low concentrations in surface soil at the Training Area T-5 Sites, inhalation of VOCs is not a significant exposure pathway. Inhalation of constituents sorbed to soil particles and inhaled as dust is a potential pathway for all of the feeding guilds at the Training Area T-5 Sites; however, the fact that the entire study area is either paved or forested precludes the

generation of significant amounts of fugitive dust. Therefore, inhalation of particulates is expected to be minimal.

Exposure of ecological receptors to groundwater is not expected to occur at the Training Area T-5 Sites. Site groundwater elevations are greater than 20 feet bgs. As such, groundwater discharge to surface water bodies (e.g., the ephemeral drainage features) is unlikely. Without discharge to a surface water body, ecological exposures to groundwater are not complete.

Semi-aquatic species (i.e., amphibians) have a significant potential for exposure to constituents in surface water and sediment as they spend a majority of their lifetime in close proximity to water bodies. Semi-aquatic species could be exposed to constituents in surface water or sediment via ingestion and dermal contact. Although these species are expected to be in close contact with surface water when it is present in the ephemeral drainage features at the site, there are significant periods of the year when the ephemeral drainage features at the Training Area T-5 Sites are dry and exposure to surface water does not occur.

Exposure to aquatic species (e.g., fish) and the feeding guilds (i.e., piscivores) that rely on aquatic species for food are not expected to be significant at the Training Area T-5 Sites. The small ephemeral drainage features at the site do not provide suitable habitat to support most aquatic species, and by association, the species that rely on them for food.

7.4.3.1 Herbivorous Feeding Guild

The major route of exposure for herbivores is through ingestion of plants that may have accumulated contaminants from the soil. Since terrestrial herbivores by definition are grazers and browsers, they could be exposed to chemicals that have accumulated in the vegetative tissues of the plants at the site. Terrestrial herbivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while grazing, grooming, or other activities. Herbivores could be exposed to surface water through ingestion of water in the ephemeral drainage features during periods of high precipitation when water is present in these creeks. However, exposure to surface water in this manner is only expected to be sporadic.

Typical herbivorous species that could be expected to occur at the Training Area T-5 Sites and are commonly used as sentinel species in ecological risk assessment include eastern cottontail (*Sylvilagus floridanus*), eastern gray squirrel (*Sciurus carolinensis*), pine vole (*Pitymys pinetorum*), whitetail deer (*Odocoileus virginianus*), and wild turkey (*Meleagris gallopavo*).

Aquatic herbivores, such as muskrat (*Ondatra zibethica*) and mallard (*Anas platyrhynchos*), are not expected to occur at the Training Area T-5 Sites due to the ephemeral nature of the drainage features present.

7.4.3.2 Invertivorous Feeding Guild

Invertivores specialize in eating insects and other invertebrates. As such, they may be exposed to site-related chemicals that have accumulated in insects and other invertebrates. Invertivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while probing for insects, grooming, or other activities. Ingestion of soil while feeding is a potential exposure pathway for invertivores since much of their food (i.e., earthworms and other invertebrates) lives on or below the soil surface. Invertivores could be exposed to surface water through ingestion of water in the ephemeral drainage features during periods of high precipitation when water is present in these creeks. However, exposure to surface water in this manner is only expected to be sporadic.

Typical invertivorous species that could be expected to occur at the Training Area T-5 Sites and are commonly used as sentinel species in ecological risk assessment include American woodcock (*Philohela minor*), carolina wren (*Thryothorus ludovicianus*), shorttail shrew (*Blarina brevicauda* or *Blarina carolinensis*), and eastern mole (*Scalopus aquaticus*). Aquatic invertivores such as the wood duck (*Aix sponsa*) and blacknose dace (*Rhinichthys atratulus*) are not expected to occur at the Training Area T-5 Sites due to the ephemeral nature of the aquatic habitat present.

7.4.3.3 Omnivorous Feeding Guild

Omnivores consume both plant and animal material in their diet, depending upon availability. Therefore, they could be exposed to chemicals that have accumulated in the vegetative tissues of plants at the site and also chemicals that may have accumulated in smaller animal tissues that the omnivores prey upon. Omnivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while feeding, grooming, or other activities. Omnivores could be exposed to surface water through ingestion of water in the ephemeral drainage features during periods of high precipitation when water is present in these creeks. However, exposure to surface water in this manner is only expected to be sporadic.

Typical omnivorous species expected to occur at the Training Area T-5 Sites and commonly used as sentinel species in ecological risk assessment include red fox (*Vulpes vulpes*), white-footed mouse (*Peromyscus leucopus*), and American robin (*Turdus migratorius*). Aquatic omnivores such as raccoon (*Procyon lotor*) and creek chub (*Semotilus atromaculatus*) are not

expected to occur at the Training Area T-5 Sites due to the ephemeral nature of the aquatic habitat present.

7.4.3.4 Carnivorous Feeding Guild

Carnivores are meat-eating animals and, therefore, are potentially exposed to site-related chemicals through consumption of prey animals that may have accumulated contaminants in their tissues. Carnivores are quite often top predators in a local food web and are often subject to exposure to contaminants that have bioaccumulated in lower trophic-level organisms or biomagnified through the food web. Food web exposures for carnivores are based on the consumption of prey animals that have accumulated COPECs from various means. Smaller, herbivores, omnivores, invertivores, and other carnivores may consume soil, plant, and animal material as food and accumulate COPECs in their tissues. Subsequent ingestion of these prey animals by carnivorous animals would expose them to COPECs. Food web exposures to metals, VOCs, and SVOCs in surface soil are expected to be minimal at the Training Area T-5 Sites because these compounds are not accumulated in animal tissues to any great extent (Shugart, 1991; U.S. Army Environmental Hygiene Agency, 1994).

Carnivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while feeding, grooming, or other activities. Carnivores could be exposed to surface water through ingestion of water in the ephemeral drainage features during periods of high precipitation when water is present in these creeks. However, exposure to surface water in this manner is only expected to be sporadic.

Typical carnivorous species expected to occur at the Training Area T-5 Sites and commonly used as sentinel species in ecological risk assessment include red-tailed hawk (*Buteo jamaicensis*), black vulture (*Coragyps atratus*), and bobcat (*Lynx rufus*).

7.4.3.5 Threatened and Endangered Species

Four species listed as threatened or endangered by the USFWS have been recorded at FTMC. These threatened and endangered species are as follows:

- Gray Bat (*Myotis grisescens*)
- Blue Shiner (*Cyprinella caerules*)
- Mohr's Barbara Buttons (*Marshallia mohrii*)
- Tennessee Yellow-Eyed Grass (*Xyris tennesseensis*).

An additional endangered species, the red-cockaded woodpecker (*Picoides borealis*), historically has inhabited the installation. However, the last remaining active cluster of red-cockaded

woodpeckers at FTMC was recorded in 1968. Subsequent surveys in 1972, 1982, and 1985 failed to find this species at FTMC. Thus, it can be concluded that red-cockaded woodpeckers no longer exist at FTMC.

The only Federally listed species that has the potential to occur in the vicinity of the Training Area T-5 Sites is the gray bat (Garland, 1996). The ephemeral drainage features in the vicinity of these sites have been designated as providing "low quality" or "moderate quality" foraging habitat for the gray bat (Garland, 1996). The other Federally listed species occur at Pelham Range or within the Choccolocco Creek Corridor.

Gray bat summer foraging habitat is found primarily over open water of rivers and reservoirs. They apparently do not forage over sections of rivers or reservoirs that have lost their normal woody vegetation along the banks (USFWS, 1982). Gray bats usually follow wooded corridors from their summer caves to the open water areas used as foraging sites. Forested areas surrounding and between caves, as well as over feeding habitats, are clearly advantageous to gray bat survival as the cover provides increased protection from predators such as screech owls. In addition, surveys have demonstrated that reservoirs and rivers that have been cleared of their adjacent forest canopy are avoided as foraging areas by gray bats (USFWS, 1982).

Most foraging occurs within 5 meters of the water's surface, usually near a shoreline or stream bank. Mist net surveys were conducted on and adjacent to FTMC in 1995. Gray bats were captured along both Choccolocco Creek (east of FTMC Main Post) and Cane Creek on Pelham Range (west of FTMC Main Post) during these mist net surveys (Garland, 1996). These preliminary data suggest that these major stream corridors at FTMC may provide at least a minimum foraging habitat for gray bats. However, gray bat surveys have not been conducted on the small ephemeral drainage features in the vicinity of the Training Area T-5 Sites. The ephemeral nature of the drainage features is expected to limit the potential for gray bats to use these drainage features for foraging.

7.4.4 Complete Exposure Pathways

For exposure to occur, a complete exposure pathway must exist between the contaminant and the receptor. A complete exposure pathway requires the following four components:

- A source mechanism for contaminant release
- A transport mechanism
- A point of environmental contact
- A route of uptake at the exposure point (EPA, 1989).

If any of these four components is absent, then a pathway is generally considered incomplete. Potentially complete and incomplete exposure pathways at the Training Area T-5 Sites are depicted in the SCM shown on Figure 7-1.

Ecological receptors may be exposed to constituents in soils via direct and/or secondary exposure pathways. Direct exposure pathways include soil ingestion, dermal absorption, and inhalation of volatile constituents and constituents adsorbed to fugitive dust. Significant exposure via dermal contact is limited to organic constituents that are lipophilic and can penetrate epidermal barriers. Mammals are less susceptible to exposure via dermal contact with soils because their fur prevents skin from coming into direct contact with soil. However, soil ingestion may occur while grooming, preening, burrowing, or consuming plants, insects, or invertebrates resident in soil.

Exposures to site-related constituents in surface water and sediment are expected to be minimal due to the ephemeral nature of the drainage features present at the site and the fact that none of the constituents detected in surface water were present at elevated concentrations relative to ESVs and naturally occurring levels.

Exposure via inhalation of fugitive dust is limited to contaminants present in surface soils at areas that are devoid of vegetation or other cover material. The amount of vegetative cover, the inherent moisture content of the soil, and the frequency of soil disturbance play important roles in the amount of fugitive dust generated at a particular site. Because the Training Area T-5 Sites are either covered with asphalt paving or vegetative cover (maintained lawn or forest), the amount of fugitive dust generated at the sites is expected to be minimal.

Secondary exposure pathways involve constituents that are transferred through different trophic levels of the food chain and may be bioaccumulated and/or bioconcentrated. This may include constituents bioaccumulated from soil into plant tissues or into terrestrial species ingesting soils. These plants or animals may, in turn, be consumed by animals at higher trophic levels.

In general, the metals and SVOCs detected in surface soil at the Training Area T-5 Sites may bioaccumulate in lower trophic level organisms (i.e., terrestrial invertebrates may bioaccumulate inorganic compounds detected in soil); however, they will not bioconcentrate through the food chain. The VOCs detected in soil and groundwater are unlikely to bioaccumulate or bioconcentrate. Therefore, food chain exposures for the constituents detected at the Training Area T-5 Sites are most likely insignificant.

A summary of the feeding guilds and potentially complete exposure pathways at the Training Area T-5 Sites is presented in Table 7-1.

7.5 Screening-Level Risk Estimation

A screening-level estimation of potential risk can be accomplished by comparing the exposure point concentration of each detected constituent in each environmental medium to a corresponding screening-level ecological toxicity value. In order to conduct the SLERA, the following steps must be followed:

- Determine appropriate screening assessment endpoints
- Determine the ecological toxicity values that are protective of the selected assessment endpoints
- Determine the exposure point concentrations of constituents detected at the site
- Calculate screening-level hazard quotients.

These steps are summarized below.

7.5.1 Ecological Screening Assessment Endpoints

Most ecological risk assessments focus on population measures as endpoints, since population responses are better defined and more predictable than are community or ecosystem responses. For screening-level assessments such as this SLERA, assessment endpoints are any adverse effects on ecological receptors, where receptors are plant and animal populations and communities, habitats, and sensitive environments.

Adverse effects on populations can be inferred from measures related to impaired reproduction, growth, and survival. Adverse effects on communities can be inferred from changes in community structure or function. Adverse effects on habitats can be inferred from changes in composition and characteristics that reduce the ability of the habitat to support plant and animal populations and communities.

Due to the nature of the SLERA process, most of the screening assessment endpoints are generic in nature (i.e., protection of sediment benthic communities from adverse changes in structure or function).

The assessment endpoints for this SLERA were identified for surface soil, surface water, and sediment and are summarized below. It is important to note that although it is unlikely for

groundwater to discharge to the ephemeral drainage features on-site due to the depth to groundwater at the site, constituents detected in groundwater were nonetheless assessed by comparing groundwater data to surface water ESVs.

- ***Soil***
  - Protection of the terrestrial invertebrate community from adverse changes in structure and function
  - Protection of the terrestrial plant community from adverse changes in structure and function.
- ***Surface Water***
  - Protection of the aquatic community from adverse changes in structure and function
- ***Sediment***
  - Protection of the benthic community from adverse changes in structure and function.

7.5.2 Ecological Screening Values

The ESVs used in this assessment represent the most conservative values available from various literature sources and have been selected to be protective of the assessment endpoints described above. These ESVs have been developed specifically for FTMC in conjunction with EPA Region 4 and are presented in the *Final Human Health and Ecological Screening Values and PAH Background Summary Report* (IT, 2000c). The ESVs used in this assessment are based on NOAELs, when available. If a NOAEL-based ESV was not available for a certain COPEC, then the most health-protective value available from the scientific literature was used in this assessment.

For each environmental medium sampled at the Training Area T-5 Sites (surface soil, surface water, sediment, and groundwater), a hierarchy has been developed which presents an orderly method for selection of ESVs. The hierarchy for selecting ESVs for surface soil is as follows:

- EPA Region 4 constituent-specific ESVs
- EPA Region 4 ESVs for general class of constituents
- EPA Region 5 ecological data quality levels (EDQL)
- EPA Region 3 Biological Technical Advisory Group (BTAG) values
- ESVs from Talmage et al. (1999).

The hierarchy for selecting ESVs for surface water, which were also used to assess groundwater data at the Training Area T-5 Sites, is as follows:

- EPA Region 4 constituent-specific ESVs
- NOAA Screening Quick Reference Tables (SQRT), chronic freshwater ambient water quality criteria
- EPA Region 5 EDQLs
- Office of Solid Waste and Emergency Response (OSWER) Ecotox Threshold values (EPA, 1996b)
- EPA Region 3 BTAG values
- Lowest chronic value from Suter and Tsao (1996)
- ESVs from Talmage et al. (1999).

The hierarchy for selecting ESVs for sediment is as follows:

- EPA Region 4 constituent-specific ESVs
- NOAA SQRTs, chronic freshwater ambient water quality criteria
- EPA Region 5 EDQLs
- OSWER ecotox threshold values
- EPA Region 3 BTAG values
- Lowest effect levels from Ontario Ministry of the Environment presented in Jones et al. (1997)
- ESVs from Talmage, et al. (1999)
- Sediment quality adverse effect threshold (AET) values from the Puget Sound Estuary Program.

7.5.3 Determination of Exposure Point Concentrations

Exposure point concentrations represent the chemical concentrations in environmental media that a receptor may contact. Since the exposure point concentration is a value that represents the most likely concentration to which receptors could be exposed, a value that reflects the central tendency of the data set is most appropriate to use for free-ranging animals that would be expected to use the site indiscriminately. Smaller, more sessile organisms with smaller home ranges may be exposed to only a portion of a site. Additionally, habitat preferences or

preferential avoidance behavior may result in exposure to only portions of a given site. Therefore, a subset of the data would be most appropriate to estimate an exposure point concentration for these species. The most conservative approach is the use of the maximum detected constituent concentrations as exposure point concentrations. At the screening-level stage, the data sets are generally not robust enough for statistical analysis and the level of conservatism in the exposure estimates is high to account for uncertainties. Therefore, in the screening-level stage, the maximum detected constituent concentration in each environmental medium is used as the exposure point concentration. The use of the maximum detected constituent concentration as the exposure point concentration ensures that the exposures will not be underestimated and, therefore, constituents will not be inadvertently eliminated from further assessment.

The statistical summaries (including the exposure point concentrations) for surface soil, surface water, sediment, and groundwater at the Training Area T-5 Sites are presented in Tables 7-2 through 7-10.

7.5.4 Screening-Level Hazard Quotients

In order to estimate whether constituents detected in environmental media at the site have the potential to pose adverse ecological risks, screening-level hazard quotients were developed. The screening-level hazard quotients were developed via a three-step process as follows:

- Comparison to ESVs
- Identification of essential macronutrients
- Comparison to naturally occurring background concentrations.

Constituents that were detected in environmental media at the Training Area T-5 Sites were evaluated against the ESVs by calculating a screening-level hazard quotient (HQ_{screen}) for each constituent in each environmental medium. An HQ_{screen} was calculated by dividing the maximum detected constituent concentration in each environmental medium by its corresponding ESV as follows:

$$HQ_{screen} = \frac{MDCC}{ESV}$$

where:

HQ_{screen} = screening-level hazard quotient;
$MDCC$ = maximum detected constituent concentration; and
ESV = ecological screening value.

A calculated HQ_{screen} value of one indicates that the MDCC is equal to the chemical's conservative ESV and is interpreted in this assessment as a constituent that does not pose the potential for adverse ecological risk. An HQ_{screen} value less than one indicates that the MDCC is less than the conservative ESV and that the chemical is not likely to pose adverse ecological hazards to most receptors. Conversely, an HQ_{screen} value greater than one indicates that the MDCC is greater than the ESV and that the chemical might pose adverse ecological hazards to one or more receptors and requires further assessment.

In order to better understand the potential risks posed by chemical constituents at the Training Area T-5 Sites, a mean hazard quotient was also calculated by comparing the arithmetic mean constituent concentration in surface soil, surface water, sediment, and groundwater to the corresponding ESV. The calculated screening-level hazard quotients for surface soil, surface water, sediment, and groundwater at the Training Area T-5 Sites are presented in Tables 7-2 through 7-10.

EPA recognizes several constituents in abiotic media that are necessary to maintain normal function in many organisms. These essential macronutrients are iron, magnesium, calcium, potassium, and sodium (EPA, 1989). Most organisms have mechanisms designed to regulate nutrient fluxes within their systems; therefore, these nutrients are generally only toxic at very high concentrations. Although iron is an essential nutrient and is regulated within many organisms, it may become increasingly bioavailable at lower soil pH values, thus increasing its potential to elicit adverse affects. Therefore, iron was not evaluated as an essential nutrient in this SLERA. Essential macronutrients were only considered COPECs if they were present in site samples at concentrations ten times the naturally occurring background concentration.

The comparison of detected constituent concentrations with naturally occurring constituent concentrations was conducted via a three-tier process outlined in a technical memorandum dated June 24, 2003 (Shaw, 2003). The first tier of the background comparison process was a comparison of the maximum detected constituent concentration to the background threshold value (BTV). A study of the natural geochemical composition associated with FTMC (SAIC, 1998) determined the mean concentrations of 24 metals in surface soil, surface water, sediment, and groundwater samples collected from presumably un-impacted areas. Per agreement with EPA Region 4, the background threshold value (BTV) for each metal was calculated as two times the mean background concentration for that metal. The BTV for each metal was used to represent the upper boundary of the range of natural background concentrations expected at FTMC, and was used as the basis for evaluating metal concentrations measured in site samples.

Site sample metal concentrations less than or equal to the corresponding BTV represent the natural geochemical composition of media at FTMC, and not contamination associated with site activity. Site sample metal concentrations greater than the corresponding BTV require further background assessment.

If maximum constituent concentrations were greater than the BTV, then the second tier of the background comparison was employed. Tier two of the background comparison consists of statistical comparisons of the site data to background data using the Slippage Test and the Wilcoxon Rank Sum (WRS) Test. If the site data failed either the Slippage Test or the WRS Test, then the site data were subjected to a geochemical evaluation to determine whether concentrations of inorganic compounds are naturally occurring or are elevated due to contamination (Tier 3). The three-tier background comparison process is described in detail in Appendix H of this report.

Thus, the first step in determining screening-level hazard quotients was a comparison of maximum detected constituent concentrations to appropriate ESVs. Constituents with HQ_{screen} values less than one were considered to pose insignificant ecological risk and were eliminated from further consideration. Constituents with HQ_{screen} values greater than one were eliminated from further consideration if they were macronutrients and their detected concentrations were less than ten-times naturally occurring levels. Those constituents that had HQ_{screen} values greater one and were not considered macronutrients were then compared to background using the three-tier background screening process. If constituent concentrations were determined to be less than their naturally occurring background concentrations, then a risk management decision could result in eliminating these constituents from further assessment.

7.6 Identification of Constituents of Potential Ecological Concern

A constituent was identified as a COPEC if the following conditions were met:

- The maximum detected constituent concentration exceeded the ESV
- The maximum detected constituent concentration was 10 times the BTV if the constituent was identified as a macronutrient
- Constituent concentrations were determined to be greater than naturally occurring levels based on the three-tier background screening process.

If a constituent in a given environmental medium did not meet these conditions, then it was not considered a COPEC and was not considered for further assessment. If a constituent met these

conditions, then it was considered a COPEC. Identification of a constituent as a COPEC indicates that further assessment of that particular constituent in a given environmental medium may be appropriate. It does not imply that a particular constituent poses risk to ecological receptors.

The COPECs that have been initially identified for surface soil, surface water, sediment and groundwater at the Training Area T-5 Sites are presented in Tables 7-2 through 7-10. None of the constituents detected in surface water were identified as COPECs using the methodologies described above. Furthermore, based on the depth to groundwater at the sites (greater than 20 feet), potential groundwater exposures were considered incomplete and COPECs were not identified in groundwater.

In order to focus future ecological assessment efforts (if necessary) on the constituents that are the most prevalent at the Training Area T-5 Sites and that have the greatest potential to pose ecological risk, additional lines of evidence were assessed. Additional lines of evidence are sometimes useful in determining whether a certain constituent is in fact site-related and a COPEC. Some of the additional lines of evidence used in the process of identifying COPECs include: 1) frequency of detection, 2) magnitude of the HQ_{screen} value, 3) spatial distribution, 4) comparison to alternative ESVs; and 5) association of a chemical with known Army activities. These additional lines-of-evidence were used to further define the COPECs at the Training Area T-5 Sites as discussed below.

7.6.1 Surface Soil at the Former Detection and Identification Area, Parcel 180(7)

The following constituents exceeded their respective ESVs, and naturally occurring levels in surface soil, and are not essential macronutrients:

- Cadmium
- Copper
- Zinc
- Anthracene
- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene.

The five PAH compounds that were initially identified as COPECs were detected at elevated concentrations in two surface soil samples (CWM-180-MW06 and CWM-180-DEP01). Cadmium was detected at an elevated concentration in one surface soil sample (CWM-180-DEP01) and copper was also detected in one surface soil sample (CWM-180-MW06) at an

elevated concentration. Since all of these constituents were detected at elevated concentrations in one or both of these two sample locations, it is reasonable to assume that a certain level of contamination is present in the surface soil at these two locations. Zinc was detected at elevated concentrations in three surface soil samples with a HQ_{screen} value of 2.2. All eight of these constituents are considered COPECs in surface soil at Parcel 180(7).

7.6.2 Surface Soil at Training Area T-5, Parcel 182(7)

Copper was detected at elevated concentrations in two of 17 surface soil samples and zinc was detected at elevated concentrations in five of 17 surface soil samples. The HQ_{screen} values for copper and zinc were calculated to be 5 and 23, respectively. Based on the frequency of detection and the HQ_{screen} values, copper and zinc were identified as COPECs in surface soil at Parcel 182(7).

7.6.3 Surface Soil at the Blacktop Training Area, Parcel 511(7) and the Fenced Yard in the Blacktop Area, Parcel 512(7)

Cadmium, copper, and zinc were detected in surface soil samples at concentrations that exceeded ESVs and naturally occurring levels. Elevated concentrations of cadmium and zinc were detected in two surface soil samples (CWM-511-DEP01 and CWM-511-DEP02), and elevated concentrations of copper were detected in one surface soil sample (CWM-511-DEP01). The HQ_{screen} values for cadmium, copper, and zinc were calculated to be 1.7, 2.98, and 2.5, respectively. Since these three constituents were detected at elevated concentrations in one or both of these two sample locations, it is reasonable to assume that a certain level of contamination is present in the surface soil at these two locations. Therefore, cadmium, copper, and zinc are considered COPECs in surface soil at Parcels 511(7) and 512(7).

7.6.4 Surface Soil at the Dog Training Area, Parcel 513(7)

The following constituents exceeded ESVs and naturally occurring levels in surface soil at Parcel 513(7):

- Cadmium
- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene.

Cadmium was detected at an elevated concentration in one of three surface soil samples (CWM-513-DEP01). The HQ_{screen} value was calculated to be 1.1. EPA (2003c) recommends ecological soil screening values (Eco-SSL) for cadmium ranging from 0.38 mg/kg (based on toxicity to

mammalian receptors) to 140 mg/kg (based on soil invertebrate toxicity). Because cadmium was only detected in one surface soil sample, the HQ_{screen} value marginally exceeds one, and the detected concentration is less than the EPA-recommended Eco-SSLs for plants and soil invertebrates, cadmium was not identified as a COPEC in surface soil at Parcel 513(7).

The four PAH compounds that were detected at elevated concentrations were all present in one surface soil sample (CWM-513-MW01) out of three samples. The HQ_{screen} values for benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene were calculated to be 1.1, 2.6, 1.2, and 1.9, respectively. Because these PAH compounds were only detected in one sample and the HQ_{screen} values only marginally exceeded 1.0, these PAH compounds were not identified as COPECs in surface soil at Parcel 513(7).

7.6.5 Surface Soil at the Dog Kennel Area, Parcel 516(7)

Barium (at CWM-516-MW02) and trichloroethene (at CWM-182-DEP07 within Parcel 516[7]) were detected in one surface soil sample each out of three samples at concentrations that exceeded ESVs and naturally occurring levels. The HQ_{screen} values for barium and trichloroethene were calculated to be 2.3 and 2.1, respectively.

The EPA (2003c) recommends an Eco-SSL for barium ranging from 330 mg/kg (based on soil invertebrate toxicity) to 1,000 mg/kg (based on toxicity to mammalian receptors). The maximum detected concentration of barium (374 mg/kg) slightly exceeds the soil invertebrate-based screening level but is below the mammalian-based screening level. Based on the fact that barium was only detected in one surface soil sample at an elevated concentration and the maximum detected concentration of barium is less than the Eco-SSL for mammalian receptors, barium was not considered a COPEC in surface soil at Parcel 516(7).

Because trichloroethene was only detected in one surface soil sample and the detected concentration only marginally exceeded the conservative ESV, trichloroethene was not considered a COPEC in surface soil at Parcel 516(7).

7.6.6 Surface Soil at the Old Burn Pit, Parcel 514(7)

The following constituents exceeded ESVs and background levels (for PAHs) in surface soil at Parcel 514(7):

- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene

- Pyrene
- 1,1,2,2-Tetrachloroethane
- Trichloroethene.

The four PAH compounds detected at elevated concentrations were present in two depositional soil samples (CWM-514-DEP01 and CWM-514-DEP02) collected from the drainage ditch immediately north of Parcel 514(7) and in the surface soil sample (CWM-514-MW07) collected just north of the same drainage ditch. Motor Pool Area 3100 is located just north of the drainage ditch and is almost entirely paved with asphalt, which could be the source of these PAH compounds. The HQ_{screen} values for benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene were calculated to be 3.7, 8.6, 3.7, and 8.3, respectively. Because these PAH compounds were found in the same two or three samples at elevated concentrations, there appears to be a component of PAH contamination present in and adjacent to the drainage ditch located immediately north of Parcel 514(7) (and south of Motor Pool 3100). Therefore, benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene were identified as COPECs in surface soil at Parcel 514(7).

The VOCs 1,1,2,2-tetrachloroethane and trichloroethene were detected in one of nine samples (CWM-514-MW09). The HQ_{screen} values for 1,1,2,2-tetrachloroethane and trichloroethene were calculated to be 1.1 and 51, respectively. Sample CWM-514-MW09 is located on the opposite site of the drainage ditch from Parcel 514(7) and is adjacent to Motor Pool Area 3100. It is likely that the two volatile organic compounds detected in this sample were associated with activities at Motor Pool Area 3100 rather than Parcel 514(7). The magnitude of the HQ_{screen} value for trichloroethene indicates there may be a component of contamination in an isolated area of surface soil at the southern corner of Motor Pool Area 3100. Since 1,1,2,2-tetrachloroethane and trichloroethene were co-located and are being investigated in association with the Old Burn Pit, both of these compounds were identified as COPECs in surface soil at Parcel 514(7).

7.6.7 Surface Water

None of the constituents detected in surface water at the Training Area T-5 Sites exceeded their respective ESVs and naturally occurring levels. Therefore, no COPECs were identified in surface water.

7.6.8 Sediment

Chromium was detected in one of five sediment samples (CWM-182-SW/SD02) at a concentration that exceeded the ESV and naturally occurring levels. The HQ_{screen} value for

chromium was calculated to be 1.2. If the EPA (1996b) Ecotox Threshold value for chromium (81 mg/kg) is used as an alternative ESV, then none of the detected sediment concentrations of chromium exceed the alternative ESV. Based on the infrequency of detection, the low magnitude of the HQ_{screen} value, and the fact that all of the detected values are less than the alternative ESV, chromium was not identified as a COPEC in sediment.

7.6.9 Groundwater

Bis(2-ethylhexyl)phthalate and 1,1,2,2-tetrachloroethane were detected in groundwater at concentrations exceeding their surface water ESVs. However, exposure pathways involving groundwater at the Training Area T-5 Sites are not complete as discussed previously. Groundwater discharge to surface water bodies (e.g., the ephemeral drainage features) is unlikely. Without discharge to the surface, ecological exposures to groundwater are not complete. Therefore, no COPECs were identified in groundwater at the Training Area T-5 Sites.

7.7 Uncertainty Analysis

Uncertainties are inherent in any risk assessment, and even more so in a SLERA due to the nature of the assessment process and the assumptions used in the process. A number of the major areas of uncertainty in this assessment are presented below.

An area of uncertainty that is inherent in a SLERA is the use of the maximum detected constituent concentration as the exposure point concentration for all receptors in a given medium. Most receptors have a home range large enough that precludes individuals from being exposed to the maximum constituent concentration for their entire lifetimes. Therefore, the actual exposure point concentration of a given constituent for most receptor species would be less than the maximum detected concentration. The use of the maximum detected constituent concentrations as the exposure point concentrations for all receptors results in an overestimation of exposure for many receptors.

Additionally, there is no consideration given to the bioavailabilty of COPECs to different organisms. In this SLERA it is assumed that all constituents are 100 percent bioavailable to all receptor organisms. It is known that many constituents (particularly inorganic compounds) have significantly lower bioavailabilities (i.e., 1 to 10 percent for some inorganics in soil) than the 100 percent that was assumed in this assessment. This assumption has the potential to greatly overestimate exposures to certain COPECs.

Some COPECs (e.g., p-cymene) do not have ESVs. The lack of toxicity data for certain COPECs makes it impossible to determine the potential for ecological risk posed by those constituents. Risks may be under- or over-estimated due to this uncertainty.

The ESVs used in this assessment are the most conservative values from the scientific literature and many are based on the most sensitive endpoint (NOAEL values) for the most sensitive species tested. A less sensitive endpoint that is still protective of the ecological populations or communities of interest may be the LOAEL or some other endpoint. The use of NOAEL-based ESVs may overestimate potential for risks from certain COPECs. Additionally, certain ESVs may not be applicable to conditions at the Training Area T-5 Sites. For instance, the soil ESVs do not take into account site-specific conditions and thus introduce a potentially significant level of uncertainty into the assessment.

It is important to note that the soil and surface water ESVs for chromium are based on toxicity studies using Cr^{+6}, which is more mobile and generally more toxic than Cr^{+3}. Measured chromium concentrations in surface soil and surface water are total chromium values. It is unknown what portion, if any, of the measured chromium in surface soil and surface water at the Training Area T-5 Sites is in the hexavalent form. Because it is likely that only a portion or none of the measured chromium in surface soil and surface water is in the hexavalent form, the ESV and subsequent HQ_{screen} values are highly conservative.

Another area of uncertainty is the inherent limitations of the hazard quotient (HQ) method for estimating risks. HQs are not explicit expressions of risk (i.e., they are not probabilities of toxicological effects occurring in an ecological population). Additionally, because HQs are ratios, after unity has been exceeded, the magnitude of the HQ has little bearing on the potential severity of adverse effects that may be anticipated. For example, an HQ of five does not indicate the potential ecological risk is greater than a HQ of three. Hazard quotients are not population measures, but rather measures based on sensitive individuals from a test population.

Another area of uncertainty is the lack of consideration of synergisms and/or antagonisms between COPECs. Although it is widely accepted that synergisms and antagonisms occur between certain constituents under certain conditions, the SLERA process does not provide methods for assessing these potential synergisms/antagonisms.

One significant source of uncertainty that may impart a non-conservative bias on the SLERA results is the exclusion of metals determined to be present at concentrations comparable to naturally occurring background concentrations from consideration as COPECs. The chemicals

excluded from selection as COPECs based solely on their comparison to background concentrations are discussed below.

As discussed previously, the exclusion of chemicals from the list of COPECs based on comparison to naturally occurring levels is performed via a three-tiered protocol (Shaw, 2003). Tier 1 – comparison of the maximum detected constituent concentration to the BTV – is generally considered to be sufficiently conservative so that the uncertainty associated with chemicals eliminated in this tier of the protocol is minimal. Therefore, only chemicals excluded as COPECs via Tiers 2 or 3 of the background screening protocol are discussed herein.

Aluminum was eliminated as a COPEC at all of the Training Area T-5 Sites based on geochemical comparison to naturally occurring levels of aluminum in soil. Per EPA (2000) guidance, aluminum toxicity is associated with soluble aluminum only. Numeric screening values for aluminum are considered inappropriate due to the uncertainty in the solubility of aluminum in any given soil type under different environmental conditions. Alternatively, potential ecological risks associated with exposure to aluminum are associated with soil pH. Aluminum is identified as a COPEC only if the soil pH is less than 5.5 (EPA, 2000). Since the pH of soils at the Training Area T-5 Sites is greater than 5.5, the exclusion of aluminum as a surface soil COPEC introduced minimal uncertainty into this SLERA.

7.7.1 Surface Soil at the Former Detection and Identification Area, Parcel 180(7)

Aluminum, arsenic, beryllium, chromium, cobalt, iron, selenium, and vanadium were eliminated from consideration as COPECs in surface soil at the Former Detection and Identification Area solely on statistical and geochemical comparisons to naturally occurring levels in soil.

Arsenic was detected in four of seven surface soil samples at concentrations that exceeded the ESV. The HQ_{screen} value for arsenic was calculated to be 3.8. EPA (2004b) recommends an Eco-SSL for arsenic ranging from 18 mg/kg (based on plant toxicity) to 46 mg/kg (based on toxicity to mammalian receptors). One surface soil sample exhibits an arsenic concentration greater than these alternative ESVs. Based on the infrequency of detection at concentrations greater than the EPA-recommended Eco-SSL, the exclusion of arsenic as a surface soil COPEC introduced minimal uncertainty into this SLERA.

Beryllium was detected in one surface soil sample at a concentration that exceeded the ESV. The HQ_{screen} value for beryllium was calculated to be 1.2. The EPA (2004b) recommends an Eco-SSL for beryllium ranging from 34 mg/kg (based on toxicity to mammalian receptors) to 40 mg/kg (based on soil invertebrate toxicity). All of the detected concentrations of beryllium were

less than the EPA-recommended Eco-SSLs. Based on the infrequency of detection at concentrations greater than the ESV, the low magnitude of the HQ_{screen} value, and the fact that all of the detected values were less than the EPA-recommended Eco-SSLs, elimination of beryllium as a COPEC in surface soil introduced minimal uncertainty to the results of this SLERA.

All seven surface soil samples at Parcel 180(7) exhibited chromium concentrations that exceeded the ESV. The HQ_{screen} value for chromium was calculated to be 159. The EPA (2004b) recommends an Eco-SSL for chromium (III) ranging from 61 mg/kg (based on toxicity to avian receptors) to 160 mg/kg (based on toxicity to mammalian receptors). Only one surface soil exhibited a chromium concentration that exceeded these EPA-recommended Eco-SSLs. Since only one surface soil sample marginally exceeded the EPA-recommended Eco-SSL for chromium (III), the elimination of chromium as a COPEC in surface soil introduced a minimal level of uncertainty to the results of the SLERA.

Cobalt was detected in one of seven surface soil samples at a concentration that exceeded the ESV. The calculated HQ_{screen} value for cobalt was 1.5. Due to the low frequency of detection at elevated concentrations and the low magnitude of the HQ_{screen} value, the elimination of cobalt as a surface soil COPEC introduced a minimal level of uncertainty to the results of the SLERA.

Iron was detected in three of seven surface soil samples at concentrations greater than the BTV. Iron is an essential macronutrient, thus, most organisms have mechanisms to regulate the levels of iron within their systems. As such, iron is only toxic at very high concentrations. Since iron was infrequently detected at elevated concentrations relative to background and it also is a macronutrient that is easily regulated, the level of uncertainty introduced into the results of the SLERA by eliminating iron from the list of COPECs is expected to be minimal.

Selenium was detected in four surface soil samples at concentrations that exceeded the ESV and vanadium was detected in seven surface soil samples at concentrations that exceeded the ESV. The HQ_{screen} values for selenium and vanadium were calculated to be 4.2 and 47.6, respectively. Elimination of these two constituents from consideration as COPECs in surface soil introduced an unknown level of uncertainty to the results of the SLERA.

7.7.2 Surface Soil at the Training Area T-5, Parcel 182(7)

Aluminum, barium, beryllium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium were eliminated from consideration as COPECs in surface soil at the Training Area T-5 Sites based solely on statistical and geochemical comparisons to naturally occurring levels.

Cobalt, lead, mercury, nickel, and selenium were detected in one surface soil sample each at concentrations that exceeded their respective ESVs. The HQ_{screen} values for these constituents were calculated to be 1.01, 1.3, 1.1, 1.02, and 1.1, respectively. Based on the low frequency of detection and the low magnitude of the HQ_{screen} values, the elimination of these metals as COPECs imparted minimal uncertainty to the results of this SLERA.

Barium was detected in two of 17 surface soil samples at concentrations that exceeded the ESV. The HQ_{screen} value for barium was calculated to be 1.2. The EPA (2004b) recommends an Eco-SSL for barium ranging from 330 mg/kg (based on soil invertebrate toxicity) to 2,000 mg/kg (based on toxicity to mammalian receptors). All of the surface soil samples exhibited barium concentrations that were less than these EPA-recommended Eco-SSLs. Since barium was infrequently detected at elevated concentrations, the HQ_{screen} value was relatively low, and all of the detected concentrations were less than the EPA-recommended Eco-SSL, the elimination of barium as a COPEC in surface soil introduced a minimal level of uncertainty to the SLERA.

Beryllium was detected in five of 16 surface soil samples at concentrations that exceeded the ESV. The HQ_{screen} value for beryllium was calculated to be 2.2. The EPA (2004b) recommends an Eco-SSL for beryllium ranging from 34 mg/kg (based on toxicity to mammalian receptors) to 40 mg/kg (based on soil invertebrate toxicity). All of the surface soil samples exhibited beryllium concentrations that were less than these EPA-recommended Eco-SSLs. Because beryllium was infrequently detected at an elevated concentration, the HQ_{screen} value was relatively low, and all of the detected concentrations were less than the EPA-recommended Eco-SSL, the elimination of beryllium as a COPEC in surface soil introduced a minimal level of uncertainty to the results of the SLERA.

Chromium was detected in all 17 surface soil samples at concentrations that exceeded the ESV. The HQ_{screen} value for chromium was calculated to be 102.5. It is important to note that the soil ESV for chromium is based on toxicity studies using Cr^{+6}, which is more mobile and generally more toxic than Cr^{+3}. Measured chromium concentrations in surface soil are total chromium values. It is unknown what portion, if any, of the measured chromium in surface soil at Parcel 182(7) is in the hexavalent form. Because it is likely that only a portion or none of the measured chromium in surface soil is in the hexavalent form, the ESV and subsequent HQ_{screen} are highly conservative. EPA (2004b) recommends an Eco-SSL for chromium (trivalent and hexavalent) ranging from 61 mg/kg (based on Cr^{+3} toxicity to avian receptors) to 380 mg/kg (based on Cr^{+6} toxicity to mammalian receptors). All of the surface soil samples exhibited chromium concentrations that were less than these EPA-recommended Eco-SSLs. Because all of the detected concentrations of chromium were less than the EPA-recommended Eco-SSLs, the

elimination of chromium as a COPEC in surface soil introduced a minimal level of uncertainty to the results of the SLERA.

Manganese was detected in three of 17 surface soil samples at concentrations that exceeded the BTV. The HQ_{screen} value for manganese was calculated to be 50.4. The level of uncertainty introduced to the SLERA through the elimination of manganese as a COPEC in surface soil remains unknown.

7.7.3 Surface Soil at the Blacktop Training Area and the Fenced Yard in the Blacktop Area, Parcels 511(7) and 512(7)

Selenium was the only constituent eliminated from consideration as a COPEC in surface soil at Parcels 511(7) and 512(7) based solely on geochemical analysis. Selenium was detected in two of eight surface soil samples at concentrations that exceeded the ESV. The maximum HQ_{screen} value for selenium was calculated to be 2.1. Based on the relative infrequency of detection and the low magnitude of the HQ_{screen} value, the elimination of selenium as a COPEC in surface soil imparted minimal uncertainty to the results of this SLERA.

7.7.4 Surface Soil at the Dog Training Area, Parcel 513(7)

Arsenic was the only constituent eliminated from consideration as a COPEC in surface soil at the Parcel 513(7) based solely on geochemical analysis. Arsenic was detected in one of three surface soil samples at concentrations that exceeded the ESV. The HQ_{screen} value for arsenic was calculated to be 2.6. Since arsenic was only detected at an elevated concentration in one surface soil sample and the HQ_{screen} value was relatively low, the elimination of arsenic as a COPEC in surface soil imparted minimal uncertainty to the results of this SLERA.

7.7.5 Surface Soil at the Dog Kennel Area, Parcel 516(7)

Selenium and zinc were the only constituents eliminated from consideration as COPECs in surface soil at the Dog Kennel Area solely based on geochemical analysis. Selenium and zinc were both detected in one of three surface soil samples at concentrations that exceeded their respective ESVs. The HQ_{screen} values for selenium and zinc were calculated to be 1.2 and 1.3, respectively. Since selenium and zinc were only detected in one surface soil sample at elevated concentrations and their calculated HQ_{screen} values are relatively low, the elimination of selenium and zinc from consideration as a COPEC in surface soil imparted minimal uncertainty to the results of this SLERA.

7.7.6 Surface Soil at the Old Burn Pit, Parcel 514(7)

Aluminum, copper, iron, lead, nickel, selenium, vanadium, and zinc were eliminated from consideration as COPECs in surface soil at Parcel 514(7) based solely on statistical and geochemical comparisons to naturally occurring levels in soil.

Iron was detected in four of nine surface soil samples at concentrations that exceeded the BTV. Iron is an essential macronutrient; thus, most organisms have mechanisms to regulate the levels of iron within their systems. As such, iron is only toxic at very high concentrations. Since the elevated iron detections were only slightly higher than background concentrations and iron is a macronutrient that is easily regulated, the level of uncertainty introduced to the results of the SLERA by the elimination of iron as a COPEC is expected to be minimal.

Copper, lead, and nickel were each detected in one of nine surface soil samples at concentrations that exceeded their respective ESVs. The HQ_{screen} values for these constituents were calculated to be 1.3, 1.03, and 1.2, respectively. The EPA (2004b) recommends an Eco-SSL for copper ranging from 54 mg/kg (based on soil invertebrate toxicity) to 95 mg/kg (based on plant toxicity). All of the surface soil samples exhibited copper concentrations that were less than these EPA-recommended Eco-SSLs. Because copper was infrequently detected at elevated concentrations, the HQ_{screen} value was relatively low, and all of the detected concentrations were less than the EPA-recommended Eco-SSL, the elimination of copper as a COPEC in surface soil introduced a minimal level of uncertainty to the results of the SLERA. Because lead was only detected in one surface soil sample at an elevated concentration and the HQ_{screen} value only marginally exceeded 1.0, the elimination of lead as a COPEC in surface soil introduced a minimal level of uncertainty to the results of the SLERA.

EPA (2004b) recommends an Eco-SSL for nickel of 38 mg/kg (based on plant toxicity). All of the surface soil samples exhibited nickel concentrations that were less than the EPA-recommended Eco-SSL. Because nickel was infrequently detected at an elevated concentration, the HQ_{screen} value was relatively low, and all of the detected concentrations were less than the EPA-recommended Eco-SSL, the elimination of nickel as a COPEC in surface soil introduced a minimal level of uncertainty to the results of the SLERA.

Zinc was detected in three of nine surface soil samples at concentrations that exceeded the ESV. The HQ_{screen} value for zinc was calculated to be 1.6. The EPA (2004b) recommends an Eco-SSL for zinc ranging from 120 mg/kg (based on soil invertebrate toxicity) to 130 mg/kg (based on plant toxicity). All of the surface soil samples exhibited zinc concentrations that were less than the EPA-recommended Eco-SSLs. Because zinc was infrequently detected at elevated

concentrations, the HQ_{screen} value was relatively low, and all of the detected concentrations were less than the EPA-recommended Eco-SSLs, the elimination of zinc as a COPEC in surface soil introduced a minimal level of uncertainty to the results of the SLERA.

Selenium was detected in four of nine surface soil samples at concentrations that exceeded the ESV and vanadium was detected in one of nine surface soil samples at a concentration that exceeded the BTV. The HQ_{screen} values that were calculated for selenium and vanadium were 3.3 and 29.7, respectively. The level of uncertainty introduced to the SLERA through elimination of these two constituents from consideration as COPECs remains unknown.

7.7.7 Surface Water

Chromium and mercury were eliminated from consideration as COPECs in surface water based solely on statistical and geochemical comparison to naturally occurring levels. Chromium was detected in one surface water sample at a concentration that exceeded the ESV. The ESV for chromium is based on toxicity to hexavalent chromium (Cr^{+6}) which is the more mobile and toxic form of chromium. The National Recommended Water Quality Criterion (EPA, 2002c) for trivalent chromium (Cr^{+3}) is 74 µg/L. All of the detected concentrations of chromium in surface water are less than the EPA-recommended water quality criterion. It is likely a significant portion, if not all, of the detected chromium in surface water is in the trivalent form and the detected concentrations of chromium would be less than the applicable criterion. Therefore, based on the infrequency of detection at elevated concentrations, the low magnitude of the HQ_{screen} value, and the fact that all of the detected concentrations are less than the EPA-recommended water quality criterion, the elimination of chromium as a COPEC in surface water introduced a minimal level of uncertainty to the results of the SLERA.

Mercury was detected in one surface water sample at a concentration that exceeded the ESV. The National Recommended Water Quality Criterion (EPA, 2002c) for mercury is 0.77 µg/L. The only detected concentration of mercury in surface water is less than the EPA-recommended water quality criterion. Based on the infrequency of detection at an elevated concentration and the fact that the only detected concentration is less that the EPA-recommended water quality criterion, the elimination of mercury as a COPEC in surface water imparts minimal uncertainty to the results of the SLERA.

7.7.8 Sediment

Cadmium and copper were eliminated from consideration as COPECs in sediment based solely on statistical and geochemical comparison to naturally occurring levels. Cadmium and copper were each detected in two of five sediment samples at concentrations that exceeded their

respective ESVs. The maximum HQ_{screen} values for cadmium and copper were calculated to be 2.6 and 1.5, respectively.

Long et al. (1995) have derived two values for sediment that describe the distribution of the toxicological effects data in the scientific literature. The lower 10^{th} percentile of the effects data for each chemical was identified and referred to as the effects range-low (ERL). The median, or 50^{th} percentile, of the effects data was identified and referred to as the effects range-median (ERM). Sediment constituent concentrations less than the ERL are rarely associated with adverse effects. Sediment constituent concentrations between the ERL and ERM are occasionally associated with adverse effects. Sediment constituent concentrations greater than the ERM are frequently associated with adverse effects. Long et al. (1995) derived the ERL and ERM values for cadmium to be 1.2 and 9.6 mg/kg, respectively. The ERL and ERM values for copper have been derived as 34 mg/kg and 270 mg/kg (Long et al., 1995).

One of the sediment samples exhibited cadmium at a concentration greater than the ERL, but less than the ERM. Based on the methodology presented by Long et al. (1995), cadmium in sediment from one location could be expected to induce adverse effects in sensitive benthic organisms rarely to occasionally, but not frequently. All of the other sediment samples exhibited cadmium concentrations less than the ERL.

All of the sediment samples exhibited copper concentrations less than the ERL. Therefore, copper in sediment is expected to rarely induce adverse effects on sensitive benthic organisms. Based on the relative infrequency of detection at elevated concentrations, the low magnitude of the HQ_{screen} values, and the fact that all but one of the sediment samples exhibit cadmium and copper concentrations less than their respective ERL values, the elimination of cadmium and copper as COPECs in sediment is expected to introduce a minimal level of uncertainty to the results of the SLERA.

7.7.9 Groundwater

Aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, thallium, vanadium, and zinc were eliminated from consideration as COPECs based solely on statistical and geochemical comparison to naturally occurring levels. Because groundwater is found at depths greater than 20 feet below the ground surface, it is unlikely that groundwater will discharge to the ephemeral drainage features at the Training Area T-5 Sites. Without groundwater discharge to a surface water body, ecological exposures are not complete. Therefore, elimination of these constituents as COPECs in groundwater imparted minimal uncertainty on the results of this SLERA.

7.8 Summary and Conclusions

The potential for ecological risks at the Training Area T-5 Sites was determined through a SLERA. This ecological screening process consisted of a characterization of the ecological setting at the sites, development of a SCM, a description of the fate and transport of constituents detected in various environmental media, a description of the ecotoxicity of the various constituents detected in site media, a description of the ecological receptors, a description of the complete exposure pathways, calculation of screening-level hazard quotients, and a description of the uncertainties within the process.

7.8.1 SLERA Summary

A number of constituents were detected in surface soil at the different Training Area T-5 Sites that exhibited maximum concentrations that exceeded their respective ESVs and naturally occurring levels. Surface soil samples from the Former Detection and Identification Area, Parcel 180(7), exhibited maximum concentrations of the following constituents that exceeded ESVs:

- Cadmium
- Copper
- Zinc
- Anthracene
- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene.

Training Area T-5, Parcel 182(7), exhibited concentrations of the following constituents that exceeded the ESVs:

- Copper
- Zinc.

Surface soil samples from the Blacktop Training Area, Parcel 511(7), and the Fenced Yard in the Blacktop Area, Parcel 512(7), exhibited maximum concentrations of the following constituents that exceeded ESVs:

- Cadmium
- Copper
- Zinc.

Surface soil samples from the Dog Training Area, Parcel 513(7), exhibited maximum concentrations of the following constituents that exceeded ESVs:

- Cadmium
- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene.

Surface soil samples from the Dog Kennel Area, Parcel 516(7), exhibited maximum concentrations of the following constituents that exceeded ESVs:

- Barium
- Trichloroethene.

Surface soil samples from the Old Burn Pit, Parcel 514(7), exhibited maximum concentrations of the following constituents that exceeded ESVs:

- Benzo(a)pyrene
- Fluoranthene
- Phenanthrene
- Pyrene
- 1,1,2,2-Tetrachloroethane
- Trichloroethene.

None of the constituents detected in surface water at the Training Area T-5 Sites exceeded ESVs or naturally occurring levels. One sediment sample exhibited chromium at a concentration that exceeded the ESV.

Bis(2-ethylhexyl)phthalate and 1,1,2,2-tetrachloroethane were detected in groundwater at the Training Area T-5 Sites at concentrations that exceeded surface water ESVs.

Consideration of additional lines of evidence resulted in the identification of the following COPECs in surface soil at the Training Area T-5 Sites:

Parcel	Surface Soil COPECs
180	**Metals:** cadmium, copper, and zinc **PAHs:** anthracene, benzo(a)pyrene, fluoranthene, phenanthrene, pyrene.
182	**Metals:** copper and zinc
511/512	**Metals:** cadmium, copper, and zinc
513	None.
514	**VOCs:** 1,1,2,2-tetrachloroethane and trichloroethene **PAHs:** Benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene
516	None.

No constituents were identified as COPECs in surface water or sediment in the ephemeral drainage features at the sites. Because of the depth to groundwater (greater than 20 feet below ground surface), ecological exposures to groundwater were considered incomplete at the Training Area T-5 Sites; therefore, no COPECs were identified in groundwater.

7.8.2 Conclusions

Several constituents (primarily metals and PAHs) were identified as COPECs in surface soil at the Training Area T-5 Sites. No COPECs were identified in groundwater, surface water, or sediment. Because several constituents were identified as COPECs in surface soil, and because conservative assessment techniques were used in the SLERA process, a more thorough assessment (e.g., Baseline Ecological Risk Assessment) is warranted to reduce uncertainties inherent in the SLERA process and to more thoroughly evaluate potential ecological risks from surface soil constituents at the Training Area T-5 Sites.

8.0 Summary, Conclusions, and Recommendations

Shaw completed SI and RI activities at the Training Area T-5 Sites, Parcels 180(7), 182(7), 511(7), 512(7), 513(7), 514(7), and 516(7), at FTMC, Alabama. SI field activities were initiated in October 2001 to determine the presence or absence of contamination. The SI results demonstrated the presence of contamination (primarily VOCs in groundwater. Therefore, RI field activities were initiated in October 2002 to determine the nature and extent of contamination.

A total of 48 surface and depositional soil samples, 32 subsurface soil samples, 102 groundwater samples, 5 surface water samples, and 5 sediment samples were collected for chemical analysis during the investigations. The samples were analyzed for metals, VOCs, SVOCs, and CWM breakdown products – except for 28 groundwater samples, which were analyzed for VOCs only during the RI. Shaw also installed 48 permanent monitoring wells at the Training Area T-5 Sites, including 37 residuum wells and 11 bedrock wells, to facilitate groundwater sample collection and to provide site-specific geological and hydrogeological data. In addition, five monitoring wells at adjacent Parcel 232Q-X were sampled during the RI to assist in determining the horizontal extent of contamination.

The primary environmental concern at the Training Area T-5 Sites is the presence of chlorinated VOCs (particularly 1,1,2,2-tetrachloroethane, carbon tetrachloride, and trichloroethene) in groundwater. The source of contamination is believed to be decontamination solutions (e.g., DANC) or certain chemical agents (e.g., CNB, CNC) used in historical CWM training activities. Other contaminants of concern included certain metals (cadmium, copper, and zinc) and PAHs in surface soil at some of the parcels.

Groundwater at the Training Area T-5 Sites has an overall northerly to northeasterly flow direction in both residuum and bedrock. Calculated vertical hydraulic gradients showed weak to strong downward gradients. The downward gradients support connectivity between the two aquifer zones. However, the concentrations of dissolved VOCs presently detected are too low for density to be a factor in vertical migration.

Based on the soil and groundwater data collected at the Training Area T-5 Sites, the most significant fate and transport pathway is within subsurface soil through the residuum and into the bedrock groundwater system. The low levels of VOCs in surface and subsurface soil suggest

that significant removal and/or subsequent leaching of organic contaminants to groundwater has occurred.

Isopleth maps were constructed showing the distribution of total chlorinated VOCs in the residuum and bedrock aquifers at the sites (Figures 4-3 through 4-6). Two major plumes are present within in the residuum (Figure 4-3): one at Parcels 511(7) and 512(7), and one at Parcel 514(7). These plumes consist mainly of chlorinated ethane and ethene compounds, particularly 1,1,2,2-tetrachloroethane and trichloroethene with lesser amounts of cis/trans-1,2-dichloroethene, 1,1,2-trichloroethane, and chloroform. The chlorinated VOC plume within Parcels 511(7) and 512(7) is approximately 450 feet long by 150 feet wide and extends to the north. The chlorinated VOC plume at Parcel 514(7) is approximately 600 feet long by 150 feet wide and extends east-northeast. A third major plume in the southern portion of Parcel 182(7), consisting mainly of carbon tetrachloride, 1,1,2,2-tetrachloroethane, and chloroform, is approximately 300 feet long by 200 feet wide and extends to the northeast. Total chlorinated VOCs present in bedrock wells (Figure 4-4) are coincident and occur beneath similar contaminants present in the overlying residuum, except at Parcel 182(7) where the contaminants appear to be restricted to the residuum. This distribution supports connectivity between the two aquifer zones. Contaminant flow distribution parallels groundwater flow direction in both residuum and bedrock. Based on the data from monitoring wells installed during this investigation and on site topography and geology, the horizontal and vertical extent of groundwater contamination has been defined.

Contaminant transport rates for VOCs in residuum ranged from approximately 33 ft/yr for tetrachloroethene to 154 ft/yr for acetone. The migration distance for chlorinated VOCs in groundwater (calculated for a 50-year period) considerably exceeds the 600-foot length of the well-defined plume that extends east-northeast from Parcel 514(7). Contaminant velocities in bedrock are low (less than 25 ft/yr). The degree of influence of fracture flow or solution porosity within the limestone bedrock present cannot be assessed from the present data.

An SRA was performed to evaluate potential risks to human receptors from exposure to environmental media at the Training Area T-5 Sites. Four plausible receptors were evaluated in the SRA: recreational site user, groundskeeper, construction worker, and resident. COCs were not identified for surface water or sediment. The primary COCs identified in the SRA were VOCs in groundwater and PAHs in surface soil. The following table summarizes the COCs by parcel and receptor. "Acceptable" indicates calculated risks were within acceptable limits; otherwise, the COC(s) are listed by medium.

Parcel	Receptor			
	Recreational Site User	Groundskeeper	Construction Worker	Resident
180	Acceptable	PAHs[a] in surface soil[c]; VOCs[b] in groundwater	Acceptable	PAHs in surface soil[c]; B(a)P in subsurface soil[c]; VOCs in groundwater
182	Acceptable	VOCs in groundwater	Acceptable	VOCs in groundwater
511/512	Acceptable	VOCs in groundwater	Acceptable	VOCs in groundwater
513	Acceptable	VOCs in groundwater	Acceptable	B(a)P in surface soil[c]; VOCs in groundwater
514	Acceptable	VOCs in groundwater	Acceptable	B(a)P in surface soil[c]; VOCs in groundwater
516	Acceptable	VOCs in groundwater	Barium in surface soil[c]	VOCs in groundwater

[a] PAHs include one or more of the following compounds: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
[b] VOCs include one or more of the following compounds: acetone, 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1-dichloroethene, carbon tetrachloride, and trichloroethene.
[c] Risk estimates for soil contribute to unacceptable estimates *only* if exposure to groundwater developed as a potable source – considered a very unlikely scenario – is included.
B(a)P – Benzo(a)pyrene.

Surface water, sediment, and soil at the various Training Area T-5 Sites are uncontaminated or so lightly contaminated that these media do not pose a significant threat to human health. Groundwater, however, has been impacted by several solvents, particularly 1,1,2,2-tetrachloroethane, trichloroethene, carbon tetrachloride, and acetone. The Training Area T-5 Sites could be released for any purpose provided that groundwater is not developed as a potable source. Low levels of PAHs in surface soil at three of the sites contribute significantly to cancer risk only if exposure to groundwater developed as a potable source is included in the evaluation.

A SLERA was performed to evaluate potential risks to ecological receptors from exposure to environmental media at the Training Area T-5 Sites. COPECs were not identified for groundwater, surface water, or sediment. Exposures to subsurface soil are unlikely for potential ecological receptors at these sites. The predominant COPECs were three metals (cadmium, copper, and zinc) and several PAHs in surface soil, as summarized in the following table:

Parcel	Surface Soil COPECs
180	**Metals:** cadmium, copper, and zinc **PAHs:** anthracene, benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene
182	**Metals:** copper and zinc
511/512	**Metals:** cadmium, copper, and zinc
513	None.
514	**VOCs:** 1,1,2,2-tetrachloroethane and trichloroethene **PAHs:** Benzo(a)pyrene, fluoranthene, phenanthrene, and pyrene
516	None.

Based on the results of the RI, no further investigation is warranted to define the nature and extent of contamination at the Training Area T-5 Sites. Shaw recommends conducting a BERA to complete the ecological risk assessment process. Following the BERA, a feasibility study should be performed to evaluate and select a remedial alternative for the protection of human health and the environment.

9.0 References

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ATTACHMENT 1

LIST OF ABBREVIATIONS AND ACRONYMS

List of Abbreviations and Acronyms

2-ADNT	2-amino-4,6-dinitrotoluene
4-ADNT	4-amino-2,6-dinitrotoluene
2,4-D	2,4-dichlorophenoxyacetic acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4,5-TP	2,4,5-trichlorophenoxypropionic acid
3D	3D International Environmental Group
AB	ambient blank
AbB3	Anniston gravelly clay loam, 2 to 6 percent slopes, severely eroded
AbC3	Anniston gravelly clay loam, 6 to 10 percent slopes, severely eroded
AbD3	Anniston and Allen gravelly clay loams, 10 to 15 percent slopes, eroded
ABLM	adult blood lead model
Abs	skin absorption
ABS	dermal absorption factor
AC	hydrogen cyanide
ACAD	AutoCadd
AcB2	Anniston and Allen gravelly loams, 2 to 6 percent slopes, eroded
AcC2	Anniston and Allen gravelly loams, 6 to 10 percent slopes, eroded
AcD2	Anniston and Allen gravelly loams, 10 to 15 percent slopes, eroded
AcE2	Anniston and Allen gravelly loams, 15 to 25 percent slopes, eroded
ACGIH	American Conference of Governmental Industrial Hygienists
AdE	Anniston and Allen stony loam, 10 to 25 percent slope
ADEM	Alabama Department of Environmental Management
ADPH	Alabama Department of Public Health
AEC	U.S. Army Environmental Center
AEDA	ammunition, explosives, and other dangerous articles
AEL	airborne exposure limit
AET	adverse effect threshold
AF	soil-to-skin adherence factor
AHA	ammunition holding area
AL	Alabama
ALARNG	Alabama Army National Guard
ALAD	δ-aminolevulinic acid dehydratase
ALDOT	Alabama Department of Transportation
amb.	amber
amsl	above mean sea level
ANAD	Anniston Army Depot
AOC	area of concern
AP	armor piercing
APEC	areas of potential ecological concern
APT	armor-piercing tracer
AR	analysis request
ARAR	applicable or relevant and appropriate requirement
AREE	area requiring environmental evaluation
AS/SVE	air sparging/soil vapor extraction
ASP	Ammunition Supply Point
ASR	Archives Search Report
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
AT	averaging time
atm-m^3/mol	atmospheres per cubic meter per mole
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all-terrain vehicle
AUF	area use factor
AWARE	Associated Water and Air Resources Engineers, Inc.
AWQC	ambient water quality criteria
AWWSB	Anniston Water Works and Sewer Board
‘B’	Analyte detected in laboratory or field blank at concentration greater than the reporting limit (and greater than zero)
BAF	bioaccumulation factor
BBGR	Baby Bains Gap Road
BCF	blank correction factor; bioconcentration factor
BCT	BRAC Cleanup Team
BERA	baseline ecological risk assessment
BEHP	bis(2-ethylhexyl)phthalate
BFB	bromofluorobenzene
BFE	base flood elevation
BG	Bacillus globigii
BGR	Bains Gap Road
bgs	below ground surface
BHC	hexachlorocyclohexane
BHHRA	baseline human health risk assessment
BIRTC	Branch Immaterial Replacement Training Center
bkg	background
bls	below land surface
BOD	biological oxygen demand
Bp	soil-to-plant biotransfer factors
BRAC	Base Realignment and Closure
Braun	Braun Intertec Corporation
BSAF	biota-to-sediment accumulation factors
BSC	background screening criterion
BTAG	Biological Technical Assistance Group
BTEX	benzene, toluene, ethyl benzene, and xylenes
BTOC	below top of casing
BTV	background threshold value
BW	biological warfare; body weight
BZ	breathing zone; 3-quinuclidinyl benzilate
C	ceiling limit value
Ca	carcinogen
$CaCO_3$	calcium carbonate
CAA	Clean Air Act
CAB	chemical warfare agent breakdown products
CACM	Chemical Agent Contaminated Media
CAMU	corrective action management unit
CBR	chemical, biological, and radiological
CCAL	continuing calibration
CCB	continuing calibration blank
CCV	continuing calibration verification
CD	compact disc
CDTF	Chemical Defense Training Facility
CEHNC	U.S. Army Engineering and Support Center, Huntsville
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERFA	Community Environmental Response Facilitation Act
CESAS	Corps of Engineers South Atlantic Savannah
CF	conversion factor
CFC	chlorofluorocarbon
CFDP	Center for Domestic Preparedness
CFR	Code of Federal Regulations
CG	phosgene (carbonyl chloride)
CGI	combustible gas indicator
ch	inorganic clays of high plasticity
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
CIH	Certified Industrial Hygienist
CK	cyanogen chloride
cl	inorganic clays of low to medium plasticity
Cl	chlorinated
CLP	Contract Laboratory Program
cm	centimeter
CN	chloroacetophenone
CNB	chloroacetophenone, benzene, and carbon tetrachloride
CNS	chloroacetophenone, chloropicrin, and chloroform
CO	carbon monoxide
CO_2	carbon dioxide
Co-60	cobalt-60
CoA	Code of Alabama
COC	chain of custody; chemical of concern
COE	Corps of Engineers
Con	skin or eye contact
COPC	chemical of potential concern
COPEC	constituent of potential ecological concern
CPOM	coarse particulate organic matter
CPSS	chemicals present in site samples
CQCSM	Contract Quality Control System Manager
CRDL	contract-required detection limit
CRL	certified reporting limit
CRQL	contract-required quantitation limit
CRZ	contamination reduction zone
Cs-137	cesium-137
CS	ortho-chlorobenzylidene-malononitrile
CSEM	conceptual site exposure model
CSM	conceptual site model
CT	central tendency
ctr.	container
CWA	chemical warfare agent; Clean Water Act
CWM	chemical warfare material; clear, wide mouth

List of Abbreviations and Acronyms *(Continued)*

CX	dichloroformoxime
'D'	duplicate; dilution
D&I	detection and identification
DAAMS	depot area agent monitoring station
DAF	dilution-attenuation factor
DANC	decontamination agent, non-corrosive
ºC	degrees Celsius
ºF	degrees Fahrenheit
DCA	dichloroethane
DCE	dichloroethene
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
DEH	Directorate of Engineering and Housing
DEHP	di(2-ethylhexyl)phthalate
DEP	depositional soil
DFTPP	decafluorotriphenylphosphine
DI	deionized
DID	data item description
DIMP	di-isopropylmethylphosphonate
DM	dry matter; adamsite
DMBA	dimethylbenz(a)anthracene
DMMP	dimethylmethylphosphonate
DNAPL	dense nonaqueous-phase liquid
DNT	dinitrotoluene
DO	dissolved oxygen
DOD	U.S. Department of Defense
DOJ	U.S. Department of Justice
DOT	U.S. Department of Transportation
DP	direct-push
DPDO	Defense Property Disposal Office
DPT	direct-push technology
DQO	data quality objective
DRMO	Defense Reutilization and Marketing Office
DRO	diesel range organics
DS	deep (subsurface) soil
DS2	Decontamination Solution Number 2
DSERTS	Defense Site Environmental Restoration Tracking System
DWEL	drinking water equivalent level
E&E	Ecology and Environment, Inc.
EB	equipment blank
EBS	environmental baseline survey
EC_{20}	effects concentration for 20 percent of a test population
EC_{50}	effects concentration for 50 percent of a test population
ECBC	Edgewood Chemical Biological Center
ED	exposure duration
EDD	electronic data deliverable
EF	exposure frequency
EDQL	ecological data quality level
EE/CA	engineering evaluation and cost analysis
Eh	oxidation-reduction potential
Elev.	elevation
EM	electromagnetic
EMI	Environmental Management Inc.
EM31	Geonics Limited EM31 Terrain Conductivity Meter
EM61	Geonics Limited EM61 High-Resolution Metal Detector
EOD	explosive ordnance disposal
EODT	explosive ordnance disposal team
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EPIC	Environmental Photographic Interpretation Center
EPRI	Electrical Power Research Institute
EPT	Ephemeroptera, Plecoptera, Trichoptera
ER	equipment rinsate
ERA	ecological risk assessment
ER-L	effects range-low
ER-M	effects range-medium
ESE	Environmental Science and Engineering, Inc.
ESL	ecological screening level
ESMP	Endangered Species Management Plan
ESN	Environmental Services Network, Inc.
ESV	ecological screening value
ET	exposure time
EU	exposure unit
Exp.	Explosives
EXTOXNET	Extension Toxicology Network
E-W	east to west
EZ	exclusion zone
FAR	Federal Acquisition Regulations
FB	field blank
FBI	Family Biotic Index
FD	field duplicate
FDC	Former Decontamination Complex
FDA	U.S. Food and Drug Administration
Fe^{+3}	ferric iron
Fe^{+2}	ferrous iron
FedEx	Federal Express, Inc.
FEMA	Federal Emergency Management Agency
FFCA	Federal Facilities Compliance Act
FFE	field flame expedient
FFS	focused feasibility study
FI	fraction of exposure
Fil	filtered
Flt	filtered
FMDC	Fort McClellan Development Commission
FML	flexible membrane liner
f_{oc}	fraction organic carbon
FOMRA	Former Ordnance Motor Repair Area
FOST	Finding of Suitability to Transfer
Foster Wheeler	Foster Wheeler Environmental Corporation
FR	Federal Register
Frtn	fraction
FS	field split; feasibility study
FSP	field sampling plan
ft	feet
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year
FTA	Fire Training Area
FTMC	Fort McClellan
FTRRA	FTMC Reuse & Redevelopment Authority
g	gram
g/m^3	gram per cubic meter
G-856	Geometrics, Inc. G-856 magnetometer
G-858G	Geometrics, Inc. G-858G magnetic gradiometer
GAF	gastrointestinal absorption factor
gal	gallon
gal/min	gallons per minute
GB	sarin (isopropyl methylphosphonofluoridate)
gc	clay gravels; gravel-sand-clay mixtures
GC	gas chromatograph
GCL	geosynthetic clay liner
GC/MS	gas chromatograph/mass spectrometer
GCR	geosynthetic clay liner
GFAA	graphite furnace atomic absorption
GIS	Geographic Information System
gm	silty gravels; gravel-sand-silt mixtures
gp	poorly graded gravels; gravel-sand mixtures
gpm	gallons per minute
GPR	ground-penetrating radar
GPS	global positioning system
GRA	general response action
GS	ground scar
GSA	General Services Administration; Geologic Survey of Alabama
GSBP	Ground Scar Boiler Plant
GSSI	Geophysical Survey Systems, Inc.
GST	ground stain
GW	groundwater
gw	well-graded gravels; gravel-sand mixtures
H&S	health and safety
HA	hand auger
HC	mixture of hexachloroethane, aluminum powder, and zinc oxide (smoke producer)
HCl	hydrochloric acid
HD	distilled mustard (bis-[dichloroethyl]sulfide)

HDPE	high-density polyethylene
HE	high explosive
HEAST	Health Effects Assessment Summary Tables
Herb.	herbicides
HHRA	human health risk assessment
HI	hazard index
H_2O_2	hydrogen peroxide
HPLC	high-performance liquid chromatography
HNO_3	nitric acid
HQ	hazard quotient
HQ_{screen}	screening-level hazard quotient
hr	hour
HRC	hydrogen releasing compound
HSA	hollow-stem auger
HSDB	Hazardous Substance Data Bank
HTRW	hazardous, toxic, and radioactive waste
'I'	out of control, data rejected due to low recovery
IASPOW	Impact Area South of POW Training Facility
IATA	International Air Transport Authority
ICAL	initial calibration
ICB	initial calibration blank
ICP	inductively-coupled plasma
ICRP	International Commission on Radiological Protection
ICS	interference check sample
ID	inside diameter
IDL	instrument detection limit
IDLH	immediately dangerous to life or health
IDM	investigative-derived media
IDW	investigation-derived waste
IEUBK	Integrated Exposure Uptake Biokinetic
IF	ingestion factor; inhalation factor
ILCR	incremental lifetime cancer risk
IMPA	isopropylmethyl phosphonic acid
IMR	Iron Mountain Road
in.	inch
Ing	ingestion
Inh	inhalation
IP	ionization potential
IPS	International Pipe Standard
IR	ingestion rate
IRDMIS	Installation Restoration Data Management Information System
IRIS	Integrated Risk Information Service
IRP	Installation Restoration Program
IS	internal standard
ISCP	Installation Spill Contingency Plan
IT	IT Corporation
ITEMS	IT Environmental Management System™
'J'	estimated concentration
JeB2	Jefferson gravelly fine sandy loam, 2 to 6 percent slopes, eroded
JeC2	Jefferson gravelly fine sandy loam, 6 to 10 percent slopes, eroded
JfB	Jefferson stony fine sandy loam, 0 to 10 percent slopes have strong slopes
JPA	Joint Powers Authority
K	conductivity
K_d	soil-water distribution coefficient
kg	kilogram
KeV	kilo electron volt
K_{oc}	organic carbon partioning coefficient
K_{ow}	octonal-water partition coefficient
$KMnO_4$	potassium permanganate
L	liter; Lewisite (dichloro-[2-chloroethyl]sulfide)
L/kg/day	liters per kilogram per day
l	liter
LAW	light anti-tank weapon
lb	pound
LBP	lead-based paint
LC	liquid chromatography
LCS	laboratory control sample
LC_{50}	lethal concentration for 50 percent population tested
LD_{50}	lethal dose for 50 percent population tested
LEL	lower explosive limit
LOAEL	lowest-observed-advserse-effects-level
LOEC	lowest-observable-effect-concentration
LRA	land redevelopment authority
LT	less than the certified reporting limit
LUC	land-use control
LUCAP	land-use control assurance plan
LUCIP	land-use control implementation plan
max	maximum
MB	method blank
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MCPA	4-chloro-2-methylphenoxyacetic acid
MCPP	2-(2-methyl-4-chlorophenoxy)propionic acid
MCS	media cleanup standard
MD	matrix duplicate
MDC	maximum detected concentration
MDCC	maximum detected constituent concentration
MDL	method detection limit
mg	milligrams
mg/kg	milligrams per kilogram
mg/kg/day	milligram per kilogram per day
mg/kgbw/day	milligrams per kilogram of body weight per day
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mh	inorganic silts, micaceous or diatomaceous fine, sandy or silt soils
MHz	megahertz
µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
MeV	mega electron volt
min	minimum
MINICAMS	miniature continuous air monitoring system
ml	inorganic silts and very fine sands
mL	milliliter
mm	millimeter
MM	mounded material
MMBtu/hr	million Btu per hour
MNA	monitored natural attenuation
MnO_4-	permanganate ion
MOA	Memorandum of Agreement
MOGAS	motor vehicle gasoline
MOUT	Military Operations in Urban Terrain
MP	Military Police
MPA	methyl phosphonic acid
MPC	maximum permissible concentration
MPM	most probable munition
MQL	method quantitation limit
MR	molasses residue
MRL	method reporting limit
MS	matrix spike
mS/cm	millisiemens per centimeter
mS/m	millisiemens per meter
MSD	matrix spike duplicate
MTBE	methyl tertiary butyl ether
msl	mean sea level
MtD3	Montevallo shaly, silty clay loam, 10 to 40 percent slopes , severely eroded
mV	millivolts
MW	monitoring well
MWI&MP	Monitoring Well Installation and Management Plan
Na	sodium
NA	not applicable; not available
NAD	North American Datum
NAD83	North American Datum of 1983
$NaMnO_4$	sodium permanganate
NAVD88	North American Vertical Datum of 1988
NAS	National Academy of Sciences
NCEA	National Center for Environmental Assessment
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
ND	not detected
NE	no evidence; northeast
ne	not evaluated
NEW	net explosive weight

List of Abbreviations and Acronyms *(Continued)*

NFA	No Further Action
NG	National Guard
NGP	National Guardsperson
ng/L	nanograms per liter
NGVD	National Geodetic Vertical Datum
Ni	nickel
NIC	notice of intended change
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NLM	National Library of Medicine
NO_3^-	nitrate
NOEC	no-observable-effect-concentration
NPDES	National Pollutant Discharge Elimination System
NPW	net present worth
No.	number
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effects-level
NR	not requested; not recorded; no risk
NRC	National Research Council
NRCC	National Research Council of Canada
NRHP	National Register of Historic Places
NRT	near real time
ns	nanosecond
N-S	north to south
NS	not surveyed
NSA	New South Associates, Inc.
nT	nanotesla
nT/m	nanoteslas per meter
NTU	nephelometric turbidity unit
nv	not validated
O_2	oxygen
O_3	ozone
O&G	oil and grease
O&M	operation and maintenance
OB/OD	open burning/open detonation
OD	outside diameter
OE	ordnance and explosives
oh	organic clays of medium to high plasticity
OH•	hydroxyl radical
ol	organic silts and organic silty clays of low plasticity
OP	organophosphorus
ORC	Oxygen Releasing Compound
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OVM-PID/FID	organic vapor meter-photoionization detector/flame ionization detector
OWS	oil/water separator
oz	ounce
PA	preliminary assessment
PAH	polynuclear aromatic hydrocarbon
PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
Parsons	Parsons Engineering Science, Inc.
Pb	lead
PBMS	performance-based measurement system
PC	permeability coefficient
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
PCE	perchloroethene
PCP	pentachlorophenol
PDS	Personnel Decontamination Station
PEF	particulate emission factor
PEL	permissible exposure limit
PERA	preliminary ecological risk assessment
PERC	perchloroethene
PES	potential explosive site
Pest.	pesticides
PETN	pentaerythritoltetranitrate
PFT	portable flamethrower
PG	professional geologist
PID	photoionization detector
PkA	Philo and Stendal soils local alluvium, 0 to 2 percent slopes
PM	project manager
POC	point of contact
POL	petroleum, oils, and lubricants
POTW	publicly owned treatment works
POW	prisoner of war
PP	peristaltic pump; Proposed Plan
ppb	parts per billion
ppbv	parts per billion by volume
PPE	personal protective equipment
ppm	parts per million
PPMP	Print Plant Motor Pool
ppt	parts per thousand
PR	potential risk
PRA	preliminary risk assessment
PRG	preliminary remediation goal
PS	chloropicrin
PSSC	potential site-specific chemical
pt	peat or other highly organic silts
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAM	quality assurance manual
QAO	quality assurance officer
QAP	installation-wide quality assurance plan
QC	quality control
QST	QST Environmental, Inc.
qty	quantity
Qual	qualifier
R	rejected data; resample; retardation factor
R&A	relevant and appropriate
RA	remedial action
RAO	remedial action objective
RBC	risk-based concentration; red blood cell
RBRG	risk-based remedial goal
RCRA	Resource Conservation and Recovery Act
RCWM	Recovered Chemical Warfare Material
RD	remedial design
RDX	cyclotrimethylenetrinitramine
ReB3	Rarden silty clay loams
REG	regular field sample
REL	recommended exposure limit
RFA	request for analysis
RfC	reference concentration
RfD	reference dose
RGO	remedial goal option
RI	remedial investigation
RL	reporting limit
RME	reasonable maximum exposure
ROD	Record of Decision
RPD	relative percent difference
RR	range residue
RRF	relative response factor
RRSE	Relative Risk Site Evaluation
RSD	relative standard deviation
RTC	Recruiting Training Center
RTECS	Registry of Toxic Effects of Chemical Substances
RTK	real-time kinematic
RWIMR	Ranges West of Iron Mountain Road
SA	exposed skin surface area
SAD	South Atlantic Division
SAE	Society of Automotive Engineers
SAIC	Science Applications International Corporation
SAP	installation-wide sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act
sc	clayey sands; sand-clay mixtures
Sch.	schedule
SCM	site conceptual model
SD	sediment
SDG	sample delivery group
SDWA	Safe Drinking Water Act
SDZ	safe distance zone; surface danger zone

SEMS	Southern Environmental Management & Specialties, Inc.
SF	cancer slope factor
SFSP	site-specific field sampling plan
SGF	standard grade fuels
Shaw	Shaw Environmental, Inc.
SHP	installation-wide safety and health plan
SI	site investigation
SINA	Special Interest Natural Area
SL	standing liquid
SLERA	screening-level ecological risk assessment
sm	silty sands; sand-silt mixtures
SM	Serratia marcescens
SMDP	Scientific Management Decision Point
s/n	signal-to-noise ratio
SO_4^{-2}	sulfate
SOD	soil oxidant demand
SOP	standard operating procedure
SOPQAM	U.S. EPA's *Standard Operating Procedure/Quality Assurance Manual*
sp	poorly graded sands; gravelly sands
SP	submersible pump
SPCC	system performance calibration compound
SPCS	State Plane Coordinate System
SPM	sample planning module
SQRT	screening quick reference tables
Sr-90	strontium-90
SRA	streamlined human health risk assessment
SRI	supplemental remedial investigation
SRM	standard reference material
Ss	stony rough land, sandstone series
SS	surface soil
SSC	site-specific chemical
SSHO	site safety and health officer
SSHP	site-specific safety and health plan
SSL	soil screening level
SSSL	site-specific screening level
SSSSL	site-specific soil screening level
STB	supertropical bleach
STC	source-term concentration
STD	standard deviation
STEL	short-term exposure limit
STL	Severn-Trent Laboratories
STOLS	Surface Towed Ordnance Locator System®
Std. units	standard units
SU	standard unit
SUXOS	senior UXO supervisor
SVOC	semivolatile organic compound
SW	surface water
SW-846	U.S. EPA's *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*
SWMU	solid waste management unit
SWPP	storm water pollution prevention plan
SZ	support zone
TAL	target analyte list
TAT	turn around time
TB	trip blank
TBC	to be considered
TCA	trichloroethane
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	tetrachlorodibenzofurans
TCE	trichloroethene
TCL	target compound list
TCLP	toxicity characteristic leaching procedure
TDEC	Tennessee Department of Environment and Conservation
TDGCL	thiodiglycol
TDGCLA	thiodiglycol chloroacetic acid
TEA	triethylaluminum
Tetryl	trinitrophenylmethylnitramine
TERC	Total Environmental Restoration Contract
THI	target hazard index
TIC	tentatively identified compound
TLV	threshold limit value
TN	Tennessee
TNB	trinitrobenzene
TNT	trinitrotoluene
TOC	top of casing; total organic carbon
TPH	total petroleum hydrocarbons
TR	target cancer risk
TRADOC	U.S. Army Training and Doctrine Command
TRPH	total recoverable petroleum hydrocarbons
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
TSDF	treatment, storage, and disposal facility
TSS	total suspended solids
TWA	time-weighted average
UCL	upper confidence limit
UCR	upper certified range
'U'	not detected above reporting limit
UIC	underground injection control
UF	uncertainty factor
URF	unit risk factor
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAEC	U.S. Army Environmental Center
USAEHA	U.S. Army Environmental Hygiene Agency
USACMLS	U.S. Army Chemical School
USAMPS	U.S. Army Military Police School
USATCES	U.S. Army Technical Center for Explosive Safety
USATEU	U.S. Army Technical Escort Unit
USATHAMA	U.S. Army Toxic and Hazardous Material Agency
USC	United States Code
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
UTL	upper tolerance level; upper tolerance limit
UXO	unexploded ordnance
UXOQCS	UXO Quality Control Supervisor
UXOSO	UXO safety officer
V	vanadium
VC	vinyl chloride
VOA	volatile organic analyte
VOC	volatile organic compound
VOH	volatile organic hydrocarbon
VQlfr	validation qualifier
VQual	validation qualifier
VX	nerve agent (O-ethyl-S-[diisopropylaminoethyl]-methylphosphonothiolate)
WAC	Women's Army Corps
Weston	Roy F. Weston, Inc.
WP	installation-wide work plan
WRS	Wilcoxon rank sum
WS	watershed
WSA	Watershed Screening Assessment
WWI	World War I
WWII	World War II
XRF	x-ray fluorescence
yd^3	cubic yards