

5.0 Contaminant Fate And Transport

This chapter discusses factors related to the fate and transport of contaminants identified at Range K.

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 Range K, Parcel 203(7) are presented and evaluated in Section 5.2. The persistence of chemicals detected at the site and factors affecting the environmental fate and transport process are discussed in Section 5.3. Table 5-1 lists the physical and chemical properties of the organic chemicals detected above ESVs or SSSLs at the site. Table 5-2 provides data on the distribution coefficient for metals. Section 5.4 evaluates the direction and rate of contaminant migration at Range K and includes Table 5-3, which summarizes the rate and distance of migration estimated for organic chemicals cited in Table 5-1. Also included in Section 5.4 are geologic cross sections of the site showing the vertical distribution of total chlorinated VOCs, trichloroethene, and 1,1,2,2-tetrachloroethane.

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 Range K, 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 Range K or to off-site locations.

Contaminant-adsorbed dust could also be released to the atmosphere through construction activities. Most of the surface area of Range K is best characterized as relatively immature mixed deciduous/coniferous forest. In view of this, the generation of fugitive dust and subsequent transfer by wind is not anticipated to be a significant transport mechanism. No major construction activities have occurred at the site, although it is reported that the site has been physically rearranged (bulldozed) (SAIC, 2000).

Site-related contamination could be released through volatilization into the air. This migration path would be limited primarily to VOCs in surface soil. 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 I) concluded that the metals detected in surface soil were naturally occurring except for four metals (beryllium, cadmium, nickel, and zinc) in one sample (RNG-203-GP02). These metals results exceeded their ESVs but were below SSSLs. However, none of the detected constituents in surface soil were identified as contaminants of potential ecological concern in surface soil at Range K (see Chapter 7.0). All organic constituents detected in surface soils were below SSSLs. Trichloroethene was detected above its ESV in one surface soil sample. Because of its relatively high vapor pressure, this chemical has a high potential to volatilize to the atmosphere. The explosive compound 1,3,5-trinitrobenzene was detected in one surface soil sample at a concentration that exceeded its ESV. Based on an

estimated Henry's law constant of $3.08 \text{ E-}09$ atmospheres per cubic meter per mole ($\text{atm}\cdot\text{m}^3/\text{mol}$), it is essentially non-volatile (Lyman et al., 1982).

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 Range K. A small ephemeral drainage feature is present approximately 200 feet south-southeast of the parcel boundary and intermittently flows to the southwest towards Cane Creek. Stream flow is only present during periods of considerable precipitation. Surface soil contaminants could be solubilized by rainwater and subsequently transported by surface runoff to the ephemeral drainage feature. 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. The geochemical evaluation concluded that the metals detected in surface soil are naturally occurring except for four metals discussed previously. One SVOC and several pesticides were detected in the surface soil samples collected. These chemicals would be strongly bound to particulate matter and may be entrained in surface water runoff and transported to the ephemeral drainage feature. However, erosion and surface runoff as a transport mechanism, although not precluded, is expected to be insignificant at Range K.

5.2.3 Surface Water and Sediment Transport

Surface water and sediment samples could not be collected from the seasonally intermittent drainage feature south-southeast of Range K, Parcel 203(7). The substrate is mostly cobbles and gravel with small depositional areas of sand and leaf litter. Due to the absence of a surface water body, surface water and sediment fate and transport mechanisms of constituents detected at Range K are not considered. However, depositional soil samples were collected from this intermittent stream (southwest of Range K) as part of the investigation of Parcel 211(7). Two VOCs, acetone and p-cymene, were detected below SSSLs and ESVs in the depositional samples.

5.2.4 Leaching from Surface and Subsurface Soils to Groundwater

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 Range K. In surface soils, 9 VOCs were detected at concentrations below their respective SSSLs; only one VOC (trichloroethene) was detected at a concentration exceeding its ESV. The only SVOC

detected in surface soils was bis(2-ethylhexyl)phthalate, a common field and laboratory contaminant. It was not detected at a concentration exceeding its SSSL or ESV. Three pesticides were detected at concentrations below their respective SSSLs and ESVs. In addition, four explosives were detected in surface soil at concentrations below their respective SSSLs. Of the four explosives detected, one compound (1,3,5-trinitrobenzene) exceeded its ESV (note: ESVs were not available for the other detected explosives). Twenty-three VOCs were detected in subsurface soil samples; however, all results were below SSSLs. The only SVOC detected was bis(2-ethylhexyl)phthalate; all of its detected concentrations were below the SSSL. The pesticide beta-BHC was detected in one sample, also at a concentration below its SSSL.

As discussed above, VOC concentrations in surface and subsurface soils were below SSSLs and ESVs, except for trichloroethene and 1,3,5-trinitrobenzene, which exceeded their respective ESVs in one sample each. The calculated soil organic carbon adsorption coefficient (K_{oc}) values for trichloroethene are indicative of a medium to high mobility. Based on a calculated K_{oc} value of 75.86 mL/g, 1,3,5-trinitrobenzene is expected to exhibit high mobility and can leach into groundwater (Agency for Toxic Substances and Disease Registry [ASTDR], 1995). However, explosive compounds show strong binding toward clay minerals and this can significantly decrease mobility. The presence of VOCs at reduced concentrations may be taken as an indication of either an original limited release of volatiles, or that leaching of contaminants from surface and subsurface soils has occurred. Precipitation percolating through the soil in the unsaturated zone has 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.

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 site appears to have an overall flow direction to the south-southwest in both residuum and bedrock. The horizontal hydraulic gradient in both residuum and bedrock is relatively low, with an approximate 7½-foot head difference across the area investigated. (Table 3-1). Calculations of vertical hydraulic gradients between residuum and bedrock (Table 3-2) are relatively small and suggest that the residuum and bedrock aquifers are in communication. 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 Range K.

5.2.6 Discharge of Groundwater to the Surface

There is no known surface water discharge in the form of springs or wetlands at Range K. 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 Range K could discharge to the ephemeral drainage feature if the potentiometric surface rises above the stream bed during periods of high precipitation. Artesian conditions were noted in wells RNG-203-MW18 and RNG-203-MW20 during heavy precipitation periods. 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. Parameters governing the environmental fate of organic chemicals occurring above SSSLs or ESVs detected at Range K are presented in Table 5-1. The organic constituents are further divided where possible into groups that share similar characteristics.

5.3.1 Chemical and Physical Processes Affecting Fate and Transport

The most important fate and transport process for organic constituents detected at Range K 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 constants, diffusion coefficients, vapor pressures, adsorption/partitioning coefficients, and degradation rates. 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 matrix 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 ($\text{atm}\cdot\text{m}^3/\text{mol}$). 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 ($>10^{-3} \text{ atm}\cdot\text{m}^3/\text{mol}$), significantly (10^{-3} to $10^{-5} \text{ atm}\cdot\text{m}^3/\text{mol}$), or limitedly ($< 10^{-5} \text{ atm}\cdot\text{m}^3/\text{mol}$) tending to volatilize.

5.3.1.3 Diffusion

Diffusion coefficients are 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 surface soils, subsurface soils, and groundwater at Range K, as summarized in Chapter 4.0. None of the 9 VOCs detected in surface soils or 23 VOCs detected in subsurface soils exceeded SSSLs. Trichloroethene exceeded its ESV in one surface soil sample. Twenty-two VOCs were detected in groundwater, of which eleven (excluding methylene chloride which was "B" flagged) exceeded their SSSLs. Table 5-1 presents the physical and chemical parameters governing the environmental fate and transport of the one VOC that exceeded its ESV and the eleven VOCs that exceeded SSSLs. These VOCs are divided into two primary groups of organic constituents: aromatic hydrocarbons and chlorinated aliphatic hydrocarbons.

Aromatic Hydrocarbons. Benzene was the only aromatic hydrocarbon detected above its SSSL at Range K. Aromatic VOCs are not likely to be persistent in soils and may be mobilized to groundwater by infiltration. If released to the soil, they are subject to rapid volatilization near the surface; that portion of a release not volatilized will be mobile to highly mobile and may leach to the groundwater. Benzene has a moderate to high solubility in water and is not expected

to significantly adsorb to soils, bioconcentrate, or hydrolyze. Benzene has fairly low K_{ow} and K_{oc} coefficients, indicating a low affinity for adsorption to organic matter. Slow biodegradation of benzene occurs via microbial processes. Active biological degradation is often indicated by reduced dissolved oxygen and localized reducing conditions. Under anaerobic conditions, slow degradation has been reported.

Chlorinated Aliphatic Hydrocarbons. Chlorinated ethanes and ethenes, and chloroform were detected at concentrations above SSSLs in groundwater at Range K. In addition, the chlorinated ethene trichloroethene exceeded its ESV in one surface soil sample. 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 solubility 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 was likely used at the site, is a solution of RH195 dissolved in 1,1,2,2-tetrachloroethane. Photolysis and hydrolysis are not expected to be significant removal mechanisms.

5.3.2.2 Semivolatile Organic Compounds

Bis(2-ethylhexyl)phthalate was the only SVOC detected in soils at Range K. None of the detections exceeded the SSSL or ESV. Phthalates are commonly associated with field and laboratory contamination and all results were “B” qualified.

In groundwater, two SVOCs (phenanthrene and bis[2-ethylhexyl] phthalate) were detected. Bis(2-ethylhexyl)phthalate exceeded its SSSL in one groundwater sample. However, as noted above, the compound is a common sample contaminant.

Phthalate Esters. Although it is a common sample contaminant, the presence of bis(2-ethylhexyl)phthalate above its SSSL in one 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.

5.3.2.3 Pesticides

Pesticides were detected in both surface and subsurface soils, but at concentrations below SSSLs and ESVs. Six pesticides were detected in groundwater. Two pesticides, heptachlor and beta-BHC, were detected at concentrations above their respective SSSLs in one well (RNG-203-MW15). Both heptachlor and beta-BHC have relatively low solubilities in water. The log K_{oc} value for heptachlor is estimated at 4.40. This value indicates a very high absorption tendency, suggesting it will absorb strongly to soils and is not likely to leach into groundwater (ATSDR, 1993a). Heptachlor is less likely to leach from soil with a high organic matter content. When released into water it adsorbs strongly to suspended material. Fate and transport assumptions for both beta-BHC and heptachlor are likely similar. The presence of the pesticide compounds in groundwater is likely the result of their absorption to suspended particulates. It is noted that the groundwater sample from RNG-203-MW15 was relatively turbid (80 nephelometric turbidity units) at the time of sample collection.

5.3.2.4 Inorganics

Many of the chemical and physical processes governing fate and transport discussed in Section 5.3.1 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 milliliters per gram (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. Site metals data were evaluated using an integrated statistical and geochemical approach (Appendix I). The evaluation concluded that the metals detected in site media are naturally occurring except for four metals (beryllium, cadmium, nickel, and zinc) in one surface soil sample and five metals (beryllium, cadmium, nickel, selenium, and zinc) in a limited number of subsurface soil samples. However, none of these metals were identified as contaminants of concern in the human health and ecological risk assessments presented in Chapters 6.0 and 7.0, respectively, of this report.

5.4 Contaminant Migration

The chemical and physical processes that are involved in the solute transport of contaminants at Range K include advection, dispersion, diffusion, and retardation. The response of these factors to the local hydrogeologic 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 travelling 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 and utilized equations for estimating the migration rate of a chemical in a soil-groundwater system is the retardation equation (Fetter, 1988):

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

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 solute'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:

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

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 site, 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 general absence of VOCs in surface and subsurface soils suggests that significant removal and/or subsequent leaching of organic contaminants to groundwater has occurred. Other than a detection of trichloroethene in one surface soil sample, only reduced concentrations below SSSLs and ESVs remain.

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 the 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.

The groundwater regime for Range K 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 southerly flow direction in both systems. Vertical hydraulic gradients were calculated for seven well clusters in the area of groundwater contamination and are

presented in Table 3-2. Five of the calculations were for flow from residuum to bedrock and two were for flow from bedrock to bedrock. The calculated gradients in general were relatively low and positive, indicating a weak and prevalent downward flow. Of the seven well clusters, only one had an upward (negative) gradient. Isopleth maps were constructed showing total chlorinated VOCs, trichloroethene, and 1,1,2,2-tetrachloroethane concentrations in residuum, bedrock, and residuum/bedrock, as shown on Figures 4-2 through 4-10. Contaminant flow distribution is to the southwest and parallels groundwater flow direction in both residuum and bedrock. Although the source area for the groundwater contamination has not been established, the maximum concentration is centered at RNG-203-MW06 in the residuum and farther downgradient at RNG-203-MW20 in bedrock. Based on the distribution of contaminants and the groundwater flow direction, the initial transport in residuum appears to be from an area at or upgradient of RNG-203-MW06. Although chlorinated VOCs were not detected in the contents of a drum located upgradient near RNG-203-MW01, this area is not precluded as a source.

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. The distribution shown by isopleth and groundwater data would suggest that at some point between RNG-203-MW06 and RNG-203-MW12 downward migration of the contaminant plume to bedrock occurred. Contaminant transport in bedrock would continue to the southwest in the direction of groundwater flow and along the strike of the bedrock. 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 through 5-6 present cross-sectional views of the distribution of total chlorinated VOCs, trichloroethene, and 1,1,2,2-tetrachloroethane in relation to the subsurface geology.

The rate and distance of contaminant migration in groundwater were estimated for both residuum and bedrock. The parameters used and the results are presented in Table 5-3. Solute transport rates for the residuum ranged from 48.8 feet per year (ft/yr) for trichloroethene to 110.2 ft/yr for vinyl chloride. Contaminant velocities in bedrock appear to be high and ranged from 21.1 ft/yr for vinyl chloride to 87.6 ft/yr for trichloroethene. In residuum, the high transport rates and migration distances over a 50-year period would support that contaminants and groundwater flow descended vertically. Assumptions for bulk density, porosity, and percent total organic carbon of the aquifer material are within ranges commonly specified in the literature for the

residuum. However, it is noted that the lithologies for cores from Range K wells are frequently described as black shales and limestones. A black color is generally indicative of a high organic carbon content. Use of a higher percentage organic carbon content than normally assumed for sedimentary rocks and residuum would increase the soil adsorption coefficient (K_d) and retardation coefficient (R_d) and, hence, decrease solute transport velocity (V_c).

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 *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, 2000b). IT (2000b) 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 on Range K were examined for currency before the SRA was performed. For example, the inhalation reference concentration (RfC) for chloroform has been recently updated (EPA, 2003a), and the SSSLs were updated accordingly.

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 was developed as a surrogate for all who may be exposed in a residential setting, and separate SSSLs were not developed for school children, municipal park visitors, 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.

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.

Some parcels are known to be used for military training, particularly by the Alabama National Guard, and this site use is likely to continue in the foreseeable future. The activities performed by military personnel are somewhat unique, incorporating some construction activities (i.e., digging foxholes and building bunkers, with bivouac and camping activities). Since none of the aforementioned receptor scenarios reflect this unique exposure scenario, military personnel were interviewed to obtain exposure information and a special national guardsperson receptor scenario was developed, which is relevant to this site.

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, 2003c). 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.

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
- Summary and conclusions.

The SRA protocol is briefly described below. The results are discussed in Section 6.2.

6.1.1 Conceptual Site Exposure Model

The CSEM identifies sources of contamination and traces their transport from source media to exposure media. It also identifies the plausible and hypothetical receptors and the relevant exposure routes evaluated in the SRA.

The history and physical features of Range K are presented in greater detail in Chapter 1.

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 Range K (Figure 6-1).

Briefly, the opening and decontamination of mortar rounds containing CWM, and the use of various solvents and decontamination fluids may have released CWM, decontamination fluids

and solvents to the surface. These chemicals may have infiltrated to subsurface soil. Chemicals in soil may leach to groundwater and remain in the groundwater beneath the range, or migrate by groundwater flow to downgradient and possibly off site locations. Contaminant sources and their release and transport mechanisms are shown on Figure 6-1.

6.1.1.2 Receptors, Exposure Media, and Exposure Routes

Range K is currently used by the Army for military and bivouac activities. Therefore, the national guardsperson is selected as the most plausible human receptor under the current site-use assumption. The recreational site user, an unauthorized youth with access to the site, must also be considered a plausible receptor under current site-use conditions because the fence that once provided security is in disrepair. The Army is expected to continue to use Range K in the future; therefore, the national guardsperson is the most plausible receptor under the future site-use assumption. It is possible, although unlikely, that the site could be developed for commercial or industrial use, in which case the groundskeeper and construction worker also are evaluated as possible human receptors. The groundskeeper represents the upper-bound on risk for long-term commercial or industrial exposure, and the construction worker represents the upper bound on risk for short-term exposure. 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 Range K.

Human receptors may come into contact with the chemicals in soil and groundwater through the pathways outlined in Figure 6-1 and explained more fully in Table 6-1.

6.1.2 Data Evaluation

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

6.1.2.1 Establish Data Sets

Separate data sets were established for each of the environmental media of interest – surface soil, subsurface soil, total soil and groundwater (see Section 6.1.2.3 for an explanation of total soil).

6.1.2.2 Select Site-Related Chemicals

Subsequent to the updated version of the IWWP, 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, 2003c; see Appendix I). Briefly, the new procedure consists of the following three-tiered process:

- **Tier 1.** The maximum detected concentration (MDC) of the metal is compared with the 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 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 I 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, 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 metals, as well as those that fail the 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.

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. The COPCs, therefore, 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 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 excavation and grading. 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 the site. Therefore, the surface and subsurface soil data sets are not combined in this manner for the total soil evaluation. Instead, 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 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.

6.1.2.4 Estimate Source-Term Concentrations

Ideally, the STC of a given COPC in soil 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. 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 set 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.

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. However, discrete plumes cannot be identified for some chemicals, in which case the MDC is conservatively selected as the STC. This matter is addressed in detail in Section 6.2.1.2.

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 exposure unit (EU) concept is important to developing reasonable risk estimates for exposure to soil. An EU is the area over which a given receptor is expected to be randomly exposed over the course of his exposure duration. For example, it is reasonable to assume that a national guardsperson, recreational site user or groundskeeper may be exposed to a relatively large area in the course of their normal activities. A construction worker, on the other hand, may be exposed to a much smaller area because the area of construction activity may be quite small. Similarly, the on-site resident may be exposed to a small area because a building lot or home site may be quite small.

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 given parcel 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. However, no chemicals were identified as COPCs in either surface or subsurface soil; therefore, the EU concept does not apply to Range K.

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 in the form of a cancer slope factor (SF) or unit risk factor (URF) for estimating cancer risk, and a threshold level called a reference dose (RfD) or reference concentration (RfC) for estimating the hazard of noncancer effects. These 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 toxicity values are incorporated into the SSSLs. They are not developed or presented separately herein; rather, they were located or developed in the IT (2000b) report. However, the toxicity values of all detected chemicals were checked to ensure they were current before the

SRA was initiated. As mentioned above, it was noted that the inhalation RfC for chloroform was recently revised (EPA, 2003a), and the SSSLs were updated accordingly.

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 incremental lifetime cancer risk (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 assumed to be 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. 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 a hazard index (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.

HI values are generally added across all COPCs and media for a given receptor. Adding HI values is probably overly conservative except for COPCs that exert their toxicity by the same mechanism(s) of toxicity. Critical effect or target organ is often used as a surrogate for mechanism of toxicity because adequate mechanistic data are all but nonexistent. Therefore,

refinement of the total HI for a given receptor is often performed by segregating COPCs and estimating HI values for each target organ.

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.

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:

$$ILCR = \frac{STC \cdot TR}{SSSLc} \quad \text{Eq. 6.1}$$

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:

$$HI = \frac{STC \cdot THI}{SSSLnc} \quad \text{Eq. 6.2}$$

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).

6.1.5.2 Protocol and Policy: Lead

Lead was not identified as a site-related chemical in any media relevant to Range K. Therefore, the protocol and policy for evaluating lead is not discussed herein.

6.1.6 Uncertainty Evaluation

This section discusses some of the more significant uncertainties inherent in risk assessment in general. Sources of uncertainty unique to Range K are addressed in Section 6.2.4.

Uncertainty is a factor in each step of an 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 uncertainties is fundamental to the understanding and reasonable use of risk assessment results.

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 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, investigation of Range K has undergone several iterations, including additional sampling. VOCs in groundwater were found to be the risk drivers, and sufficient data were obtained to discern some of the plumes and trends in groundwater concentrations of these compounds. Overall, uncertainty about the adequacy of the sampling program is considered to be minimal for Range K.

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). 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. Uncertainty arises by eliminating background metals from further evaluation in the quantitative risk assessment. These metals are addressed in the uncertainty discussion specific to Range K in Section 6.2.4

6.2 Results

6.2.1 Data Sets

The surface and subsurface soil data sets each consist of 13 samples taken from 13 co-located sample points across Range K proper and downgradient of the site (Tables 6-2 and 6-3). All samples were analyzed for metals, nitroaromatic compounds, SVOCs, and VOCs, and nine samples were analyzed for CWM breakdown products, organochlorine pesticides and PCBs, chlorinated herbicides, orthosulfur compounds (sulfur mustard derivatives), and organophosphate pesticides.

The groundwater data set consists of 74 samples taken from 25 monitoring wells (MW) on and downgradient (south) of Range K (Table 6-4). Eighteen samples were analyzed for metals, nitroaromatic compounds and SVOCs, and 14 samples were analyzed for CWM breakdown products, chlorinated herbicides, organophosphate pesticides, organochlorine pesticides and PCBs, and nitrate/nitrite. All samples were analyzed for VOCs, which are known to be the risk-drivers for the site and have been shown to have migrated several hundred feet downgradient from the site proper.

6.2.2 Chemicals of Potential Concern

Chemicals detected in Range K soil include metals, nitroaromatic compounds, organochlorine pesticides, and VOCs (Tables 6-5 and 6-6). Site-related metals in surface soil include beryllium, cadmium, nickel, and zinc (Table 6-5). Site-related metals in subsurface soil include beryllium, cadmium, nickel, selenium, and zinc (Table 6-6). No explanation is apparent for the occurrence of these metals as site-related because none are associated with CWM. All the organic chemicals were selected as site-related.

All concentrations of site-related chemicals were sufficiently low that none were selected as COPCs in surface soil (Table 6-7) or subsurface soil (Table 6-8). Consequently, a data set was not developed for total soil.

Chemicals detected in groundwater include metals, several organochlorine pesticides, nitroaromatic compounds, two orthosulfur compounds, two SVOCs, and several VOCs (Table 6-9). All of the metals were determined to be present at concentrations comparable to background. The VOCs include several petroleum-related hydrocarbons, most of which were limited to the September 2003 sample collected from RNG-203-MW22 (Appendix G). The other VOCs are various chlorinated solvent residues (Table 6-9), which were somewhat more widespread in geographic distribution.

COPCs in groundwater include two organochlorine pesticides, one nitroaromatic compound, one orthosulfur compound, one SVOC, and several VOCs (Table 6-10). SVOCs are limited to a single J-qualified detection of bis(2-ethylhexyl)phthalate, a.k.a. di(2-ethylhexyl)phthalate (DEHP). DEHP is a constituent of plastics (Hazardous Substance Data Bank [HSDB], 2004) that commonly leaches into water from laboratory plasticware to appear as a contaminant in groundwater samples. In other words, it is likely that DEHP gained access to the water during laboratory processing after the point that its presence would have been reflected in the sample blanks. Nonetheless, DEHP is conservatively selected as a COPC and included in the quantitative risk estimates of the SRA.

The MDCs were selected as the STCs for the organochlorine pesticides, nitroaromatic compound, orthosulfur compound, and DEHP because no discernable plumes were apparent for these COPCs (Table 6-10). The petroleum-related VOCs were present at concentrations sufficiently low that they were not selected as COPCs. The chlorinated solvent data sets reflect many samples from 25 wells taken from June 2000 to October 2003. The data are sufficient to identify plumes, and to observe time/concentration trends (Table 6-11), which permit estimation of more reasonable STCs for these chemicals. Only those chlorinated solvent residues identified as COPCs in Table 6-10 were subjected to the plume and trend evaluation in Table 6-11.

Table 6-11 presents concentrations of the 10 chlorinated VOCs selected as COPCs in Table 6-10. The concentrations are presented for each MW and each sample date for which data were reported. Rejected data, such as those carrying “R” or “B” validation qualifiers are not included. The data for each COPC are arranged by well location in the left hand column, and by sampling date across the page. The wells are arranged in ascending numerical order, which roughly approximates their north-to-south orientation (Figure 2-1). The exception is MW01, which is south of MW04 and north of MW06. The sample dates are arranged from oldest to most recent. The values presented are detected concentrations (mg/L) unless the value is followed by a “U” qualifier, in which case the sample returned nondetect and the value presented is the MDL, to

provide greater perspective for discerning trends. The residential cancer and noncancer SSSLs are presented below each chemical name to provide additional perspective.

The following observations regarding the chlorinated VOCs can be made from Table 6-11:

- Generally, chlorinated VOC concentrations in MW01, MW02 and MW04, the northernmost wells, are holding steady or decreasing slightly.
- Chlorinated VOC concentrations in MW06, approximately 200 feet south of MW01, generally appear to be holding steady or increasing slightly.
- Chlorinated VOC concentrations in MW13 appear to have peaked in 2002 but fallen in 2003.
- Chlorinated VOC concentrations in MW18, MW20 and MW21 appear to have decreased or increased slightly; however, data are available only from one sampling event in 2002 and one sampling event in 2003, which limits the ability to discern trends with confidence.
- Concentrations in MW22 and MW24 do not appear to be as high as in the more northerly wells, although data are available only from one sampling event in 2003. Trends at these most southerly locations cannot be established.
- Although the data are limited, it appears that concentrations are greater in bedrock wells compared with residuum wells, particularly at the southern extent of the plume (compare data from MW22 [residuum well] with MW20 [bedrock well]).

The most complete sampling and analysis for chlorinated VOCs was performed in the latter half of 2003 (i.e., more monitoring wells were sampled at this time than at any previous sampling event). STCs for these compounds were estimated only from the results from the latest sampling and analytical event. This ensures that only the most recent data, which more accurately reflect current site conditions and the potential for exposure, were used for STC estimation. STC estimation is discussed below for each chlorinated VOC.

1,1,2,2-Tetrachloroethane (1,1,2,2-TCA). The most concentrated part of the plume currently appears to fall in the area of MW18 and MW20 (Table 6-11). The concentrations measured from these wells, 1.70E-1 and 3.10E-1 mg/L, respectively, are little changed from those measured in the previous year. The average, 2.4E-1 mg/L, is estimated as the STC.

1,1,2-Trichloroethane (1,1,2-TCA). It is difficult to discern a plume for this chemical (Table 6-11). However, concentrations in all wells except MW06 and possibly MW20 appear to be

decreasing. Given the uncertainty regarding the migration of this chemical, it seems prudent to adopt the highest concentration measured from the last sampling round, 6.00E-3 mg/L in MW06, as the STC.

1,1-Dichloroethene (1,1-DCE). It is difficult to discern a plume for this chemical (Table 6-11). Concentrations in all wells except MW06 appear to be decreasing. Given the uncertainty regarding the migration of this chemical, it seems prudent to adopt the highest concentration measured from the last sampling round, 2.70E-4 mg/L in MW06, as the STC.

1,2-Dichloroethane (1,2-DCA). It is difficult to discern a plume for this chemical (Table 6-11). Concentrations in all wells except MW20 and possibly MW01 appear to be decreasing. Given the uncertainty regarding the migration of this chemical, it seems prudent to adopt the highest concentration measured from the last sampling round, 4.30E-4 mg/L in MW20, as the STC.

Chloroform. The most concentrated part of the plume currently appears to fall in a fairly large area involving MW18, MW20 and MW21 (Table 6-11). Concentrations in wells MW18 and MW20 appear to be decreasing; concentrations in MW21 may be increasing. The average from the latest sampling round from these 3 MWs, 1.07E-2 mg/L, is estimated at the STC.

cis-1,2-Dichloroethene (cis-DCE). The cis-DCE plume appears to be large, but highest concentrations are in the area of MW01 and MW06 (Table 6-11). Concentrations in MW01 appear to be dropping slowly, but concentrations in MW06 appear to be increasing slowly. Concentrations further south at MW18 and MW20 appear to be decreasing. An STC of 7.25E-2 mg/L is estimated as the average of the concentrations from the latest sampling round from MW01 and MW06.

Tetrachloroethene (perchloroethene; PERC). The PERC plume appears to be large, with concentrations decreasing at MW01, generally holding steady at MW04, increasing at MW06, and decreasing slightly at MW18 and MW20 (Table 6-11). It seems prudent to adopt the highest concentration at MW06, 4.00E-3 mg/L, as the STC for this chemical.

trans-1,2-Dichloroethene (trans-DCE). The most concentrated part of the plume appears to involve the area of MW01 and MW06 (Table 6-11). Concentrations in MW01 have been slowly but steadily decreasing but concentrations in MW06 have been slowly but steadily increasing. Concentrations at MW18 and MW20 further to the south are lower and appear to be decreasing.

It seems prudent to average the most recent results from MW01 (3.20E-2 mg/L) and MW06 (1.00E-2 mg/L) to estimate the STC of 2.10E-2 mg/L.

Trichloroethene (TCE). More data are available for TCE than any other VOC.

Concentrations in the northern wells (MW01, MW02, and MW04) are relatively low, generally holding steady or decreasing (Table 6-11). Highest concentrations are in MW06, which appears to be holding steady, and in MW18 and MW20, which appear to be decreasing. It seems prudent to average the most recent results from MW06 (1.10E-1 mg/L), MW18 (2.90E-1 mg/L) and MW20 (3.00E-1 mg/L) to estimate the STC of 2.33E-1 mg/L.

Vinyl Chloride (VC). It is difficult to discern a plume for this chemical (Table 6-11). Highest concentrations appear in MW01 and MW04. Concentrations in MW01 and MW04 appear to be decreasing slowly but sporadically. Concentrations in MW06 appear to be slowly increasing. Given the uncertainty about the migration of this chemical, it seems prudent to adopt 3.70E-3 mg/L, the highest concentration from the latest sampling round, as the STC.

6.2.3 Risk Characterization

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 6-12. As noted above, no chemicals were identified as COPCs in surface or subsurface soil. Therefore, ILCR and HI values compiled in Table 6-12 are limited to those associated with groundwater. Documentation is provided in the form of receptor- and medium-specific tables that detail the hazard from exposure to each COPC. The numerical results and their interpretation are discussed by receptor and site-use scenario.

National Guardsperson - Current Site Use. The national guardsperson is evaluated as the most likely receptor under the current site use scenario because the site is currently used for military exercises. The national guardsperson is assumed to be exposed to total soil. COPCs were not identified in surface or subsurface soil; therefore, it is concluded that exposure to Range K does not pose an unacceptable cancer risk and is unlikely to induce adverse noncancer health effects for the current national guardsperson.

National Guardsperson - Future Site Use. The national guardsperson is evaluated as the most likely receptor under the future site use scenario because the current site use is expected to continue into the future. The national guardsperson in the future is assumed to be exposed to total soil, and also to groundwater developed as a potable source. COPCs were not identified in

surface or subsurface soil. The total HI from exposure to COPCs in groundwater of $2.48E-1$ (Tables 6-12 and 6-13) is below the threshold level of 1. The total ILCR from exposure to groundwater of $1.81E-4$ (Table 6-12), largely from 1,1,2,2-TCA, with small but significant contributions from 1,1,2-TCA, TCE, and VC (Table 6-13) exceeds the EPA risk management range. It should be noted that STCs of 1,1,2-TCA, TCE, and VC exceed their respective EPA (2002c) maximum contaminant levels (MCL) (Table 6-10). No MCL is available for 1,1,2,2-TCA. It is concluded that exposure to groundwater is unlikely to induce adverse noncancer health effects, but does pose an unacceptable cancer risk for the future national guardsperson.

Recreational Site User - Current Site Use. The recreational site user is evaluated as a potential receptor under the current site use scenario because the fence around the parcel is broken down and access is not restricted. The recreational site user is assumed to be exposed to surface soil. As noted above, COPCs were not identified in surface soil; therefore, ILCR and HI values were not estimated (Table 6-12). It is concluded that exposure to Range K 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 very similar to the current site-use scenario, except that he is assumed to be exposed to total soil instead of surface soil, assuming that some development of the site may have occurred. As noted above, COPCs were not identified in surface or subsurface soil; therefore, ILCR and HI values were not estimated (Table 6-12). It is concluded that exposure to Range K 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 Range K is not currently maintained. 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 HI summed across COPCs in groundwater of $5.04E-1$ (Tables 6-12 and 6-14) falls below the threshold level of 1. The total ILCR from exposure to groundwater of $1.99E-4$ (Table 6-12), largely from 1,1,2,2-TCA, with small but significant contributions from beta-BHC, 1,1,2-TCA, TCE, and VC (Table 6-14) exceeds the EPA risk management range. As noted above, STCs of 1,1,2-TCA, TCE and VC exceed their respective MCLs. No MCLs are available for beta-BHC or 1,1,2,2-TCA. It is concluded that exposure to groundwater is unlikely to induce adverse noncancer health effects, but does pose an unacceptable cancer risk for the future groundskeeper.

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 HI summed across all COPCs in groundwater of $5.04E-1$ (Tables 6-12 and 6-15) falls below the threshold level of 1. The total ILCR from exposure to groundwater of $7.45E-6$ (Tables 6-12 and 6-15) falls below the EPA risk management range. It is concluded that exposure to Range K is unlikely to induce adverse noncancer health effects or pose an unacceptable cancer risk for the future construction worker.

On-Site Resident - Future Site Use. The on-site resident is assumed to be exposed to total soil and groundwater developed as a potable source. The total HI summed across COPCs in groundwater of $4.09E+0$ (Table 6-12), due largely to TCE but with significant contributions from nitrobenzene, 1,4-oxathiane, 1,1,2,2-TCA and cis-1,2-DCE (Table 6-16), exceeds the threshold level of 1. The total ILCR from exposure to groundwater of $1.34E-3$ (Table 6-12), largely from 1,1,2,2-TCA but with significant contributions from beta-BHC, heptachlor, DEHP, 1,1,2-TCA, 1,1-DCE, benzene, PERC, TCE, and VC (Table 6-16) exceeds the EPA risk management range. STCs of DEHP, 1,1,2-TCA, cis-1,2-DCE, TCE, and VC exceed their MCLs. MCLs are unavailable for beta-BHC, nitrobenzene, 1,4-oxathiane, and 1,1,2,2-TCA.

The total HI of $4.09E+0$ was segregated by target organ (Table 6-17). The liver and kidney have total HI values exceeding the threshold of 1. It is concluded that exposure to COPCs in groundwater poses an unacceptable cancer risk and raises concern for adverse noncancer health effects for the future on-site resident.

6.2.4 Uncertainty Analysis

Generic sources of uncertainty that may affect the numerical results of the SRA and their interpretation were discussed in Section 6.1.6.

Probably the most important source of uncertainty regarding Range K pertains to the exclusion of background metals from the quantitative risk assessment. This matter is discussed only in regards to risk for the national guardsperson, the most plausible receptor for the site. 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 6-5 and 6-6). Metals for which cancer risk might be an issue for the national guardsperson are limited to arsenic and chromium. ILCR values of $1.15E-5$ and $9.17E-6$ could

be estimated for the national guardsperson from the MDCs of arsenic and chromium, respectively, in soil. Arsenic is the only metal for which an association with CWM is reasonable, since it is a constituent of Lewisite (Opresko et al., 1998). The potential that arsenic in soil may be present as a result of site activity remains a source of uncertainty that could impart a small non-conservative bias to the results of the SRA.

Aluminum is the only metal in soil with an MDC that exceeds its noncancer-based SSSL for the national guardsperson. However, the exceedance was less than a factor of 10, indicating that an HI calculated for aluminum would fall below the threshold level of 1. Therefore, the exclusion of aluminum as a COPC in soil is judged to contribute minimal uncertainty to the SRA.

Groundwater. Several metals in groundwater were excluded from COPC selection based on their Tier 2 or Tier 3 analysis (Table 6-9). Metals for which cancer risk might be an issue for the national guardsperson are limited to arsenic, for which an ILCR of 2.42E-4 can be estimated. The potential that arsenic in groundwater may be present as a result of site activity remains a source of uncertainty that could impart a significant non-conservative bias to the results of the SRA.

Several metals in groundwater with MDCs that exceed their noncancer SSSLs for the national guardsperson were excluded at the Tier 2 or Tier 3 stage, including arsenic, cadmium, iron, and manganese (Table 6-9). However, the exceedance was less than a factor of 10 for cadmium, iron, and manganese, indicating that an HI calculated for these metals would fall below the threshold level of 1. Therefore, the exclusion of these metals as COPCs in groundwater is judged to contribute minimal uncertainty to the SRA. An HI of 1.40E+0, which would be equivalent to the threshold level of 1 when rounded to one significant figure, can be calculated for arsenic. However, if arsenic had been erroneously selected as a background chemical in both soil and groundwater, the HI would exceed the threshold level of 1, raising concern for adverse noncancer health effects.

In summary, the potential for erroneously excluding background metals from COPC selection is judged to impart no significant uncertainty to the results of the SRA with the exception of arsenic, which is the only excluded metal with a rational association with CWM.

Another significant source of uncertainty is the manner in which STCs were estimated for the chlorinated VOCs in groundwater. The most significant risk drivers in groundwater were 1,1,2,2-TCA, TCE, and VC, as indicated by the evaluation for the on-site resident, the most

highly exposed potential receptor. In other words, cancer risk and noncancer hazard estimates would fall within acceptable ranges were it not for these three chemicals. The STCs for 1,1,2,2-TCA and TCE were based largely on data from MW18 and MW20. The STC for VC was based largely on data from MW01 and MW04. It is noteworthy that VC was not detected in two samples from MW18 and MW20. 1,1,2,2-TCA and TCE, however, were detected in MW01 and/or MW04, but at concentrations substantially below their STCs. Therefore, it is likely that the STCs overstate the potential for simultaneous exposure to these three chemicals, which imparts a conservative bias to the risk assessment.

A minor source of uncertainty pertains to the detection of DEHP in groundwater. Although its presence most likely reflects laboratory contamination, it was included as a COPC and carried through the quantitative assessment. Its contribution to risk, however, was low.

6.2.5 Conclusions

Range K is expected to be used for continued military training for which the national guardsperson is the most relevant exposure scenario. The recreational site user was included because there is no effective security to preclude unauthorized entrance to the site. The groundskeeper, construction worker, and resident were included in the evaluation in the unlikely event that the site could be developed for other purposes in the future. The national guardsperson is assumed to be exposed to total soil under the current site-use scenario, and also to groundwater developed as a potable source – a very unlikely possibility – under the future site-use scenario. The recreational site user is assumed to be exposed to surface soil under the current site-use assumption and to total soil under the future site-use assumption. The groundskeeper is assumed to be exposed to total soil and to groundwater developed as a potable source under the future site-use scenario. The construction worker and on-site resident are assumed to be exposed to total soil and groundwater developed as a potable source under the future site-use scenario.

Soils at Range K are lightly contaminated with metals, organochlorine pesticides, nitroaromatic compounds and VOCs, but concentrations were sufficiently low so that no chemicals were selected as COPCs. Groundwater, however, was more heavily contaminated with organochlorine pesticides, nitroaromatic explosives, orthosulfur compounds, SVOCs, and VOCs. Two classes of VOCs were identified: petroleum-related hydrocarbons and chlorinated solvents. The petroleum-related hydrocarbons were present at relatively low levels. COPCs in groundwater include low levels of two organochlorine pesticides, a nitroaromatic compound, DEHP (probably as a laboratory contaminant), and several VOCs largely limited to chlorinated

solvents. STCs for the chlorinated solvents were generally estimated as the average concentration of the most contaminated part of the groundwater plume. Risk drivers were limited to the chlorinated solvents 1,1,2,2-TCA, TCE, and VC.

The risk assessment for the national guardsperson and recreational site user under the current site-use scenario and for the recreational site user under the future site-use scenario fell within acceptable limits because exposure for these receptors is limited to soil. The risk assessment for the national guardsperson under the future site-use scenario failed because the cancer risk associated with groundwater developed for potable use exceeds the EPA risk-management range. Similarly, the risk assessment for the groundskeeper and on-site resident failed because the cancer risk associated with groundwater developed for potable use exceeds the EPA risk-management range. In addition, groundwater COPCs contributed to an HI that exceeded the threshold level of 1 for the resident. The risk assessment for the construction worker passed because exposure to groundwater was sufficiently short term that the cancer risk did not exceed the risk-management range. The results of the risk assessment are summarized below.

Risk Summary by Receptor^a			
Risk or Hazard Consideration	Surface Soil	Subsurface Soil	Groundwater
<i>National Guardsperson, Current Site Use</i>			
Cancer risk ^b	Acceptable	Acceptable	NE
Noncancer hazard ^c	Acceptable	Acceptable	NE
<i>National Guardsperson, Future Site Use</i>			
Cancer risk ^b	Acceptable	Acceptable	1,1,2,2-TCA, (1,1,2-TCA, TCE, VC)
Noncancer hazard ^c	Acceptable	Acceptable	Acceptable
<i>Recreational Site User, Current Site Use</i>			
Cancer risk ^b	Acceptable	NE	NE
Noncancer hazard ^c	Acceptable	NE	NE
<i>Recreational Site User, Future Site Use</i>			
Cancer risk ^b	Acceptable	Acceptable	NE
Noncancer hazard ^c	Acceptable	Acceptable	NE
<i>Groundskeeper, Future Site Use</i>			
Cancer risk ^b	Acceptable	Acceptable	1,1,2,2-TCA, (beta-BHC, 1,1,2-TCA, TCE, VC)
Noncancer hazard ^c	Acceptable	Acceptable	Acceptable
<i>Construction Worker, Future Site Use</i>			
Cancer risk ^b	Acceptable	Acceptable	Acceptable
Noncancer hazard ^c	Acceptable	Acceptable	Acceptable
<i>On-Site Resident, Future Site Use</i>			
Cancer risk ^b	Acceptable	Acceptable	1,1,2,2-TCA, TCE, VC, (beta-BHC, heptachlor, DEHP, 1,1,2-TCA, 1,1-DCE, benzene, PERC)

Risk Summary by Receptor ^a			
Risk or Hazard Consideration	Surface Soil	Subsurface Soil	Groundwater
Noncancer hazard ^c	Acceptable	Acceptable	TCE, (nitrobenzene, 1,4-oxathiane, 1,1,2,2-TCA, cis-1,2-DCE)
^a Cancer risk and noncancer hazard are presented as "acceptable" (see footnotes b and c), or the chemicals of concern (COC) for unacceptable results are listed. Risk-drivers are in bold type , lesser COCs are in parentheses. ^b Cancer risk is termed "acceptable" if the total ILCR summed across all relevant media rounded to one significant figure does not exceed 1E-4. ^c Noncancer hazard is termed "acceptable" if the total HI for all target organs rounded to one significant figure does not exceed the threshold level of 1. NE = Receptor not exposed to this medium.			

The foregoing identifies 1,1,2,2-TCA, TCE, and VC as risk drivers for groundwater at Range K. The STCs of TCE and VC exceed their MCLs; no MCL exists for 1,1,2,2-TCA. The STCs of 1,1,2-TCA, identified as a COC for the national guardsperson, groundskeeper, and resident, and DEHP, identified as a COC for the resident, also exceed their MCLs. A preliminary cleanup level can be estimated for 1,1,2,2-TCA by setting the STCs of the other COCs equal to their MCLs and back-calculating a 1,1,2,2-TCA concentration that yields a total ILCR (rounded to one significant figure) that does not exceed 1E-4. This is accomplished in Table 6-18, which estimates a preliminary cleanup level for 1,1,2,2-TCA of 1.55E-2 mg/L.

In summary, Range K in its current condition poses no unacceptable health risk to any of the receptor scenarios described above unless the groundwater is developed as a potable source. Exposure to groundwater developed as a potable source would pose an unacceptable cancer risk to the national guardsperson, groundskeeper, and resident, and would pose a noncancer hazard to the resident.