U.S. Environmental Protection Agency
Region V
Waste Management Division

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FINAL REPORT
HUMAN HEALTH RISK ASSESSMENT
NEW BRIGHTON/ARDEN HILLS
SUPERFUND SITE INCLUDING
TWIN CITIES ARMY AMMUNITION PLANT
RAMSEY COUNTY, MINNESOTA
VOLUME I

WORK ASSIGNMENT NO. 04-5140
ARCS CONTRACT NO. 68-W8-0084

APRIL, 1991

ARCS V

Remedial Planning Activities at
Selected Uncontrolled
Hazardous Waste Sites – Region V

prc
PRC Environmental Management, Inc.

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PRC Environmental Management, Inc.

EXECUTIVE SUMMARY

PRC Environmental Management, Inc. (PRC) received Work Assignment 04-5P40 under U.S. Environmental Protection Agency (U.S. EPA) ARCS Contract No. 68-W8-0084 to perform a risk assessment of the New Brighton/Arden Hills Superfund site, including Twin Cities Army Ammunition Plant (TCAAP). This human health risk assessment report (Risk Assessment) assesses risks to human health posed by the New Brighton/Arden Hills Superfund site in Ramsey, Anoka, and Hennepin Counties, Minnesota. The site consists of TCAAP and any other areas contaminated by migration of hazardous substances from TCAAP. Off-TCAAP areas include parts of seven cities: New Brighton, St. Anthony, Arden Hills, Shoreview, Mounds View, Columbia Heights, and Minneapolis.

BACKGROUND

The U.S. Army owns the TCAAP facility, and Federal Cartridge Company (FCC) has operated the facility during most of its existence. TCAAP has been used to manufacture, store, and test small arms ammunition and related materials since 1941. Other TCAAP activities include those of tenants residing at the facility. Information from past studies indicates that between 1941 and 1981, waste material was disposed of at 14 source areas within TCAAP. The U.S. EPA and the Minnesota Pollution Control Agency (MPCA) have determined that hazardous substances, pollutants, and contaminants from the site have been released into the environment. As a result of these releases, the New Brighton/Arden Hills Superfund site has been ranked No. 43 on the National Priorities List (NPL).

Section 104(i)(6) of the Comprehensive Environmental Response, Compensation & Liability Act (CERCLA) requires the Agency for Toxic Substances and Disease Registry (ATSDR) to conduct health assessments for every site included or proposed for inclusion on the NPL. The ATSDR health assessment is generally qualitative, whereas a human health risk assessment, the subject of this report, is generally quantitative.

ATSDR conducted a health assessment at the New Brighton/Arden Hills site and summarized its findings in a report entitled Preliminary Health Assessment for the New Brighton/Arden Hills NPL site (ATSDR, 1989). ATSDR concluded that the New Brighton/Arden Hills site is a potential health concern because of the risk to human health from possible exposure to hazardous substances; ingestion of and direct contact with on- and off-TCAAP ground water and off-TCAAP surface water and sediment were identified as exposure pathways of concern.

Section 300.68 of the National Contingency Plan provides that a remedial investigation (RI) and feasibility study (FS) be performed for hazardous waste sites that may require cleanup. Argonne National Laboratory (ANL), a contractor to the U.S. Army, prepared an RI report on contaminated areas within the boundaries of TCAAP (ANL, 1990). Concurrently, Camp, Dresser, and McKee, Inc. (CDM), a contractor to MPCA, prepared an RI report on regional ground-water contamination (off-TCAAP areas) to determine the extent of contaminant migration from TCAAP (CDM, 1991).

This risk assessment is a link between the RI reports and the upcoming FS. The risk assessment is based primarily on data presented in the two RI reports and was prepared following the most recent U.S. EPA guidance for conducting risk assessments (1989a). The objective of this risk assessment is to determine the magnitude and probability of actual and potential harm to public health and welfare posed by actual or threatened releases of hazardous substances from TCAAP. The risk assessment will be used to guide selection and evaluation of remedial alternatives during the FS.

This risk assessment addresses potential risks to human health based on current and future exposures to hazardous substances. Because various remedial actions have already taken place within the New Brighton/Arden Hills site, risks are evaluated taking into account all remedial actions having taken place or in existence as of January 1991.

In addition to current and future exposures, human receptors may have received exposures both on- and off-TCAAP in the past, before any remedial actions had taken place. In accordance with U.S. EPA guidelines (1989a), this risk assessment does not address the magnitude or probability of risks to human health associated with past exposures. Nonetheless, such risks should be considered in addition to current and future risks when evaluating the total impact on human health of actual or threatened releases of hazardous substances from TCAAP.

This risk assessment is presented in six chapters. The purpose of each chapter is described below:

- Chapter 1 provides a historical summary and describes the TCAAP facility.
- Chapter 2 describes the selection of chemicals of potential concern evaluated in the risk assessment.
- Chapter 3 characterizes the exposure setting both on- and off-TCAAP, discusses the fate and transport of chemicals of potential concern, identifies exposure pathways, and calculates exposures for chemicals of potential concern via each exposure pathway.

- Chapter 4 evaluates the toxicological properties of each chemical of potential concern and presents and discusses applicable standards and guidelines developed to protect human health and the environment for each chemical of potential concern.
- Chapter 5 characterizes potential risks to humans from exposure to chemicals of potential concern via each identified exposure pathway.
- Chapter 6 presents the general conclusions of the risk assessment.

The entire report has been reviewed by U.S. EPA, MPCA, and other responsible parties to confirm its compliance with requirements of federal and state laws, rules, regulations, guidance, and policy regarding preparation of risk assessments.

CHEMICALS OF POTENTIAL CONCERN

Hazardous substances have been measured in five media (ground water, surface water, sediment, surface soil, and subsurface soil) on- and off-TCAAP. Sampling data used in this risk assessment were obtained primarily from two sources: (1) the on-TCAAP RI report (ANL, 1990) and (2) the off-TCAAP RI (CDM, 1991). These data were evaluated according to U.S. EPA procedures (1989a) to identify the chemicals of potential concern for this risk assessment. Chemicals of potential concern were identified based on an evaluation of the data showing medium-specific arithmetic mean sample concentrations to be statistically greater than medium-specific background concentrations. Medium- and location-specific chemicals of potential concern identified are presented in Appendix B. In total, 54 chemicals are identified as chemicals of potential concern. The most widespread of these chemicals are the following:

- Heavy metals, including antimony, cadmium, chromium, nickel, and silver
- Volatile halogenated organic chemicals, including chloroform, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethene, 1,1,1-trichloroethane, and trichloroethene
- A semivolatile organic chemical, bis(2-ethylhexyl)phthalate

In addition, two gross radioactive parameters, gross alpha and gross beta, are identified as being of potential concern.

EXPOSURE ASSESSMENT

In Chapter 3, exposure to chemicals of potential concern is evaluated under two sets of land use conditions: (1) current and probable future condition under which the U.S. Army owns TCAAP and access to TCAAP is restricted and (2) reasonable maximum exposure (RME) future

land use conditions under which the U.S. Army no longer owns TCAAP and the associated land is developed as mixed residential and commercial property.

The assumption of mixed residential and commercial development on-TCAAP under RME future land use conditions was agreed to by U.S. EPA, MPCA, the U.S. Army, and TCAAP lessee representatives. Assumption of mixed residential and commercial development requires description of the environmental condition in terms of an upper-bound estimate of potential exposures and risks to human health on-TCAAP in the future. The U.S. Army has noted that, although it is reasonable to assume that future on-TCAAP land use will reflect development similar to that of surrounding areas, some restrictions may be placed on the location and extent of future development. The U.S. Army requires that an Environmental Baseline Study (EBS) of Army-owned property be performed before any real estate property transaction takes place. The EBS describes the environmental condition of the property.

Exposure pathways are developed based on evaluation of the physical setting on- and off-TCAAP, fate and transport of chemicals of potential concern, and observed or assumed activity patterns of existing or future populations. Exposure pathways combine four elements: (1) an exposure medium, (2) an exposure point, (3) an exposed population (receptors), and (4) an exposure route. Exposure pathways evaluated under current land use conditions are summarized in Table ES-1; and exposure pathways evaluated under RME future land use conditions are summarized in Table ES-2.

Of the four exposure pathway elements described in Tables ES-1 and ES-2, exposure medium, exposed population, (receptors), and exposure route are more or less self-explanatory in the context of the tables. However, the fourth exposure pathway element, exposure point, requires some clarification.

An exposure point is a location where people are exposed to a chemical or chemicals in a particular medium or media. For the purposes of this risk assessment, the definition and location of exposure points vary depending on the medium of concern. Exposure points are summarized below for each exposure medium:

TABLE ES-1

CURRENT LAND USE CONDITIONS
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
POTENTIAL PATHWAYS ON-TCAAP				
Ground Water	On-TCAAP drinking water supply	On-TCAAP employees and residents	Ingestion, inhalation of volatiles while showering, and dermal absorption while bathing	No. On-TCAAP ground water is passed through air strippers and a carbon filter prior to use as a potable water supply. According to the U.S. Army, treated water meets the Minnesota Department of Health (MDH) Standards for drinking water (MDH, 1989, U.S. Dept. of the Army, 1991).
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal absorption and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment such as gloves and masks, if necessary, and monitoring equipment.
Surface Soil	On-TCAAP exposure areas	On-TCAAP maintenance workers	Incidental ingestion, inhalation of fugitive dusts, and dermal absorption	Yes. However, exposure in parts or all of individual exposure areas may be limited or nonexistent because of thick vegetation, clay caps, or fill material that prevents contact with underlying soil. In fact, generation of and exposure to fugitive dusts at the 14 exposure areas for which soil data are available are expected to be minimal and are not evaluated under current land use.
Subsurface Soil	On-TCAAP exposure areas	Construction workers	Incidental ingestion, dermal absorption, and inhalation of fugitive dusts	Yes. Construction work such as foundation excavation or sewer or underground pipeline repair work within on-TCAAP exposure areas may occur. See exposure and risk discussions pertaining to construction activities under RME future land use (Table ES-2).
Air	Major on-TCAAP work stations (offices and manufacturing areas) and Army housing	On-TCAAP employees and residents	Inhalation of volatile organics	Yes.
Surface Water and Sediment	Rice Creek (on-TCAAP portion), Sunfish Lake, Marsden Lake, and miscellaneous small areas of collected surface water	On-TCAAP maintenance workers and Minnesota Department of Natural Resources (MDNR) staff working within the Sunfish Lake fishery	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. However, exposure is assumed to be very infrequent.
Surface Water	Rice Creek (on-TCAAP portion) and Sunfish Lake	On-TCAAP workers	Ingestion of fish	No. Sunfish Lake is used to raise hatchlings but cannot support a standing population; workers are assumed to not fish in the on-TCAAP portion of Rice Creek. Exposure to hatchlings raised in Sunfish Lake and used to stock other lakes is not evaluated because exposure concentrations in grown fish are expected to be small (see discussion in Section 3.3.4.2.1).

TABLE ES-1 (Continued)

CURRENT LAND USE CONDITIONS
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
POTENTIAL PATHWAYS OFF-TCAAP				
Ground Water	Private wells located downgradient of TCAAP within the ground-water contamination plume extending southwest of TCAAP; and private wells located north of TCAAP opposite Source Area A	Local residents	Ingestion, inhalation of volatiles while showering, and dermal contact while bathing	Yes. The number of existing private drinking water wells is small. Most off-TCAAP residents receive their drinking water from municipal sources. However, if the currently functioning granular activated carbon (GAC) treatment systems fail, residents could be exposed to contaminated ground water until the failure is detected. Private wells located immediately north of Source Area A in Shoreview and others in the vicinity of Round Lake are used for drinking water. In addition, private drinking water wells may exist in other off-TCAAP cities. For example, New Brighton has no specific ordinance that prohibits installation and use of private drinking water wells.
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal absorption and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment, such as gloves and masks, if necessary, and monitor equipment.
Surface Soil	Off-TCAAP residential and commercial/industrial areas	Local residents and employees	Individual ingestion, inhalation of fugitive dusts, and dermal absorption	Unknown. Information on the quality of off-TCAAP surface soil is not available. Potential off-TCAAP exposure to contaminated surface soil originating on-TCAAP cannot be accurately quantified but is insignificant relative to potential exposure to other media, especially ground water, and is not evaluated in this risk assessment.
Air	Off-TCAAP residential areas	Local residents	Inhalation of volatile organics	Yes.
Surface Water and Sediment	Rice Creek (portion immediately off-TCAAP) and Round Lake	Local residents	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. Swimming is assumed to be very infrequent. Most exposure is assumed to take place when persons wade in the creek.
Surface Water	Rice Creek (portion immediately off-TCAAP) and Round Lake	Local residents	Ingestion of fish	Yes.

TABLE ES-1 (Continued)

CURRENT LAND USE CONDITIONS
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
Surface Water and Sediment	Off-TCAAP surface water bodies (excluding Rice Creek and Round Lake) downgradient of TCAAP, including Long Lake and Valentine Lake	Local Residents	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediment	No. Available data do not indicate that chemicals originating at TCAAP have significantly impacted nearby surface water bodies.
Deer and Small Game	Locations to which meat from slaughtered on-TCAAP animals is distributed	Private citizens	Ingestion of meat	Yes. The on-TCAAP deer population is harvested each year, and most of the meat is distributed to charity groups and private citizens. The rest of the meat is destroyed. Small game such as rabbits or pheasants may feed on-TCAAP, migrate off-TCAAP, and be bagged by hunters. Ingestion of game in general is evaluated by investigating deer exposure data.

TABLE ES-2

RME FUTURE LAND USE CONDITIONS[1]
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
POTENTIAL PATHWAYS ON-TCAAP				
Ground Water	Private wells installed within current TCAAP boundaries	Local residents	Ingestion, inhalation of volatiles while showering, and dermal contact while bathing	Yes. It is assumed that any wells installed to serve industrial or commercial development within current TCAAP boundaries will be closely regulated and will comply with existing regulations that require ground-water treatment if contamination is detected.
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal absorption and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment, such as gloves and masks, if necessary, and monitoring equipment.
Surface Soil	On-TCAAP exposure areas	Local residents	Incidental ingestion, inhalation of fugitive dusts, and dermal contact	Yes. Exposure may be limited by placement of clean topsoil on top of native soil during residential development. Employees of commercial or industrial operations located on-TCAAP are assumed not to be exposed. Emission of and exposure to fugitive dusts from surface soils are expected to be minimal and are not evaluated.
Subsurface Soil	On-TCAAP exposure areas	Construction workers	Incidental ingestion, inhalation of fugitive dust, and dermal contact	Yes. Exposure is evaluated in terms of residential construction. However, exposure may also occur as a result of other construction or repair activities such as sewer or underground pipeline repair work.
Surface Water and Sediment	Rice Creek (on-TCAAP portion), Sunfish Lake, Marsden Lake, and miscellaneous small areas of surface water	Local residents and MDNR staff working at the Sunfish Lake fishery	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. Swimming is expected to be very infrequent. Most exposure is assumed to take place when persons are wading.
Surface Water and Sediment	Rice Creek (on-TCAAP portion)	Local residents	Ingestion of fish	No. Exposure of fish from Sunfish Lake is assumed not to occur because Sunfish Lake cannot support a year-round fish population. Fingerlings are used to stock local lakes. Exposure to relocated fingerlings is not evaluated because tissue concentrations in grown fish are assumed to be small (see discussion in Section 3.3.4.2.1).

TABLE ES-2 (Continued)

RME FUTURE LAND USE CONDITIONS[1]
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
Air	On-TCAAP exposure areas	Local residents and employees of future commercial and industrial operations	Inhalation of volatile organics	Yes. It is assumed that future remedial activities will include continued operation of existing ground-water and soil gas extraction/treatment systems that release volatile organics into the atmosphere.
Soil Gas	Basements of residences located within on-TCAAP exposure areas	Local residents	Inhalation of volatile organics	Yes. Evaluation of this pathway is qualitative in nature.
Home-Grown Vegetables and Fruits	On-TCAAP exposure areas	Local residents	Ingestion	Yes.
POTENTIAL PATHWAYS OFF-TCAAP				
Ground Water	Private wells located downgradient of TCAAP within the ground-water contamination plume extending southwest of TCAAP and located north of TCAAP opposite Source Area A	Local residents	Ingestion, inhalation of volatiles while showering, and dermal contact while bathing	Yes. The number of existing private drinking water wells is small. Most off-TCAAP residents receive their drinking water from municipal sources. However, if the current GAC treatment systems fail, residents could be exposed to contaminated ground water until the failure is detected. Private wells located immediately north of Source Area A in Shoreview are used for drinking water. In addition, private drinking water wells may exist in other off-TCAAP cities. For example, New Brighton has no specific ordinance that prohibits installation and use of private drinking water wells.
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal absorption and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment such as gloves and masks, if necessary, and monitoring equipment.
Surface Soil	Off-TCAAP residential and commercial/industrial areas	Local residents and employees	Incidental ingestion, inhalation of fugitive dust, and dermal absorption	Unknown. Information on the quality of off-TCAAP surface soil is not available. Potential off-TCAAP exposure to contaminated surface soil originating on-TCAAP cannot be accurately quantified but is insignificant relative to potential exposure to other media, especially ground water, and is not evaluated in this risk assessment.

TABLE ES-2 (Continued)

RME FUTURE LAND USE CONDITIONS[1]
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
Air	Off-TCAAP residential areas	Local residents	Inhalation of volatile organics	Yes.
Surface Water and Sediment	Rice Creek (portion immediately off-TCAAP) and Round Lake	Local residents	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. Swimming is assumed to be very infrequent. Most exposure is assumed to take place when persons are wading.
	Rice Creek	Local residents[2]	Ingestion of fish	Yes.
Surface Water and Sediment	Off-TCAAP surface water bodies (excluding Rice Creek and Round Lake) downgradient of TCAAP, including Long Lake and Valentine Lake	Local residents[2]	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	No. Available data do not indicate that chemicals originating at TCAAP have significantly impacted nearby surface water bodies.

Notes:

1 Future land use is evaluated under two sets of conditions: (1) probable exposure conditions – under these conditions, TCAAP is assumed to continue operating as it is currently, with exposure pathways the same as under current conditions; and (2) RME conditions – residential and commercial/industrial development is assumed to take place within current TCAAP boundaries, and private drinking water wells are assumed to be installed within the ground-water plume southwest of TCAAP. Only pathways under RME conditions are summarized in this table.

2 Local residents in this instance include persons living outside current TCAAP boundaries. Exposure may take place within current TCAAP boundaries or in Rice Creek immediately outside the boundaries.

Ground Water

Ground-water exposure points are termed "exposure areas" and are shown in Figures 1-3, 1-4, and 1-5.

- On-TCAAP exposure areas (see Figure 1-3) are of two types: Class I and Class II. Class I exposure areas include each of the 14 source areas as well as those monitoring wells identified with each source area in the on-TCAAP RI (ANL, 1990). The remainder of TCAAP was divided into Quadrants (X1, X2, X3, and X4), each of which is defined as a class II exposure area.
- Off-TCAAP exposure areas are defined in terms of TCE concentrations in a plume flowing southwest from TCAAP. Unit 3 ground-water exposure areas are shown in Figure 1-4; Unit 4 ground-water exposure areas are shown in Figure 1-5.

Surface and Subsurface Soils

Surface and subsurface soil exposure points are also termed exposure areas and include each of the 14 on-TCAAP source areas (see Figure 1-2).

Surface Water and Sediment

Surface water and sediment exposure points include specific surface water bodies such as Rice Creek, Round Lake, and Sunfish lake and miscellaneous surface water bodies, termed exposure areas, within several of the 14 on-TCAAP source areas. Surface water and sediment exposure areas are shown in Figures 1-3 and 1-4.

Airborne VOCs

Airborne VOC exposure points are termed "receptor locations". Thirty-seven on-TCAAP receptor locations are shown on Figure F-2 and 10 off-TCAAP receptor locations are shown on Figure F-3.

Exposure doses, normalized for time and body weight, are calculated for each exposure pathway using pathway-specific equations similar to Equation ES-1:

$$I = \frac{C \times CR \times EF \times YE}{BW \times AT} \qquad \text{(ES-1)}$$

where

I	=	Intake: the amount of chemical at the exchange boundary (mg/kg of body weight per day)
C	=	Chemical concentration: the average concentration contacted over the exposure period (e.g., mg/L of water)
CR	=	Contact rate: the amount of contaminated medium contacted per unit of time or event (e.g., L/day)
EF	=	Exposure frequency: how often the exposure occurs (e.g., days/year)
YE	=	Years of exposure: how long the exposure occurs (e.g., years)
BW	=	Body weight: the average body weight over the exposure period (kg)
AT	=	Averaging time: period over which exposure is averaged (e.g., days).

For the purposes of this risk assessment, probable exposures are calculated based on medium-specific arithmetic average chemical concentrations. Under RME conditions, the upper 95-percent confidence limit of the arithmetic mean concentration or the maximum concentration, whichever is less, is used as the concentration term. The medium-specific concentrations are presented in Appendix A. The remaining pathway-specific exposure parameters are presented and discussed in Appendix C. Exposure to noncarcinogenic chemicals is evaluated for acute and chronic exposure periods, and exposure to carcinogenic chemicals is evaluated for an average lifetime exposure. The pathway-specific exposure estimates are presented in Appendix D.

TOXICITY ASSESSMENT

Chapter 4 briefly reviews the toxicity data for each chemical of potential concern. More extensive toxicological summaries for each chemical of potential concern as well as for gross alpha and gross beta radiation are presented in Appendix H. Also, chemical-specific exposure standards, criteria, and guidelines established to protect human health and the environment are presented and discussed. Some of these criteria, specifically the reference doses (RfD) and slope factors (SF), are used later in the risk assessment to characterize risks from exposure to noncarcinogenic chemicals and carcinogenic chemicals, respectively.

RISK CHARACTERIZATION

Chapter 5 quantifies risks for each current and future land use exposure pathway. Risks are quantified and evaluated in three different manners: (1) for individual chemicals of potential

concern, (2) for multiple chemicals within specific exposure pathways, and (3) across multiple exposure pathways, if appropriate. In addition, Chapter 5 includes a qualitative discussion of risks associated with exposure to lead, gross alpha and gross beta radiation, and volatile organic compounds (VOC) in soil gas.

Carcinogenic risk estimates are termed "upper-bound excess lifetime cancer risks" (risks) and are calculated using Equation ES-2:

$$\text{Risk} = \text{ALD} \times \text{SF} \qquad \text{(ES-2)}$$

where

ALD = Average lifetime dose (mg/kg/day)

SF = Slope factor $(\text{mg/kg/day})^{-1}$

The carcinogenic risk estimates represent the incremental probability that an individual will develop cancer over a lifetime as a result of exposure to a carcinogen (e.g., 1E-06 or 1×10^{-6} translates to one additional case of cancer in an exposed population of one million). According to the revised National Contingency Plan (U.S. EPA, 1990b), the target range for carcinogenic risks from exposures at a Superfund site after remediation may be between 1E-04 and 1E-06. In general, a potential upper-bound excess lifetime cancer risk of 1E-06 is used by U.S. EPA as a point of departure or bench mark.

Noncarcinogenic risk estimates are termed "hazard quotients" (HQ) and are calculated using Equation ES-3:

$$\text{Hazard Quotient} = \text{ED/RfD} \qquad \text{(ES-3)}$$

where

ED = Exposure dose (mg/kg/day)

RfD = Reference dose (mg/kg/day).

Exposure dose and RfD are expressed in the same units and represent the same exposure period (whenever possible). An HQ greater than one indicates a potential for noncarcinogenic health effects. However, the probability of noncarcinogenic health effects is not related to the amount by which the HQ exceeds one. As with carcinogenic risks, noncarcinogenic risks are estimated for individual chemicals, for multiple chemicals within a specific pathway, and across multiple pathways.

The total noncarcinogenic risk for each exposure pathway is estimated using Equation ES-4.

$$\text{Hazard Index (HI)} = ED_1 / RfD_1 + ED_2 / RfD_2 + \ldots + ED_i / RfD_i \quad \text{(ES-4)}$$

where

ED_i = Exposure dose (or intake) for the i^{th} substance: for acute exposure periods, E_i is calculated as a 1-day dose; for a chronic exposure period, E_i is calculated as a chronic daily intake averaged over the length of each age group. In each case, E_i is presented in mg/kg/day.

RfD_i = Reference dose for the i^{th} substance, where the RfD represents the same exposure period as the exposure dose described above.

Pathway-specific risk estimates are presented in Appendix D. Risks from exposure to individual chemicals as well as to multiple chemicals within each pathway are presented. Carcinogenic risks from multiple chemicals are calculated by summing the risks for individual chemicals. This procedure follows U.S. EPA guidelines and assumes that chemicals have the same target organs and mechanisms of action. Noncarcinogenic risks, in contrast, are evaluated by summing target organ- or chemical effect-specific risks. Significant risks from exposure via multiple pathways for each exposure area are summarized in Tables 5-3 through 5-26.

Risks to human health from exposure to chemicals of potential concern released from TCAAP vary widely among exposure pathways in particular exposure areas. Risks associated with potential exposures to each medium are highlighted below for the major exposure conditions. As appropriate, maximum upper-bound excess lifetime cancer risks under RME conditions and chemicals contributing most to risks (both carcinogenic and noncarcinogenic) are identified.

On-TCAAP Risks Under Current and Probable Future Land Use Conditions

- Exposures to ground water present little or no risk. All ground water passes through an air stripper/GAC system that removes contaminants before the ground water is used as potable water on-TCAAP.
- Exposures to surface soil by maintenance workers present an upper-bound excess lifetime cancer risk greater than 1E-06 only in Exposure Area C (3E-05; PAHs) and HQs greater than one in Exposure Areas A, F, H, and 129-3 (antimony).

- Exposures to surface water and sediment are associated with upper-bound excess lifetime cancer risks less than 1E-07, and HQs less than one.

- Exposures to VOCs released from on-TCAAP remedial actions are associated with upper-bound excess lifetime cancer risks less than 1E-06, and HQs are less than 1E-02.

On-TCAAP Risks Under RME Future Land Use Conditions

- Exposures to ground water present upper-bound excess lifetime cancer risks greater than 1E-06 in many exposure areas for Units 1 (Exposure Areas A, C, H, I, J, and K), 3 (Exposure Areas D, E, F, G, H, I, K, 129-3, 129-5, 129-15, X2, X3, and X4), and 4 (Exposure Areas I, X3-Upper, X3-Middle, and X3-Deep). The greatest total upper-bound excess lifetime cancer risk is for Unit 3 ground water in Exposure Area D (8E-02; trichloroethene). HQs exceed one only in the following exposure areas: A, I, J, and K -- Unit 1 (antimony, 1,2-dichloroethene, and manganese); D, G, and X3 -- Unit 3 (1,1,1-trichloroethane, methylene chloride, 1,2-dichloroethene, and 1,1-dichloroethene); and X3-Upper -- Unit 4 (arsenic).

- Exposures of residents to surface and subsurface soils present total upper-bound excess lifetime cancer risks greater than 1E-06 only in Exposure Areas C, E, and 129-3; the major contributors to risks in these exposure areas are PAHs, PCBs, and 2,4-dinitrotoluene, respectively. HQs exceed one for residents in Exposure Areas A, F, H, and 129-3; the major contributor to risks in these exposure areas is antimony.

- Exposures to surface water and sediment present negligible risks. All upper-bound excess lifetime cancer risks are less than 1E-07. HQs exceed one only for acute exposure under RME conditions involving ingestion of fish from Rice Creek (silver) and dermal contact with Sunfish Lake sediment (antimony).

- Exposures to VOCs released from on-TCAAP remedial actions present upper-bound excess lifetime cancer risks greater than 1E-06 in all Class I and Class II exposure areas except Exposure Areas A and B. The greatest risk exists at a location south of Building 116 (7E-05) under RME conditions. All HQs are less than one.

- Exposures to home-grown vegetables and fruits present upper-bound excess lifetime cancer risks greater than 1E-06 only in Exposure Areas C (1E-03; PAHs) and E (7E-06; PCBs). HQs exceed one only in Exposure Areas A, F, and 129-3 (antimony).

Off-TCAAP Risks Under Current, Probable Future, and RME Future Land Use Conditions

- Exposures to ground water present upper-bound excess lifetime cancer risks greater than 1E-06 in all exposure areas for Units 1, 3, and 4 and present HQs greater than one in exposure areas for Units 3 (Exposure Area 3Y) and 4 (Exposure Area 4X). The greatest upper-bound excess lifetime cancer risk is in Exposure Area 3Z (1E-02; trichloroethene, 1,1-

dichloroethene, 1,1-dichloroethane, and 1,2-dichloroethane); the lowest risk is in Exposure Area S (3E-07). HQs exceed one only in Exposure Areas 3Y and 4X (1,1,2-trichloroethane and antimony, respectively).

- Exposures to surface water and sediment present negligible risks. All upper-bound excess lifetime cancer risks are less than 1E-07. HQs exceed one only for acute ingestion of fish from Rice Creek by children (silver).

- Exposures to VOCs released from on-TCAAP remedial actions present negligible risks. All upper-bound excess lifetime cancer risks are less than 1E-06, and all HQs are less than 1E-01.

Finally, development of the risk assessment, from data collection to risk characterization, involves use of data, procedures, and assumptions that are subject to many uncertainties. Primary areas of uncertainty impact the exposure assessment and risk characterization. Tables ES-3 and ES-4 present specific areas of uncertainty and their probable effects (underestimation and overestimation) for the exposure assessment and risk characterization, respectively. The uncertainties must be considered as part of any meaningful evaluation of the numerical risk estimates.

In general, many areas of uncertainty in this risk assessment are interpreted in such a way as to provide upper-bound risk estimates. Actual risks associated with various exposure pathways are unlikely to exceed the risk values estimated for RME conditions. However, risk values estimated in this risk assessment for probable exposure conditions should be interpreted cautiously; these values may underestimate actual risks.

General Conclusions

- Risks under current and probable future land use conditions are generally lower than risks under RME future land use conditions. Exposure to contaminated media is limited by existing institutional controls and interim remedial actions, such as restricted on-TCAAP access, the existence and use of uncontaminated public drinking water supplies, and the on-TCAAP drinking water system.

- Total on-TCAAP risks are greater than total off-TCAAP risks.

- Exposures to ground water and VOCs released from on-TCAAP remedial actions present the greatest risks. Exposure to contaminated ground water will probably be limited because of the availability of uncontaminated municipal drinking water supplies and, in some cities, requirements to use these supplies rather than private drinking water wells. However, a significant number of persons will be exposed to VOCs released from on-TCAAP remedial actions.

TABLE ES-3

AREAS OF UNCERTAINTY AND EFFECTS ON EXPOSURE ESTIMATES

Area of Uncertainty	May Overestimate Exposure	May Underestimate Exposure	May Overestimate or Underestimate Exposure
Exposure Pathway Identification			
Assumption of RME future land use (residential, commercial, and industrial development within TCAAP boundaries)	X		
Assumption that certain pathways such as inhalation of fugitive dusts are insignificant and fact that these pathways are not evaluated (except for construction workers)		X	
Inability to calculate exposure doses for certain pathways such as inhalation of VOCs released into ambient air from the ground surface or released into basements of current and future buildings		X	
Exposure Parameters and Assumptions			
Assumptions regarding population characteristics, such as body weight, surface area, and life expectancy, and exposure characteristics, such as frequency, duration, and amount of intake, may not be representative of actual exposure conditions.			X
Assumption of Steady-State Conditions			
Chemical concentrations measured in or estimated from the on-TCAAP RI or off-TCAAP RI are assumed to remain constant and to represent current and future environmental conditions.	X		
Environmental Chemical Characterization			
Potential seasonal variations ignored			X
Nonrandom sample collection	X		
Sample Size			X
Types of sample analysis (non-GC/MS versus GC/MS)			X
Replacement of ND results with a value equal to one-half the sample detection limit			X
Comparison to background levels			X
High detection limits	X		
Modeling Procedures			
Potential transformation processes are not evaluated.			X
Assumption that all VOCs emitted are trichloroethene (carcinogenic risks) or 1,1,1-trichloroethane (noncarcinogenic risks)			X

TABLE ES-4

AREAS OF UNCERTAINTY AND EFFECTS ON RISK ESTIMATES

Area of Uncertainty	May Overestimate Risk	May Underestimate Risk	May Over-or Underestimate Risk
Risk Factors			
– Extrapolation Most risk factors are extrapolated from animal test results. Extrapolations may be made for species, exposure dose, and exposure period; extrapolations are generally conservative.	X		
– Adjustment of Oral Risk Factors In order to characterize risks from dermal exposures, generally expressed as absorbed doses, oral risk factors are adjusted to account for oral absorption efficiency.	X		
– Slope Factors (SF) SFs represent upper 95-percent confidence limit values; carcinogenic risks calculated using SFs generally represent upper-bound estimates.	X		
– Lack of Risk Factors Risks from exposure to chemicals with no available chemical-specific or substitute risk factors cannot be quantitatively characterized.		X	
Risk Summations			
Risks from chemical mixtures are characterized by summing the individual chemical risks. This procedure assumes that chemicals have the same toxic end points and mechanisms of action and do not interact, either synergistically or antagonistically. These assumptions may be incorrect.			X
Exposure Periods			
Acute exposures are characterized by comparison to subchronic risk factors. Evaluating exposures using risk factors based on a longer exposure period is conservative.	X		

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GLOSSARY OF TERMS
USED IN NEW BRIGHTON/ARDEN HILLS RISK ASSESSMENT

Absorb -- To take in chemicals into the soil matrix.

Absorption Factor -- A value representing the amount of a substance that is actually absorbed.

Acute -- Referring to a short time period, such as a single event or the events over a single day.

Air Stripping -- A cleanup process that uses air flow to remove volatile organic compounds (VOCs) from contaminated water. When the water comes into contact with air, the contaminants volatilize into the air; the air may then be treated before emission into the atmosphere.

Analytes -- The chemicals for which a sample is analyzed.

Annual Monitoring Plan -- A plan to monitor concentrations of chemicals of potential concern and their migration.

Aquifer -- A rock or soil formation through which ground water moves easily, and that has sufficient capacity to transmit water to wells and springs.

Aquitard -- A rock formation that does not readily yield water to wells or springs, but may serve as a storage unit for ground water.

Ambient Water Quality Criteria -- Criteria that reflect the latest scientific knowledge on the effects of pollutants on public health and aquatic life.

Arithmetic Mean -- An average value calculated by adding all individual values and dividing that sum by the number of individual values added together.

Assay -- The analysis of samples to determine their compositions.

Average Lifetime Dose -- The total intake from all exposures in a given exposure period divided by 70 years.

Averaging Time -- The period of time over which a dose is averaged.

Background -- Concentrations of substances in the environment that may not be attributable to the site or site activities.

Bedrock -- The solid rock underlying soil or sediment.

Bioaccumulation -- The process whereby an organism takes up and retains a substance.

Bioconcentration -- The concentration of a substance in an organism as a result of bioaccumulation.

Bioconcentration Factor -- A value indicating the fractional increase in a substance's concentration as a result of bioaccumulation.

Biodegradation -- The breakdown of a substance over time as a result of biological processes.

Biotransformation -- Conversion of a material to a new form through natural processes that occur in living organisms.

Carcinogenic -- Having the potential to cause cancer.

Chemical of Potential Concern -- A chemical identified on- or off-site, in concentrations significantly above background, whose presence can be attributed to the site.

Chlorinated Hydrocarbon -- A chemical compound composed of hydrogen, carbon, and chlorine.

Chronic -- Referring to a long time period such as months or years.

Chronic Daily Intake -- The total intake for a particular chronic period of time, averaged over that time period.

Complexation -- The process whereby two or more compounds consolidate, resulting in one new compound.

Comprehensive Environmental Response, Compensation, and Liability Act -- A federal law passed in 1980 and modified in 1986 by the Superfund Amendments and Reauthorization Act. The acts created a special tax that goes into a trust fund, commonly known as Superfund, for investigating and cleaning up abandoned or uncontrolled hazardous waste sites.

Conductivity -- The ability of a geologic formation to allow ground water to pass through.

Confining Layer -- A geologic formation that is impermeable to water, to the extent that it prevents water from moving between aquifers. Confining layers are also referred to as aquitards or storage units.

Consolidation -- The process whereby soft earth materials become firm and coherent rock.

Demographics -- The characteristics (such as density, distribution, and vital statistics) of human populations in an area.

Desorption -- A process whereby substances, previously contained in or on the surface of soils, are released into the environment.

Electromagnetic Inductance -- An on-site test used to determine the characteristics of materials underlying the site.

Elimination -- To be naturally removed from the body.

Environmental Persistence -- Refers to the length of time a substance can remain in the environment before breaking down.

Eutrophy -- A phase in the development of a lake in which increased minerals and nutrients reduces the oxygen in the water, leading to conditions favoring plant over animal life.

Exchange Boundary -- Biological boundaries through which substances move, such as the skin, the lining of the lungs, or the lining of the gastrointestinal tract.

Excrete -- To be naturally removed from the body.

Exposure Area -- A distinct area in which a population may be exposed to a chemical concentration significantly different from concentrations in adjacent areas.

Exposure Dose -- The amount of a substance which an organism may potentially come in contact with.

Exposure Pathway -- The course a chemical or physical substance takes from a source to an exposed organism. This describes the way in which an individual or population is exposed to chemical or physical substances at or originating from a site. Common pathways include inhalation, ingestion, and dermal contact.

Extrapolation -- Using response data for a particular dose level to estimate the response at another dose level.

Feasibility Study -- A study that examines the health, environmental, and economic impacts of remedial alternatives, as well as the technical capabilities required to implement them.

Federal Facilities Agreement -- An agreement between a department of the federal government and U.S. EPA that facilitates the clean-up of a federal facility.

Fetotoxicity -- The degree to which a pregnant mother's exposure to a substance can result in the death of her unborn child.

Gas Chromatography -- A technique for separating and analyzing complex mixtures of organic compounds.

Gastrointestinal -- Any part of the digestive tract.

Gavage -- A scientific study technique that involves depositing a substance directly into an animal's stomach through a tube.

Glacial Till -- Unsorted sediment deposited directly by a glacier.

Glaciofluvial -- Defining deposits formed by rivers issuing from glaciers.

Gross Alpha -- The total amount of alpha radiation present. Alpha rays are composed of positively charged particles, and are very soft and easily absorbed.

Gross Beta -- The total amount of beta radiation present. Beta rays are composed of negatively charged particles and are much more penetrating than alpha rays.

Gross Radiation -- The total amount of radiation present indiscriminate of type.

Hazard Index -- A value indicating the probability of noncarcinogenic adverse health effects.

Hazardous Substance -- Any substance determined to posses properties with the potential to have adverse effects on human health and the environment.

Health Advisory -- A form of official notice issued to protect exposed populations from adverse health effects when contaminant concentrations exceed certain levels.

Henry's Law -- A scientific law stating that the solubility of a nonreactive gas in a dilute solution is proportional to its partial pressure above the solution.

Henry's Law Constant -- See Henry's Law.

Hepatotoxicity -- Ability of a substance to have adverse health effects on the liver.

Hot Spot -- A small, definable area having a significantly higher concentration of a chemical of potential concern than the immediate surrounding area.

Human Health Evaluation -- A part of the risk assessment evaluating the risk of adverse health effects to humans as the result of exposure to chemicals of potential concern.

Hydrogeology -- Study of ground water with particular emphasis to its chemistry, mode of migration, and relation to geologic environment.

Illuvation -- The transport of soluble substances by percolating water from the surface soil layer to a deeper soil layer.

Industrial Source Complex Long-Term Model -- An EPA-recommended model for estimating the ambient air concentration of chemicals of potential concern downwind from a source.

Ingestion -- Introduction of a substance into the digestive system.

Inorganic -- Chemical elements and compounds that do not contain organic carbon.

In-situ Treatment -- "In place" treatment that takes place without removing the contaminated media.

Integrated Risk Information System (IRIS) -- An EPA database containing verified Reference Doses, Slope Factors, and up-to-date health risk and EPA regulatory information for numerous chemicals. It is EPA's preferred source of toxicity information for Superfund.

Isopleth -- A line connecting points that have the same physical property.

Kame -- A stratified, low mound of glaciofluvial sand, silt, and gravel.

Lacustrine Plain -- A plain produced in or formed by a lake.

Lens -- A geologic deposit bounded by convergent surfaces, thick in the middle and thinning toward the edges.

Mass Spectroscopy -- A technique for evaluating a substance's chemical composition based on the substance's ability to absorb various wavelengths of radiation.

Maximum Contaminant Level -- An enforceable federal standard for the maximum permissible level of contaminants in drinking water.

Metabolism -- The sum of physical and chemical processes by which an organism, through a transformation process, converts compounds into energy.

Metabolize -- See metabolism.

Mobility -- The ease with which a substance moves.

Moraines -- An accumulation of rock debris formed and transported by a glacier.

National Oil and Hazardous Substances Pollution Contingency Plan -- Implemented under CERCLA 1980, this regulation governs implementation of the Superfund program.

National Priorities List -- A listing of all Superfund sites, ranking them based on the degree to which they present a potential threat to human health and the environment.

Noncarcinogenic -- Not having the ability to cause cancer.

Nontoxic -- Having no known adverse health effects.

Off-TCAAP -- Areas surrounding the Twin Cities Army Ammunition Plant facilities.

On-TCAAP -- The areas that comprise the Twin Cities Army Ammunition Plant facilities.

Organic -- Chemical compounds containing organic carbon and possessing a relatively complex structure.

Oxidation -- The loss of one or more electrons by an atom or molecule; or, the combination of a substance with oxygen.

Peat -- A compact, porous mass of vegetative matter that has undergone early chemical change toward carbonization.

Perennial Lake -- A lake that retains water in its basin throughout the year and is usually not subject to extreme fluctuation in levels.

Permeability -- A measure of a material's ability to transmit water.

Permeability Constant -- See permeability.

Permissible Exposure Limit -- A standard set by the Occupational Safety and Health Administration regulating worker exposure to chemical and physical hazards.

Photooxidation -- The loss of one or more electrons by an atom or molecule as a result of exposure to sunlight radiation.

Piezometer -- A device for determining ground-water levels and flow potential.

Plume -- The boundary of concentrated contamination.

Polychlorinated Biphenyls (PCBs) -- A family of organic compounds used since 1926 in electric transformers as insulators and coolants and in lubricants, carbonless copy paper, adhesives, and caulking compounds. PCBs do not break down into harmless compounds, but instead, remain in the environment for years. U.S. EPA banned the use of PCBs in 1976. Long-term exposure to PCBs can cause liver damage and cancer.

Potentiometric -- Having to do with, or displaying the elevation of, ground water in an aquifer.

Precipitation -- Occurs when a solid or liquid forms within a solution and subsequently falls out of the solution. Rain and snow are examples of precipitation.

Quadrant -- A sub-area (1/4) of a site defined by dividing the site into four sections.

Radioisotope -- A form of a chemical element that spontaneously undergoes radioactive decay, changing from one radioisotope to another, and resulting in the emission of radioactivity.

Reasonable Maximum Exposure -- The highest exposure that is reasonably expected to occur at a site.

Receptors -- Populations potentially exposed to a substance.

Recommended Allowable Limit -- A drinking water standard established by the Minnesota Department of Health.

Reference Dose -- An EPA-specified dose below which exposure to a particular substance should not result in adverse health effects.

Release -- Introduction of a chemical of potential concern into the environment.

Remedial Action -- Action taken to reduce the risk of adverse effects, from a hazardous waste site, on human health and the environment to acceptable levels.

Remedial Investigation -- A study to determine the nature and extent of contamination at a hazardous waste site.

Renal -- Referring or related to the kidneys.

Risk Assessment -- An evaluation of the health and environmental risks posed by a hazardous waste site, and the possible adverse effects.

Slope Factor -- A value that describes a chemical's potential for causing cancer in a population, via a particular exposure route. This value is used to estimate an upper-bound probability of an individual developing cancer as a result of lifetime exposure to a particular level of a potential carcinogen.

Sludge -- A partly solid and partly liquid material that is produced by some water treatment processes.

Soil Boring -- A cylinder of soil removed for evaluation.

Soil Gas Survey -- Sampling and evaluation of gases present in the subsurface soil.

Soil-to-Skin Adherence Factor -- A value representing the mass of soil that can adhere to a given area of skin.

Solution Cavities -- A cavity formed in soluble rock.

Sorption -- The external and internal retention of a substance.

Sorted -- The end result of particles having been grouped together by size and other characteristics of similarity.

Source Areas -- Refer to the 14 specific areas of contamination identified on-TCAAP and the associated air strippers.

Source Control Wells -- Wells located and monitored to detect movements of chemicals of potential concern from their source. These wells are used to extract contaminated ground water and to control the migration of contaminated ground water.

Subchronic -- A less-than-chronic period of time.

Thermal Treatment -- Removal or destruction of organic compounds through heating.

Threshold Limit Value -- Maximum limits of occupational exposure to chemical and physical hazards suggested by the American Conference of Governmental and Industrial Hygienists.

Till Plains -- Areas of unsorted, unconsolidated glacial deposits.

Topographic -- Illustrating the various elevations of a particular area.

Toxicity -- The capacity of a substance to produce adverse health effects.

Transformation -- Change from one form to another.

Transmutation -- Change from one species to another.

Uncertainty Factor -- The margin of error involved in estimations.

Unconsolidated -- Not consolidated, loose.

Unity -- Reaching the value 1.

Upper Confidence Limit -- An upper-bound estimate of the actual population mean for a set of sample data.

Upper-bound -- An estimate that is sufficiently high enough to approximate a population mean, while allowing for variability within the sample data.

Uptake -- The amount of a substance which can be found in an organism, as a result of the organism being exposed to that substance.

Vitrified -- Converted into glass, or glassy substances, due to heat induction.

Volatile Organic Compounds (VOCs) -- A group of chemicals that contain organic carbon and readily volatilize, changing from liquids to gases, when exposed to air.

Volatilization -- The mass transfer of volatile organic compounds when exposed to air.

Watershed -- The drainage basin of a stream or river.

LIST OF ACRONYMS AND ABBREVIATIONS
NEW BRIGHTON/ARDEN HILLS RISK ASSESSMENT

3M	-	Minnesota Mining and Manufacturing Corporation
AB	-	Absorption Factor
AF	-	Soil-to-skin Adherence Factor
ALD	-	Average Lifetime Dose
ANL	-	Argonne National Laboratory
ARCS	-	Alternative Remedial Contract Strategy
AT	-	Averaging Time
ATSDR		Agency for Toxic Substances and Disease Registry
AWQS	-	Ambient Water Quality Standards
BDF	-	Bioconcentration Factor
BGRS	-	Boundary Ground-Water Recovery System
BW	-	Body Weight
C^a	-	Concentration
CAG	-	Carcinogenic Advisory Group
CDC	-	Center for Disease Control
CDI	-	Chronic Daily Intake
CDM	-	Camp, Dresser, and McKee, Incorporated
CERCLA		Comprehensive Environmental Response, Compensation and Liability Act
$CF(2)^b$	-	Conversion Factor or Concentration in Fish
CFR	-	Code of Federal Regulations
CNS	-	Central Nervous System
CR	-	Contract Rate
CRAVE		Carcinogen Risk Assessment Verification Endeavor
DF	-	Desorption Factor
E	-	Scientific Notation (1E-01 = 1×10^{-1})
ED	-	Exposure Duration
EF	-	Exposure Frequency
EPA	-	United States Environmental Protection Agency
FCC	-	Federal Cartridge Corporation
FFA	-	Federal Facility Agreement
FI	-	Fraction Ingested
FS	-	Feasibility Study
GI	-	Gastrointestinal
GC/MS		Gas Chromatograph/Mass Spectroscopy
HA	-	Health Advisory
HEAST		Health Effects Assessment Summary Tables
HI	-	Hazard Index
HQ	-	Hazard Quotient
I	-	Intake
IR(2)	-	Ingestion Rate or Inhalation Rate
IRIS	-	Integrated Risk Information System
IRP	-	Installation Restoration Program
ISCLT	-	Industrial Source Complex Long-Term Model
ISV	-	In-Situ Volatilization
Kg	-	Kilogram
L	-	Liter
LPH	-	Lactic Dehydrogenase
MCCC	-	Metropolitan Council Chamber of Commerce
MCL	-	Maximum Contaminant Level
MCLG	-	Maximum Contaminant Level Goal
MDH	-	Minnesota Department of Health
MDOT	-	Minnesota Department of Transportation

MDTED		Minnesota Department of Trade and Economic Development
MPCA	-	Minnesota Pollution Control Agency
NA(2)	-	Not Applicable or Not Available
NCP	-	National Contingency Plan
ND	-	Not Detected
NLM	-	National Library of Medicine
NPL	-	National Priority List
PAHs	-	Polycyclic Aromatic Hydrocarbons
PC	-	Permeability Constant
PCBs	-	Polychlorinated Biphenyls
pCi	-	picocurie
PEL	-	Permissible Exposure Limit
ppm	-	Parts Per Million
ppb	-	Parts Per Billion
PRC	-	PRC Environmental Management, Incorporated
RAL	-	Recommended Allowable Limit
RfD	-	Reference Dose
RFRA	-	Request For Response Action
RI	-	Remedial Investigation
RME	-	Reasonable Maximum Exposure
SA	-	Surface Area
SC	-	Source Control
SF	-	Slope Factor
SGOT	-	Serum Glutamic Oxaloacetic Transaminase
TCAAP		Twin Cities Army Ammunition Plant
TCE	-	Trichloroethylene
TGRS	-	TCAAP Ground-Water Recovery System
TOC	-	Total Organic Carbon
TLV	-	Threshold Limit Value
UCL	-	Upper Confidence Level
VOC	-	Volatile Organic Compound
WQS	-	Water Quality Standard
X1	-	Northwest Quadrant
X2	-	Northeast Quadrant
X3	-	Southwest Quadrant
X4	-	Southeast Quadrant
YE	-	Years of Exposure

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[a] May be followed by letter indicating media. CS is Concentration in Soil; CW is Concentration in Water; CF is Concentration in Fish.

[b] Parenthetical value indicates acronym or abbreviation is used to represent more than one word or phrase. Multiple representatives are presented, and should be interpreted considering context of use.

CHAPTER 1

INTRODUCTION

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CHAPTER 1
INTRODUCTION

The New Brighton/Arden Hills Superfund site consists of the Twin Cities Army Ammunition Plant (TCAAP) located in Ramsey, Anoka, and Hennepin Counties, Minnesota, and any adjoining areas determined to be contaminated by migration of hazardous substances or contaminants from TCAAP. The U.S. Army owns the TCAAP facility, and Federal Cartridge Corporation (FCC) has operated the facility during most of its existence. TCAAP has been used to manufacture, store, and test small arms ammunition and related materials since 1941. Other TCAAP activities include those of tenants residing at the facility. Most of the facility is currently on standby status. However, two major private companies still use part of the facility for commercial and defense-related operations. These companies are Minnesota Mining and Manufacturing Company (3M) and Honeywell, Inc.

Information from past studies indicates that between 1941 and 1981, waste material was disposed of at 14 disposal areas or subsites within TCAAP. The U.S. Environmental Protection Agency (U.S. EPA) and the Minnesota Pollution Control Agency (MPCA) have determined that hazardous substances, pollutants, or contaminants have been released into the environment. Releases from the subsites, primarily Source Areas D, G, and I, have contributed to contamination of off-TCAAP areas as well. As a result of these releases, the New Brighton/Arden Hills site has been ranked No. 43 on the National Priorities List (NPL), established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The U.S. Army, U.S. EPA, and MPCA entered into a federal facilities agreement (FFA) in 1987 to ensure that environmental impacts associated with the TCAAP site are thoroughly investigated and that appropriate steps are taken to protect public health, welfare, and the environment. In accordance with the Installation Restoration Program (IRP), which addresses environmental concerns at U.S. Army installations throughout the world, the U.S. Army initiated a remedial program to remove and treat contaminated ground water at several locations within TCAAP, extract contaminated vapors from soils at two subsites (Source Areas D and G), and excavate and incinerate polychlorinated biphenyls (PCB)-contaminated soils at one subsite (Source Area D). The Argonne National Laboratory (ANL), a contractor for the U.S. Army, has prepared a remedial investigation (RI) report on contaminated areas within the boundaries of TCAAP (ANL, 1990). Concurrently, Camp Dresser and McKee, Inc. (CDM), a contractor for MPCA, prepared an RI report on off-TCAAP ground water to determine the extent of contaminant migration from TCAAP (CDM, 1991).

In accordance with CERCLA, U.S. EPA requires that a risk assessment consisting of human health evaluation and environmental assessment be conducted at every Superfund site. PRC Environmental Management, Inc. (PRC), received a work assignment from U.S. EPA to perform a risk assessment of the New Brighton/Arden Hills site. This work assignment was issued under U.S. EPA ARCS Contract No. 68-W8-0084. The U.S. Army subsequently expressed interest in participating in development of the risk assessment report.

Section 104(i)(6) of CERCLA requires the Agency for Toxic Disease Substances and Disease Registry (ATSDR) to conduct health assessments for every site included or proposed for inclusion on the National Priorities List (NPL). The ATSDR health assessment, which is fairly qualitative, should be distinguished from the EPA human health evaluation portion of a risk assessment, which is more quantitative (U.S. EPA, 1989a). Under this CERCLA mandate, ATSDR conducted a health assessment at the New Brighton/Arden Hills site. At the time of this assessment, a complete environmental characterization of the site had not been done, therefore, this health assessment was designated as preliminary. ATSDR summarized their finding in a report entitled Preliminary Health Assessment for the New Brighton/Arden Hills NPL Site (ATSDR, 1989a). In its assessment, ATSDR examined the background and physical characteristics of the site; conducted a site visit; interviewed New Brighton/Arden Hills area residents and reviewed their medical records; and investigated available reports and data on potential contamination sources, including TCAAP, and non-source specific contamination. Specific references used in the preliminary health assessment are listed in ATSDR (1989a). ATSDR concluded that the New Brighton/Arden Hills site is of potential health concern because of the risk from possible exposure to hazardous substances that could result in adverse health effects. Specifically, ingestion and direct contact with on- and off-TCAAP ground water, contaminated with VOCs, and off-TCAAP surface water and sediment were identified as exposure pathways of concern and should be further evaluated. Also, possible psychological or physical health effects are realized by area residents and they should be dealt with care and compassion. Finally, based on available information, ATSDR concluded that no health study could be performed at the time the preliminary health assessment was completed, however, this decision would be reevaluated following the completion of additional characterization of the site.

U.S. EPA, the U.S. Army, MPCA, and their contractors, including PRC, met to determine the scope of the risk assessment report and to identify organizations that would be responsible for various sections of the report. It was decided that PRC would be responsible for human health risk assessment (Risk Assessment) and that the U.S. Army would be responsible for the environmental assessment. The risk assessment was to be conducted under current and future land use scenarios and under reasonable maximum exposure (RME) and probable conditions. The 95-percent upper bound confidence limit values about the arithmetic means were to be used for

calculating risks under RME conditions. The arithmetic mean values were to be used for calculating risks under probable conditions. The exposure scenarios and values for parameters in exposure dose calculations were determined during the meeting.

When necessary PRC consulted other sources, but information presented in this risk assessment was primarily derived from information contained in the on- and off-TCAAP RI reports (ANL, 1990 and CDM, 1991 respectively). Readers requiring information beyond that presented in this risk assessment, particularly details on the site description, background, and contamination, are referred to these reports.

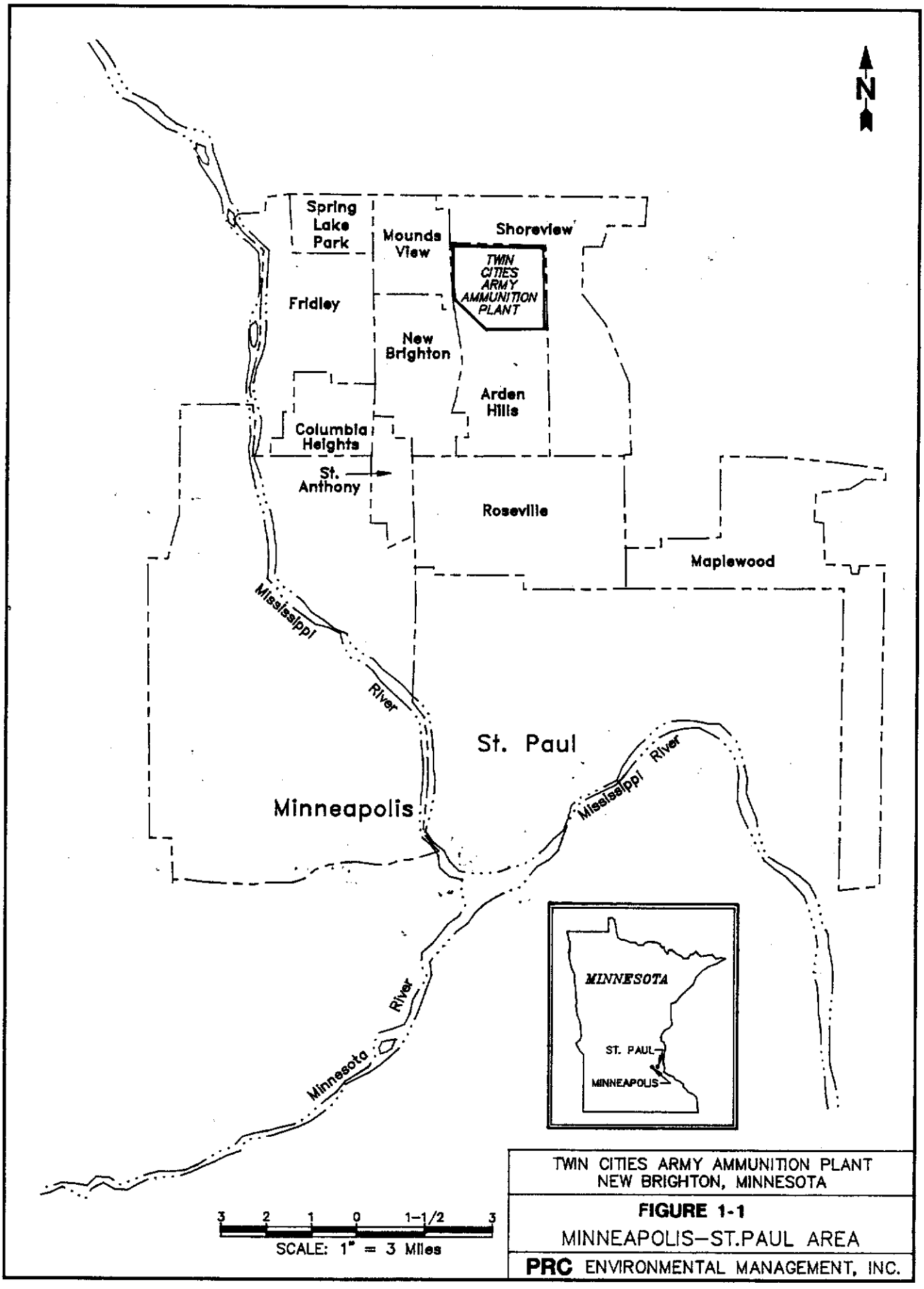
1.1 SITE BACKGROUND

This section presents a general description of the New Brighton/Arden Hills site, discusses individual areas within the site, and provides a brief site history. The site description is derived from the ANL (1990) and CDM (1991) RI reports. Additional site background information is available in these reports. Contaminant concentrations used in this risk assessment are presented in Appendix A.

1.1.1 Site Description

The New Brighton/Arden Hills site is in the northern part of the Minneapolis-St. Paul metropolitan area (Figure 1-1). As presently defined, the site covers much of the U.S. Geological Survey's New Brighton, Minnesota, 7.5-minute quadrangle. For historical and administrative reasons, the site is divided into two areas. TCAAP is the general source area. As shown in Figure 1-2, TCAAP includes 14 (marked as A through K, 129-3, 129-5, 129-15) individual source areas and the rest of the facility. The off-TCAAP area (see Figures 1-3 and 1-4 includes portions of several municipalities. The outer boundaries of the site enclose all areas affected by contamination originating within TCAAP.

The site consists of gently rolling, postglacial terrain with several hills and surface water bodies, including lakes and streams, but no extreme relief. The most striking feature is a kame in the central part of TCAAP, that is about 200 feet above the lower land. The site includes swamps and lakes around the edges of the installation. Several aquifers lie underneath the on- and off-TCAAP areas. Aquifer Units 1, 3, and 4 are water-yielding formations and have been monitored since 1984. The site (including the on- and off-TCAAP areas) is suburban industrial areas (primarily TCAAP itself and the area near its southwest corner), commercial areas along major roads, and recreational areas (primarily around the lakes). The physical setting of the New Brighton/Arden Hills site is discussed further in Chapter 3.

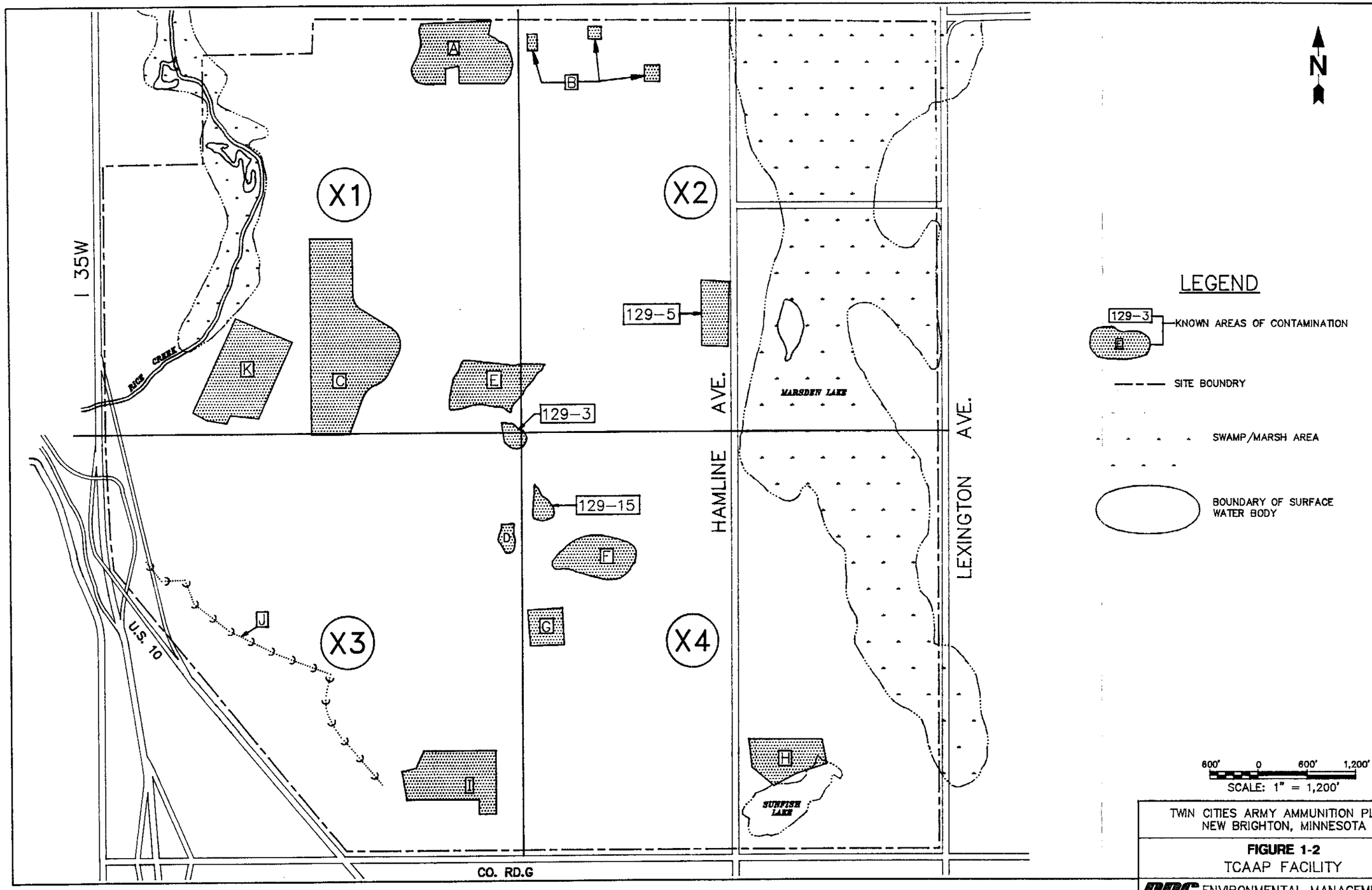


TWIN CITIES ARMY AMMUNITION PLANT
NEW BRIGHTON, MINNESOTA

FIGURE 1-1

MINNEAPOLIS–ST.PAUL AREA

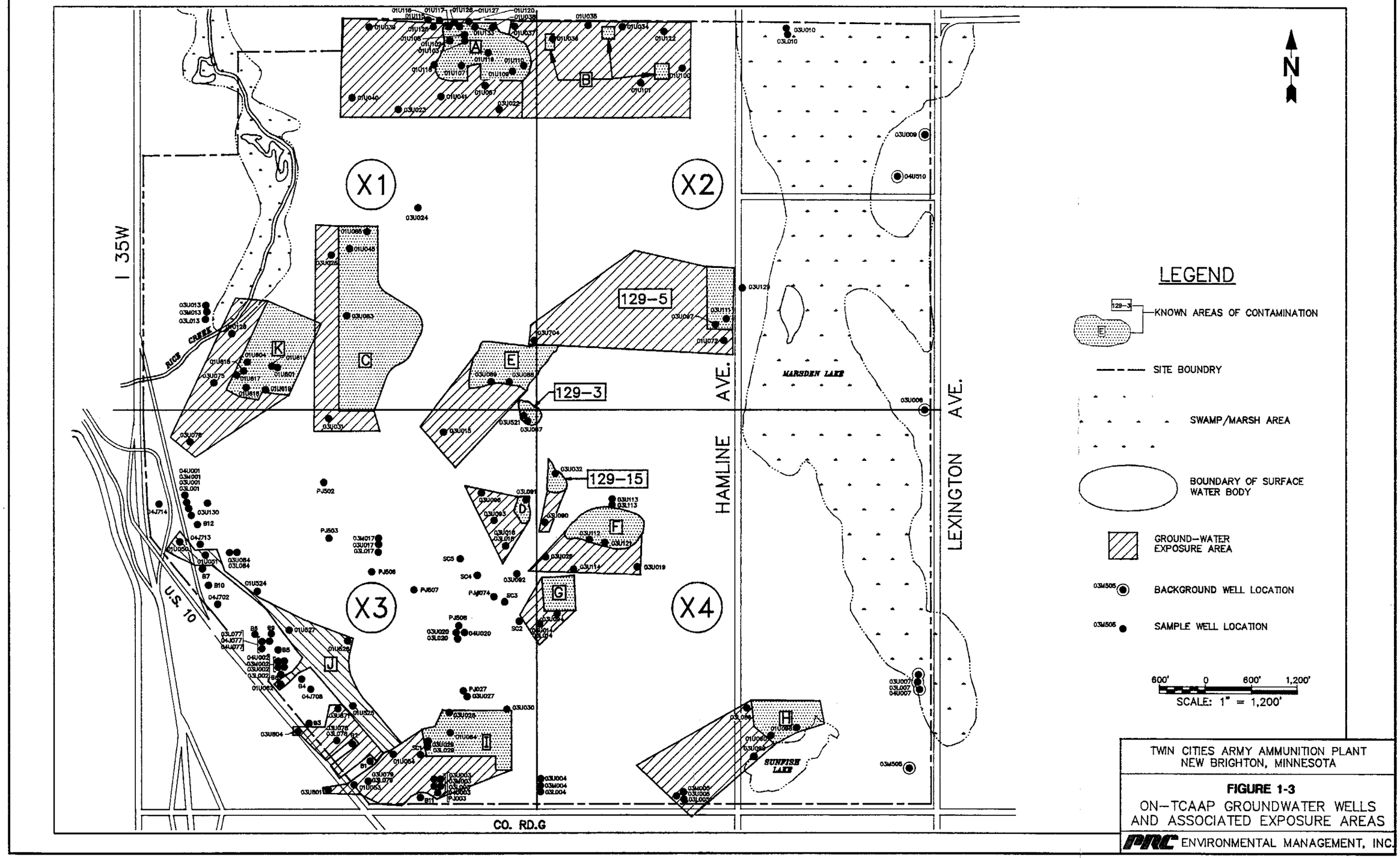
PRC ENVIRONMENTAL MANAGEMENT, INC.



TWIN CITIES ARMY AMMUNITION PLANT
NEW BRIGHTON, MINNESOTA

FIGURE 1-2
TCAAP FACILITY

PRC ENVIRONMENTAL MANAGEMENT, INC.



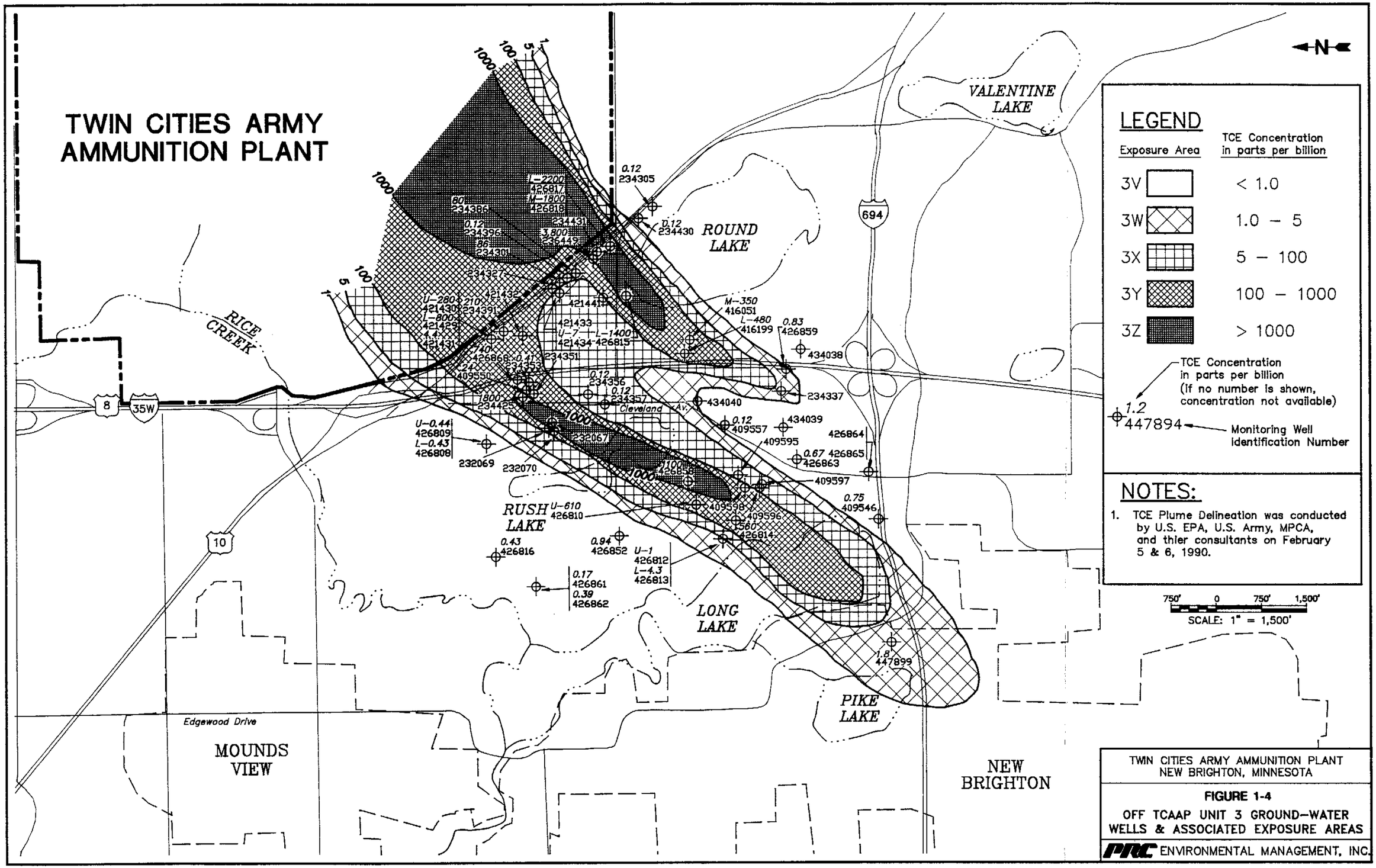
TWIN CITIES ARMY AMMUNITION PLANT
NEW BRIGHTON, MINNESOTA

FIGURE 1-3

ON-TCAAP GROUNDWATER WELLS AND ASSOCIATED EXPOSURE AREAS

PRC ENVIRONMENTAL MANAGEMENT, INC.

TWIN CITIES ARMY AMMUNITION PLANT



LEGEND

Exposure Area	TCE Concentration in parts per billion
3V	< 1.0
3W	1.0 – 5
3X	5 – 100
3Y	100 – 1000
3Z	> 1000

TCE Concentration in parts per billion (if no number is shown, concentration not available)

1.2
447894 — Monitoring Well Identification Number

NOTES:

1. TCE Plume Delineation was conducted by U.S. EPA, U.S. Army, MPCA, and thier consultants on February 5 & 6, 1990.

750' 0 750' 1,500'
SCALE: 1" = 1,500'

TWIN CITIES ARMY AMMUNITION PLANT
NEW BRIGHTON, MINNESOTA

FIGURE 1-4

OFF TCAAP UNIT 3 GROUND-WATER WELLS & ASSOCIATED EXPOSURE AREAS

PRC ENVIRONMENTAL MANAGEMENT, INC.

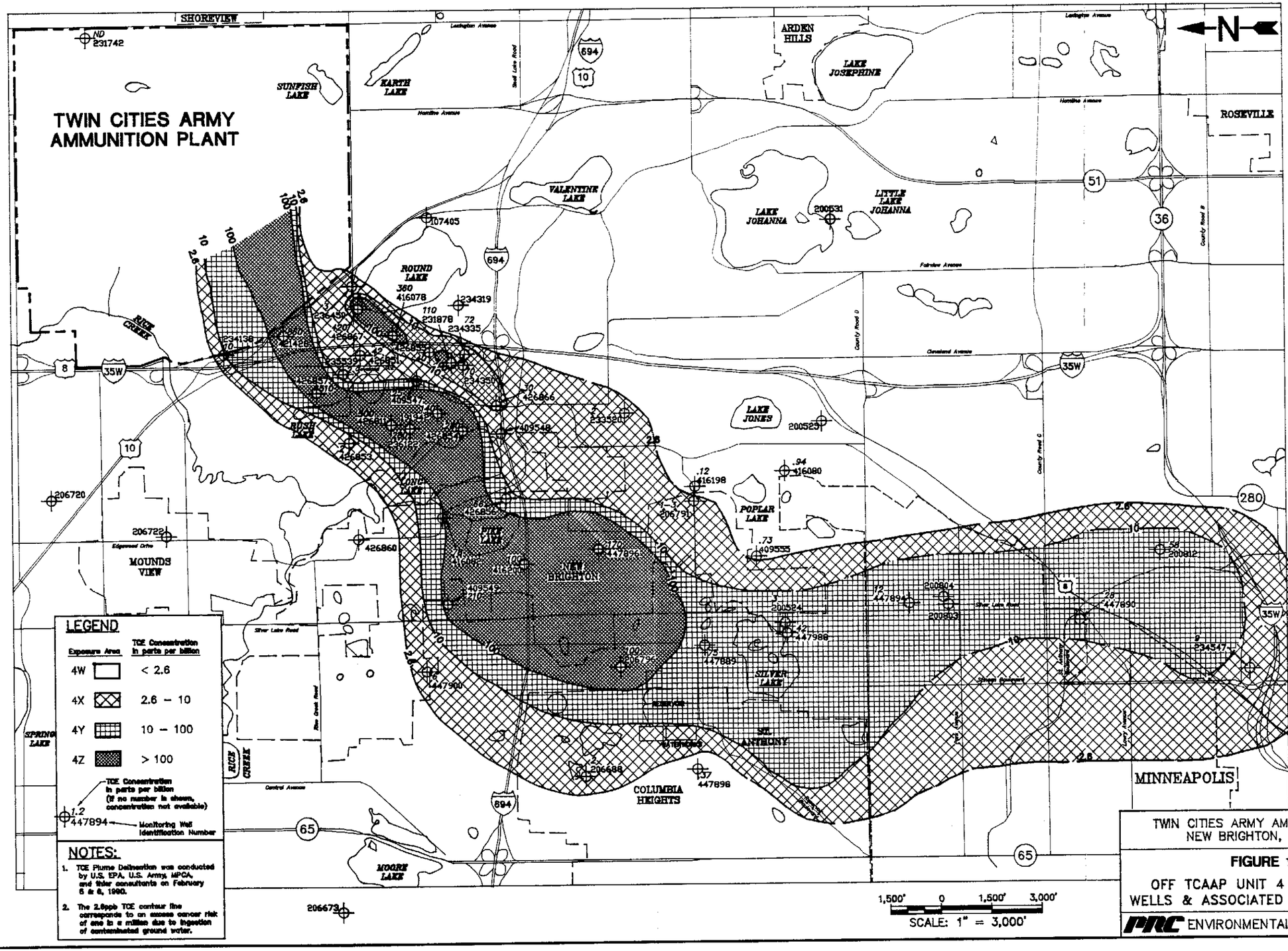
1.1.2 Exposure Areas

The on-TCAAP area of the site was divided into "exposure areas." For soils and air, the exposure areas were the same as the source areas. For ground water, the on-TCAAP area was divided into exposure areas that included the source areas and associated monitoring wells, as defined in the on-TCAAP RI (ANL, 1990). In consultation with U.S. EPA, PRC divided the entire remainder of the TCAAP facility (excluding exposure areas) into four Quadrants referred to as Exposure Areas X1, X2, X3, and X4 (see Figure 1-2). On-TCAAP ground-water wells and the 18 exposure areas (including the four Quadrants) are shown in Figure 1-3. For air, PRC selected 47 receptor locations that included the source areas, the Quadrants, and other on- and off-TCAAP locations. The procedure used to select receptor locations is discussed in detail in Appendix F. Receptor locations for air are shown in Figures F-2 and F-3.

Several small surface water bodies lie within the source areas. These are evaluated as contaminated media within each source area. However, several large surface water bodies lie within TCAAP but outside the source areas. PRC assumed that these large water bodies are accessible to all workers and residents associated with the New Brighton/Arden Hills site; an exception is Sunfish Lake, part of which lies inside Source Area H.

The off-TCAAP study area is very large. Three aquifer units (Units 1, 3 and 4) contain contaminated ground water in the study area. Contaminant concentration levels vary widely within this area and between aquifer units. Therefore, the average concentration for each contaminant may not be a representative value for the entire study area.

The U.S. Army, U.S. EPA, MPCA, and their contractors addressed ground-water concentrations during a meeting at TCAAP on February 5 and 6, 1990. For Aquifer Units 3 and 4, two ground-water plume delineation maps were developed during this meeting. Figure 1-4 shows the plume delineation for Unit 3, and Figure 1-5 shows the plume delineation for Unit 4. The plume delineation maps divided the off-TCAAP study area into several exposure areas. The boundaries of the exposure areas were drawn based on the trichloroethene (TCE) concentration levels in the ground-water wells as of 1987 (Quarter 16). The outermost exposure area drawn by the group (shown in Figure 1-4 with wells containing TCE levels from 1 to 5 μg/L) contain wells with TCE concentrations comparable to 2.6 μg/L which reflect an additional cancer risk of one per million from drinking contaminated ground water. PRC added another exposure area for Unit 3 encompassing all wells outside this exposure area delineated in the meeting at TCAAP. The rationale for an additional exposure area involved the fact that other contaminants in addition to TCE contribute to the additional carcinogenic risk and cumulatively may exceed the 10^{-6} excess cancer risk.



TWIN CITIES ARMY AMMUNITION PLANT
NEW BRIGHTON, MINNESOTA

FIGURE 1-5

OFF TCAAP UNIT 4 GROUNDWATER WELLS & ASSOCIATED EXPOSURE AREAS

PRC ENVIRONMENTAL MANAGEMENT, INC.

The extent of the ground-water plumes and the contaminant concentration levels within the plumes are expected to change over time. However, modelling data predicting the extent of the plumes and concentration levels were not available. Contractors to the U.S. Army are currently developing a contaminant transport model. For the purposes of this risk assessment, PRC assumed steady-state conditions. The contaminant plume delineations in the maps are merely estimates used solely for the purposes of this risk assessment. PRC identified exposure areas based on the maps drawn in the meeting at TCAAP. Wells located within the exposure areas were identified. Although some wells may contain TCE levels outside the concentration ranges specified for a particular exposure area, such wells were still listed within that exposure area. In its evaluation, PRC included all wells for which MPCA provided data.

Five exposure areas were identified for Unit 3 wells: 3V, 3W, 3X, 3Y, and 3Z (see Figure 1-4). TCE concentration ranges vary from less than 1 µg/L for Area 3V to more than 1,000 µg/L for Area 3Z. TCE concentration ranges used for Unit 3 and Unit 4 wells are approximate. Table 1-1 lists Unit 3 wells with associated exposure areas and TCE concentration ranges.

Similarly, Exposure Areas 4W, 4X, 4Y, and 4Z were identified for Unit 4 wells (see Figure 1-5). Table 1-2 lists Unit 4 wells with associated exposure areas and TCE concentration ranges.

In addition, another exposure area (Source Area S) was defined for Unit 1. Source Area S lies to the north of TCAAP in Shoreview (see Figure 1-1). Ground-water quality data and well locations for this area are available from FCC (1988). The wells in Exposure Area S are listed in Table 1-3.

Exposure areas are discussed individually below. Each is discussed in detail in Section 3.2 with emphasis on possible environmental contamination. Discussions of on-TCAAP Quadrants (X1, X2, X3, and X4) exclude other exposure areas contained within the Quadrants.

1.1.2.1 Source Area A

Source Area A is in the central part of TCAAP adjacent to the northern boundary. It includes the relatively recent indoor firing range, Building 308, and a former farmstead. The area has been used for burning explosive wastes and for burying a variety of wastes, including sewage sludge, spent solvents, and mercury-contaminated cartridge crack cases. (In this risk assessment, the term "solvents" is a generic term that is not intended to refer to any particular type of solvent.) The area is relatively flat and partly swampy.

TABLE 1-1

UNIT 3 WELLS USED FOR OFF-TCAAP RISK ASSESSMENT

Exposure Area	TCE Concentration Range (ppb)	Well ID
3V	< 1	234305
		234430
		409546
		409556
		409557
		416081
		426808
		426809
		426816
		426852
		426861
		426862
		426863
		426864
		426865
		434038
		434039
		434040
3W	1 - 5	234337
		426859
		447899
		426812
		426813
3X	5 - 100	234356[1]
		234357[1]
		409595
		409596
		409597
		421433
		421434
3Y	100 - 1,000	232069
		232070
		234301
		234327
		234351
		234353
		234386[1]
		234391[1]
		234396[1]
		409550
		409598
		416051
		416199
		426814
		421431
		421429

TABLE 1-1 (CONTINUED)

UNIT 3 WELLS USED FOR OFF-TCAAP RISK ASSESSMENT

Exposure Area	TCE Concentration Range (ppb)	Well ID
		421432
		421430
		426810
		426868
3Z	> 1,000	232067
		234425
		234431
		236449
		421441
		426815
		426817
		426818
		426858

Notes:

The well listing is based on a plume delineation developed by the U.S. Army, U.S. EPA, and MPCA on February 5 and 6, 1990.

[1] TCE was not detected in this well, but the well's location on the map in Figure 1-4 indicates that it should exhibit a TCE concentration in the range listed and, therefore, this well was included in calculating ground-water concentrations for the designated exposure area.

TABLE 1-2

UNIT 4 WELLS USED FOR OFF-TCAAP RISK ASSESSMENT

Exposure Area	TCE Concentration Range (ppb)	Well ID
4W	< 2.6	107405
		200525
		200531
		206673
		206720
		206722
		233221[1]
		234319
		409555
		416080
		416198
		426860
		447898
4X	2.6 - 10	206688
		206791
		234138
		235539
		236450
		233520
		234547
		409548[1]
		426851
		426853
		447900
4Y	10 - 100	200803
		200804
		200812
		200524
		234350
		234335
		409547
		416082
		426855
		426856
		426866
		447889
		447890
		447894
		447988

TABLE 1-2 (CONTINUED)

UNIT 4 WELLS USED FOR OFF-TCAAP RISK ASSESSMENT

Exposure Area	TCE Concentration Range (ppb)	Well ID
4Z	> 100	191942
		206796
		231878
		236122
		409549
		416078
		416200
		421428
		426811
		426854
		426857
		426867
		447896

Notes:

The well listing is based on a plume delineation developed by the U.S. Army, U.S. EPA, and MPCA on February 5 and 6, 1990.

[1] The TCE concentration for this well was not within the range specified, but the well's location on the map in Figure 1-5 indicates that it should exhibit a TCE concentration in the range listed and, therefore, this well was included in calculating ground-water concentrations for the designated exposure area.

TABLE 1-3

UNIT 1 WELLS USED FOR OFF-TCAAP RISK ASSESSMENT

Exposure Area	Well ID
S	1783 PI
	1747 HI
	1755 OA
	1831 CI
	1740 PI
	1724 PI
	5573 FA
	1761 OA
	1800 LO
	1725 OA
	1705 TE
	1788 LO
	1775 TE
	1754 TE
	1724 TE
	1733 PI
	1754 PI
	5564 SC
	1755 TE
	5561 FA
	5533 FA
	5540 SC
	1587 LO
	1774 PI
	5567 FA

1.1.2.2 Source Area B

Source Area B is immediately east of Source Area A. Area B consist of three small areas of contamination as shown in Figure 1-2. Source Area B includes several former farmsteads and swampy areas. It was used for disposal of sewage sludge and possibly for burning various wastes. Part of the area was used as a landfill.

1.1.2.3 Source Area C

Source Area C is in the central part of TCAAP. It is generally flat and includes Building 190 at the south. A number of old disposal areas exist in Source Area C, primarily in the northern part. Past disposal activities in the area include burning oil and solvents in pits, burning lumber (both clean and contaminated), and decontaminating machines with a pit pyre made from wood and fuel oil.

1.1.2.4 Source Area D

Source Area D is on the kame in the central part of TCAAP. Here pits were excavated and a mixture of water and smokeless powder was poured in; when the water had drained, the powder was burned. Oil containing PCBs, solvents, and other wastes, including rags, primer explosives, and other explosives, was similarly disposed of. Also, cyanide wastes were put in a special pit to be neutralized.

1.1.2.5 Source Area E

Source Area E is on the central kame north of Source Area D. It is partially wooded, especially in the southeastern portion. Miscellaneous wastes and debris were dumped in this area in a ravine, which was closed by 1949. In addition, wastes were burned at various times in other portions of the area.

1.1.2.6 Source Area F

Source Area F is in the central part of TCAAP just south of the kame. It has been used for burning various explosives and tracer compounds and for disposing of mercury and cyanide wastes. The area was used as a burning ground until the 1980s.

1.1.2.7 Source Area G

Source Area G is located in the southcentral part of TCAAP, southeast of the kame. Materials disposed of in Source Area G include rubble, asphalt, fluorine compounds, sweepings from burning areas, and urethane and polyvinyl chloride plastic materials.

1.1.2.8 Source Area H

Source Area H is in the southeastern part of TCAAP on the northwestern side of Sunfish Lake (also called Ryan Lake). A location in the eastern part of the area was used for burning explosive wastes. Other parts of the area have been used for dumping and burying industrial wastes, including paint, incinerator ash, and solvents.

1.1.2.9 Source Area I

Source Area I in the southwestern part of TCAAP consists of Building 502, its outbuildings, and the adjacent land. Building 502 has two stories with a floor area of 345,065 square feet. It has been used to produce 0.30-caliber ammunition and 105-mm shells and to store machine tools. In 1958, Minneapolis-Honeywell Regulation Company (now Honeywell, Inc.) assumed control and has since used it for government and private contracts. These have included manufacturing 30-mm ammunition, some of which contains depleted uranium, and storing liquid wastes of many types.

1.1.2.10 Source Area J

Source Area J, including its exposure area, occupies a large part of the southwestern corner of TCAAP. It consists of a portion of the TCAAP sanitary and storm sewer system and the land potentially affected by system leakage. The area includes combined sanitary and process lines serving Buildings 501, 502, 503, and 576 along the south side of TCAAP. The lines travel to a detention tank (Building 165) and on to the main pumping station (Building 118), both on the west side of TCAAP. Sewage is pumped to a connection with the Minneapolis sewer system about 5 miles southwest of TCAAP. Source Area J also includes portions of the storm sewer systems (both pipes and drainage ditches) leading from Buildings 501, 502, and 503 to Round Lake (see Figure 1-4) and an overflow pipe leading from Building 118 to Round Lake. The overflow pipe was blocked off in 1982 and 1983.

1.1.2.11 Source Area K

Source Area K in the west-central part of TCAAP includes Building 103, a major component of the original plant, and associated outbuildings and land. Building 103 is a 410,810-square-foot building used to produce 0.50-caliber ammunition, store and renovate government-owned machine tools, and to manufacture fuses, mines, and related products. Building 103 has been occupied solely by Honeywell since 1960. The storage operations involved considerable use of paints, preservatives, degreasers, and other solvents.

1.1.2.12 Source Area 129-3

Source Area 129-3 is a small area on the central kame near the center of TCAAP. The area was used for disposal of wastewater, most of which was contaminated with lead styphnate and other primer materials, in the 1970s. After the water leached into the ground or evaporated, residue in the pits was burned to destroy the explosive materials.

1.1.2.13 Source Area 129-5

Source Area 129-5 is former farmland in the east-central part of TCAAP. Several pits were used to burn powder and ammunition and to dispose of solvents. These operations ceased in about 1951. In the 1970s, much of the affected area was mined by the Arsenal Sand and Gravel Company.

1.1.2.14 Source Area 129-15

Source Area 129-15 is in the central part of TCAAP, running along the eastern portion of the kame. This site was used as a dump and burial ground for demolition debris, construction debris, and other wastes during the 1970s. Materials excavated in the area as part of the IRP include urethane and polyvinyl chloride plastics.

1.1.2.15 Northwest Quadrant

The Northwest Quadrant (Exposure Area X1) is the part of TCAAP that is within Section 9 (Township 30 North, Range 23 West) but excludes Source Areas A, B, C, E, and K. This Quadrant includes a part of Rice Creek, which enters from the north and exits to the west in the southern part of the Quadrant, and some TCAAP-owned residences along the western edge. The residences are occupied by military personnel and their dependents.

1.1.2.16 Northeast Quadrant

The Northeast Quadrant (Exposure Area X2) is the part of TCAAP within Section 10 (T30N, R23W) but excludes Source Areas B and 129-5. Most of its eastern part is called Marsden Lake, which is primarily a swamp. Much of its western part has been quarried for sand and gravel by the Arsenal Sand and Gravel Company.

1.1.2.17 Southwest Quadrant

The Southwest Quadrant (Exposure Area X3) is the part of TCAAP within Section 16 (T30N, R23W) but excludes Source Areas D, I, and J. This Quadrant includes most of the developed (factory) portions of TCAAP as well as much of the central kame. The contribution to the overall risk from current operations of Southwest Quadrant factories is outside the scope of this risk assessment. The factories are regulated under Resource Conservation and Recovery Act (RCRA) and other hazardous waste and material handling regulations, rather than CERCLA or Superfund Amendments and Reauthorization Act (SARA).

1.1.2.18 Southeast Quadrant

The Southeast Quadrant (Exposure Area X4) is the part of TCAAP within Section 15 (T30N, R23W) but excludes Source Areas F, G, and H. Sunfish Lake, a perennial lake, is adjacent to Source Area H in the southeastern part of this Quadrant, and part of Marsden Lake is in the northeastern part.

1.1.2.19 Off-TCAAP Ground-Water Area

The Off-TCAAP Ground-Water Area includes any land that contains (or may contain) contaminated ground water associated with the New Brighton/Arden Hills site. This land includes New Brighton, Arden Hills, Saint Anthony, Mounds View, Shoreview, Columbia Heights, and northeastern Minneapolis. Public drinking water supply wells in some of these areas were shut down because of contamination. The Off-TCAAP Ground-Water Area consists of 10 subsites distinguished by the levels of contamination in specific aquifer units. Source Area S is to the north of TCAAP but all other off-TCAAP areas are to the southwest of TCAAP along the pathway of the contaminant plume. Procedures used to delineate the off-TCAAP areas are described in Chapter 3.

1.1.2.20 Off-TCAAP Surface Area

The Off-TCAAP Surface Area includes land surface water, and sediment that contain (or may contain) surface contamination from TCAAP. The area includes water bodies affected by surface runoff from TCAAP such as Round Lake (from Source Area J and others) and Rice Creek. These and other areas are probably affected by contaminated ground water as well. Because PRC has no specific data on such contamination, consideration of this area is limited to the effects of estimated and inferred contaminant concentrations.

1.1.3 Site History

The following history of the New Brighton/Arden Hills site is based on reports by U.S. EPA and MPCA (1987), ANL (1987 and 1990), and CDM (1991). It covers events relevant to site contamination: its creation, discovery, investigation, and remediation.

Construction of the Twin Cities Ordnance Plant, now TCAAP, began in August 1941. The plant occupied 2,370 acres of farmland, most of Sections 9, 10, 15, and 16 of Township 30 North, Range 23 West, Ramsey County, Minnesota. Production began in the Phase I plant in February 1942, although construction was not considered complete until January 15, 1943, when 323 buildings and associated utilities and services were finished. The facility was operated by FCC and produced billions of rounds of small arms ammunition (0.30 caliber and 0.50 caliber). Buildings 501 and 502 were operated for a time by other contractors to manufacture 105-mm and 155-mm projectiles. Production ceased in 1945 with the end of World War II.

After World War II, the Ordnance Corps of the U.S. Army operated TCAAP directly. The main activities were storing machinery (often from other facilities) and reclaiming ammunition. In the latter process, ammunition was unpacked and sorted, usable rounds were repacked, and unserviceable rounds were salvaged for components.

During the Korean War, FCC resumed production of small arms ammunition at the site. In 1957, the entire plant was put on standby status. TCAAP was reactivated in 1965 to produce 7.62-mm and 5.56-mm small arms ammunition. Production ceased in 1973 (except for test runs of a new line of production machinery in 1975), and the plant was returned to standby status in 1976.

Numerous TCAAP buildings and areas have been leased to other organizations for their use, sometimes for U.S. government work. Following are examples of organizations that have operated on TCAAP:

- U.S. Army Reserve -- Buildings 535 and 537 since 1970
- General Mills -- railroad tracks for helium storage from 1962 through 1981
- Honeywell -- numerous buildings for manufacturing ammunition and other items. Except from 1965 through 1974, most manufacturing at TCAAP since 1958 has been done by Honeywell under leases
- 3M -- Buildings 113, 575, and others for manufacture of products (often radioactive) from 1953 to the present
- Toni Company -- Building 587 for manufacture of permanent wave solution from 1948 through 1951.

Appendix C of the Preliminary Assessment of TCAAP (ANL, 1987) contains lists of all known leases and of all buildings, their uses, and approximate dates of use.

The first environmental complaints related to TCAAP were received by the Minnesota State Department of Health in 1953; nearby residents complained of bad odors and water discoloration in Round Lake. This was caused by cutting and cooling oils, graphite, grease, and other lubricants from shell manufacturing operations in Buildings 501 and 502 that were flushed through the storm sewers to Round Lake. Subsequent construction of additional sewers allowed collection of storm sewer discharge for treatment.

In 1978, the U.S. Army Toxic and Hazardous Materials Agency released an installation assessment of TCAAP as Report No. 129 of IRP. This report noted extensive on-TCAAP waste disposal activities. MPCA gained access to the report in 1981 and began to collect water samples for analysis for volatile organic compounds (VOC) and metals. A number of contaminated wells were found, including residential wells and one small public water supply well at the Arden Manor Trailer Park in Arden Hills. These events initiated a series of investigations by the U.S. Army and MPCA that have continued to the present. Honeywell soon began additional investigations of buildings it leased.

The first notable result of these studies was discovery of chronically toxic concentrations of volatile organics in the drinking water wells of TCAAP, New Brighton, Arden Hills, and Saint Anthony. Use of affected wells was discontinued and substitute water supplies were provided, including bottled water, alternate supply systems, new wells, and treatment plants. In 1982, the area was placed in Group I (highest priority) of the NPL as the New Brighton/Arden Hills site.

MPCA issued its first Request for Response Action (RFRA) to the U.S. Army, FCC, and Honeywell in June 1983 in order to regulate investigatory and remedial activities on TCAAP. MPCA also began its own off-TCAAP activities through its contractor, CDM. Honeywell started some off-TCAAP activities, and U.S. EPA assumed a general oversight role under the National Contingency Plan (NCP). RIs began in the fall of 1983. Quarterly ground-water monitoring began in early 1984. The first FFA in the country was signed in 1987 (U.S. EPA and MPCA, 1987) to direct actions at the site. Basically, the U.S. Army conducts on-TCAAP actions, U.S. EPA and MPCA conduct off-TCAAP actions, and U.S. EPA and MPCA share overall oversight responsibilities, with U.S. EPA having final decision on the final risk assessments for the entire site.

In addition to the water supply provisions described above, various interim remedial actions have been carried out, including the following:

- Soils contaminated with PCBs were excavated and stored at Source Area D in 1985. These soils were thermally treated in 1989.
- Honeywell carried out a removal for off-TCAAP disposal of contaminated solids in soil near Building 502 (Source Area I) and in sewer system sediments. The U.S. Army finished cleaning sewers in 1986.
- Honeywell installed a passive system in 1985 to collect ground water from the vicinity of Building 103 (Source Area K), which began operation in 1986. Ground water is treated using air stripping to remove VOCs, and treated water is discharged to Rice Creek under a National Pollutant Discharge Elimination System (NPDES) permit.
- The U.S. Army started in-situ soil vapor extraction and treatment systems in the unsaturated zones of Source Areas D and G in 1986.
- The U.S. Army implemented the Boundary Ground-Water Recovery System (BGRS) in 1987. This system initially consisted of six wells along the southwestern corner of TCAAP. Volatile organics were stripped from recovered water, which was then discharged into the gravel pit (excavated by Arsenal Sand and Gravel Company) in the Northeast Quadrant. In 1989, the system was expanded to 12 wells, and a fourth air stripping tower was added to treat the additional ground-water flow.
- Honeywell installed a source control (SC) well (SC1) in Source Area I in 1986. Ground water is treated at SC1 using air stripping and is then discharged to BGRS for further treatment and disposal.
- The U.S. Army installed four additional SC wells downgradient of Source Areas D and G. Ground water from these wells is pumped to BGRS for treatment and disposal. The designation TCAAP Ground-Water Recovery System (TGRS) is now used to refer to the entire system, including the BGRS and SC wells.

- The U.S. Army installed a ground-water extraction and treatment system at Source Area A in 1988. The system includes one pumping well; extracted ground water is treated with granular activated carbon. The treated water is discharged into a creek within Area A which feeds into Rice Creek.

- In 1987, TCAAP checked all underground storage tanks and removed or replaced those that were unnecessary, leaking, or potentially dangerous.

Several studies have been completed for on-TCAAP areas. These studies are summarized in the RI reports (CDM, 1990 and ANL, 1990). Results of these studies are incorporated into relevant portions of this risk assessment.

1.2 SCOPE OF RISK ASSESSMENT

The objective of this risk assessment is to evaluate the magnitude and probability of actual or potential harm to public health, welfare, and the environment posed by actual or threatened releases of hazardous substances from TCAAP. Collective demographic, geographic, physical, chemical, and biological factors are carefully evaluated to assess the impact of an actual or potential release of hazardous substances from the site. U.S. EPA generally requires that a risk assessment support all administrative and judicial enforcement actions under CERCLA.

Section 300.68 of the NCP provides that an RI and feasibility study (FS) be performed for hazardous waste sites that may require cleanup. The risk assessment is a link between the RI and FS. The risk assessment can help evaluate (1) the threats to potentially affected populations and environments posed by hazardous substances and (2) remedial actions that can be considered to abate such threats.

PRC's methodology used in this risk assessment is based on U.S. EPA guidelines in the Risk Assessment Guidance for Superfund -- the Human Health Evaluation Manual (1989a). PRC followed this guidance in developing health risk information, but the U.S. Army followed the Environmental Evaluation Manual (U.S. EPA, 1989b) for its environmental assessment. PRC's approach to conducting the human health risk assessment at the large and complex TCAAP site is described in the following paragraphs.

U.S. EPA (1989a) suggests that health risk information be developed for scenarios based only on RME conditions. However, the U.S. Army, U.S. EPA, MPCA, and their contractors decided to evaluate a probable case scenario in addition to RME. RMEs are based on the 95-percent upper-bound limit of the confidence interval of the standard error of the arithmetic mean value for contaminant concentrations in a particular medium, but the probable case scenario

is generally based on the arithmetic mean value for the same data set. The RME represents the reasonable maximum exposure possible, but the probable case is more likely to represent the exposure that receptors will experience. The arithmetic mean was used for contaminant concentrations rather than the geometric mean or some other value because U.S. EPA guidance requires it (1989a).

U.S. EPA (1989a) also states that risk assessments are to be conducted under current and future land use conditions. However, available guidance does not specifically state how future land use should be defined. In the case of TCAAP, present land use conditions represent the most probable land use scenario for the future. Under RME conditions, future land use includes residential and commercial development.

Several interim measures implemented at TCAAP emit volatile organic contaminants to the atmosphere. These measures include the in situ vapor extraction units at Source Areas D and G and the TGRS ground-water strippers. To evaluate carcinogenic risks from air emission sources associated with remedial activities, PRC used an air dispersion model, the Industrial Source Complex Long-Term (ISCLT) model, to estimate air concentrations at specific receptor locations. Available data (Weston, 1988) indicate that trichloroethene (TCE) is the major constituent (over 80 percent) of the total air emission load. The potential emission load for other volatiles is insignificant compared to the TCE emission load. For TCE, toxicity data are available only for evaluating carcinogenic risk. PRC evaluated carcinogenic risks using exposure from inhalation of TCE over a long period of time. To evaluate acute noncarcinogenic risks, PRC used another air dispersion model (Turner, 1970) to estimate air concentrations at receptor locations. PRC assumed that 1,1,1-trichloroethane constitutes all the volatiles capable of exerting an acute effect; available data indicate that the potential emission load of other volatiles is insignificant compared to that of 1,1,1-trichloroethane.

1.3 ORGANIZATION OF RISK ASSESSMENT REPORT

A risk assessment involves evaluating the following factors: the existing extent of contamination in various environmental media; the potential for contaminants to migrate within and between media; the environmental persistence and toxicity of the contaminants; site-specific factors that influence possible routes of human and environmental exposure to contaminants; populations that could be exposed to contaminants; and potential risks resulting from exposure. The following paragraphs outline the information contained in the rest of this report.

In Chapter 2, PRC introduces the chemicals of potential concern that are evaluated in subsequent chapters. Chemicals of potential concern are identified for each exposure area.

In Chapter 3, PRC characterizes the exposure setting, identifies exposure pathways, and discusses the fate and transport of the chemicals of potential concern in the environment. The chapter reviews the physical and chemical properties of each indicator chemical and evaluates how these properties affect movement of chemicals through different environmental media (soil, ground water, surface water, sediment, and air). Specific site characteristics that affect fate and transport of indicator chemicals, such as climate and geologic and hydrogeologic features, are also discussed. The chapter then evaluates the likelihood of exposure to indicator chemicals at the site through different potential exposure scenarios. Depending on the information available, the chapter presents either quantitative estimates of exposure (mg of contaminant per kg of body weight per days of exposure) or a qualitative evaluation of exposure. Uncertainties associated with the exposure assessment are summarized. The most significant routes of exposure serve as the bases for the risk assessment in Chapter 5.

In Chapter 4, PRC evaluates the toxicologic properties of indicator chemicals. The chapter is not intended to be a comprehensive review but rather a summary of indicator chemical toxicology in light of potential exposure routes at the site. The chapter includes basic information on how chemicals are absorbed, metabolized, and excreted by the body as well as information on potential acute and chronic health effects caused by exposure to each chemical. Finally, the chapter includes applicable standards and guidelines on exposure to each indicator chemical, such as acceptable drinking water concentrations and occupational exposure limits.

In Chapter 5, PRC characterizes the potential risks from exposure to indicator chemicals released from the site under current and future land use conditions. For some exposure routes, only a qualitative characterization of risks is possible. For other exposure routes, a quantitative risk characterization is made by comparing exposure estimates from Chapter 3 with standards and guidelines from Chapter 4. The quantitative risk assessment for carcinogenic indicator chemicals is expressed as a probability of developing cancer from exposure to the chemicals. Noncarcinogenic chemicals are addressed by comparing estimated exposure levels with published guidelines for acceptable exposure. Source area-specific uncertainties as well as uncertainties associated with the risk assessment process are summarized.

Finally, in Chapter 6 PRC summarizes the results of the risk assessment. The chapter briefly describes each potential exposure route and summarizes potentially significant risks.

CHAPTER 2

IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

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CHAPTER 2
IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

In this chapter, PRC identifies chemicals found at TCAAP that are of potential concern to humans and the environment. The data sources and methodology for this identification are addressed first, followed by summaries of results of various site investigations. Specific results for each environmental area are discussed in turn. The most widespread chemicals at the site identified as chemicals of potential concern include the following:

- Inorganics such as antimony, cadmium, chromium, nickel, and silver
- Volatile organics such as trichloroethene; 1,1,1-trichloroethane; 1-2-dichloroethene, 1,1-dichloroethene; 1,1-dichloroethane; and chloroform
- A semivolatile organic, bis(2-ethylhexyl)phthalate

For detailed discussion of the contaminants identified at the site, refer to the on-TCAAP and off-TCAAP RIs, ANL (1990) and CDM (1991), respectively.

2.1 DATA COLLECTION

Several site investigations have been performed at the New Brighton/Arden Hills site. ANL conducted the on-TCAAP investigations; these are summarized in the on-TCAAP RI (ANL 1990). CDM, working for the MPCA, conducted the off-TCAAP investigations; these are summarized in the off-TCAAP RI (CDM 1991).

The on-TCAAP RI (ANL, 1990) is a multi-media investigation that used a variety of methods at areas known to have been involved in waste disposal and at selected areas where wastes were believed to have migrated. The following techniques were used to locate potential foci of contamination:

- Electromagnetic inductance surveys
- Ground-penetrating radar surveys
- Soil gas surveys

The following techniques were used to determine definitive contaminant concentrations:

- Surface soil sampling
- Soil trenching

- Soil borings
- Subsurface soil sampling
- Monitoring well installation
- Ground-water sampling
- Surface water sampling
- Sediment sampling

In addition to the on-TCAAP investigations conducted by ANL, other sources provided data on ground-water contaminants. Existing on-TCAAP wells have been sampled and assayed by the U.S. Army on a quarterly basis since 1984. The U.S. Army provided PRC with data from Quarter 16 (November 1987) through Quarter 24 (October 1989). For this risk assessment, PRC used data collected during the RIs conducted by ANL, which coincided with the 16th quarterly sampling. However, some wells were not sampled during Quarter 16. For such wells, PRC used more recent data from the quarterly samplings nearest to the 16th. For pumping wells connected to BGRS, PRC used data presented in the Annual Monitoring Plan - Volume 1 (U.S. Army, 1990). To analyze organics in ground water, the U.S. Army used gas chromatography/mass spectrometry (GC/MS) and non-GC/MS methods. The non-GC/MS methods have lower detection limits, and their data quality is considered more appropriate than that of the GC/MS methods for the purpose of conducting the risk assessment. At the suggestion of the U.S. Army, and concurrence by EPA, PRC used non-GC/MS data instead of GC/MS data if both types were available. PRC used GC/MS data only if non-GC/MS data were not available for a specific sample.

Data used by PRC to develop this risk assessment are contained primarily in the on-TCAAP and off-TCAAP RI reports, ANL, 1990 and CDM, 1991, respectively. A complete listing of all data used in this risk assessment along with detection limits for each chemical in each media are presented in ANL (1990), CDM (1991), and FCC (1988). The on-TCAAP RI report (ANL, 1990) is currently undergoing further review and data used by PRC may be revised as a result of the review. Also, other source areas within TCAAP may be identified, requiring further review. The risk assessment may be updated as new data is developed. Finally, this risk assessment acknowledges that on-TCAAP RI sampling results revealed unknown compounds that must still be identified. However, because risks associated with on-TCAAP exposure are not likely to be dominated by these tentatively identified compounds (TIC), PRC did not include them among the chemicals of potential concern. This position with regards to TICs is consistent with U.S. EPA guidance, which holds that when the number of TICs relative to target analyte list (TAL) and target compound list (TCL) chemicals is small and historical information does not suggest the presence of a particular TIC, then the TICs should not be included in the risk assessment (U.S. EPA, 1989a).

The off-TCAAP studies (CDM, 1991) have concentrated on investigating ground-water contamination. Specific investigatory activities include the following:

- Installation of piezometers and monitoring wells
- Well sampling and analysis, and well water level measurement
- Soil sampling and analysis for consolidation and permeability
- Aquifer tests for conductivity and similar parameters

PRC used off-TCAAP ground-water data from CDM (1991) as well as data collected for Shoreview (Source Area S) Unit 1 wells (FCC, 1988). Although some data collected at off-TCAAP locations were included by ANL in its on-TCAAP report (1990), PRC did not use these data.

Air concentrations of contaminants were not monitored at either on- or off-TCAAP areas. PRC used the ISCLT air dispersion model to estimate air concentrations of VOCs emitted from sources associated with ongoing remedial actions. TCE and 1,1,1-trichloroethane levels in air were estimated for 47 on- and off-TCAAP locations. PRC also used models to calculate inhalation exposures resulting from showering with contaminated ground water and inhaling fugitive dusts during excavation of soils.

PRC calculated the arithmetic mean value and the 95-percent upper-bound confidence limit value about the arithmetic mean for each medium at each exposure area and aquifer unit. PRC followed U.S. EPA guidance (1989a) for all such calculations. The results are listed in Appendix A. For each exposure area and media, the arithmetic mean and the 95 percent upperbound confidence limit value about the arithmetic mean are presented. Appendix B contains lists of chemicals of potential concern for each exposure area.

2.2 DATA EVALUATION

Results from the RI studies were first reviewed by the sponsoring agency (the U.S. Army or MPCA) using relevant U.S. EPA guidelines (such as Data Validation Guidelines for Organic and Inorganic Analyses). The RI reports were forwarded to U.S. EPA and were reviewed by U.S. EPA and PRC personnel.

As noted earlier, PRC followed U.S. EPA guidance for selecting chemicals of potential concern. The procedure used to select chemicals of potential concern was based on the criterion

discussed in Section 2.2.1. Issues of uncertainty related to data evaluation and the selection of chemicals of potential concern are discussed in Section 2.2.2.

2.2.1 Comparison With Background Levels

To identify chemicals of potential concern, statistical tests were conducted using the sample concentrations available for each medium and corresponding background levels. The purposes of these tests were to establish that compounds encountered in the samples were attributable to contamination at the site and to separate these compounds from others naturally present in the environment. Details of the statistical test procedure, including data and data sources used for background levels, are presented in Appendix J.

In most cases, if an organic compound was detected in a sample, it was also identified as a chemical of potential concern. Tetrachloroethane was found in background ground-water samples. Also trichloroethene was detected in background surface water samples. However, because the presence of these compounds were probably linked to TCAAP contamination; as a result, tetrachloroethane and trichloroethene, even if present at levels comparable to background levels, were still included as chemicals of potential concerns. Trichloroethene and tetrachloroethane were not considered chemicals of potential concern if these were not detected in any sample from a particular exposure area.

2.2.2 Uncertainty

The primary uncertainty associated with on-TCAAP soils data is that the data came from discrete samples and not from the entire facility. Exposure areas within TCAAP were selected by evaluating records of past site activities. Within each exposure area, soil sampling locations were selected by conducting geophysical surveys and soil gas measurements. These soils data are therefore biased because most samples were collected from the more contaminated portions of the site. In addition, the extent of soil contamination within TCAAP has not been fully defined.

Uncertainties associated with on-TCAAP ground-water data result from the fact that data were drawn from samples collected over a period of time during different quarters. Variations in contaminant concentrations over time are not accounted for in this risk assessment. In addition, there have been variations in the analytical techniques used.

Organic and inorganic chemicals were identified in ground water, surface water, sediment, surface soils, and subsurface soils within TCAAP. The on-TCAAP RI team collected soil gas samples from 3 feet below the land surface and analyzed for certain halogenated and

aromatic hydrocarbons. However, the reported values are expressed in "relative" units. As a result, information available to PRC was not sufficient to estimate soil gas levels. PRC, therefore, was unable to quantitatively assess risk from contaminants in soil gas.

PRC used several sources to identify background locations for all media. Uncertainties are associated with the appropriateness of these background locations.

Data used to calculate risks from inhaling contaminants in air were estimates derived using different models. Uncertainties associated with such estimates are discussed further in Appendices E and F.

2.3 CHEMICALS OF POTENTIAL CONCERN IN EXPOSURE AREAS

In this section, PRC identifies chemicals of potential concern in each exposure area. Different contaminant concentration levels were reported for samples collected during different sampling events. Decisions made by PRC on the use of such data are discussed in Section 2.1. For a comprehensive discussion of site contamination, refer to the on-TCAAP and off-TCAAP RI reports, ANL (1990) and CDM (1991), respectively.

Tables listing organic and inorganic chemicals of potential concern for each medium in each environmental area are presented in Appendix B. In addition, those chemicals of potential concern for which quantitative risk evaluation is not possible are also noted in these tables.

2.3.1 Source Area A

Source Area A has been studied since 1983 when remedial investigation began. During the most recent investigations (ANL, 1990), a full array of studies was done on five subareas identified as disposal pits and trenches. These studies found a wide variety of waste materials, including buried drums, shell casings, glass bottles, cardboard filters, brick, concrete and metal scrap. Spent solvents and sewage sludge are known to have been disposed of in Source Area A. The most pervasive contamination was VOCs in ground water. The primary "hot spot" is Well 01U108 in the northwestern part of this area. Significant concentrations are also found in nearby Wells 01U115, 01U016, 01U117, and 01U126. The highest concentrations found for 1,2-dichloroethene, tetrachloroethane, and trichloroethene in ground water are 670 ug/L, 260 ug/L, and 150 ug/L, respectively. Organic chemicals of potential concern in ground water include benzene, 1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene, tetrachloroethane, bis(2-ethylhexyl) phthalate, and xylene.

Soil gas samples showed 1,1-trichloroethane and 1,1,2,2-tetrachloroethane, as well as the chemicals found in ground water in the vicinity of Well 01U108 and in two more areas 100 and 200 meters to the east. Benzene, toluene, and xylene were found in soil gas in three areas: two intense areas about 200 meters east and 100 meters south of Well 01U108 and at the well itself (the first area also showed chlorinated hydrocarbons), a third area about 150 meters southwest of the well. Xylene was the only chemical of potential concern identified in subsurface soil. Based on the selection criteria discussed in Section 2.2, no organic compounds were identified as a chemical of potential concern in surface soil, surface water, or sediment.

Interpreting inorganic assay results is difficult because background samples may contain most analytes. Ground-water samples from Source Area A and other areas usually contained barium at levels well below the drinking water maximum contaminant level (MCL). Of the other metals assayed for, the most significant was manganese, which was found in ground water in concentrations as high as 1,200 μg/L (Well 01U119) and 2,000 μg/L (Well 01U108); however, the mean contamination concentration was found to be not significantly different from background. Inorganic chemicals of potential concern identified in ground water are silver, cadmium, chromium, lead, antimony, and zinc in Unit 1 and cadmium in Unit 3. The chemicals of potential concern in surface and subsurface soils are silver, cadmium, chromium, and copper. In addition, antimony and nickel were identified as chemicals of potential concern in surface and subsurface soil, respectively. Surface water samples did not contain any inorganics above background levels. Copper and lead were identified as chemicals of potential concern in sediments.

Gross alpha and gross beta were identified as chemicals of potential concern (actually gross alpha and gross beta are more accurately referred to as parameters rather than chemicals; the term chemicals is used for consistency) in surface and subsurface soils.

2.3.2 Source Area B

As in Source Area A, ground water in Source Area B has been monitored since 1984, and a full array of studies was recently done (ANL, 1990). Levels of contamination in Source Area B are much lower than those in Source Area A. Although 1,1,1-trichloroethane, trichloroethene, and toluene were found in several soil gas samples, the only evidence for the source of these emissions is low concentrations of trichloroethene and 1,1,1-trichloroethane (up to 30 and 10 μg/L, respectively) in a few of the older (pre-1987) ground-water samples. Trans-1,2-dichloroethene and xylene are the only two organics identified as chemicals of potential concern in ground water.

Inorganic assays of ground water found pervasive but relatively low concentrations of barium (up to 290 µg/L in Well 01U100) and manganese (up to 910 µg/L in Well 01U034) in recent samples. However, the upper-bound 95-percent confidence level value of the arithmetic mean for manganese concentrations was comparable to background levels. Although hot spots of different contaminants probably exist in this or other areas, considering the number of chemicals contributing to the total risk, such hot spots are not expected to contribute significantly to the total risk. Cadmium, although it was detected in low concentrations, was detected at a level significantly above background and was therefore identified as a chemical of potential concern in ground water. Chromium was the only chemical (organic or inorganic) identified as a chemical of potential concern in surface and subsurface soils. Copper and lead were identified as chemicals of potential concern in sediments.

2.3.3 Source Area C

Source Area C was first studied in 1983 by taking a few soil samples and by installing and sampling monitoring wells. The site was recently studied with a full array of tests. The soil gas assay found 1,1,1-trichloroethane, trichloroethene, benzene, toluene, and xylene in the northern part of the area near Well 01U085. However, ground-water assays found only low levels of toluene, trichloroethene, and bis(2-ethylhexyl) phthalate, so the contaminant source for the soil gas chemicals was not defined. Assays of soil samples from trenches dug in the area found considerable concentrations of polycyclic aromatic hydrocarbons in the ash layers but no VOC contamination. All of the organics detected were identified as chemicals of potential concern in the specific media.

The most significant inorganic contamination was found in samples from Aquifer Unit 1 wells. Recent assays found up to 2,000 µg/L of manganese, 530 µg/L of barium, 3.12 µg/L silver, 2.73 µg/L of chromium, and traces of cadmium. All of these inorganics, except barium, were identified as chemicals of potential concern in Unit 1 ground water. One surface water sample contained measurable manganese (2,000 µg/L), silver (3.0 µg/L), and thallium (4.8 µg/L). Manganese, silver, and thallium were identified as chemicals of potential concern in surface water. Copper was the only chemical of potential concern identified in sediments. Chromium was the only chemical of potential concern identified in surface and subsurface soils.

2.3.4 Source Area D

About 1,400 cubic yards of PCB-contaminated soil was excavated at Source Area D and stored in 1985. These soils were stockpiled, covered with a liner, and thermally treated in 1989. The residue, including all inorganic contaminants, was buried on-TCAAP. In addition, an in situ

volatilization system (ISV) has been installed under a clay cap to remove VOCs. As a result of the operating ISV system, only limited studies have been done on the current status of Source Area D for media other than ground water.

Most of the remaining contamination is in the ground water. The organic contaminants are trichloroethene (up to 79,000 μg/L) and 1,1,1-trichloroethane (up to 9,300 μg/L). Trichloroethene and 1,1,1,-trichloroethane were the two organic chemicals of potential concern identified in Source Area D.

Of the wells assayed in the Source Area D, Well 03U093 had the highest concentrations of most inorganic constituents. These include manganese (1,800 μg/L), barium (220 μg/L), chromium (3.5 μg/L), cadmium (0.19 μg/L) and zinc (30 μg/L). Manganese and barium concentrations were comparable to background levels. Copper and lead were identified as chemicals of potential concern in sediments. Nickel, thallium, and gross beta were identified as chemicals of potential concern in surface water.

2.3.5 Source Area E

Source Area E was not thoroughly studied until recently. Soil gas surveys found substantial concentrations of trichloroethene and lesser concentrations of 1,1,1-trichloroethane. No VOCs were found in soil samples from the area. Only trace concentrations of PCB Aroclor 1260 and bis(2-ethylhexyl)phthalate were found in soil and ground water, respectively. Ground water also contained tetrachloroethane at levels comparable to background concentrations. PRC included tetrachloroethane as a chemical of potential concern. The source of those soil gas contaminants has not yet been identified. Understanding of organic contamination in Source Area E ground water is complicated by the fact that samples from some upgradient wells (such as 03U705 in Exposure Area "129-5") contained more contamination (26 μg/L of tetrachloroethane and 6.6 μg/L of 1,1,1-tetrachloroethane) than was found within Source Area E or in downgradient wells.

Some evidence exists of inorganic contamination in Source Area E ground water. Silver, cadmium, and chromium were identified as chemicals of potential concern. In surface and subsurface soils, the chemicals of potential concern include silver, cadmium, chromium, copper, mercury, and nickel. Silver, chromium, cyanide, and nickel were identified as chemicals of potential concern in surface waters.

2.3.6 Source Area F

Source Area F has been studied intermittently since 1983. Soil gas surveys of the area found relatively high concentrations of trichloroethene and 1,1,1-trichloroethane. Recent soil assays failed to identify the sources of the soil gas contaminants. None of the organic compounds was identified as a chemical of potential concern in surface or subsurface soils. In recent ground-water assays, concentrations of up to 860 µg/L of 1,1,1-trichloroethane and 150 µg/L of trichloroethene were found. Organic chemicals of potential concern in ground water include 1,1-dichloroethene, bis(2-ethylhexyl)phthalate, and chloroform in addition to trichloroethene and 1,1,1-trichloroethane.

Source Area F has significant inorganic contamination in soils. Borehole SB056 surface soil samples contained very high (2,300 mg/kg) concentrations of lead. Other samples from the same borehole showed lead concentrations ranging from not detected to 25 mg/kg, with intermediate values in three deeper samples (7.3 meters was the greatest sample depth). Lead was identified as a chemical of potential concern in surface soils. In addition, cadmium, chromium, copper, nickel, and antimony were identified as inorganic chemicals of potential concern in both surface and subsurface soils. Silver and mercury were also identified as chemicals of potential concern in subsurface soils.

Silver, cadmium, chromium, lead, and zinc were identified as chemicals of potential concern in ground water.

2.3.7 Source Area G

Recent studies at Source Area G included only soil and ground-water sampling; as in Source Area D, the ISV system installed in this area interfered with other studies. No organic compounds were identified as chemicals of potential concern in Source Area G soil samples. However, the ground water contained significant amounts of various contaminants. Contaminants (and maximum concentrations) found included trichloroethene (18,000 µg/L); 1,1,1-trichloroethane (9,100 µg/L); 1,2-dichloroethene (2,300 µg/L); 1,1-dichloroethane (830 µg/L); methylene chloride (5,400 µg/L); and bis(2-ethylhexyl)phthalate (37 µg/L). All these compounds were identified as chemicals of potential concern in ground water.

Regarding inorganics, copper and nickel were identified as chemicals of potential concern in sub surface soils. Cadmium and chromium were identified as chemicals of potential concern in ground water. Cadmium, copper, mercury, and lead were identified as chemicals of potential

concern in sediments. Gross beta radiation was measured in significant amounts in surface and subsurface soils and in ground water.

2.3.8 Source Area H

Source Area H has been studied intermittently since 1983. The site recently underwent a full array of tests. Soil gas surveys found areas with high concentrations of trichloroethene and 1,1,1-trichloroethane. Soil assays failed to identify the source of these emissions and found no organic contamination.

Toluene and bis(2-ethylhexyl)phthalate were found in Aquifer Unit 1 samples; the highest concentrations were 23 ug/L and 80 ug/L, respectively. The compounds 1,2-dichloroethene, trichloroethene, and 1,1,1-trichloroethane were found in one out of five Unit 3 ground-water samples at concentrations of 4.2 ug/L, 8.4 ug/L, and 0.97 ug/L, respectively. All of the organic compounds detected in ground water were considered as chemicals of potential concern.

Significant inorganic contamination was found in this area. Silver, cadmium, chromium, antimony, copper, and nickel were identified chemicals of potential concern in both surface and subsurface soils. Copper was identified as a chemical of potential concern in sediments. Aquifer Units 1 and 3 were both found to be contaminated with inorganics; silver, chromium, and cadmium were identified as chemicals of potential concern in both units; and Unit 1 also had nickel, lead, and zinc as chemicals of potential concern.

2.3.9 Source Area I

Source Area I is the most studied area at TCAAP. It has been studied for environmental contamination since 1953 (when excess oil and grease were found in a storm sewer outlet to Round Lake and Valentine Lake) and for industrial hygiene purposes since 1954 (because of exposure of workers to oil mists, metal dusts, carbon monoxide, and toluene vapors, among other emissions). Some 1967 studies found excessive discharges of cyanide and other pollutants to the sewer system. In 1983, studies found trichloroethene and manganese in various media. Soil samples contained up to 13,500 mg/kg (1.35 percent) PCBs; the most contaminated soils were removed for off-TCAAP disposal. Similarly, contamination in sewer lines (up to 4,300 mg/kg of PCBs, up to 2,500 mg/kg of uranium, and concentrations of various other metals) led to general cleaning of the lines and off-TCAAP disposal of collected sediments. PCBs were not detected in surface or subsurface soils during the on-TCAAP RI (ANL, 1990).

Aquifer Units 1, 3, and 4 were found to be contaminated with organics. Significant organic contamination in the area consists of chlorinated hydrocarbons in ground water. The major contaminant is trichloroethene at concentrations of up to 7,000 µg/L. Other contaminants identified as chemicals of potential concern include 1,2-dichloroethene; trans-1,2-dichloroethene; 1,1,1-trichloroethane; 1,1,2-trichloroethane; 1,1-dichloroethane; 1,2-dichloroethane, 1,1-dichloroethene, vinyl chloride, and bis(2-ethylhexyl)phthalate. Tetrachloroethane was identified as a chemical of potential concern because its arithmetic mean concentration was found to be higher than the proposed MCL. See Table B-9 for a list of organics identified as chemicals of potential concern in specific aquifer units.

Aquifer Units 1 and 3 were found to be contaminated with inorganics. Inorganic chemicals of potential concern identified in ground water include silver, cadmium, chromium, manganese, and lead in Unit 1 and silver, cadmium, cyanide, chromium, and zinc in Unit 3. Manganese was identified as a chemical of potential concern in surface water. Copper and lead were identified as chemicals of potential concern in sediments.

Gross beta was identified as a chemical of potential concern in surface water.

2.3.10 Source Area J

Source Area J consists in large part of the sewer system draining Source Area I, so studies of one have generally included the other. Routine sewer monitoring for oil and grease began in 1942. In 1967, this monitoring was extended to other analytes, including hexavalent chromium and lead. Regular assays for organic contaminants began in 1982; earlier tests had identified but not quantified the presence of trichloroethene and xylene. Studies in the early 1980s led to a major cleaning of the sewer system and off-TCAAP disposal of collected sediments. The chemicals found most widely spread out at highest concentrations in ground water and soils during these studies were PCBs, uranium, and other various metals; however, substantial concentrations of trichloroethene and 1,2-dichloroethene were also found in sediments and associated waters.

Postremoval data for Source Area J are relatively limited. Three soil borings were done at locations likely to be affected by large amounts of exfiltration. The borehole samples contained no detectable organic contamination. Recent ground-water sampling in Unit 1 found such organics as trichloroethene, 1,1,1-trichloroethane and bis(2-ethylhexyl)phthalate and such inorganics as silver, cadmium, chromium, cyanide, and lead, which were identified as chemicals of potential concern

Silver, chromium, and nickel were identified as chemicals of potential concern in surface and subsurface soils.

Gross alpha and gross beta were measured in subsurface soils and ground water and are considered chemicals of potential concern in this area.

2.3.11 Source Area K

Source Area K environmental contamination was first studied in 1967. That study resulted in elimination of cyanide discharges and implementation of a discharge monitoring system, similar to the one for Source Area I. This monitoring and other early studies found a number of contaminants in water (discharges, surface water, and ground water) and soil (including sediments). Many contamination problems were alleviated by engineering measures such as a tile drain that collects ground water and removes VOC contamination.

Despite such controls, significant contamination remains at Source Area K. For example, ground-water monitoring has found concentrations of trichloroethene as high as 120,000 μg/L in Well 01U611. Organic chemicals of potential concern identified are 1,2-dichloroethene and trichloroethene for Unit 1 and bis(2-ethylhexyl)phthalate for Unit 3. Inorganic chemicals of potential concern are cadmium, chromium, lead, and zinc for Unit 1.

In sediments, copper and lead were identified as chemicals of potential concern.

Bis(2-ethylhexyl)phthalate and trichloroethene were identified as chemicals of potential concern in surface water.

2.3.12 Source Area 129-3

Source Area 129-3 was little studied until recently. The most notable finding was the apparent passage of a plume of trichloroethene (containing some 1,1,1-trichloroethane) past Well 03U521 in 1985. However, recent studies detected only trichloroethene in ground water.

Recent soil gas studies found high levels of trichloroethene in surface and subsurface soils in the southern part of the area, along with other organic compounds. A sample from trench TR031 had 120 mg/kg of trichloroethene, 520 mg/kg of di-n-butyl phthalate, and 6.6 mg/kg of 2,4-dinitrotoluene. These compounds, along with bis(2-ethylhexyl)phthalate, N-nitrosodiphenylamine, and toluene, were selected as chemicals of potential concern in both surface and subsurface soils.

Silver, antimony, cadmium, chromium, and cyanide were identified as inorganic chemicals of potential concern in both surface and subsurface soils. Silver, chromium, and lead were identified in ground water.

2.3.13 Source Area 129-5

Source Area 129-5 was first studied in 1983. The only notable findings in early studies were low concentrations of chlorinated hydrocarbons and metals in ground-water samples. Recent studies included a full array of tests.

Soil gas surveys found an area of 1,1,1-trichloroethane. However, organic compounds were not detected in any of the other media monitored except for Unit 3 ground water. 1,1,1-trichloroethene, bis(2-ethylhexyl)phthalate, and trichloroethene were identified as chemicals of potential concern in Unit 3 ground water.

Chromium and nickel were identified as inorganics chemicals of potential concern in subsurface soil. Chemicals of potential concern identified are nickel in Unit 1 and cadmium in Unit 3.

2.3.14 Source Area 129-15

Source Area 129-15 was first studied in 1983. Soil gas surveys in 1987 found an area of contamination that included 1,1,1-trichloroethane, benzene, trichloroethene, xylene, and toluene. Results from the surveys indicated that the contamination was confined within Source Area 129-15 boundaries. Results of recent ground-water assays show detectable concentrations of 1,1,1-trichloroethane, trichloroethene, chloroform, and 1,2-dichloroethene in Unit 3. All of these compounds are considered chemicals of potential concern. Organic compounds were not detected in surface or subsurface soils.

Among inorganics, chromium was identified as a chemical of potential concern in surface soil, subsurface soil, and ground water. Other inorganics identified as chemicals of potential concern include nickel in subsurface soil; silver and cadmium in ground water; and copper and lead in sediments.

Gross alpha and gross beta were identified as parameters of potential concern in surface soil, subsurface soil, and ground water.

2.3.15 Areas X1, X2, X3, and X4

The Northwest (X1), Northeast (X2), Southwest (X3), and Southeast (X4) Quadrants within TCAAP consist of the portions of TCAAP outside the fourteen source areas discussed above. Because investigations at TCAAP have concentrated on possible waste disposal areas, the only data available for these quadrants came from ground-water monitoring wells. These wells are used to (1) determine background concentrations of contaminants and (2) follow the migration of contamination plumes. Additional data are available from other wells, especially those supplying drinking water to TCAAP and those in such remediation systems as TGRS.

Areas X1, X2, and X4 were found to be contaminated with fewer than ten compounds each. Area X3 contained a large number of compounds identified as chemicals of potential concern. All the compounds identified as chemicals of potential concern in the four areas are listed in Tables B-15 through B-18 in Appendix B.

2.3.16 Off-TCAAP Ground Water

As noted earlier, except for the Rick Creek and Round Lake surface water bodies, the only off-TCAAP medium studied is ground water. The off-TCAAP RI (CDM, 1991) summarized earlier ground-water studies (especially from Phase I, completed in 1985) and presented results of recent ground-water studies (Phase IA -- field studies ended in December 1988). This section is a summary of off-TCAAP ground-water contamination.

The major ground-water plume extends to the southwest from TCAAP in Aquifer Units 3 and 4 and splits into two lobes. The northern lobe is greater, extending at least 5 miles from TCAAP (see Figure 1-5); the southern lobe has not been detected past Highway I-694. The Hillside aquifer (Unit 3) is the more contaminated. In the plume, trichloroethene is the predominant contaminant, and 1,1,1-trichloroethane is the next. In the northern lobe, trichloroethene levels are typically three times greater than 1,1,1-trichloroethane levels; most wells within this lobe have ratios of trichloroethene concentration to 1,1,1-trichloroethane concentration between 2 to 1 and 10 to 1, but a few have similar concentrations of the two contaminants. In the southern lobe, trichloroethene levels are usually over ten times greater than 1,1,1-trichloroethene levels and in most cases, 1,1,1-trichloroethane is not even detected.

In addition, wells monitored at locations north of TCAAP showed concentrations of several organics in Aquifer Unit 1. The organics detected include chloroform, 1,2-dichloroethene, and trichloroethene.

Large numbers of organic and inorganic compounds were identified as chemicals of potential concern in Aquifer Units 3 and 4 off-TCAAP. Tables B-19 through B-24 in Appendix B list all compounds identified as chemicals of potential concern in off-TCAAP ground water.

2.3.17 Surface Water

Water and sediment samples were collected during the RI studies from surface water bodies at on-TCAAP locations and at two off-TCAAP locations including Rice Creek, Round Lake, Sunfish Lake, and Marsden Lake. Data from past studies are not adequate to use in this risk assessment.

Organic compounds were not detected in downgradient portions of the water bodies. However, trichloroethene was detected at one location in Rice Creek upgradient of TCAAP. Tables B-25 through B-28 in Appendix B list all chemicals identified as chemicals of potential concern in surface water bodies.

2.4 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

This risk assessment should ideally present the individual and cumulative risks to human health and the environment from exposure to all contaminants identified in each medium at or near the site. PRC compared concentration levels for each chemical with background levels and identified chemicals of potential concern. However, PRC did not eliminate any organic chemical from further consideration even if it was present at levels comparable to background. SF or RfD values are not available for a number of contaminants. Thus, a quantitative estimate of the additional risk from these chemicals of potential concern is not possible. PRC discusses the risk from such chemicals qualitatively if adequate information is available.

Quantitative risk estimates were performed using all contaminants identified as chemicals of potential concern for which risk factors (SFs or RfDs) are available. Trichloroethene is the most significant contaminant because it is the most pervasive and because it is a moderately potent carcinogen. The compound 1,1,1-trichloroethane is the noncarcinogenic organic chemical of greatest concern because it is the next most pervasive organic chemical. Chemicals of potential concern identified in each exposure area are presented in Appendix B and are summarized in Table 2-1.

TABLE 2-1

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Exposure Area:	A				B				C				
Media:	SS	SB	GW	SD	SS	SB	GW	SD	SS	SB	GW	SW	SD
ORGANICS													
Acetone	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzene	-	-	1	-	-	-	-	-	-	-	-	-	-
Benzoic Acid	-	-	-	-	-	-	-	-	-	-	-	-	-
Bromodichloromethane	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Butanone	-	-	-	-	-	-	-	-	-	-	-	-	-
N-Butylbenzylphthalate	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbon Tetrachloride	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorethane	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethene	-	-	1	-	-	-	-	-	-	-	-	-	-
cis-1,2-Dichlorothene	-	-	-	-	-	-	-	-	-	-	-	-	-
trans-1,2-Dichloroethene[a]	-	-	1	-	-	-	1	-	-	-	-	-	-
Di-n-butylphthalate	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-
Di-n-octylphthalate	-	-	-	-	-	-	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	-	-	1	-	-	-	-	-	-	-	1	-	-
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylene Chloride	-	-	-	-	-	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	-	-	-	-	-	-	-	-	-	-	-	-	-
PAHs	-	-	-	-	-	-	-	-	X	X	-	-	-
PCB (Aroclor-1260)	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenol	-	-	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene[b]	-	-	1	-	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1,2-Trichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	-	-	1	-	-	-	-	-	-	-	3	-	-
1,1,2-Trichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-
Toluene	-	-	-	-	-	-	-	-	-	-	3	-	-
Vinyl Chloride	-	-	-	-	-	-	-	-	-	-	-	-	-
Xylenes	-	X	1	-	-	-	1	-	-	-	-	-	-
INORGANICS													
Aluminum	-	-	-	-	-	-	-	-	-	-	-	-	-
Antimony	X	-	1	-	-	-	-	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium	X	X	1,3	-	-	-	1	-	-	-	1	-	-
Calcium	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromium	X	X	1	-	X	X	-	-	X	X	1	-	-
Cobalt	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper	X	X	-	X	-	-	-	X	-	-	-	-	X
Cyanide	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead[c]	-	-	1	X	-	-	-	X	-	-	-	-	-
Magnesium	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-	1	X	-
Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel	-	X	-	-	-	-	-	-	-	-	-	-	-
Potassium	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver	X	X	1	-	-	-	-	-	-	-	1	X	-
Sodium	-	-	-	-	-	-	-	-	-	-	-	-	-
Thallium	-	-	-	-	-	-	-	-	-	-	-	X	-
Vanadium	-	-	-	-	-	-	-	-	-	-	-	-	-
Zinc	-	-	1	-	-	-	-	-	-	-	-	-	-
RADIOACTIVES													
Gross Alpha[c]	X	X	-	-	-	-	-	-	-	-	-	-	-
Gross Beta[c]	X	X	-	-	-	-	-	-	-	-	-	-	-

TABLE 2-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Exposure Area:	D			E				F		
Media:	GW	SW	SD	SS	SB	GW	SW	SS	SB	GW
ORGANICS										
Acetone	-	-	-	-	-	-	-	-	-	-
Benzene	-	-	-	-	-	-	-	-	-	-
Benzoic Acid	-	-	-	-	-	-	-	-	-	-
Bromodichloromethane	-	-	-	-	-	-	-	-	-	-
2-Butanone	-	-	-	-	-	-	-	-	-	-
N-Butylbenzylphthalate	-	-	-	-	-	-	-	-	-	-
Carbon Tetrachloride	-	-	-	-	-	-	-	-	-	-
Chlorethane	-	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-	3
1,1-Dichloroethane	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethene	-	-	-	-	-	-	-	-	-	3
1,2-Dichloroethene	-	-	-	-	-	-	-	-	-	-
cis-1,2-Dichlorothene	-	-	-	-	-	-	-	-	-	-
trans-1,2-Dichloroethene[a]	-	-	-	-	-	-	-	-	-	-
Di-n-butylphthalate	-	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	-	-	-	-	-	-	-	-	-	-
Di-n-octylphthalate	-	-	-	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	-	-	-	-	-	3	-	-	-	3
Ethylbenzene	-	-	-	-	-	-	-	-	-	-
Methylene Chloride	-	-	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	-	-	-	-	-	-	-	-	-	-
PAHs	-	-	-	-	-	-	-	-	-	-
PCB (Aroclor-1260)	-	-	-	X	X	-	-	-	-	-
Phenol	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene[b]	-	-	-	-	-	3	-	-	-	-
1,1,1-Trichloroethane	3	-	-	-	-	-	-	-	-	3
1,1,2-Trichloroethane	-	-	-	-	-	-	-	-	-	-
Trichloroethene	3	-	-	-	-	-	-	-	-	3
1,1,2-Trichloroethene	-	-	-	-	-	-	-	-	-	-
Toluene	-	-	-	-	-	-	-	-	-	-
Vinyl Chloride	-	-	-	-	-	-	-	-	-	-
Xylenes	-	-	-	-	-	-	-	-	-	-
INORGANICS										
Aluminum[c]	-	-	-	-	-	-	-	-	-	-
Antimony	-	-	-	-	-	-	-	X	X	-
Arsenic	-	-	-	-	-	-	-	-	-	-
Cadmium	3	-	-	X	X	3	-	X	X	3
Calcium[c]	-	-	-	-	-	-	-	-	-	-
Chromium	3	-	-	X	X	3	X	X	X	3
Cobalt	-	-	-	-	-	-	-	-	-	-
Copper	-	-	X	X	X	-	-	X	X	-
Cyanide	-	-	-	-	-	-	X	-	-	-
Iron[c]	-	-	-	-	-	-	-	-	-	-
Lead[c]	-	-	X	-	-	-	-	X	-	-
Magnesium[c]	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-
Mercury	-	-	-	X	X	-	-	-	X	-
Nickel	-	X	-	X	X	-	X	X	X	-
Potassium[c]	-	-	-	-	-	-	-	-	-	-
Silver	-	-	-	X	X	3	X	-	-	3
Sodium[c]	-	-	-	-	-	-	-	-	X	-
Thallium	-	X	-	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-	-	3
Zinc	3	-	-	-	-	-	-	-	-	3
RADIOACTIVES										
Gross Alpha[c]	-	-	-	-	-	-	-	-	-	-
Gross Beta[c]	-	X	-	-	-	-	-	-	-	-

TABLE 2-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Exposure Area:	G				H				I		
Media:	SS	SB	GW	SD	SS	SB	GW	SD	GW	SW	SD
ORGANICS											
Acetone	-	-	-	-	-	-	-	-	-	-	-
Benzene	-	-	-	-	-	-	-	-	-	-	-
Benzoic Acid	-	-	-	-	-	-	-	-	-	-	-
Bromodichloromethane	-	-	-	-	-	-	-	-	-	-	-
2-Butanone	-	-	-	-	-	-	-	-	-	-	-
N-Butylbenzylphthalate	-	-	-	-	-	-	-	-	-	-	-
Carbon Tetrachloride	-	-	-	-	-	-	-	-	-	-	-
Chlorethane	-	-	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	-	-	3	-	-	-	-	-	3	-	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	1	-	-
1,1-Dichloroethene	-	-	-	-	-	-	-	-	1,3	-	-
1,2-Dichloroethene	-	-	3	-	-	-	3	-	1,3	-	-
cis-1,2-Dichlorothene	-	-	-	-	-	-	-	-	-	-	-
trans-1,2-Dichloroethene[a]	-	-	-	-	-	-	-	-	3	-	-
Di-n-butylphthalate	-	-	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	-	-	-	-	-	-	-	-	-	-	-
Di-n-octylphthalate	-	-	-	-	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	-	-	3	-	-	-	1	-	1,3	-	-
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-
Methylene Chloride	-	-	3	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	-	-	-	-	-	-	-	-	-	-	-
PAHs	-	-	-	-	-	-	-	-	-	-	-
PCB (Aroclor-1260)	-	-	-	-	-	-	-	-	-	-	-
Phenol	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene[b]	-	-	-	-	-	-	-	-	3	-	-
1,1,1-Trichloroethane	-	-	3	-	-	-	3	-	1,3,4	-	-
1,1,2-Trichloroethane	-	-	-	-	-	-	-	-	3	-	-
Trichloroethene	-	-	3	-	-	-	3	-	1,3,4	-	-
1,1,2-Trichloroethene	-	-	-	-	-	-	-	-	-	-	-
Toluene	-	-	-	-	-	-	1	-	-	-	-
Vinyl Chloride	-	-	-	-	-	-	-	-	1	-	-
Xylenes	-	-	-	-	-	-	-	-	-	-	-
INORGANICS											
Aluminum[a]	-	-	-	-	-	-	-	-	-	-	-
Antimony	-	-	-	-	X	X	-	-	-	-	-
Arsenic	-	-	-	-	-	-	-	-	-	-	-
Cadmium	-	-	3	X	X	X	1,3	-	1,3	-	-
Calcium[a]	-	-	-	-	-	-	-	-	-	-	-
Chromium	-	-	3	-	X	X	1,3	-	1,3	-	-
Cobalt	-	-	-	-	-	-	-	-	-	-	-
Copper	-	X	-	X	X	X	-	X	-	-	X
Cyanide	-	-	-	-	-	-	-	-	3	-	-
Iron[a]	-	-	-	-	-	-	-	-	-	-	-
Lead[a]	-	-	-	X	-	-	1	-	1	-	X
Magnesium[a]	-	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	1	X	-
Mercury	-	-	-	X	-	-	-	-	-	-	-
Nickel	-	X	-	-	X	X	1	-	-	-	-
Potassium[a]	-	-	-	-	-	-	-	-	-	-	-
Silver	-	-	-	-	X	X	1,3	-	1,3	-	-
Sodium[a]	-	-	-	-	-	-	-	-	-	-	-
Thallium	-	-	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-	-	-	-
Zinc	-	-	-	-	-	-	1	-	3	-	-
RADIOACTIVES											
Gross Alpha[a]	-	-	-	-	-	-	-	-	-	-	-
Gross Beta[a]	X	X	3	-	-	-	-	-	-	X	-

TABLE 2-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Exposure Area:	J						129-3		
Media:	SS	SB	GW	GW	SW	SD	SS	SB	GW
ORGANICS									
Acetone	-	-	-	-	-	-	-	-	-
Benzene	-	-	-	-	-	-	-	-	-
Benzoic Acid	-	-	-	-	-	-	-	-	-
Bromodichloromethane	-	-	-	-	-	-	-	-	-
2-Butanone	-	-	-	-	-	-	-	-	-
N-Butylbenzylphthalate	-	-	-	-	-	-	-	-	-
Carbon Tetrachloride	-	-	-	-	-	-	-	-	-
Chlorethane	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-
1,1-Dichloroethene	-	-	-	-	-	-	-	-	-
1,2-Dichloroethene	-	-	-	1	-	-	-	-	-
cis-1,2-Dichlorothene	-	-	-	-	-	-	-	-	-
trans-1,2-Dichloroethene[a]	-	-	-	-	-	-	-	-	-
Di-n-butylphthalate	-	-	-	-	-	-	X	X	-
2,4-Dinitrotoluene	-	-	-	-	-	-	X	X	-
Di-n-octylphthalate	-	-	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	-	-	1	3	X	-	X	X	-
Ethylbenzene	-	-	-	-	-	-	-	-	-
Methylene Chloride	-	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	-	-	-	-	-	-	X	X	-
PAHs	-	-	-	-	-	-	-	-	-
PCB (Aroclor-1260)	-	-	-	-	-	-	-	-	-
Phenol	-	-	-	-	-	-	-	-	-
Tetrachloroethene[b]	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	-	-	1	-	-	-	-	-	-
1,1,2-Trichloroethane	-	-	-	-	-	-	-	-	-
Trichloroethene	-	-	1	1	X	-	X	X	3
1,1,2-Trichloroethene	-	-	-	-	-	-	-	-	-
Toluene	-	-	-	-	-	-	X	X	-
Vinyl Chloride	-	-	-	-	-	-	-	-	-
Xylenes	-	-	-	-	-	-	-	-	-
INORGANICS									
Aluminum[c]	-	-	-	-	-	-	-	-	-
Antimony	-	-	-	-	-	-	X	-	-
Arsenic	-	-	-	-	-	-	-	-	-
Cadmium	-	-	1	1	-	-	X	X	-
Calcium[c]	-	-	-	-	-	-	-	-	-
Chromium	X	X	1	1	-	-	X	X	3
Cobalt	-	-	-	-	-	-	-	-	-
Copper	-	-	-	-	-	X	-	-	-
Cyanide	-	-	1	-	-	-	X	X	-
Iron[c]	-	-	-	-	-	-	-	-	-
Lead[c]	-	-	1	1	-	X	-	-	3
Magnesium[c]	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-
Mercury	-	-	-	-	-	-	-	-	-
Nickel	X	X	-	-	-	-	-	-	-
Potassium[c]	-	-	-	-	-	-	-	-	-
Silver	X	X	1	-	-	-	X	X	3
Sodium[c]	-	-	-	-	-	-	-	-	-
Thallium	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-	-
Zinc	-	-	-	1	-	-	-	-	-
RADIOACTIVES									
Gross Alpha[c]	-	X	1	-	-	-	-	-	-
Gross Beta[c]	-	X	1	-	-	-	-	-	-

TABLE 2-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Exposure Area:	129-5			129-15				X1	X2	X3	X4
Media:	SS	SB	GW	SS	SB	GW	SD	GW	GW	GW	GW
ORGANICS											
Acetone	-	-	-	-	-	-	-	-	-	-	-
Benzene	-	-	-	-	-	-	-	-	-	-	-
Benzoic Acid	-	-	-	-	-	-	-	-	-	-	-
Bromodichloromethane	-	-	-	-	-	-	-	-	-	-	-
2-Butanone	-	-	-	-	-	-	-	-	-	-	-
N-Butylbenzylphthalate	-	-	-	-	-	-	-	-	-	-	-
Carbon Tetrachloride	-	-	-	-	-	-	-	-	-	-	-
Chloroethane	-	-	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	3	-	-	-	3,4	-
1,1-Dichloroethane	-	-	-	-	-	-	-	-	-	3,4	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-	3,4	-
1,1-Dichloroethene	-	-	-	-	-	-	-	-	-	3,4	-
1,2-Dichloroethene	-	-	-	-	-	3	-	-	-	3,4	3
cis-1,2-Dichlorothene	-	-	-	-	-	-	-	-	-	-	-
trans-1,2-Dichloroethene[a]	-	-	-	-	-	-	-	-	-	-	-
Di-n-butylphthalate	-	-	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	-	-	-	-	-	-	-	-	-	-	-
Di-n-octylphthalate	-	-	-	-	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	-	-	3	-	-	-	-	-	-	3	3
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-
Methylene Chloride	-	-	-	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	-	-	-	-	-	-	-	-	-	-	-
PAHs	-	-	-	-	-	-	-	-	-	-	-
PCB (Aroclor-1260)	-	-	-	-	-	-	-	-	-	-	-
Phenol	-	-	-	-	-	-	-	-	-	-	-
Tetrachloroethene[b]	-	-	-	-	-	-	-	-	-	3	-
1,1,1-Trichloroethane	-	-	3	-	-	3	-	-	-	3,4	-
1,1,2-Trichloroethane	-	-	-	-	-	-	-	-	-	3,4	-
Trichloroethene	-	-	3	-	-	3	-	-	3	3,4	-
1,1,2-Trichloroethene	-	-	-	-	-	-	-	-	-	-	-
Toluene	-	-	-	-	-	-	-	-	-	-	-
Vinyl Chloride	-	-	-	-	-	-	-	-	-	3	-
Xylenes	-	-	-	-	-	-	-	-	-	4	-
INORGANICS											
Aluminum[c]											
Antimony	-	-	-	-	-	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-	-	-	-	4	-
Cadmium	-	-	3	-	-	3	-	-	3	1,3,4	-
Calcium[c]											
Chromium	-	X	-	X	X	3	-	-	-	1,3	3
Cobalt	-	-	-	-	-	-	-	-	-	-	-
Copper	-	-	-	-	-	-	X	-	-	-	-
Cyanide	-	-	-	-	-	-	-	-	-	3	-
Iron[c]											
Lead[c]	-	-	-	-	-	-	X	3	3	1,3	3
Magnesium[c]											
Manganese	-	-	-	-	-	-	-	-	-	-	-
Mercury	-	-	-	-	-	-	-	-	-	-	-
Nickel	-	X	1	-	X	-	-	-	-	3,4	-
Potassium[c]											
Silver	-	-	-	-	-	3	-	-	-	1,3	3
Sodium[c]											
Thallium	-	-	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-	-	-	-
Zinc	-	-	-	-	-	-	-	-	-	3	-
RADIOACTIVES											
Gross Alpha[c]	-	-	-	X	X	3	-	-	-	1,3,4	3
Gross Beta[c]	-	-	-	X	X	3	-	-	-	1,3,4	3

TABLE 2-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Expoure Area:	S	V	W	X	Y	Z	Rice Creek	Round Lake		Sunfish Lake		Marsden Lake	
Media:	GW	GW	GW	GW	GW	GW	SW	SW	SD	SW	SD	SW	SD
ORGANICS													
Acetone	-	-	-	-	3	4	-	-	-	-	-	-	-
Benzene	-	3	-	4	-	-	-	-	-	-	-	-	-
Benzoic Acid	-	3	4	4	-	4	-	-	-	-	-	-	-
Bromodichloromethane	-	-	-	-	4	-	-	-	-	-	-	-	-
2-Butanone	-	-	-	-	3	-	-	-	-	-	-	-	-
N-Butylbenzylphthalate	-	-	-	4	-	-	-	-	-	-	-	-	-
Carbon Tetrachloride	-	-	4	-	-	-	-	-	-	-	-	-	-
Chlorethane	-	3	-	-	3	-	-	-	-	-	-	-	-
Chloroform	1	3	4	4	3,4	3	-	-	-	-	-	-	-
1,1-Dichloroethane	-	3	3,4	3,4	3,4	3,4	-	-	-	-	-	-	-
1,2-Dichloroethane	-	3	-	3	3,4	3,4	-	-	-	-	-	-	-
1,1-Dichloroethene	-	3	3,4	3,4	3,4	3,4	-	-	-	-	-	-	-
1,2-Dichloroethene	1	-	-	-	3	3,4	-	-	-	-	-	-	-
cis-1,2-Dichlorothene	-	-	4	4	3,4	4	-	-	-	-	-	-	-
trans-1,2-Dichloroethene[a]	-	-	-	-	3	-	-	-	-	-	-	-	-
Di-n-butylphthalate	-	-	-	4	-	-	-	-	-	-	-	-	-
2,4-Dinitrotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-
Di-n-octylphthalate	-	3	-	4	-	3	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	-	3	4	4	-	-	-	-	-	-	-	-	-
Ethylbenzene	-	3	-	-	3	-	-	-	-	-	-	-	-
Methylene Chloride	-	-	4	-	3,4	-	-	-	-	-	-	-	-
N-Nitrosodiphenylamine	-	-	-	-	-	-	-	-	-	-	-	-	-
PAHs	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB (Aroclor-1260)	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenol	-	-	-	-	-	3	-	-	-	-	-	-	-
Tetrachloroethene[b]	-	-	4	3,4	3,4	4	-	-	-	-	-	-	-
1,1,1-Trichloroethane	-	3	3,4	3,4	3,4	3,4	-	-	-	-	-	-	-
1,1,2-Trichloroethane	-	-	4	3,4	3,4	3,4	-	-	-	-	-	-	-
Trichloroethene	-	3	3,4	3,4	3,4	3,4	-	-	-	-	-	-	-
1,1,2-Trichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-
Toluene	-	-	-	4	4	4	-	-	-	-	-	-	-
Vinyl Chloride	-	-	-	-	-	-	-	-	-	-	-	-	-
Xylenes	-	-	-	-	3,4	-	-	-	-	-	-	-	-
INORGANICS													
Aluminum[c]	-	3	4	4	-	3,4	-	-	-	-	-	-	-
Antimony	-	-	-	4	-	-	-	-	-	-	X	-	-
Arsenic	-	-	-	-	-	-	-	-	-	-	-	-	-
Barium	-	-	-	4	-	3	-	-	-	-	-	-	-
Cadmium	-	-	-	4	-	-	-	-	-	-	-	X	-
Calcium[c]	-	3	4	4	-	3,4	-	-	-	-	-	-	-
Chromium	-	3	4	4	-	3,4	X	-	-	-	X	-	-
Cobalt	-	-	-	4	-	-	-	-	X	-	-	-	-
Copper	-	3	4	4	-	3,4	-	-	-	-	X	-	X
Cyanide	-	-	-	4	-	-	X	-	X	x	-	-	-
Iron[c]	-	3	4	4	-	3,4	-	-	-	-	-	-	-
Lead[c]	-	3	-	4	-	3,4	-	-	-	-	X	-	-
Magnesium[c]	-	3	4	4	-	3,4	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel	-	3	4	4	-	3,4	X	-	-	-	-	X	-
Potassium[c]	-	3	4	4	-	3,4	-	-	-	-	-	-	-
Silver	-	-	-	-	-	-	X	-	-	-	-	-	-
Sodium[c]	-	3	4	4	-	3,4	-	-	-	-	-	-	-
Thallium	-	-	-	-	-	-	-	X	-	-	-	X	-
Vanadium	-	3	-	4	-	3	-	-	-	-	-	-	-
Zinc	-	3	4	-	-	3,4	-	-	-	-	-	-	-
RADIOACTIVES													
Gross Alpha[c]	-	-	-	-	-	-	-	-	-	-	-	-	-
Gross Beta[c]	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 2-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Notes:

[a] Risk factors are not available for this compound. Risk factors for 1,2-dichloroethene were used.

[b] Although tetrachloroethene was not present at concentrations significantly higher than background levels, it was included as a chemical of potential concern due to its known association with the site.

[c] Risk factors are not available for these compounds. However, a qualitative discussion of potential risk is included in Chapter 5.

SS = Surface Soil

SB = Subsurface Soil

GW = Ground Water

SW = Surface Water

SD = Sediment

- = Not identified as Chemical of Potential Concern

X = Identified as Chemical of Potential Concern

1 = Identified as Chemical of Potential Concern in Ground Water Unit 1

3 = Identified as Chemical of Potential Concern in Ground Water Unit 3

4 = Identified as Chemical of Potential Concern in Ground Water Unit 4

CHAPTER 3

EXPOSURE ASSESSMENT

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CHAPTER 3
EXPOSURE ASSESSMENT

In this chapter, PRC assesses the potential for exposure to contaminants at the New Brighton/Arden Hills site. First, the physical setting of the site, including its climate, vegetation, soil types, surface hydrology, regional geology, and hydrogeology, is described along with particular areas of concern. Second, information regarding human populations at or near the site is presented. Third, potential exposure scenarios involving contaminants at the site and specific populations affected are identified and discussed; the potential extent of exposure of the identified populations for each exposure scenario is also presented. Potential risks to the identified populations depend on the nature and extent of exposure; these potential risks are further discussed in Chapter 5. Unless otherwise indicated, information presented in this chapter was obtained from the on-TCAAP and off-TCAAP RIs, ANL (1990) and CDM (1991), respectively.

3.1 PHYSICAL SETTING

TCAAP and adjoining off-TCAAP affected areas are located in the Western Lake Section of the Central Lowland Physiographic Province. This province is characterized by such glacial features as till plains, moraines, lakes, and lacustrine plains. Because of the nature of the contamination and the complex physical setting at the site, this section discusses the characteristics not only of the site as a whole but also of individual source areas.

3.1.1 Climate

The site climate is generally classified as subhumid continental. Winters are very cold, and summers are short and fairly warm. Precipitation is moderate and fairly well distributed throughout the year. Mean daily maximum temperatures for the years 1951 through 1980 ranged from 20 degrees Fahrenheit (°F) in January to 83° F in July; mean daily minimum temperatures during the same period were 2° F in January and 63° F in July (World Almanac, 1990). Average daily minimum temperatures are below freezing (32° F) from November through March. The mean annual precipitation for the years 1956 through 1974 was 28.4 inches, similar to the 40-year average of 26.1 inches calculated from data presented in the Phase I RI. Annual precipitation for the years following 1972 averaged 26.8 inches. Most precipitation occurs during spring and summer months, with June and July having the highest average monthly totals.

3.1.2 Vegetation and Wildlife

TCAAP and affected off-TCAAP areas are located in the Rice Creek watershed. Rice Creek and its surrounding marshes and woodlands provide cover for a variety of vegetation and wildlife. More than 80 species of birds, 14 species of reptiles, 18 species of mammals, and 100 species of plants have been cataloged by the Rice Creek Nature Trail Citizens' Committee. The Rice Creek basin, with its extensive backwaters and oxbows, provides a nesting habitat for water fowl. Much of the lowland area adjacent to Rice Creek has lush and vigorous vegetation resulting from rich soils carried downstream and moist soil conditions. A dense forest canopy creates a wildlife habitat well suited for small animals.

3.1.3 Soil Types

Two major types of soils exist within the New Brighton/Arden Hills site: those formed predominantly in outwash and those formed predominantly in glacial till. Outwash soils are underlain by fine to gravelly, coarse sand and range from excessively drained to poorly drained. Typically, soils exhibiting better drainage are found on upland areas and level to steep slopes. Very poorly drained, organic soils occur in large bogs and small depressions. Much of the study area has been developed and is considered urban land (that is, developed land) by the Soil Conservation Service.

3.1.4 Surface Hydrology

The New Brighton/Arden Hills study area lies primarily within the lower radius of the Rice Creek watershed, a 183-square-mile watershed. Rice Creek is a left-bank tributary of the Mississippi River; it empties into the Mississippi near River Mile 862. Rice Creek meanders across the northwestern portion of TCAAP and leaves TCAAP at approximately the middle of the western boundary (see Figure 1-2). Among the many small lakes located in the Rice Creek basin, Marsden Lake and Sunfish Lake lie within TCAAP along its eastern border; Turtle Lake is just east of TCAAP; Snail Lake and Karth Lake are southeast of TCAAP; Round Lake and Valentine Lake lie to the south of TCAAP; and Rush, Long, and Pike Lakes lie to the southwest of TCAAP.

Drainage from the southwest Quadrant of TCAAP is diverted through ditches and a culvert system that eventually empties into Round Lake south of TCAAP. The drainage then passes through several lakes and into the lower reaches of Rice Creek before arriving at the Mississippi River. Surface waters in the Rice Creek watershed are not currently used for drinking water, but they are used for recreational purposes, including boating, fishing, and

canoeing. The lakes are suffering from eutrophy believed to be related to land use (agriculture, lawn care, and urban runoff) rather than to any major contaminant source in the basin.

3.1.5 Regional Geology

The regional geology of the New Brighton quadrangle influences soil types, the surface drainage pattern, and the ground water hydrology. The regional geology consists of a bedrock basin that has been eroded to form an irregular surface upon which a complex series of unconsolidated glacial sediments was deposited. For further details on the regional geology of the site, refer to ANL (1990) and CDM (1991).

3.1.6 Hydrogeology

Within the New Brighton/Arden Hills study area, ground water is found in both bedrock and glacial deposit aquifers. On top of the irregular bedrock surface, a series of unconsolidated glacial sediments has been deposited. Several of these units are water bearing and have been affected by the spread of contaminants from TCAAP.

The Prairie du Chien/Jordan Sandstone aquifer is the principal aquifer in the Twin Cities Basin. This unit is referred to as Unit 4. Permeability in the Prairie du Chien/Jordan Sandstone aquifer is controlled by the extent of fractures and joints in the Prairie du Chien unit and the porosity of the Jordan Sandstone unit. Ground-water flow through this aquifer is generally in a west-southwest to south-southwest direction off-TCAAP toward the Mississippi River. Recharge to the Prairie du Chien/Jordan Sandstone aquifer occurs by infiltration through the overlying glacial units. Aquifer performance tests involving the Prairie du Chien/Jordan Sandstone aquifer as well as subsequent modeling suggest that a semiconfining layer may exist between the Jordan Sandstone and Prairie du Chien units.

The Hillside Sand and the Arsenal Sand are referred to as Unit 3. Within the New Brighton quadrangle, the Hillside/Arsenal Sand outcrops in four areas: Arsenal Kame within TCAAP; the southwestern corner of the quadrangle within Minneapolis; two small areas in Columbia Heights in the vicinity of Silver Lake; and along the southern edge of Snail Lake. Except for the exposure in Minneapolis, the Hillside/Arsenal Sand directly overlies the Prairie du Chien/Jordan Sandstone aquifer; the other three surface exposures provide direct recharge to both units. The ground water in the Unit 3 flows predominantly southwest.

The Twin Cities Till overlies the Hillside Sand in much of the area and is referred to as Unit 2. The Twin Cities Till acts as a confining layer, preventing direct hydraulic communication between the overlying Lacustrine Deposits and the Hillside Sand below.

The Lacustrine Deposits (Unit 1) are predominantly fine to medium sands with interbedded silt layers and occasional minor peat and clay layers. These units form the shallow surface aquifer between and to the north of the Hilltop and Arden Hills moraines. Private wells installed in Unit 1 exist to the north of TCAAP (FCC, 1988). Ground water in this unit is perched and discontinuous. Any ground-water flow is localized and toward the closest small lake.

3.1.7 Physical Characteristics of Areas of Concern

Fourteen source areas within TCAAP have been the focus of RI activities. The physical characteristics of these areas vary significantly. Along with these specific source areas, the RI studied the whole TCAAP property for ground-water contamination. However, contamination of media other than ground water was not addressed in the off-TCAAP RI (CDM, 1991). For the purposes of this risk assessment, TCAAP has been divided into four Quadrants. Off-TCAAP areas to the north and southwest where the contaminant plumes have begun to spread are also discussed. This subsection summarizes the physical characteristics of each of these areas of concern.

Northwest Quadrant of TCAAP

The Northwest Quadrant (X1) of TCAAP contains Source Areas A, C, E, K, and part of 129-3. Rice Creek runs across the northwestern corner of Quadrant X1 from the northern boundary to the western boundary. A few small, swampy areas exist in this Quadrant; they are east of Source Area C and southeast of Source Area A. The only other surface water features are the drainage ditches that take surface drainage toward Rice Creek. The site slopes gently from the southeastern corner of Quadrant X1 toward the west-northwest.

Surface soils vary across the Quadrant, depending on the glacial deposit in which the soil was developed. In the southeastern corner of Quadrant X1, where Unit 3 is at the surface, the soil is very sandy. Over the rest of the Quadrant, the soils are predominantly sandy silts and clayey silts. Patches of organic-rich layers or black peat exist in the swampy areas.

Unit 1 forms an unconfined, shallow surface aquifer over most of Quadrant X1. In general, ground water in Unit 1 flows to the west. One notable exception is in the northwestern

portion of Source Area A, where the water flows to the northwest toward a housing development across the northern boundary of TCAAP. Unit 2 is present beneath Unit 1 in Quadrant X1, preventing hydraulic communication between Unit 1 and Unit 3. Unit 3, the Hillside/Arsenal Sand, is exposed at the surface in the southeastern corner of Quadrant X1 and is present beneath Unit 2 in the rest of the Quadrant. Ground water in Unit 3 flows to the southwest. The bedrock aquifer, Unit 4, lies below Unit 3 and flows to the southwest.

Northeast Quadrant of TCAAP

The Northeast Quadrant (X2) of TCAAP contains Source Areas B and 129-5. The eastern half of Quadrant X2 is occupied by a swampy area known as Marsden Lake. The topography of Quadrant X2 varies greatly. Marsden Lake is very flat, while the quarry is a notable low point. Marsden Lake and several drainage ditches are the only surface water features in the Quadrant with the exception of water which collects in the quarry.

Surface soils vary across the Quadrant with the different glacial deposits exposed at the surface. In the eastern portion of Quadrant X2, a layer of organic material from the lake exists, and the soil is sandy silt. The soil is predominantly silty clay where Unit 2 is exposed. Very sandy soils exist where Unit 3 sands are exposed.

Surface runoff and shallow ground water (Unit 1) flow toward Marsden Lake on the eastern side of the kame. The ground water in Unit 3 flows to the southwest.

Southwest Quadrant of TCAAP

The Southwest Quadrant (X3) of TCAAP contains Source Areas D, I, J, and part of 129-3. No natural surface water bodies exist in this Quadrant, but a system of storm sewers and drainage ditches does exist. This drainage system empties into several lakes outside the TCAAP boundary, including Round, Valentine, Rush, and Long Lakes.

In the northeastern portion of Quadrant X3, where Unit 3 is at the surface, the soil is very sandy. In the southeastern portion of Quadrant X3, the tills of Unit 2 are exposed at the surface. Soils developed on the tills are either silty clays or sandy clays. Over the rest of Quadrant X3, Unit 1 is at the surface. Soils in these areas are predominantly silty.

Unit 1 forms an unconfined, shallow surface aquifer in the western portion of Quadrant X3. Unit 2 acts as an aquitard, preventing hydraulic communication with the underlying Unit 3 aquifer. Unit 3 is at the surface in the northeastern corner of Quadrant X3, allowing direct

recharge to the Unit 3 aquifer. In the eastern half of the Quadrant, the Unit 3 aquifer behaves as an unconfined aquifer. In the western half of Quadrant X3, the Unit 3 aquifer exhibits the characteristics of a confined aquifer. Ground water in the Unit 3 aquifer flows generally to the southwest.

Southeast Quadrant of TCAAP

The Southeast Quadrant (X4) of TCAAP contains Source Areas F, G, H, and 129-15. Most of the eastern half of Quadrant X4 is occupied by Marsden Lake. Sunfish Lake is also located in the eastern portion of the Quadrant. Drainage ditches in Quadrant X4 discharge into Sunfish Lake and Marsden Lake.

The Twin Cities Till (Unit 2) is the glacial unit exposed at the surface of most of Quadrant X4, except in the northwestern corner where Unit 3 is at the surface of the kame. Surface soils are predominantly silty clays derived from weathering of Unit 2. In the northwestern corner, the soil is very sandy. In the eastern portion of Quadrant X4, a thin layer of organic material may date from a time when the lakes were at a higher level.

Unit 1 is not present in this Quadrant, so no shallow aquifer exists here. Surface runoff drains toward Marsden Lake in the east and Sunfish Lake in the southeast. Unit 3 is beneath the till in this Quadrant. In the northwestern corner of Quadrant X4, the Unit 3 aquifer is recharged directly. Ground water in the Unit 3 aquifer flows to the southwest.

Source Area A

Source Area A has been subdivided into five subareas, numbered A-1 through A-5, based on locations of former waste management activities. The topography of Source Area A is relatively flat, the relief varying by 5 to 10 feet across the area. Wooded portions include the northeastern corner and several small stands of trees within the eastern half of the area. A swamp exists in the southeastern corner of the area and extends to the eastern side of the area. The rest of the area is covered by grasslands that include a former farm.

Soils in Source Area A are loamy, fine sand. The former waste management locations within this area have a top layer of artificial fill. The fill consists of construction debris, ash, ceramic tile, scrap metal, asphalt, steel casings, and other materials.

The eastern part of Source Area A is dissected by a small drainage channel that runs from northeast to southwest, ending at Rice Creek west of the area. As mentioned previously, a

swampy area exists at the southeastern corner of Source Area A. The area contains no other surface water features.

Source Area A is underlain by all four hydrologic units of interest. The Lacustrine Deposits (Unit 1) vary in thickness from 15 feet in the southeastern corner of Source Area A to 28 feet in the western portion of the area. The water table is 10 to 15 feet below the ground surface in Source Area A. The ground water in Unit 1 generally flows to the west, but it flows to the northwest just north and west of Well 01U108.

The Twin Cities Till (Unit 2) underlies the entire source area. Units 3 and 4 lie beneath the Twin Cities Till. Little is known about Units 3 and 4 beneath Source Area A because most of the monitoring wells are screened in Unit 1. Ground-water flow in Units 3 and 4 is probably to the southwest; a partial hydraulic connection probably exists between these two units.

Source Area B

Source Area B consists of three subareas, numbered B-1, B-2, and B-3 from west to east. All three subareas are former farmsteads. Vegetation varies from grasslands with groves of trees to swamps. In Area B-1, the relief is less than 3 feet, and a low-lying swamp exists in the southeastern corner. The relief in Area B-2 is less than 7 feet; except for a knoll in the northwestern corner, Area B-2 is swampy. In Area B-3, the relief is 10 feet, and the highest point exists in the southwestern corner. A drainage ditch dissects a swampy area in the northwestern corner of Area B-3.

Soils in Source Area B vary among the subareas. In Area B-1, the soil consists primarily of fine sand. Few soil data are available for Area B-2, but the soil in the northwestern corner probably consists of fine sand and silt. In the swampy parts of Area B-2, organic silt is probably present near the surface with sandy silt, silty sand, and gravel below.

Source Area B is underlain by all four hydrologic units of interest. Because no deep monitoring wells exist in Source Area B, the local characteristics of Units 2, 3, and 4 are unknown.

Source Area C

Railroad tracks and a swamp lie immediately to the east of Source Area C. The swamp discharges water to Rice Creek west of Source Area C through a drainage ditch that runs across

Source Area C. The area is relatively flat, showing only a gentle dip toward the drainage ditch from both the south and north.

Source Area C is covered by a layer of black, decomposed peat above a layer of fine sand and sandy clay of Lacustrine origin. Trenches constructed in areas of former waste burning pits reveal that a clayey, artificial fill was laid over the black peat. In some areas, this artificial fill contains charred wood, metal, concrete, and asphalt.

Unit 1 (Lacustrine Deposits) forms the unconfined surface aquifer in Source Area C. Ground-water flow in Unit 1 is toward the drainage ditch that cuts across Source Area C. However, in the area north of Source Area C, ground water tends to flow to the northwest. Unit 2 (Twin Cities Till) is present beneath Unit 1 throughout Source Area C. Unit 3 (Hillside/ Arsenal Sand) is present beneath Source Area C.

Source Area D

In Source Area D, the surface generally slopes gently to the east and south. Contaminated surface soil has either been excavated and backfilled with clean, silty sand fill or capped with clay. No surface water, drainage ditches, or swampy areas exist in Source Area D.

Soil in Source Area D consists of the medium-fine to coarse sand of the Hillside/Arsenal Sand unit. In pit areas where waste disposal activities occurred, silty sand fill or a clay cap has replaced the natural sand.

Units 1 and 2 are not present beneath Source Area D. Unit 3 is at the surface. Unit 4 lies below Unit 3 beneath Source Area D.

Source Area E

Source Area E slopes to the northwest (30-foot elevation difference). The area is partially wooded, and scattered thickets of brush also exist. No surface water features are present within Source Area E.

Natural soils at Source Area E consist of brown and yellow silty sands and gravel. Fill materials, including sand and gravel, have been applied to the surface of Source Area E. Some portions of the area also contain up to 10 feet of clay fill material that may have been used to cap previous land disposal areas.

Units 1 and 2 are not present beneath Source Area E. Unit 3 is at the surface; the area provides direct recharge for the Unit 3 aquifer. Unit 4 is not present beneath Source Area E because of erosion of the bedrock valley.

Source Area F

Source Area F encompasses 10.1 acres of gently rolling land that was once a pasture. Grass covers most of the area. No surface water exists in Source Area F.

Soils at Source Area F consist mainly of brown silty clay because Unit 2 (Twin Cities Till) covers much of the surface. In some places, the till has been removed and replaced with artificial fill. Unit 3 lies beneath Unit 2 in Source Area F. In the north-central portion of the area along a northern access road and small hill, the till (Unit 2) is not present and the Hillside/Arsenal Sand (Unit 3) is at the surface; the associated soil is silty sand.

Source Area G

Source Area G slopes gently from west to east and then drops off sharply (about 25 feet) along the southeastern boundary of the area. This area contains a landfill that has altered the surface soils and topography.

Surface soils in Source Area G consist of fill materials, including dark brown to yellowish brown silty clay and dark brown to dark gray silty sand with gravel lenses. Waste materials lie under the fill in the southern part of the area. The depth of the fill and waste materials varies across the area from 0 to 30 feet.

Unit 1 is not present beneath Source Area G. The Twin Cities Till (Unit 2) underlies the fill and waste materials of the area. Ground water lies beneath Source Area G at a depth of 130 feet; this is probably the upper Unit 3 aquifer.

Source Area H

Source Area H slopes gently to the south and east. The area has a light cover of grass and a few scattered stands of trees. Sunfish Lake receives surface water from a ditch that enters the lake from the west. Water leaves Sunfish Lake at the northeastern end and flows northeast to Marsden Lake. A swampy area lies to the north of the northeastern corner of Source Area H.

Surface soils at Source Area H are silty clays derived from weathering of the Twin Cities Till (Unit 2) except in the southwestern corner of the area where Unit 1 is at the surface. In the southwestern corner, the soils contain more silt and also sand. Along the shore of Sunfish Lake, a thin layer of organic material may exist that was deposited when the lake was at a higher level than at present.

Unit 1 is present only in the southwestern corner of Source Area H. The Twin Cities Till (Unit 2) is present throughout Source Area H. Unit 3 is present beneath Unit 2. Below Unit 3, the bedrock beneath the area belongs to the Prairie du Chien unit (Unit 4).

Source Area I

Surface drainage from Source Area I flows southwest into Round Lake. From Round Lake, water flows south into Valentine Lake and then northwest into the southern end of Long Lake. Rice Creek flows into the northern end of Long Lake after leaving TCAAP and then flows out of Long Lake and discharges into the Mississippi River.

Surface soils of Source Area I vary with the complex surficial glacial geology in the area. Unit 1, consisting of sandy silts, lies beneath Building 502 and in the southwestern corner of the area. Unit 2, consisting of silty clays, is also exposed beneath Building 502 and in the western and southern portions of the area. In the northeastern portion of the area, sandy soils have been developed in Unit 3, which is at the surface here.

Unit 1 deposits form a perched, discontinuous aquifer in the vicinity of Source Area I. Near Source Area I, the Unit 3 aquifer is generally unconfined; an unsaturated zone exists immediately below the Unit 2 till and above the water table. The Unit 3 aquifer becomes confined west of the intersection of Highways 10 and 96. Within Source Area I to the east of Building 502, Unit 3 is exposed at the ground surface, and the aquifer is directly recharged by infiltration of surface water and precipitation. Both the Prairie Du Chien and Jordan Sandstone members of Unit 4 are present beneath Source Area I.

Source Area J

Source Area J contains sanitary and process waste lines, and some segments of the storm sewer drainage system. The sewer system is entirely underground and is composed primarily of vitrified clay pipe with some cast-iron pipe.

Soils at Source Area J range from sands to sandy clays. In the western portion of the area, soils are dominated by interlayers of silty fine and medium sands with occasional lenses of organic peat. Surface soils in the eastern portion of Source Area J range from fine and silty fine sands to sandy clay and clayey sand.

Unit 1 is continuous in the western portion of Source Area J but is very discontinuous in the eastern portion of the area. The depth to the water table is typically less than 10 feet, and ground water in Unit 1 flows to the west and northwest. Unit 2 (Twin Cities Till) is present beneath all of Source Area J. The Unit 3 aquifer is present beneath Unit 2 under all of Source Area J. Ground-water flow in Unit 3 is generally to the west with local components of flow to the northwest and southwest. The Prairie du Chien formation of Unit 4 lies beneath Unit 3 in the vicinity of Source Area J. No Unit 4 monitoring wells are located in Source Area J, so the local hydrologic properties of Unit 4 are unknown. Ground-water flow is presumed to be to the west-southwest toward the Mississippi River.

Source Area K

Source Area K occupies approximately 21 acres, most of which is covered by Building 103. Surface runoff from Source Area K is directed through storm sewers that discharge into Rice Creek.

Surface soils at Source Area K were developed in the sand and silts of Unit 1. In portions of the area not covered by Building 103 and its associated structures, exposed surface soil consists of dark brown to black topsoil and sand with some vegetation and fill. At depths greater than 1 foot, soils are predominantly brown, medium to fine sand with some silt and pebbles.

Unit 1 lies beneath Source Area K. The till (Unit 2) is up to 45 feet thick beneath the area. A mound in the till beneath Building 103 directs some ground-water flow to the northwest and some to the west. Unit 3 is beneath Unit 2. Ground-water flow within Unit 3 is to the west-southwest. The bedrock aquifer (Unit 4) also lies beneath Source Area K.

Source Area 129-3

Source Area 129-3 slopes gently to the northwest. No surface water features exist in the area. Light vegetation covers the area.

Natural soils in Source Area 129-3 consist of brown to gray, fine to coarse sands and gravels. Extensive fill exists in the area, including sand, clay, ash (charred areas), sludge, wood debris, railroad ties, and chunks of concrete and asphalt.

Units 1 and 2 are not present beneath the area. Unit 3 is at the surface. Source Area 129-3 provides direct recharge to the Unit 3 aquifer. Ground water flows to the southwest in Unit 3. Because no Unit 4 well exists in the area, the local hydrologic properties of the bedrock are unknown.

Source Area 129-5

Source Area 129-5 slopes gently from west to east. A gully runs west to east across the center of the area. Marsden Lake lies to the east of Source Area 129-5.

Two types of soil exist in Source Area 129-5. In the southeastern portion of the area, the surface soil is brown, fine to medium sand related to the Lacustrine Deposits (Unit 1). In the southwestern portion of Source Area 129-5, the surface soil is more clayey because it was developed in the Twin Cities Till (Unit 2).

Unit 1 (Lacustrine Deposits) is found in the eastern portion of the area. Because of the surface topography, ground water in Unit 1 is presumed to flow to the east toward Marsden Lake. Unit 2 is approximately 30 feet thick beneath Source Area 129-5. In the northern portion of the area, where Unit 3 is exposed in sand and gravel pits, direct recharge occurs to the Unit 3 aquifer. Ground water in Unit 3 flows to the southwest.

Source Area 129-15

Source Area 129-15 slopes to the south-southeast with a total elevation change of 67 feet from north to south. The area is heavily vegetated with trees and grass. No surface water exists in Source Area 129-15.

The soil in Source Area 129-15 is very sandy. Past landfilling activities in the western portion of the area resulted in artificial fill containing building debris and some ash.

Units 1 and 2 are not present beneath Source Area 129-15. Unit 3 is at the surface. Source Area 129-15 provides direct recharge to the Unit 3 aquifer. Because no Unit 4 well exists in the area, the local hydrologic properties of the bedrock are unknown.

Off-TCAAP Area North of TCAAP

Contaminants from TCAAP may be moving to the north in the Unit 1 aquifer toward an area of Shoreview. The off-TCAAP area of concern abuts the northern TCAAP boundary northwest of Source Area A. Rice Creek runs through the area before crossing TCAAP.

Soils in the area are expected to be sandy silts and loamy sand because of the presence of the Lacustrine Deposits (Unit 1) at the surface. Unit 1 sediments are approximately 30 feet thick in the area, and the water table is 10 to 15 feet below the surface. Ground-water data from Source Area A indicate that the local flow in this aquifer is to the northwest. The Twin Cities Till (Unit 2) acts as an aquitard, inhibiting hydraulic communication between Unit 1 and the deeper aquifers (Units 3 and 4). Units 3 and 4 are present beneath Unit 2. Ground water in Units 3 and 4 flows to the southwest, the direction of regional flow.

Off-TCAAP Area Southwest of TCAAP

Southwest of TCAAP in New Brighton, contaminants from TCAAP have been detected in wells drawing water from Unit 3. The characteristics of this area are comparable to those of the western portion of Quadrant X3.

The area immediately southwest of TCAAP includes Round, Valentine, Rush, and Long Lakes. These lakes receive surface drainage from Quadrant X3. Rice Creek flows into and out of the northern end of Long Lake on its way to the Mississippi River.

Surface soils in the area were developed in the Lacustrine Deposits of Unit 1. These soils are expected to range from sandy silts to sandy loam.

Unit 1 forms an unconfined, shallow, surface aquifer in the area. Ground water in this aquifer flows toward the closest lake. Unit 2 (Twin Cities Till) has an irregular upper surface that controls the locations of the lakes. Unit 3 is below the till. Ground water in Unit 3 flows to the southwest. Drilling data show a clayey till at the base of Unit 3 between Round and Rush Lakes. This clayey till inhibits local hydraulic communication between Unit 3 and the underlying bedrock aquifer (Unit 4).

3.2 POTENTIALLY EXPOSED POPULATIONS

This section characterizes on- and off-TCAAP populations according to their proximity to the site, activity patterns, and inclusion of sensitive subpopulations. Populations are first characterized under current land use conditions and then under future land use conditions.

For the purposes of this risk assessment, the on-TCAAP site is defined as the 4-square-mile area shown in Figure 1-1. Off-TCAAP refers to all areas outside the TCAAP site but within the United States Geological Survey's (USGS) New Brighton, Minnesota, 7.5-minute quadrangle. More specifically, the off-TCAAP area is that portion of the New Brighton quadrangle that is or may be impacted by chemicals originating at TCAAP, except as noted. The off-TCAAP area includes parts of three counties, Ramsey, Anoka, and Hennepin, and seven cities or villages: New Brighton, St. Anthony, Arden Hills, Shoreview, Mounds View, Columbia Heights, and portions of Minneapolis.

3.2.1 Current Land Use Conditions

In this report, current land use conditions represent how land is presently developed both on- and off-TCAAP. Current (January 1991) land use conditions are described and populations are characterized, first for the on-TCAAP site and then for the off-TCAAP area. Pregnant and nursing women working or living on- or off-TCAAP represent a potentially sensitive subpopulation. Several chemicals of potential concern can cause mutagenicity, terotoxicity, or teratogenic effects. These chemicals include arsenic, lead, mercury, and PAHs. (Refer to chemical-specific discussions in Chapter 4 and in Appendix H.) Children also represent a potentially sensitive subpopulation.

3.2.1.1 On-TCAAP Current Land Use Conditions

TCAAP is a government-owned, contractor-operated installation; FCC has been the primary operating contractor. TCAAP includes seven major production buildings and numerous auxiliary buildings and supporting utilities. Presently, most of TCAAP is on standby status. However, two major lessees occupy the site:

- 3M, which has manufactured self-luminous materials, medical products, and static eliminators at the site since the late 1950s
- Honeywell, which has manufactured fuses and ammunition at the site since the late 1950s

As of February 1989, approximately 2,100 people were employed or trained on-TCAAP (FCC, 1989a). These include employees of FCC, 3M, and Honeywell; members of the U.S. Army and Army Reserve (the Army Reserve is developing a training facility in the southeastern corner of TCAAP); and personnel from the Minnesota Department of Transportation (MDOT), which leases land in the northwestern corner of TCAAP. The U.S. Army also maintains 14 staff houses along the northwestern border of TCAAP for families of Army personnel. As of February 1989, 58 people lived in the staff houses: 26 adults (including the Army personnel) and 32 children (FCC, 1989a).

Access to and within TCAAP is controlled. The entire site is bordered by a 6-foot-high, chainlink fence topped by triple-strand barbed wire. The boundary is patrolled by guards. No unauthorized access to TCAAP is possible. Areas within TCAAP used for Army staff housing, leased by MDOT, or used by the Army Reserve are isolated from the manufacturing and operational area of TCAAP; persons living, working, or training in the three areas do not have free access to the rest of TCAAP. Finally, within the manufacturing and operational area of TCAAP, the FCC, 3M, and Honeywell facilities are separated by fences. Access to the interior of TCAAP is controlled by FCC and is limited primarily to guard and maintenance personnel.

Most personnel employed on-TCAAP work indoors in manufacturing areas or offices. Others, such as guards, maintenance workers, and fire department personnel, may spend a significant amount of time working outdoors. Army Reserve personnel often train outdoors, but MDOT personnel work primarily indoors. Finally, the families of Army personnel living in on-TCAAP staff housing may spend significant portions of time both indoors and outdoors. No regular recreational activities exist on-TCAAP except those for persons living in the staff housing.

3.2.1.2 Off-TCAAP Current Land Use Conditions

The off-TCAAP area encompasses portions of Ramsey, Anoka, and Hennepin Counties in the north-central portion of the Twin Cities metropolitan area. In general, off-TCAAP is suburban in character, is becoming increasingly urban to the south, and is rural to the northeast. According to the 1980 census, the population in the New Brighton quadrangle area is approximately 100,000. Single-family housing is predominant throughout much of the area, with commercial activities along major thoroughfares and in retail centers. Industrial developments are located throughout the area (CDM, 1991). Residential areas virtually surround TCAAP, with the heaviest development to the west-southwest (Mounds View, New Brighton, and Columbia Heights) and east-southeast (Shoreview). The area south of TCAAP becomes more densely

populated with distance from the site, eventually peaking in northeastern Minneapolis, approximately 6 miles south.

Off-TCAAP surface waters are not currently used for drinking water. However, the lakes (including Round, Rush, and Turtle) and Rice Creek are heavily used for boating, fishing, and canoeing.

In addition to water-related recreational activities, many parks, playgrounds, and sporting facilities exist in the area. People use these facilities for outdoor recreational activities throughout the year. During the warmer months, activities include swimming, boating, fishing, running, and other sports. During the winter, activities include skating, skiing, hiking, and ice fishing.

Cities that border or are located close to TCAAP are briefly discussed below and are shown in Figure 1-1. They include New Brighton, St. Anthony, Arden Hills, Shoreview, Mounds View, Columbia Heights, and northeastern Minneapolis.

New Brighton

The City of New Brighton is southwest of TCAAP and to the north-northeast of Minneapolis within Ramsey County. The population of New Brighton was estimated at 22,798 in 1989 [Metropolitan Council Chambers of Commerce (MCCC), 1989a]. Seven schools with grades K through 12 serve approximately 4,800 students in New Brighton (MCCC, 1989b). Schools located within 2 miles of the site include Irondale, Pike Lake, Bel Air, and Silver Oak. Recreational areas include Rush Lake, Round Lake, and local parks. A 63-acre industrial park is also located within city limits.

St. Anthony

St. Anthony is located in Ramsey and Hennepin Counties 4 miles southwest of TCAAP. Its population was estimated at 8,334 for the year 1989 (MCCC, 1989a). Schools include Parkview Elementary School and St. Anthony Senior High School. Several parks and a shopping center serve St. Anthony residents.

Arden Hills

Arden Hills is located 6 miles north-northeast of Minneapolis. It had an estimated population of 9,667 in 1989 (MCCC, 1989a). TCAAP is approximately the northern third of

Arden Hills, and TCAAP's southern and southwestern boundaries are within Arden Hills. Schools include Turtle Lake, Arden Hills, and Mounds View, all within 1 mile of TCAAP. Two parks located 2 to 3 miles from TCAAP are used for recreational purposes.

Shoreview

Shoreview is located in Ramsey County approximately 8 miles northeast of Minneapolis. Shoreview borders the northern and eastern boundaries of TCAAP and extends to the southeast of TCAAP. The population of Shoreview for the year 1989 was estimated at 24,087 (MCCC, 1989a). Nine public schools with grades K through 12 serve approximately 8,000 students (MCCC, 1989b). Schools within 3 miles of TCAAP include Island Lake, St. Odelia, and William. Three recreational parks, Turtle Lake Park, Island Lake Park, and Snail Lake Park, are located within 2 miles of TCAAP. An industrial park is also located within city limits.

Mounds View

Mounds View is located in Ramsey County approximately 8 miles north of Minneapolis. Mounds View is on TCAAP's western boundary and extends to the northwest of TCAAP. The population of Mounds View was estimated at 12,738 for the year 1989 (MCCC, 1989a). Two schools (grades K through 6) serve 840 students and are located within 2 miles of TCAAP (MCCC, 1989b). A 53-acre industrial park is located within city limits.

Columbia Heights

Columbia Heights is located in Anoka County about 2.5 miles southwest of TCAAP. The population of Columbia Heights was estimated at 20,039 for the year 1989 (MCCC, 1989a). Four public schools with grades K through 12 are located within 4 miles of TCAAP; they serve approximately 3,370 students. Recreational areas in the city include Silver Lake, Sullivan Lake, Huset Park, LaBelle Park, and other local parks.

Minneapolis

Minneapolis is located about 6 miles southwest of TCAAP in Hennepin County. The population of Minneapolis was estimated at 358,166 for the year 1989 (MCCC, 1989a). Forty-two public schools within the city serve over 40,800 students. Numerous parks and recreational areas, including the Wirth Memorial Parkway and the Central Mississippi Riverfront, lie within the city.

3.2.2 Future Land Use Conditions

Future land use conditions represent the range of possible land uses that may exist at some point in the future. The NCP (U.S. EPA, 1990b) requires that exposures and risks at Superfund sites be evaluated for both current and future land uses. However, neither the NCP nor available guidance (U.S. EPA, 1989a) specifically states how future land uses should be defined. Future land uses may include a change in activities associated with current land use or a change in the land use of the site or the surrounding area.

As stated in Section 3.2.1, pregnant and nursing women represent a potentially sensitive subpopulation both on- and off-TCAAP.

3.2.2.1 On-TCAAP Future Land Use Conditions

The most likely scenario is that the U.S. Army will continue to operate TCAAP. Should the U.S. Army abandon TCAAP, future land use would likely reflect the surrounding area, which is currently largely suburban with scattered industrial developments. Alternative future land uses for all or parts of TCAAP may include construction of a sports complex with multiple playing fields; creation of a park; or residential, commercial, or industrial development. Although future development of TCAAP as a sports complex or park may be more likely to occur, residential development is more likely to generate the greatest exposures.

U.S. EPA's Risk Assessment Guidance for Superfund (1989a) defines RME as the highest exposure that is reasonably likely to occur. In a scoping meeting attended by U.S. Army, U.S. EPA, MPCA, and TCAAP lessee (Honeywell and FCC) representatives, it was determined that the assumption of residential development at TCAAP is consistent with the requirement to estimate the RME expected to occur (U.S. EPA, 1989a). It has been noted by the U.S. Army that while it is reasonable to assume "that future land use would move in the direction and reflect development similar to the surrounding area", some restrictions may be placed on the location and extent of future development (Thies, 1990). According to Thies (1990) the U.S. Army requires that an Environmental Baseline Study (EBS) be performed before a real property transaction can take place. The EBS outlines the known environmental condition of the property.

In this context, the risk assessment can be thought of as the presentation of an upper-bound estimate of the risks to human health associated with development throughout TCAAP, consistent with the existing development surrounding TCAAP. An evaluation of these potential risks to human health is necessary before restricting development in any way or in determining the necessary extent of remediation.

For the purposes of this risk assessment, probable future on-TCAAP land use is assumed to be identical to current use. However, under RME conditions, it was a group decision that future on-TCAAP land use should include mixed residential, commercial, and industrial development similar to that currently found immediately off-TCAAP. This determination was made with the understanding that although mixed development is less likely to occur than other land uses, the assumption of mixed development is conservative and represents the upper-bound limit of the future extent of exposure on-TCAAP.

Through discussions with the U.S. Army, U.S. EPA, MPCA, and their contractors, it was decided that for this risk assessment, future residential and industrial or commercial development would be assumed to resemble current off-TCAAP development. Development could take place anywhere within current TCAAP boundaries except in the area occupied by Marsden Lake; current (and presumably future) regulations allow development of wetlands areas only under limited circumstances. Existing TCAAP production buildings, auxiliary buildings, and supporting utilities as well as MDOT and Army Reserve operations are assumed to have been removed to make way for future development. Existing remedial operations, including the BGRS/TGRS well and air stripping system, Source Area K and Source Area I air strippers, Source Area D and Source Area G in-situ volatilization (ISV) systems, and Source Area A ground-water treatment system, are assumed to remain active, which would influence future on-TCAAP development.

The public is assumed to have access throughout TCAAP under RME conditions. Future activity patterns, including work and recreation patterns, are assumed to be similar to those currently found off-TCAAP (refer to Section 3.2.1.2). Finally, at least some on-TCAAP residences are assumed to have installed private drinking water wells. Currently, installation and use of such wells is not allowed in Arden Hills (City Ordinance 28-90). However, future use of private wells is assumed in order to reflect RME conditions.

3.2.2.2 Off-TCAAP Future Land Use Conditions

Future off-TCAAP land use conditions are assumed to be identical to current off-TCAAP land use conditions. However, under RME conditions, residences are assumed to have installed and used private drinking water wells, although current city ordinances generally prohibit such installation and use. The number of private drinking water wells installed and used in violation of city ordinances and state regulations is expected to be small. However, in order to fully evaluate potential exposures and risks to residents under RME conditions, this potential use is assumed in this risk assessment.

Only remedial and removal actions being conducted as of December 1989 are under consideration for both current and future land use conditions.

3.3 IDENTIFICATION OF EXPOSURE PATHWAYS

In this section, exposure pathways through which contaminants come in contact with the exposed population are identified. First, site-specific fate and transport characteristics in each medium are discussed. Second, exposure points, the points of potential human contact with each contaminated medium, are described. Finally, exposure pathways for specific media are identified.

3.3.1 Sources and Receiving Media

Known sources of contamination at the New Brighton/Arden Hills site include the 14 source areas and the air emission sources created by remedial activities. Receiving media within TCAAP include surface soil, subsurface soil, soil gas, surface water, sediment, ground water, and air. This risk assessment does not include an evaluation of contaminants that may potentially be associated with soil gas. The soil gas data presented in the on-TCAAP RI, ANL (1990) are qualitative; the report lacked information that would allow quantification. The receiving media evaluated for off-TCAAP locations are air and ground water. Contamination of off-TCAAP media is thought to originate primarily in Source Areas D, G, and I. Off-TCAAP surface soil and water bodies could be contaminated by soil runoff from TCAAP and particulate deposition. However, the controlled drainage and vegetative cover on-TCAAP make runoff to off-TCAAP locations and wind erosion unlikely. For a detailed description of the drainage control features at the site, refer to the on-TCAAP RI, ANL (1990). Furthermore, PRC assumes that the impact on human health from such exposure routes would be minimal.

3.3.2 Fate and Transport in Release Media

This subsection addresses the fate and transport of the chemicals of potential concern identified at the New Brighton/Arden Hills site. The chemicals of potential concern are tabulated in Appendix B. The procedure used to select these chemicals of potential concern is described in Chapter 2.

Processes that affect the distribution of a contaminant in the environment include transfer processes (sorption, bioaccumulation, and volatilization) and transformation processes (photolysis, oxidation, hydrolysis, sorption, bioaccumulation, biotransformation/biodegradation). These

processes are defined in Appendix G. In general, the extent to which these processes affect fate and transport depends on the environmental medium and the physicochemical properties of the contaminant. Physical-chemical properties of organic chemicals of potential concern are listed in Table 3-1. The general environmental behavior of organic and inorganic chemicals of potential concern is discussed in Appendix G.

The behavior of a particular contaminant at a specific site is influenced by site-specific characteristics. The physical-chemical characteristics of a contaminant and the site-specific characteristics determine the ultimate fate and transport. The following paragraphs discuss the fate and transport of contaminants of potential concern in soil, surface water and sediment, ground water, and air at the New Brighton/Arden Hills site.

In addition to the chemicals of potential concern, RI sampling results revealed the presence of unknown compounds that remain to be identified. These unknown compounds may affect the fate and transport of the chemicals of potential concern. Until the unknown compounds can be identified, however, the nature and extent of their impact cannot be estimated.

3.3.2.1 Soil Fate and Transport

Inorganic contaminants present in the surface and subsurface soils at the site include silver, cadmium, chromium, copper, lead, nickel, antimony, manganese, and cyanide. Mercury was also found in surface soils. All the inorganics are expected to bind strongly onto the soils and to migrate slowly with percolating and runoff water. They are not expected to be found in ground water, especially at off-TCAAP locations. However, with the exception of copper, antimony, and mercury, other inorganics were detected at concentrations above background in on-TCAAP ground-water wells. In addition, copper and antimony were detected in off-TCAAP wells, probably because the sandy material throughout the site inhibits sorption. Furthermore, a direct route exists to Units 3 and 4 from Source Areas E, 129-3, and 129-15.

The major transport pathway for inorganics is expected to be suspended sediment in runoff water. Suspended inorganics from several source areas would discharge into surface water bodies. Runoff from other areas, such as Source Areas A, E, 129-3, and 129-15, that are at higher elevations would go directly to the aquifers or to surrounding source areas. Soil runoff to off-TCAAP locations is not likely because of controlled drainage and vegetative cover.

TABLE 3-1

PHYSICAL CHEMICAL PROPERTIES OF ORGANIC CHEMICALS OF POTENTIAL CONCERN

	Molecular Weight[a]	Solubility in Water[a] (mg/L)	Henry's Law Constant[a] (atm m^3/mol)	Log Octanol/ Water Partition Coefficient[a]	K_{oc}[a] (mL/g)	Fish BCF[a] (L/kg)
Acetone	58	1.00 E + 06	2.06 E-05	-0.24	2.2	-
Benzene	78	1.75 E + 03	5.59 E-03	2.12	83	5.2
Benzoic Acid	122[b]	2.9 E + 03[c]	-	1.87[b]	-	-
Bromodichloromethane	164[b]	4.7 E + 03[d]	2.41 E-03[d]	1.88[b]	61[d]	-
2-Butanone	72	2.68 E + 05	2.74 E-05	0.26	4.5	0
Carbon Tetrachloride	154	7.57 E + 02	2.41 E-02	2.64	110	19
Chloroform	119	8.20 E + 03	2.87 E-03	1.97	31	3.75
1,1-Dichloroethane	99	5.50 E + 03	4.31 E-03	1.79	30	-
1,2-Dichloroethane	99	8.52 E + 03	9.78 E-04	1.48	14	1.2
1,1-Dichloroethene	97	2.25 E + 03	3.40 E-02	1.84	65	5.6
Trans-1,2-Dichloroethene	97	6.30 E + 03	6.56 E-03	0.48	59	1.6
Cis-1,2-Dichloroethene	97	3.50 E + 03	7.58 E-03	0.70	49	1.6
Dichloromethane	85	2.00 E + 04	2.03 E-03	1.30	8.8	5
2,4-Dinitrotoluene	182	2.40 E + 02	5.09E-06	2.00	45	3.8
Ethylbenzene	106	1.52 E + 02	6.43 E-03	3.15	1100	37.5
Methylene Chloride	85	2.00 E + 04	2.03 E-03	1.30	8.8	5
N-nitrosodiphenylamine	198[b]	4.0 E + 01[b]	6.6 E-04[d]	3.13[b]	1202[b]	217[b]
Phenol	94	9.3 E + 04	4.54 E-07	1.46	14.2	1.4
Phthalate Esters[e]	312-391[d]	4.0 E - 01 - 3.0 E + 00[d]	3 E-07 - 1.7 E-05[d]	3.6 E+05 - 7.4 E+09[d]	1.7 E+05 - 3.6 E+09[d]	-
PCBs	328	3.10 E-02	1.07 E-03	6.04	5.3 E+05	1E+05
PAHs[f]	202-252	1.20 E-03 - 2.06 E-01	1.55 E-06 - 6.46 E-06	4.9 - 6.06	3.8 E+04 - 5.5 E+06	1150
Tetrachloroethene	166	1.50 E + 02	2.59 E - 02	2.6	364	31
Toluene	92	5.35 E + 02	6.37 E-03	2.73	300	10.7
1,1,1-Trichloroethane	133	1.50 E + 03	1.44 E-02	2.5	152	5.6
1,1,2-Trichloroethane	133	4.50 E + 03	1.17 E-03	2.47	56	5
Trichloroethene	131	1.10 E + 03	9.10 E-03	2.38	126	10.6
Vinyl Chloride	63	2.67 E + 03	8.19 E-02	1.38	57	1.17
Xylenes (mixed)	106	1.98 E + 02	7.04 E-03	3.26	240	-

Notes:

- \- Data not available
- a U.S. EPA (1986a) unless otherwise noted
- b National Library of Medicine (1990)
- c Verschueren (1977)
- d Mabey and others (1982)
- e Based on values for bis(2-ethylhexyl)phthalate, Di-n-octyl phthalate, and butyl benzyl phthalate
- f Based on values for fluoranthene and benzo(a)pyrene

Among the organic contaminants of concern, PCBs and PAHs were detected in subsurface soils in Source Area E, and Source Area C, respectively. In addition xylene was detected in surface soils in Source Area A. In addition, in Source Area 129-3, several organic compounds were detected in both surface and subsurface soils. These compounds included 2,4-dinitrotoluene, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, n-nitrosodiphenylamine, toluene, and trichloroethene. PCBs and PAHs have strong sorption potential and very low mobility. PCBs in surface soil will volatilize slowly; PCBs may also biodegrade but at very slow rates. Toluene and trichloroethene (TCE) present in surface soil will also volatilize to the atmosphere. PCBs and PAHs are expected to remain sorbed onto subsurface soils. Rain water percolating through subsurface soils is not expected to leach out PCBs and PAHs and transport them to deeper soils or ground water. VOCs, if present at high concentrations in percolating water, could potentially facilitate transport of compounds such as PCBs and PAHs. However, VOCs were not detected in subsurface soils at locations where PCBs or PAHs were detected. Xylene, present in subsurface soils, may leach into ground water. The organics present in Source Area 129-3 are expected to be mobile. Soil in this source area is composed of sand and gravel that will provide a weak sorption site. Furthermore, Source Area 129-3 provides direct recharge to Unit 3.

Fugitive dust emissions are not expected to be a significant pathway for organics or inorganics at the site under current land use conditions because most of the source areas are covered with vegetation.

3.3.2.2 Surface Water and Sediment Fate and Transport

Surface water may be contaminated through atmospheric deposition, surface water runoff, and ground-water infiltration. Inorganic contaminants identified in on-TCAAP surface water bodies include silver, manganese, thallium, chromium, cyanide, nickel, and cadmium. The most significant transport mechanism for these inorganic constituents is complexation and eventual precipitation out of the water column. The only organic contaminant detected in surface water is bis(2-ethyl hexyl)phthalate, which is expected to sorb onto suspended particulates and settle out of the water column into the sediments.

None of the organic contaminants were detected at levels above background in sediment samples. All the inorganics are expected to remain sorbed to sediments.

3.3.2.3 Ground-Water Fate and Transport

Many organic and inorganic contaminants of potential concern were detected at above-background levels in both on-TCAAP and off-TCAAP wells. Because some of these contaminants

have low mobility, such as all the inorganics and the phthalates in off-TCAAP wells, contaminant contribution to ground water has apparently continued over a long period. The ultimate fate of these contaminants is sorption onto subsurface soils.

Many volatile compounds were also detected in ground water. The extent to which organic contaminants bind and sorb to soils is influenced by total organic carbon (TOC) content, which influences the K_{OC} values of these contaminants. The TOC content of the subsurface soils is not known. However, TOC content in saturated zone soils is expected to be low. The volatile compounds are all expected to move along with the ground water. Concentrations, however, will decrease because of dilution and dispersion. Some volatiles may also biodegrade.

3.3.2.4 Atmospheric Fate and Transport

VOCs emitted from the TGRS will enter the atmosphere. In addition, several inorganics, PCBs, PAHs, and xylene present in surface and subsurface soils may enter the atmosphere as fugitive dust during construction activities.

The VOCs released from the air strippers used for remedial activities may disperse and move both on- and off-TCAAP. PRC used dispersion models to estimate TCE and 1,1,1-trichloroethane concentrations at several locations both on and off-TCAAP. Although several volatiles were detected in ground water and may potentially be emitted from the TGRS, PRC selected only TCE and 1,1,1-trichloroethene for reasons discussed in Appendix F. The ultimate fate of the VOCs is primarily dilution and to some extent photooxidation.

Contaminants entering the atmosphere as fugitive dust are expected to be removed by dry deposition and rainfall.

3.3.3 Exposure Points

An exposure point is a location where people are exposed to a chemical or chemicals in a particular medium or media. Exposure points can be specific or general. For the purposes of this risk assessment, the definition and location of exposure points vary depending on the medium of concern. For example, exposures to VOCs emitted into the ambient air as part of existing on-TCAAP remedial activities were evaluated for specific exposure points such as particular on-TCAAP office buildings and off-TCAAP residences. Exposures to chemicals in surface water and sediment were evaluated for specific on-TCAAP or off-TCAAP surface water bodies, such as Rice Creek, Round Lake, and Marsden Lake. Finally, exposures to chemicals in soils, airborne VOCs,

and chemicals in miscellaneous surface water bodies were evaluated for each of the 14 source areas defined in the on-TCAAP RI (ANL, 1990).

In contrast, exposure to ground water was evaluated at exposure points not readily identifiable from the maps provided in the on-TCAAP and off-TCAAP RIs (ANL, 1990 and CDM, 1991). Ground-water exposure points were created specifically for this risk assessment and are termed "exposure areas." These exposure areas are shown in Figures 1-3, 1-4, 1-5, and are briefly discussed below.

On-TCAAP exposure areas are of two types: Class I and Class II (see Figure 1-3). Class I exposure areas include each of the 14 source areas as well as those monitoring wells identified with each source area in the on-TCAAP RI (ANL, 1990). The rest of TCAAP was divided into Quadrants, each of which was defined as a Class II exposure area. Class II exposure areas are considered representative of on-TCAAP exposure not related to known source areas.

Off-TCAAP exposure areas were defined based on the degree of ground-water contamination. Representatives of the U.S. Army, MPCA, FCC, and Honeywell prepared a generalized series of isopleths encompassing a ground-water plume flowing southwest from TCAAP (see Figures 1-4 and 1-5). The isopleths were based on the concentrations of TCE measured in Units 3 and 4. Although these isopleths do not represent the exact distribution of other chemicals in off-TCAAP ground water, they do serve as a useful tool to address the general pattern of ground-water contamination identified in the off-TCAAP RI (CDM, 1991). Using a single set of isopleths, exposure points were made consistent for all chemicals. One additional exposure area was defined: a series of private drinking water wells located in Shoreview immediately north of Source Area A. This exposure area is termed Area S.

Private drinking water wells in addition to those in Area S are known to exist off-TCAAP. However, no complete list of off-TCAAP private drinking water wells exists. Table 3-4 in Section 3.3.4.2.2 describes the presence of off-TCAAP private wells identified in discussions with city officials.

3.3.4 Exposure Pathways

This subsection combines potential exposure points with specific exposure routes -- such as ingestion, inhalation, and dermal contact -- to create a series of exposure pathways. On-TCAAP and off-TCAAP exposure pathways are discussed for specific media, first under current land use conditions and then under future land use conditions.

3.3.4.1 Exposure Pathways Under Current Land Use Conditions

Under current land use conditions, exposure will take place both on-TCAAP and off-TCAAP. Table 3-2 summarizes exposure pathways under current land use conditions. Exposure in each Class I exposure area is assumed to occur only within individual source areas and not within the rest of the exposure area.

3.3.4.1.1 On-TCAAP Exposure Pathways (Current Land Use)

Potential on-TCAAP exposures are associated with six media: ground water, surface soil, subsurface soils, air, and surface water and sediment. Exposure points and exposure routes for each medium are discussed below.

<u>On-TCAAP Ground Water</u>

All potable water provided on-TCAAP for drinking, bathing, and household use by employees, authorized visitors, and residents of Army staff housing is treated by TGRS, which consists of the BGRS and the SC wells. Ground water from TGRS, including effluent from the Building 502 treatment system (Source Area I), is passed through airstripping towers that reduces organic chemicals below detection limits. The treated water then passes through softeners and finally a carbon filter before being distributed for use on-TCAAP as potable water. Because no chemical exposure exists, this exposure point (TGRS-supplied water) is not evaluated further in risk assessment. However, users of on-TCAAP ground water could be exposed if the existing treatment system failed. It is assumed that such exposure would last for a short time, only until the system was fixed or an alternative water supply was provided. Therefore, exposure as a result of treatment system failure is not evaluated.

Exposure to ground water (via dermal contact and inhalation) may also occur at pump-out wells, where maintenance workers may have limited exposure. Also, sampling workers may have limited exposure when sampling on-TCAAP monitoring wells. Exposures of both maintenance workers and sampling workers are assumed to be minimal because of safe work practices, including use of personal protective equipment and monitoring equipment. Because minimal chemical exposures would result in little or risk to human health, these exposures are not evaluated further in this risk assessment.

TABLE 3-2

CURRENT LAND USE CONDITIONS
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
POTENTIAL PATHWAYS ON-TCAAP				
Ground Water	On-TCAAP drinking water supply	On-TCAAP employees and residents	Ingestion, inhalation of volatiles while showering, and dermal contact while bathing	No. On-TCAAP ground water is passed through air strippers and a carbon filter prior to use as a potable water supply. According to the U.S. Army, treated water meets the Minnesota Department of Health (MDH) standards for drinking water (MDH, 1989, U.S. Dept. of the Army, 1991).
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal contact and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment, such as gloves and masks, if necessary, and monitoring equipment.
Surface Soil	On-TCAAP exposure areas	On-TCAAP maintenance workers	Incidental ingestion, inhalation of fugitive dusts, and dermal contact	Yes. However, exposure in parts or all of individual exposure areas may be limited or nonexistent because of thick vegetation, clay caps, or fill material that prevents contact with underlying soil. In fact, generation of and exposure to fugitive dusts are expected to be minimal and are not evaluated under current land use.
Subsurface Soil	On-TCAAP exposure areas	Construction workers	Incidental ingestion, dermal contact, and inhalation of fugitive dusts	Yes. Construction work such as foundation excavation or sewer or underground pipeline repair work within on-TCAAP exposure areas may occur. See exposure and risk discussions pertaining to construction activities under RME future land use (Table 3-3).
Air	Major on-TCAAP work stations (offices and manufacturing areas) and Army housing	On-TCAAP employees and residents	Inhalation of volatile organics	Yes.
Surface Water and Sediment	Rice Creek (on-TCAAP portion), Sunfish Lake, Marsden Lake, and miscellaneous small areas of collected surface water	On-TCAAP maintenance workers and Minnesota Department of Natural Resources (MDNR) staff working within the Sunfish Lake fishery	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. However, exposure is assumed to be very infrequent.
Surface Water	Rice Creek (on-TCAAP portion) and Sunfish Lake	On-TCAAP workers	Ingestion of fish	No. Sunfish Lake is used to raise hatchlings but cannot support a standing population; workers are assumed to not fish in the on-TCAAP portion of Rice Creek. Exposure to hatchlings raised in Sunfish Lake and used to stock other lakes is not evaluated because exposure concentrations in grown fish are expected to be small (see discussion in Section 3.3.4.2.1).

TABLE 3-2 (Continued)

CURRENT LAND USE CONDITIONS
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
POTENTIAL PATHWAYS OFF-TCAAP				
Ground Water	Private wells located downgradient of TCAAP within the ground-water contamination plume extending southwest of TCAAP; and private wells located north of TCAAP opposite Source Area A	Local residents	Ingestion, inhalation of volatiles while showering, and dermal contact while bathing	Yes. The number of existing private drinking water wells is small. Most off-TCAAP residents receive their drinking water from municipal sources. However, if the currently functioning granular activated carbon (GAC) treatment systems fail, residents served by private wells could be exposed to contaminated ground water until the failure is detected. Private wells located immediately north of Source Area A in Shoreview and others in the vicinity of Round Lake are used for drinking water. In addition, private drinking water wells may exist in other off-TCAAP cities. For example, New Brighton, Columbia Heights and Minneapolis have no specific ordinance that prohibits installation and use of private drinking water wells.
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal contact and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment, such as gloves and masks, if necessary, and monitoring equipment.
Surface Soil	Off-TCAAP residential and commercial/industrial areas	Local residents and employees	Individual ingestion, inhalation of fugitive dusts, and dermal contact	Unknown. Information on the quality of off-TCAAP surface soil is not available. Potential off-TCAAP exposure to contaminated surface soil originating on-TCAAP cannot be accurately quantified but is insignificant relative to potential exposure to other media, especially ground water, and is not evaluated in this risk assessment.
Air	Off-TCAAP residential areas	Local residents	Inhalation of volatile organics	Yes.
Surface Water	Rice Creek (portion immediately off-TCAAP) and Round Lake	Local residents	Ingestion of fish	Yes.
Surface Water and Sediment	Rice Creek (portion immediately off-TCAAP) and Round Lake	Local residents	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. Swimming is assumed to be very infrequent. Most exposure is assumed to take place when persons wade in the creek.

TABLE 3-2 (Continued)

CURRENT LAND USE CONDITIONS
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
Surface Water and Sediment	Off-TCAAP surface water bodies (excluding Rice Creek and Round Lake) downgradient of TCAAP, including Long Lake and Valentine Lake	Local Residents	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	No. Available data do not indicate that chemicals originating at TCAAP have significantly impacted nearby surface water bodies.
Deer and Small Game	Locations to which meat from slaughtered on-TCAAP animals is distributed	Private citizens	Ingestion of meat	Yes. The on-TCAAP deer population is harvested each year, and most of the meat is distributed to charity groups and private citizens. The rest of the meat is destroyed. Small game such as rabbits or pheasants may feed on-TCAAP, migrate off-TCAAP, and be bagged by hunters. Ingestion of game in general is evaluated by investigating deer exposure data.

On-TCAAP Surface Soil

The TCAAP site is secure under current operations. Its boundaries are regularly patrolled, and no unauthorized access is possible. On-TCAAP housing is separated from the operational portion of the site by a series of barbed wire fences and locked gates. Most on-TCAAP employees work indoors in office buildings and manufacturing areas. These are located along or near the western and southwestern boundaries of TCAAP, away from most of the 14 identified source areas (see Figure 1-2). On-TCAAP maintenance workers regularly work outdoors and do maintenance work at the source areas.

Surface and near-surface soils in most of the 14 source areas were sampled during the on-TCAAP RI (ANL, 1990). Organic contaminants were infrequently detected in surface soil, but heavy metals were frequently detected. Ordnance may also be present. On-TCAAP maintenance workers may be exposed to chemicals in surface soil via three exposure routes: (1) incidental ingestion when food is ingested with unwashed hands or unwashed hands are placed directly in the mouth; (2) dermal absorption from dermal contact with surface soil or from deposition of fugitive dusts on exposed skin; and (3) inhalation of fugitive dusts generated at the source areas by wind or by heavy machinery or motor vehicles. Additional source areas may be identified in the future. To the extent that additional source areas exist and are not evaluated in this risk assessment, the total extent of exposure may be underreported.

The degree of exposure to surface soil via inhalation of fugitive dusts depends on the amounts of vegetation, clean fill, and manmade clay capping; these may prevent or limit exposure. For example, much of the surface soil in Source Area D is either excavated, covered with clean fill, or capped with clay, so the extent of exposure would be small. In contrast, much of Source Area F is covered with a light vegetative cover, that may reduce but will not eliminate exposure to surface soil. Because of the presence of relatively extensive vegetation and manmade coverings at the 14 Class I exposure areas, risk from exposure to fugitive dusts from these areas is assumed to be insignificant compared with risk from exposure via incidental ingestion or dermal contact. Therefore, inhalation of particulates is not evaluated under current land use conditions.

Unlike surface soils in the 14 Class I exposure areas, surface soils in the Class II exposure areas were not sampled during the on-TCAAP RI (ANL, 1990). No historical sampling data are available for the Class II exposure areas. On-TCAAP employees may be exposed to surface soils in these areas, specifically those near the southwestern boundary of TCAAP. Because of the lack of soil sampling data, exposure to surface soils in the Class II exposure areas is not evaluated in this risk assessment. Presumably such exposure is insignificant compared with other pathways of

exposure; historical records do not indicate any past disposal or treatment operations in the Class II exposure areas.

On-TCAAP Subsurface Soil

Exposure to on-TCAAP subsurface soil may occur as a result of construction activities, including foundation excavation and sewer or underground pipeline repair work. The extent of exposure depends primarily on the location and duration of construction activities. Exposure related to residential construction is evaluated under RME future land use conditions (refer to Section 3.3.4.2.1) and is also used to represent exposures to subsurface soil under current and probable future land use conditions.

On-TCAAP Air

Remedial actions at TCAAP by the U.S. Army and Honeywell have concentrated on three activities: (1) contaminant source control, (2) ground-water remediation, and (3) storage tank remediation. The first two activities have employed systems that release VOCs into the atmosphere. These sources of VOC emissions are briefly described below.

ISV systems are installed in Source Areas D and G. The ISV systems operate by inducing a vacuum within the soil column, causing an airflow within the soil and releasing VOCs from the soil surface into this airflow. The airflow is subsequently released into the ambient air. The ISV units at Source Areas D and G have removed approximately 45 tons of VOCs per area since operations began in 1986.

In Source Area K, collected ground water from a collection drain is pumped through an air stripper, and VOCs are released into the ambient air. This remediation system has operated since September 1986.

TGRS consists of two primary parts: (1) BGRS and (2) the five SC wells. BGRS currently consists of 12 wells (B1 through B12) located along the southwestern boundary of TCAAP. Eight of these wells are installed within Unit 3, and four are installed within Unit 4. The BGRS wells are connected in series to a treatment system consisting of four air stripping towers. The five SC wells (SC1 through SC5) include two wells downgradient from Source Area D; two wells downgradient from Source Area G; and one well downgradient from Source Area I. These wells are connected to BGRS. Ground water collected by the SC wells is treated by the four air stripping towers. (Ground water from SC1 is first treated by an air stripping tower in Source Area I and then is routed to the four-tower system for additional treatment.)

According to data from March through December 1989, the total amount of VOCs removed by the BGRS/TGRS for 1989 was 19,510 pounds (Fullen, 1990). Of this total, approximately 251 pounds was removed by well SC1 (Source Area I). The Source Area K well removed approximately 25 pounds of VOCs. Therefore, the Source Area I and K wells removed approximately 1.4 percent of the total amount of VOCs removed by the BGRS/TGRS system and the Source Area K well. If 100 percent of the VOCs removed is subsequently released into the ambient air via the air stripping towers, the Source Area I and K air strippers contribute approximately 1.4 percent of the total volume of VOCs released. Because these two sources contribute a small percentage of the VOC emissions, they are not considered when quantitatively evaluating exposure to chemicals from air emission sources.

Employees, authorized visitors, and persons living in on-TCAAP housing may be exposed to chemicals via inhalation from the air emission sources. Exposure is assumed to take place equally indoors and outdoors. Emissions from three point sources (the four BGRS/TGRS air stripping towers, the Source Area D ISV system, and the Source Area G ISV system) are likely to be transported throughout TCAAP and are modeled to various exposure points within TCAAP. These exposure points include major TCAAP work stations, each of the 14 Class I exposure areas, and the center point of each of the Quadrants. The selection of these exposure points is described in Appendix F. Modeled air concentrations from each of the point sources are summed to give a single set of air concentrations at each of the exposure points.

On-TCAAP Surface Water and Sediment

Sampling during the on-TCAAP RI included the on-TCAAP portion of Rice Creek, Sunfish Lake, and Marsden Lake, and a number of small, miscellaneous surface water bodies, primarily drainage ditches (ANL, 1990). Figure 1-2 shows the locations of these surface water bodies. As discussed earlier, minimal chemical contamination was detected in most surface water and sediment samples.

Exposure to surface water and underlying sediment on-TCAAP is expected to be very infrequent. On-TCAAP maintenance workers may have to enter the surface water bodies to clean out clogged drain pipes or for other tasks. Exposure to surface water may take place via dermal absorption and incidental ingestion if on-TCAAP employees accidentally fall into the water or when MDNR staff members wade in Sunfish Lake as part of their work at the fishery. Exposure to sediments underlying the surface waters may take place via dermal absorption. Fish living in Rice Creek (on-TCAAP) and in Sunfish Lake may bioconcentrate chemicals found in surface water and sediment. However, it is assumed that on-TCAAP employees and MDNR staff

members who have access to the surface water bodies will not fish in the on-TCAAP portion of Rice Creek or in Sunfish Lake. Ingestion of fish from on-TCAAP surface water bodies is therefore an incomplete exposure pathway and is not evaluated further in this risk assessment.

3.3.4.1.2 Off-TCAAP Exposure Pathways (Current Land Use)

Potential exposures off-TCAAP are associated with six media: ground water, surface soil, air, surface water and sediment, and meat from deer and small game. Exposure points and exposure routes associated with each of these media are discussed below.

Off-TCAAP Ground Water

Currently, most residents living off-TCAAP receive their potable water from municipal water supply wells. The water from these wells is either contaminant-free when drawn from the ground or, in the case of the municipal water supply wells of New Brighton and St. Anthony, is run through activated carbon treatment systems that reduce contamination to required levels before being distributed to the public. Residents may be exposed to contaminated ground-water if the current GAC treatment systems fail. Such failures are expected to be infrequent and to be quickly repaired.

However, a small number of private wells are being used as potable water supply sources. Most notable is a series of private wells located in Shoreview (Exposure Area S) immediately north of Source Area A. A number of these private wells are known to have been installed in Unit 1 (FCC, 1988). Furthermore, officials from off-TCAAP municipalities have acknowledged that a small number of additional unidentified private water supply wells may exist off-TCAAP (Mineton, 1990; Proper, 1990; and Lonbeski, 1990). The U.S. Army has stated that it conducted a private well search in the area of the ground-water plume extending southwest from TCAAP and that no private wells were identified (McCleery, 1990; no documentation available). In addition, the State of Minnesota plans to conduct an additional well search in the future. Therefore, the present number of private wells within the plume extending southwest from TCAAP is almost certainly very small, but the exact number cannot be determined at this time.

Exposure to chemicals in ground water may occur via three routes: (1) ingestion, (2) inhalation of volatiles during showering, and (3) dermal absorption during bathing. If any of the water users are commercial/industrial operations, then exposure would be assumed to occur primarily via ingestion unless specific instances of bathing could be documented. Persons living across from Source Area A who receive their potable water from shallow private wells (Unit 1) are assumed to be exposed to chemicals within this water via all three routes.

Off-TCAAP Surface Soil

Off-TCAAP surface soil may be contaminated by the transport off-TCAAP of contaminated surface soil from on-TCAAP exposure areas. Such transport may occur via two primary mechanisms: (1) migration of fugitive dusts and (2) transport of soil particles off-TCAAP by surface water runoff. The degree to which off-TCAAP surface soil is contaminated is unknown; off-TCAAP surface soil samples were not collected and analyzed during either the on-TCAAP RI (ANL, 1990) or off-TCAAP RI (CDM, 1991).

The amount of contaminated surface soil transported off-TCAAP from on-TCAAP source areas is assumed to be small. Furthermore, the concentrations of chemicals within any soil transported off-TCAAP would be greatly diluted by dispersion during transport as well as by subsequent mixing with native off-TCAAP soil. Exposure to chemicals in off-TCAAP surface soil will therefore be insignificant compared to potential exposure to chemicals in other media, especially ground water. Thus, exposure to chemicals in off-TCAAP surface soil is not evaluated in this risk assessment.

Off-TCAAP Air

As described in Section 3.3.4.1.1, three on-TCAAP emission point sources are evaluated in this risk assessment: (1) the four BGRS/TGRS air stripping towers, (2) the Source Area D ISV system, and (3) the Source Area G ISV system. VOCs emitted from these sources are likely to be transported off-TCAAP. Therefore, in this risk assessment they are modeled to points throughout the surrounding residential and commercial/industrial area.

Potential exposure points shown in Figure F-3 of Appendix F include residential housing located immediately across from Source Area A, the Arden Manor Trailer Park, and other off-TCAAP points. The selection of off-TCAAP exposure points is described in Appendix F. Modeled air concentrations from each point source are summed to give a single set of air concentrations at each exposure point. Off-TCAAP local residents and employees may be exposed via inhalation to VOCs contained in the air emissions. Exposure is assumed to take place equally indoors and outdoors.

Off-TCAAP Surface Water and Sediment

Water from the portion of Rice Creek that would be affected by runoff or discharges from TCAAP is classified as suitable for domestic consumption after treatment, sport or

commercial fishing, and aquatic recreation of all kinds, including bathing. At present, the surface waters in the Rice Creek basin are not used for drinking water. However, recreational use of lakes and Rice Creek occurs, including canoeing and fishing on Rice Creek. In fact, the off-TCAAP portion of Rice Creek along the western boundary of TCAAP is heavily fished during the spring.

In this risk assessment, surface water and sediment exposure pathways are evaluated quantitatively only for the portion of Rice Creek immediately off-TCAAP and for Round Lake. Persons may be exposed to surface water via dermal contact and incidental ingestion; exposure to sediments would occur via dermal contact. In addition, fish in the surface water bodies may bioconcentrate chemical contaminants present in the surface water or sediment. Therefore, persons may be exposed to chemical contaminants by eating such fish.

Surface water and sediment samples were collected from Rice Creek immediately outside the western TCAAP boundary during the on-TCAAP RI (ANL, 1990). Because these samples showed minimal organic and inorganic chemical contamination, it is assumed that no chemical contamination is being transported via Rice Creek into the lakes of the Rice Creek basin downstream of TCAAP, including Long Lake (see Figure 1-4). However, the possibility exists that these lakes are hydraulically connected to ground water in Unit 1. Round Lake is located within 1/4 mile of TCAAP's southwestern boundary, and chemicals present in the ground water may be discharging into the lake.

In the past, process wastes from portions of Buildings 501 and 502 were put directly into a storm sewer discharging to Round Lake. Process wastes from Plant II buildings and forge operations were diverted to Round Lake, if necessary. Process wastes have not been discharged into Round Lake except under emergency conditions since the sewer system was modified between 1953 and 1955. Four sediment samples and a single surface water sample from Round Lake collected in 1985 as part of the Force Main Remedial Investigation (CDM, 1988) showed minimal chemical contamination and no VOC contamination. The Force Main RI (CDM, 1988) concluded that public health and the environment were not significantly impacted at Round Lake. Furthermore, surface water and sediment samples collected during the on-TCAAP RI (ANL, 1990) showed minimal chemical contamination. Specifically, no organic chemicals were detected in Round Lake surface water or sediment during the on-TCAAP RI. The following four inorganic chemicals were detected in surface water (maximum concentrations measured): barium (590 μg/L), copper (1.73 μg/L), manganese (1,200 μg/L), and thallium (10.6 μg/L). Two inorganic chemicals were detected in sediment (maximum concentrations measured): copper (24.8 mg/kg) and lead (23.9 mg/kg).

Surface water and sediment data are lacking for the portion of Rice Creek downstream of Long Lake as well as for Long Lake and Valentine Lake. However, sampling data from upstream locations show minimal chemical contamination. Specifically, in the portion of Rice Creek upstream of Long Lake but within or downstream of TCAAP, no organic chemicals were detected in surface water samples collected during the on-TCAAP RI (ANL, 1990) and only trichloroethene (maximum concentration measured 2.1 μg/L) was detected in Rice Creek upstream of TCAAP. On the other hand, the following four inorganic chemicals were detected at levels above background in Rice Creek surface water upstream of Long Lake but downstream of TCAAP (maximum concentrations measured): silver (2.48 μg/L), chromium (2.73 μg/L), cyanide (13.8 μg/L), and nickel (7.76 μg/L). No sediment samples were collected from Rice Creek during the on-TCAAP RI (ANL, 1990).

As discussed above, surface water sampling data for Rice Creek immediately upstream of Long Lake show no organic contamination and minimal inorganic contamination (ANL, 1990). These data suggest that surface water and sediment further downstream in Long Lake itself and in Rice Creek contain little or no chemical contamination. Also as discussed above, surface water and sediment data from Round Lake showed no organic contamination and minimal inorganic contamination (ANL, 1990). Round Lake drains into Valentine Lake; because minimal contamination has been measured in Round Lake, it is assumed that the surface water and sediment of Valentine Lake also contain little or no chemical contamination.

Sampling data are unavailable, and available data from upstream locations show minimal chemical contamination. Therefore, exposure pathways involving the portion of Rice Creek downstream of Long Lake as well as Long Lake and Valentine Lake are not evaluated in this risk assessment.

Off-TCAAP Deer and Small Game

A significant white-tailed deer population exists at TCAAP. The deer are allowed to roam throughout nonoperational portions of TCAAP. Through ingestion of surface water, dermal contact with surface soil and sediment, inhalation of VOCs and fugitive dusts, and ingestion of vegetation containing fugitive dusts, the deer may have bioconcentrated particular chemical contaminants. The size of the on-TCAAP deer population is regulated by an annual hunt. Meat from the deer is given to charity groups and private citizens; excess meat is destroyed. Off-TCAAP persons may therefore be exposed to chemical contamination originating at TCAAP by eating contaminated deer meat.

In addition, small game such as rabbits and pheasants may feed on-TCAAP, migrate off-TCAAP, and be bagged by hunters. Off-TCAAP persons may therefore be exposed to chemical contamination by ingesting contaminated small game meat.

3.3.4.2 Exposure Pathways Under Future Land Use Conditions

Under future land use conditions, exposures will take place both on- and off-TCAAP. Exposure points and exposure routes are discussed below according to media, first for on-TCAAP and then for off-TCAAP. Exposure pathways under future land use conditions are summarized in Table 3-3. Exposure pathways listed in Table 3-3 and exposure points and exposure routes discussed below are assumed to occur under RME conditions. Probable future land use is assumed to be identical to current land use conditions, which are summarized in Table 3-2 and discussed in Section 3.3.4.1.

3.3.4.2.1 On-TCAAP Exposure Pathways (Future Land Use)

Exposures on-TCAAP are associated with the following media: ground water, soils (both surface and subsurface), surface water and sediment, air, soil gas, and home-grown vegetables and fruits. Exposure points and exposure routes for each medium are discussed below.

<u>On-TCAAP Ground Water</u>

Under future land use conditions, it is assumed that residential, commercial, and industrial development will take place within current TCAAP boundaries. Furthermore, it is assumed that at least some residences or businesses will obtain potable water from private wells completed within Unit 1, 3, or 4. Wells installed to serve commercial or industrial operations are assumed to be closely regulated and to comply with existing ground-water treatment regulations. However, persons may take it upon themselves to install and use private wells (in some instances illegally). Installation and use of private wells are not expected to be common considering community awareness of TCAAP contamination and in fact are unlikely. However, because ground-water contamination is by far the most significant exposure pathway at TCAAP, this scenario is retained to represent a potential exposure pathway under RME conditions. If the U.S. Army abandons TCAAP and residential, commercial, or industrial development replaces existing operations, community awareness of TCAAP contamination may diminish somewhat.

TABLE 3-3

RME FUTURE LAND USE CONDITIONS[1]
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
POTENTIAL PATHWAYS ON-TCAAP				
Ground Water	Private wells installed within current TCAAP boundaries	Local residents	Ingestion, inhalation of volatiles while showering, and dermal contact while bathing	Yes. Only local residents are considered receptors because it is assumed that any wells installed to serve industrial or commercial development within current TCAAP boundaries will be closely regulated and will comply with existing regulations that require ground-water treatment if contamination is detected.
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal absorption and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment, such as gloves and masks, if necessary, and monitoring equipment.
Surface Soil	On-TCAAP exposure areas	Local residents	Incidental ingestion, inhalation of fugitive dusts, and dermal contact	Yes. Exposure may be limited by placement of clean topsoil on top of native soil during residential development. Employees of commercial or industrial operations located on-TCAAP are assumed not to be exposed. Emission of and exposure to fugitive dusts from surface soils are expected to be minimal and are not evaluated.
Subsurface Soil	On-TCAAP exposure areas	Construction workers	Incidental ingestion, inhalation of fugitive dust, and dermal contact	Yes. Exposure is evaluated in terms of residential construction. However, exposure may also occur as a result of other construction or repair activities such as sewer or underground pipeline repair work.
Surface Water and Sediment	Rice Creek (on-TCAAP portion), Sunfish Lake, Marsden Lake, and miscellaneous small areas of surface water	Local residents and MDNR staff working at the Sunfish Lake fishery	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. Swimming is expected to be very infrequent. Most exposure is assumed to take place when persons are wading.
	Rice Creek (on-TCAAP portion)	Local residents	Ingestion of fish	No. Exposure of fish from Sunfish Lake is assumed not to occur because Sunfish Lake cannot support a year-round fish population. Fingerlings are used to stock local lakes. Exposure to relocated fingerlings is not evaluated because tissue concentrations in grown fish are assumed to be small (see discussion in Section 3.3.4.2.1).

TABLE 3-3 (Continued)

RME FUTURE LAND USE CONDITIONS[1]
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
Air	On-TCAAP exposure areas	Local residents and employees of future commercial and industrial operations	Inhalation of volatile organics	Yes. It is assumed that future remedial activities will include continued operation of existing ground water and soil gas extraction/treatment systems that release volatile organics into the atmosphere.
Soil Gas	Basements of residences located within on-TCAAP exposure areas	Local residents	Inhalation of volatile organics	Yes. Evaluation of this pathway is qualitative in nature.
Home-Grown Vegetables and Fruits	On-TCAAP exposure areas	Local residents	Ingestion	Yes.
POTENTIAL PATHWAYS OFF-TCAAP				
Ground Water	Private wells located downgradient of TCAAP within the ground-water contamination plume extending southwest of TCAAP and located north of TCAAP opposite Source Area A	Local residents	Ingestion, inhalation of volatiles while showering, and dermal contact while bathing	Yes. The number of existing private drinking water wells is small. Most off-TCAAP residents receive their drinking water from municipal sources. However, if the current GAC treatment systems fail, residents served by private wells could be exposed to contaminated ground water until the failure is detected. Private wells located immediately north of Source Area A in Shoreview are used for drinking water. In addition, private drinking water wells may exist in other off-TCAAP cities. For example, New Brighton, Columbia Heights, and Minneapolis have no specific ordinance that prohibits installation and use of private drinking water wells.
	Pump-out wells and monitoring wells	Maintenance workers and sampling workers	Dermal contact and inhalation of volatiles	Yes. However, exposure is expected to be minimal because of safe work practices, including use of personal protective equipment, such as gloves and masks, if necessary, and monitoring equipment.
Surface Soil	Off-TCAAP residential and commercial/industrial areas	Local residents and employees	Incidental ingestion, inhalation of fugitive dust, and dermal contact	Unknown. Information on the quality of off-TCAAP surface soil is not available. Potential off-TCAAP exposure to contaminated surface soil originating on-TCAAP cannot be accurately quantified but is insignificant relative to potential exposure to other media, especially ground water, and is not evaluated in this risk assessment.

TABLE 3-3 (Continued)

RME FUTURE LAND USE CONDITIONS[1]
POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS TO CHEMICALS ORIGINATING AT TCAAP

Exposure Medium	Exposure Point	Receptors	Routes of Exposure	Pathways Complete?/Discussion
Air	Off-TCAAP residential areas	Local residents	Inhalation of volatile organics	Yes.
Surface Water and Sediment	Rice Creek (portion immediately off-TCAAP) and Round Lake	Local residents	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	Yes. Swimming is assumed to be very infrequent. Most exposure is assumed to take place when persons are wading.
	Rice Creek	Local residents[2]	Ingestion of fish	Yes.
	Off-TCAAP surface water bodies (excluding Rice Creek and Round Lake) downgradient of TCAAP, including Long Lake and Valentine Lake	Local residents[2]	Dermal contact with surface water, incidental ingestion of surface water, and dermal contact with sediments	No. Available data do not indicate that chemicals originating at TCAAP have significantly impacted nearby surface water bodies.

Notes:

1 Future land use is evaluated under two sets of conditions: (1) probable exposure conditions -- under these conditions, TCAAP is assumed to continue operating as it is currently, with exposure pathways the same as under current conditions; and (2) RME conditions -- residential and commercial/industrial development is assumed to take place within current TCAAP boundaries, and private drinking water wells are assumed to be installed within the ground-water plume southwest of TCAAP. Only pathways under RME conditions are summarized in this table.

2 Local residents in this instance include persons living outside current TCAAP boundaries. Exposure may take place within current TCAAP boundaries or in Rice Creek immediately outside the boundaries.

Ground-water exposure points consist of private wells located all on-TCAAP Class I and Class II exposure areas, and completed in Units 1, 3, and 4, where present. Residents may be exposed to chemical contaminants via three exposure routes: (1) ingestion, (2) inhalation of volatiles during showering and other household activities such as dishwashing, and (3) dermal contact while bathing. As stated above, wells installed to provide potable water for commercial or industrial operations are not evaluated in this risk assessment.

As stated in Section 3.3.4.1.1, limited exposure to ground water may occur at pump-out wells and monitoring wells and would involve maintenance workers and sampling workers, respectively. Because such exposures are expected to result in little chemical exposure and thus little risk to human health, these exposures are not evaluated further in this risk assessment.

The only routes for exposure to alpha and beta radiation are inhalation and ingestion; dermal contact is irrelevant unless it leads to ingestion or to absorption through the skin because of the chemical nature of the radioisotope. Inhalation would result from fugitive dust generation and from the process of transmutation, which is unique to radioactive decay. The ingestion mechanisms for radioisotopes are identical to those for other chemicals.

Risk factors, including carcinogenic SFs and RfDs, are not available for gross alpha and gross beta (see Chapter 5 for a detailed discussion of risk factors). The Nuclear Regulatory Commission (NRC) has developed whole body exposure standards for workers in restricted areas (10 CFR 20.101) and for the general population in unrestricted areas (10 CFR 20.105). These standards are presented in units of REM (effective radiation energy absorbed per unit of mass).

Available sampling data (ANL, 1990) are in units of curies (disintegration per unit time) per volume. In order to compare exposures in units of curies to standards in units of REM, the specific radioactive isotopes present must be known or estimated. This is necessary because isotopes vary widely in their rates of disintegration.

Insufficient information is available to identify or estimate specific radioactive isotopes on-TCAAP. As a result, it would not be possible to convert exposure doses for comparison to NRC standards. Therefore, this risk assessment does not include a quantitative exposure assessment for radioactivity (gross alpha and gross beta). A qualitative evaluation of the risks related to exposure to gross alpha and gross beta radiation is presented in Section 5.4.

On-TCAAP Surface and Subsurface Soils

Residential, commercial, and industrial development may occur in any Class I or Class II exposure area within TCAAP boundaries. However, because soil sampling data are available only for the 14 source areas defined in the on-TCAAP RI (ANL, 1990), this risk assessment evaluates exposure from development only within these 14 areas. Exposure from development elsewhere in each Class I exposure area and within all the Class II exposure areas is not evaluated because no surface or subsurface soil sampling data from these areas exist. However, soil contamination in these areas is not expected to be significant because they were not identified as potential source areas after a comprehensive review of historical records (ANL, 1990).

Employees of future commercial or industrial operations are assumed to have no exposure to surface or subsurface soils for two reasons: (1) most employees are assumed to spend their working time indoors and (2) paved land surfaces at these operations will prevent exposure to soils among employees who do work outdoors. On the other hand, children living in future residences may be exposed to surface soil while playing in their neighborhood or yards, and adults may be exposed during yard work and gardening activities.

The degree of exposure to chemical contaminants in surface soil depends on two primary factors: (1) the presence of vegetation and (2) the placement of clean topsoil over the native soil during development to facilitate growth of grass. Residences are assumed to have standard suburban lawns of the type found off-TCAAP. Grass will certainly limit emission of fugitive dusts over much of each residential property. However, grass will not eliminate contact with underlying soil by children playing in yards. Similarly, grass will not eliminate contact with underlying soil by adults doing yard work such as weed removal. Gardening necessarily involves dermal contact with soils, although some adults may limit exposure by wearing work gloves.

Children and adults living in residential developments may be exposed to chemicals in surface soil via three exposure routes: (1) incidental ingestion when food is ingested with unwashed hands or an unwashed hand is placed directly in the mouth; (2) inhalation of fugitive dusts from areas of exposed surface soil such as gardens; and (3) dermal absorption as a result of dermal contact with surface soils or fugitive dusts. However, as discussed in Section 3.3.4.1.1 for on-TCAAP exposure to surface soil under current conditions, emission of fugitive dusts and subsequent exposure via inhalation are expected to be minimal because of the presence of a layer of topsoil and extensive vegetation. Therefore, exposure to fugitive dusts is not evaluated for future residents.

When an individual residence is constructed, subsurface soil will be brought to the surface during excavation. For RME conditions, it will be assumed that excavated subsurface soil is spread over native surface soil during landscaping activities and in effect becomes surface soils. Exposure to subsurface soil at the surface is evaluated along with exposure to native surface soil as described above.

Finally, workers building future residential, industrial, and commercial developments may be exposed to surface and subsurface soils during construction activities. Again, exposures are evaluated only within the 14 source areas. The potential exposure routes will be the same as those described above. However, exposure to fugitive dusts is evaluated for construction workers, which is not the case for future residents.

On-TCAAP Surface Water and Sediment

Surface water bodies are described in the previous discussion of current land uses (see Section 3.3.4.1.1). These surface water bodies are shown in Figure 1-4. Residents may be exposed to surface water and sediment in the surface water bodies as a result of recreation. The deepest of the surface water bodies are Rice Creek and Sunfish Lake, both 2 to 5 feet deep. Therefore, it is assumed that swimming will occur infrequently and that exposure will take place as a result of wading in or walking through the surface water bodies.

Residents may also fish in Rice Creek. Fish living in the creek may bioconcentrate chemicals found in surface water and sediment. Residents may be exposed to chemical contaminants as a result of ingesting contaminated fish. Rice Creek supports a fish population, but Sunfish Lake does not. Because Sunfish Lake freezes to the bottom during the winter, it cannot support a standing fish population. However, Sunfish Lake has been used in the past to raise hatchlings. The lake is stocked with fingerlings by MDNR in the spring; the hatchlings are captured and removed in the fall and are used to stock area lakes. It is assumed that this practice will continue under future land use conditions.

MDNR staff may be exposed to surface water and sediment, primarily via dermal absorption as they work in the fishery. However, because the fish raised in Sunfish Lake are so small, it is assumed that no fish directly from Sunfish Lake will be caught and ingested by future residents. These fish may be caught and ingested after they have been placed in other lakes. However, this would occur only after the fish have grown much larger and after concentrations of chemicals in their tissues, if any, have been greatly reduced through metabolic processes. In addition, as the fingerlings grow, any contamination accumulated on-TCAAP would be distributed throughout an increasing amount of tissue. Therefore, tissue concentrations may

decrease as the fish grow and tissue mass increases. Because tissue concentrations are be expected to be small, exposure to hatchlings raised in Sunfish Lake and used to stock other lakes is not evaluated in this risk assessment. However, tissue concentrations could be evaluated by sampling fish from lakes stocked with hatchlings from Sunfish Lake. If the concentrations were significant, this pathway could then be evaluated.

On-TCAAP Air

The three on-TCAAP emission point sources are described in Section 3.3.4.1.1. Potential exposure points shown in Figures F-2 and F-3 of Appendix F include each of the Class I and Class II exposure areas. Modeled air concentrations from each of the point sources are summed to give a single set of air concentrations at each of the exposure points. Exposure is assumed to take place indoors as well as outdoors. Residents or employees of commercial or industrial operations will be exposed via inhalation. The estimation of air concentrations at each exposure point is described in Appendix F.

The on-TCAAP RI (ANL, 1990) measured "relative" concentrations of five volatile chemicals: 1,1,1-trichloroethene, toluene, xylene, trichloroethene, and benzene in soil gas at various source areas. The volatile chemicals are expected to make their way into the basements of future on-TCAAP residences or commercial buildings to some extent. Residents or workers in these buildings could then be exposed to these chemicals via inhalation. However, because available data is insufficient to quantify the concentration of each chemical within buildings at each source area, the extent of exposure cannot be quantified.

On-TCAAP Vegetables and Fruits

It is assumed that future residences will have gardens in which vegetables and fruits are grown. Many vegetables and fruits take up chemical contaminants from the soil in which they grow. The degree of uptake depends on the plant and chemical involved, although classes of plants and chemicals may have similar uptake values. For this risk assessment, it is assumed that residents grow a standard collection of root crops, leafy vegetables, and garden fruits. Because soil contaminant concentrations are known only for the 14 source areas identified in the on-TCAAP RI (ANL, 1990), the potential exposure points considered consist of only these 14 source areas. Residents may be exposed to chemical contamination in the vegetables and fruits via ingestion.

3.3.4.2.2 Off-TCAAP Exposure Pathways (Future Land Use)

Potential exposures off-TCAAP are associated with five media: ground water, surface soil, air, surface water, and sediment. The exposure points and exposure routes for these media are identical to those described for current off-TCAAP conditions except for ground water, which is discussed below.

Under current land use conditions, the only private wells being used to supply potable water off-TCAAP are a small number of private drinking water wells located north of TCAAP, opposite Exposure Area A. However, other private wells exist in off-TCAAP areas. These wells and applicable city-specific water supply ordinances are identified in Table 3-4. The U.S. Army has stated that it could not identify any private wells within the plume extending southwest from TCAAP (McCleery, 1990; no documentation available). Nonetheless, under future land use and RME conditions, it is assumed that private wells may be installed off-TCAAP within the estimated extent of the ground-water plume southwest of TCAAP. As stated above, wells installed to serve commercial or industrial operations are assumed to comply with existing ground-water treatment regulations. However, use of private wells is evaluated as a potential exposure pathway under RME conditions.

The exposure points consist of private wells located within each off-TCAAP exposure area and completed in Units 1, 3, and 4, where present (see Figures 1-4 and 1-5). Residents may be exposed to chemical contaminants via three exposure routes: (1) ingestion, (2) inhalation of volatiles during showering, and (3) dermal contact while bathing. As stated above, wells installed to provide potable water for commercial or industrial operations are not evaluated in this risk assessment.

3.4 QUANTIFICATION OF EXPOSURE

This section discusses how the magnitude, frequency, and duration of exposure are quantified for the populations and pathways described in Sections 3.2 and 3.3 and summarized in Tables 3-2 and 3-3. Exposures are quantified for both on- and off-TCAAP, for current and future land uses, and under RME and probable conditions.

Exposure is defined as the contact of an organism with a chemical or physical agent. An exposure may occur over a period of time; if so, the total exposure can be divided by the time period to calculate an average exposure per unit of time. An average exposure can be expressed in terms of body weight. All exposures quantified in this risk assessment are normalized for time

TABLE 3-4

PRIVATE DRINKING WATER SUPPLY WELLS AND CITY-SPECIFIC WATER SUPPLY ORDINANCES

City	Private Drinking Water Supply Wells	Water Supply Ordinances
City of Arden Hills	Arden Manor trailer park, located across from the southwest corner of TCAAP, has a private drinking water well system. The city is not aware of any other private drinking water supply wells.	City Ordinance 28-90 requires that any habitat hook up to city water. Private wells may be used for sprinkling or irrigating lawns or gardens.
City of Shoreview	Private drinking water supply wells do exist in the city -- some immediately north of TCAAP, across from Source Area A.	City policy is not to grant permits for installation and use of private drinking water wells. However, the city has no ordinance prohibiting such installation and use.
City of Mounds View	Approximately 15 residences have private drinking water supply wells.	The city ordinance generally requires use of city water as a primary water supply source and for drinking water use. However, one part of the ordinance requires such use only when the city distribution system extends past a property. The Director of Public Works (Minetor, 1990) indicated that this discrepancy would be eliminated by spring or summer 1990. Private wells may be used to supply water for irrigation and lawn sprinkling. Water from such wells cannot be mixed with city water.
City of New Brighton	The Director of Public Works (Proper, 1990) was confident that most city residents are hooked up to city water. However, a small number of private wells may be used to supply drinking water.	The city has no ordinance requiring persons to hook up to city water or limiting installation and use of private drinking water wells.

TABLE 3-4 (Continued)

PRIVATE DRINKING WATER SUPPLY WELLS
AND CITY-SPECIFIC WATER SUPPLY ORDINANCES

City	Private Drinking Water Supply Wells	Water Supply Ordinances
City of St. Anthony	The Public Works Department (Lorbeski, 1990) is aware of only one drinking water supply well at the Laurie Grove Trailer Court at 2400 Kinsie Avenue along the border of the city.	City Ordinance 325.20 requires that all residences and commercial/industrial operations be hooked up to the St. Anthony water supply.
City of Columbia	The Public Works Superintendent (Jolly, 1991) stated that all residents are hooked up to city water. A few private wells exist, but they are used for sprinkling or irrigating lawns or gardens.	The city has no ordinance requiring persons to hook up to city water or limiting installation and use of private drinking water wells.
City of Minneapolis	The Engineering Assistant of the Minneapolis Water Department (Allison, 1991) stated that there are private wells within the city but that these are used primarily for commercial operations and not for drinking water.	The city recommends using city water but has no ordinances requiring persons to hook up to city water or limiting installation and use of private drinking water wells.

and body weight, are presented in units of mg of chemical/kg of body weight per day, and are termed "intakes." Equation 3-1 presents a generic equation for calculating chemical intakes (U.S. EPA, 1989a):

$$I = \frac{C \times CR \times EF \times YE}{BW \times AT} \quad (3\text{-}1)$$

where

I	=	Intake; the amount of chemical at the exchange boundary (mg/kg of body weight per day)
C	=	Chemical concentration; the average concentration contacted over the exposure period (e.g., mg/L of water)
CR	=	Contact rate; the amount of contaminated medium contacted per unit of time or event (e.g., liters per day)
EF	=	Exposure frequency; how often the exposure occurs (days/year)
YE	=	Years of exposure; how long the exposure occurs (years)
BW	=	Body weight; the average body weight over the exposure period (kg)
AT	=	Averaging time; period over which exposure is averaged (days)

Variations of Equation 3-1 were used to calculate pathway-specific exposures to the chemicals of potential concern. The equations used for each pathway are described below.

3.4.1 Intake Variables

In Equation 3-1, three types of variables are used to calculate intakes: (1) chemical-related: chemical concentration (C); (2) population: contact rate, exposure frequency and years of exposure, and body weight (CR, EF, YE, and BW); and (3) assessment-related: averaging time (AT). These three variable types are discussed below.

3.4.1.1 Chemical Concentration

The concentration term in the intake equation is the arithmetic average of the concentration contacted over the period of exposure (U.S. EPA, 1989a). The arithmetic average is regarded as a reasonable estimate of the concentration that may be contacted over time. However, the primary focus of this risk assessment is to quantify exposures and characterize risks under RME conditions (U.S. EPA, 1989a). Because of inherent uncertainties involved in calculating average concentrations of chemicals in the environment, the upper-bound 95-percent

confidence limit on the arithmetic average is used as the concentration term under RME conditions. However, when the 95-percent confidence limit exceeds the maximum concentration measured for a given exposure point, the maximum concentration is used to represent RME conditions. This approach is consistent with the definition of RME as the maximum exposure reasonably expected to occur at a site. On the other hand, exposures under probable exposure conditions are quantified using the arithmetic average as the concentration term. Media statistics, for each exposure area including the arithmetic mean and the upper 95-percent confidence interval, are presented in Appendix A. Calculations are made only for the chemicals of potential concern discussed in Chapter 2 and presented in Appendix B.

3.4.1.2 Population

Population variables describe the exposed population and describe how much, how frequently, and how long people are exposed to contaminated media. These variables are specific to each exposure pathway on- and off-TCAAP, for current and future land use, and under RME and probable exposure conditions. Pathway-specific population variables for each of the exposure pathways summarized in Tables 3-2 and 3-3 are presented in a series of tables and discussed in Appendix C. The combination of all intake variables reflects RME and probable exposure conditions for each exposure pathway. Therefore, individual pathway-specific population variables must be considered in the context of other intake variables for that pathway.

3.4.1.3 Averaging Time

Exposures may be calculated using several averaging times. For acute toxicants, the averaging time is the shortest period of time that could produce a toxic effect. For the purposes of this risk assessment, the potential for acute toxic effects is assessed using an averaging time of 1 day or a single event. Longer-term exposures to noncarcinogenic chemicals are assessed using an averaging time equal to the period of exposure. As described in Appendix C, population variables were identified for specific age groups. Each age group is considered a distinct period of exposure. In assessing longer-term exposure to noncarcinogenic chemicals, the averaging time equals the length of each pathway-specific age group. Finally, exposure to chemical carcinogens is prorated over an entire lifetime to reflect the scientific opinion that the formation of cancer is a nonthreshold response. This issue is discussed in detail in Chapter 4.

3.4.2 Quantification of Exposure Under Current Land Use Conditions

Pathway-specific exposures to chemicals of potential concern are discussed below for each exposure pathway. As necessary, specific issues of chemical concentration, population variables,

or averaging time are discussed for each exposure pathway. Exposures are discussed for current land use conditions; on-TCAAP exposures are discussed first, followed by off-TCAAP exposures. Parameter values are discussed in Appendix C. Results of exposure calculations are presented in Appendix D. Risk estimates are discussed in Chapter 5.

3.4.2.1 On-TCAAP Quantification of Exposure (Current Land Use)

Potential on-TCAAP exposures under current land use conditions are associated with five media: ground water, surface soil, air, and surface water and sediment. Pathway-specific exposures for each of these media are discussed below.

3.4.2.1.1 On-TCAAP Ground-Water Exposures

All potable water provided on-TCAAP for personal use is treated by TGRS, which reduces contaminant concentrations in ground water below detection limits. Because no chemical exposure exists via this medium, pathway-specific exposures are not evaluated.

3.4.2.1.2 On-TCAAP Surface Soil Exposures

On-TCAAP maintenance workers may be exposed to surface soil while working in the Class I exposure areas. Exposure may occur via incidental ingestion, dermal contact, and inhalation of fugitive dusts.

Exposure to surface soils, however, depends on three factors, (1) vegetation, (2) clean fill, and (3) manmade clay caps, at some or all of the exposure areas. Because most of the exposure areas are covered by at least one of these materials, fugitive dust emissions are assumed to be minimal and therefore are not evaluated. Exposure via incidental ingestion and dermal contact could occur as a result of maintenance activities that require dermal contact with surface soils. Such exposure will not occur where clean fill or clay caps prevent contact with native surface soil, but may occur in areas where only vegetation is present. Although vegetation greatly restricts fugitive dusts, it provides less protection for persons conducting maintenance or repair activities at or beneath the ground surface. The frequencies of exposure used to calculate chronic exposure may overestimate the amount of actual exposure.

No soil sampling data are available in the on-TCAAP RI report (ANL, 1990) for Source Area I (Building 501). Similarly, surface soil samples were not collected in Area K (Building 103) during the RIs. However, past studies have shown surface soil contamination in Source Areas K and I with TCE, PCBs, cyanide, and selected metals (ANL, 1990). Areas I and K are

comprised primarily of their respective buildings as well as associated walkways, parking lots, and loading docks. As a result, both areas have minimal vegetation. Exposure to surface soil in these areas is very unlikely and is not evaluated in this risk assessment. Surface soil sampling data are also lacking for Source Areas D and G. Both areas are partially covered by clay caps, have additional areas of clean fill, and are heavily vegetated [93 and 96 percent, respectively (FCC, 1989b)]. Therefore, exposure to surface soil in these areas is also not evaluated in this risk assessment.

Exposure to surface soil is evaluated for the remaining Class I exposure areas. Exposure doses via incidental ingestion are calculated using Equation 3-2:

$$ED = \frac{CS \times IR \times IF \times EF \times YE}{BW \times AT} \qquad (3\text{-}2)$$

where

ED	=	Exposure dose (mg/kg/day)
CS	=	Chemical concentration in soil (mg/kg)
IR	=	Ingestion rate (kg/day)
DF	=	Fraction ingested from contaminated source (assume 1)
EF	=	Exposure frequency (days/year)
YE	=	Years of exposure (years)
BW	=	Body weight (kg)
AT	=	Averaging time; period over which exposure is averaged (days)

Parameter values used to calculate exposures are presented in Appendix C with the following exceptions. For acute exposures, EF, YE, and AT all equal 1; in other words, the exposure dose is calculated based on a single exposure. Longer-term or chronic exposures for noncarcinogenics are evaluated for each age group under the assumption that YE equals the values presented in Appendix C for age group-specific years of exposure and AT equals YE x 365 days/year; in other words, exposures are prorated over the length of each age group. Finally, exposure to chemical carcinogens is prorated over an entire lifetime. Specifically, an average dose is calculated for each age group (AT is assumed to be 70 years x 365 days/year). The age group-specific doses are then summed to produce the average lifetime dose. This methodology is used for all exposure pathways.

The desorption factor accounts for desorption of a chemical from the soil matrix. For all exposures, a value of 1 was used for DF; this is the default value recommended by U.S. EPA (1989a). More importantly, this value reflects the assumption that the desorption factor in humans is the same as that in test animals used to establish the toxicity factors. In other words, if the exposure dose in humans was adjusted for degree of desorption, the toxicity factors would have to be similarly adjusted to reflect the degree of desorption in the test animals. None of the

currently available toxicity factors is based on exposing test animals via ingestion to chemicals in a soil matrix. Because very few chemical-specific desorption factors are available, and because virtually no information exists on differences in desorption in humans and test animals, this risk assessment assumes a value of 1 for DF in humans and did not attempt to adjust the ingestion-specific toxicity factors.

Exposure doses via dermal contact (acute, chronic, and lifetime average) were calculated using Equation 3-3:

$$ED = \frac{CS \times SA \times AF \times AB \times EF \times YE}{BW \times AT} \qquad (3\text{-}3)$$

The parameters are the same as those defined for Equation 3-2, with the following exceptions:

SA = Skin surface area available for contact (cm^2/day)
AF = Soil-to-skin adherence factor (kg/cm^2)
AB = Absorption factor

Calculation of dermal exposures is subject to considerable uncertainty. For example, under actual conditions, AF may vary depending on what type of soil each person is exposed to. However, exposures are estimated using a single value for AF. In some instances, AB is estimated according to chemical class, but under actual conditions AB may vary for chemicals within each chemical class. Therefore, estimated dermal exposures should be interpreted cautiously.

3.4.2.1.3 On-TCAAP Air Exposures

VOCs are emitted from three point sources: (1) the four BGRS/TGRS air stripping towers; (2) the Source Area D ISV system, and (3) the Source Area G ISV system. The emissions were modeled to various exposure points within TCAAP. The exposure points are shown in Figures F-2 and F-3 in Appendix F; they include major on-TCAAP work stations, on-TCAAP housing, each of the 14 Class I and 4 Class II exposure areas, and points along the TCAAP boundary. The two models used are the ISCLT model (U.S. EPA, 1989c) and Turner (1974). These models present a single set of estimated air concentrations at each exposure point; the set represents the sum of the modeled air concentrations from each point source. The methodology employed, TCAAP-specific input parameters, selection of exposure points, and estimated air concentrations are presented and discussed in Appendix F.

The ISCLT model calculates long-term air concentrations of carcinogenic VOCs found in the ground water. Trichloroethene is the compound found most frequently and at the highest concentrations in the ground water recovered by the BGRS system, although it is not the only compound found. Available air emissions data present only total pounds of VOCs released from the airstrippers and ISV systems (see Appendix F); no emissions data are available for individual compounds. Because the compound mixture in the emissions from the airstrippers may not be the same as that in the ground water captured by BGRS, the compound mixture cannot be accurately estimated using the proportions present in the ground water. For the purposes of evaluating carcinogenic risks, PRC assumed that the estimated air contaminant concentrations from both the airstrippers and the ISV systems are made up entirely of trichloroethene. (The selection and use of trichloroethene alone to evaluate carcinogenic risks associated with inhalation of volatile chemicals are described in detail in Appendix F.)

Similarly, to evaluate acute noncarcinogenic risks, it was assumed that emitted volatiles are composed of 1,1,1-trichloroethane. The reasons for this assumption are discussed in Appendix F.

Exposure doses via inhalation (acute, chronic, and lifetime average) are calculated using Equation 3-4:

$$ED = \frac{CA \times IR \times ET \times EF \times YE}{BW \times AT} \qquad (3\text{-}4)$$

The parameters are the same as those defined for Equation 3-2 with the following exceptions:

CA = Contaminant concentration in air (mg/m^3)
IR = Inhalation rate (m^3/hr)
ET = Exposure time or duration of each event (hr/day)

The calculation of air concentrations is described in Appendix F.

3.4.2.1.4 On-TCAAP Surface Water and Sediment Exposures

On-TCAAP maintenance workers may be exposed infrequently to surface water and sediment as a result of entering on-TCAAP surface water bodies to clean out clogged drain pipes, performing other tasks, or accidentally falling in. On-TCAAP surface water bodies include the on-TCAAP portion of Rice Creek, Sunfish Lake, Marsden Lake, and several miscellaneous

surface water bodies (see Figure 1-2). Exposure to surface water may occur via dermal contact or incidental ingestion; exposure to sediment may occur via dermal contact.

Exposures to contaminants in surface water via incidental ingestion are calculated using Equation 3-5:

$$ED = \frac{CW \times IR \times EF \times YE}{BW \times AT} \quad (3\text{-}5)$$

The parameters are the same as those defined for Equation 3-2 with the following exceptions:

CW = Chemical concentration in water (mg/L)
IR = Ingestion rate (L/day)

Similarly, exposures to contaminants in surface water via dermal contact are calculated using Equation 3-6:

$$ED = \frac{CW \times SA \times PC \times CF \times EF \times YE}{BW \times AT} \quad (3\text{-}6)$$

The parameters are the same as those defined previously with the following exceptions:

PC = Chemical-specific permeability constant (cm/hr)
CF = Volumetric conversion factor for water (1L/1000 cm^3)

Finally, exposures to sediment via dermal contact are calculated using Equation 3-2 with the same parameter exceptions as those made for dermal contact with soil (see Section 3.5.2.1.2). The decision to use the same methodology for sediment as is used for soil reflects a conservative approach. Adherence factors for sediment are likely to be much less than those for soil, because contact with water may wash sediment off skin. Therefore, exposure estimates presented for dermal contact with sediment probably overestimate the actual exposure doses.

3.4.2.2 Off-TCAAP Quantification of Exposure (Current Land Use)

Potential exposures off-TCAAP under current land use conditions are associated with five media: ground water, air, surface water and sediment, and deer and small game meat. Pathway-specific exposure doses are discussed below for each medium.

3.4.2.2.1 Off-TCAAP Ground-Water Exposures

A small number of private wells are located north of TCAAP in Shoreview, opposite Exposure Area A. Private ground-water wells may exist off-TCAAP for which no record exists. For example, the City of New Brighton has no ordinance requiring residents to hook up to city water or prohibiting installation and use of private drinking water wells (Proper, 1990). The New Brighton Director of Public Works stated that a small number of unregistered private wells may be used for potable water (Proper, 1990).

For the purposes of this risk assessment, exposure doses are calculated for a series of five off-TCAAP exposure areas (isopleths) located southwest of TCAAP (see Figures 1-4 and 1-5) as well as for the known private drinking water wells completed in Unit 1 north of TCAAP in Shoreview (Area S). Exposure doses are calculated for areas southwest of TCAAP to account for the few private wells that may be located in these areas.

Exposure to chemicals in ground water may occur via three routes: (1) ingestion, (2) inhalation of volatiles during showering, and (3) dermal contact during bathing.

Exposures to ground water via ingestion are calculated using Equation 3-7:

$$ED = \frac{CW \times IR \times EF \times YE}{BW \times AT} \qquad (3\text{-}7)$$

The parameters are the same as those defined previously.

For inhalation of volatiles, exposures are calculated using the model developed by Foster and Chrostowski (1987) as described in Appendix E. For dermal contact, exposures are calculated using Equation 3-6 (see Section 3.4.2.1.4).

3.4.2.2.2 Off-TCAAP Air Exposures

Emissions of VOCs off-TCAAP were modeled from a series of on-TCAAP point sources using the ISCLT model and Turner (1974). Concentrations were modeled to points along the TCAAP boundary to give an indication of the air concentrations leaving TCAAP. Concentrations were also modeled to several points up to 1 mile southwest of TCAAP within residential areas. The exposure points are shown in Figures F-2 and F-3 in Appendix F. The methodology

employed, TCAAP-specific input parameters, and estimated air concentrations along the TCAAP boundary and off-TCAAP are presented and discussed in Appendix F.

As stated earlier, this risk assessment assumes that the estimated air concentrations are made up entirely of trichloroethene for carcinogenic risks and of 1,1,1-trichloroethane for noncarcinogenic risks. This is a conservative approach that may overestimate the actual risks associated with inhalation of VOCs. This issue is discussed further in Chapter 5.

Exposures via inhalation of volatile emissions are calculated using Equation 3-4 (see Section 3.4.2.1.3).

3.4.2.2.3 Off-TCAAP Surface Water and Sediment Exposures

As discussed earlier, off-TCAAP exposure to surface water and sediment is evaluated only for Round Lake and for the portion of Rice Creek from immediately outside the western boundary of TCAAP to approximately the point where Rice Creek enters Long Lake. Persons may be exposed to surface water via dermal contact and incidental ingestion (RME conditions only) and to sediment via dermal contact. The portion of Rice Creek immediately outside TCAAP's western boundary is fished extensively during the spring; persons may be exposed to compounds that have bioconcentrated in fish caught in this area.

Exposures associated with incidental ingestion and dermal contact with surface water and dermal contact with sediment are calculated using Equations 3-5, 3-6, and 3-2, respectively, as described in Sections 3.4.2.1.4 (Equations 3-5 and 3-6) and 3.4.2.1.2 (Equation 3-2). Exposures to contaminants present in fish tissue are calculated using Equation 3-8:

$$ED = \frac{CF \times IR \times FI \times EF \times YE}{BW \times AT} \qquad (3\text{-}8)$$

The parameters are the same as those defined previously with the following exceptions:

CF = Contaminant concentration in fish (mg/kg)
FI = Fraction ingested from contaminated source
IR = Ingestion rate (kg/day)

Contaminant concentrations in fish are calculated by multiplying surface water concentrations by chemical-specific bioconcentration factors.

3.4.2.2.4 Off-TCAAP Ingestion of Deer and Small Game Meat

Meat from deer harvested each year at TCAAP is distributed to charity groups and private citizens. This deer meat was analyzed by the Minnesota Department of Health (MDH) in October 1989 (Schulte, 1990). The analysis indicated that the meat had no detectable concentrations of PCBs, although these results were questioned by the state reviewer. The analysis also indicated that metal concentrations (arsenic, cadmium, chromium, lead, methylmercury, selenium, silver, and zinc) were well below levels of concern, based on the assumption of a 70-kg adult ingesting 30 grams of meat per day and back-calculating from chemical-specific reference doses (see Chapter 4) developed for food. In particular, lead concentrations in meat samples from TCAAP deer were found to be less than or equal to 0.1 mg/kg. MDH stated that the deer meat was safe for consumption at the rate of at least one meal per week. However, MDH noted high lead levels in two deer fat samples and recommended that the fat not be used in cooking (Schulte, 1990). Based on this analysis, no further calculation of exposure doses is performed in this risk assessment.

Because MDH determined that deer meat is safe for consumption, it is assumed that consumption of small-game such as rabbits and pheasants that feed on-TCAAP is also safe. Therefore, no calculation of exposure doses is performed in this risk assessment.

3.4.3 Quantification of Exposure Under Future Land Use Conditions

Pathway-specific exposures to chemicals of potential concern are discussed below for each exposure pathway. As necessary, specific issues of chemical concentration, population variables, or averaging time are discussed for each exposure pathway. Exposures are discussed for future land use conditions; on-TCAAP exposures are discussed first, followed by off-TCAAP exposures. Parameter values are discussed in Appendix C. Results of exposure calculations are presented in Appendix D. Risk estimates are discussed on Chapter 5.

Under future land use conditions, exposures may occur both on- and off-TCAAP. Future land use is evaluated both under probable case and RME conditions. Probable future land use conditions are assumed to be the same as current conditions (see Section 3.4.2). Under RME future land use conditions, TCAAP is vacated by the U.S. Army and is developed as residential, commercial, and industrial property. Exposures associated with RME future land use are discussed below.

Steady-state conditions are assumed in evaluating future conditions; that is, future concentrations are assumed to be the same as those measured or calculated under existing

conditions. However, because of various fate and transport mechanisms and existing remedial measures such as the BGRS/TGRS and ISV systems, actual future compound concentrations in most media will be lower than those measured in the on-TCAAP RI (ANL, 1990) and off-TCAAP RI (CDM, 1991) or those calculated from current emissions data. For example, VOC emissions from TCAAP remedial activities in 1987 totaled 39,602 pounds (Weston, 1988). In 1989, the total was reduced to 19,510 pounds (Fullen, 1989). In the future, VOC emissions may be further reduced as contaminant levels in the ground water continue to drop as a result of remedial activities. Therefore, the exposure doses estimated for future land use conditions probably overestimate the actual exposure doses.

3.4.3.1 On-TCAAP Quantification of Exposure (Future Land Use)

Potential on-TCAAP exposures under future land use conditions are associated with the following media: ground water, surface and subsurface soils, surface water and sediment, air, soil gas, and home-grown vegetables and fruits. Pathway-specific exposures for each medium are discussed below. Future residential, commercial, and industrial development on-TCAAP is assumed not to interfere with existing remediation efforts, which are assumed to be maintained in the future.

3.4.3.1.1 On-TCAAP Ground-Water Exposures

Under future land use conditions, it is assumed that, as part of residential, commercial, and industrial development within current TCAAP boundaries, at least some residences or businesses, will obtain their potable water from private wells completed within Unit 1, 3, or 4. Installation and use of private drinking water wells are prohibited by the City of Arden Hills (TCAAP is located within Arden Hills) and are unlikely, especially considering public awareness of existing ground-water contamination. However, exposure to ground water may occur to a limited extent under RME future land use conditions.

Exposures to chemicals in ground water may occur via three routes: (1) ingestion, (2) inhalation of volatiles driven out of solution during showering, and (3) dermal contact during bathing. Exposures to ground water via ingestion and dermal absorption are calculated as described in Section 3.4.2.2.1. Exposures via inhalation are calculated using the methodology described in Appendix E. Parameter values used in exposure calculations are presented and discussed in Appendix C.

3.4.3.1.2 On-TCAAP Surface and Subsurface Soil Exposures

Residences and commercial and industrial operations may be developed within current TCAAP boundaries. However, because soil sampling data are available only for the 14 source areas defined in the on-TCAAP RI, exposures are evaluated only within these 14 areas, with the following exceptions. Exposures are not evaluated for Source Areas D and G, which are not expected to be developed because of the ISV systems. Children and adults playing or walking in these areas are not expected to be exposed because of the clay caps, clean fill, and heavy vegetation covering much of the two areas.

Exposures are also not evaluated for Source Areas I and K. Soil samples were not obtained from these areas during the on-TCAAP RI. Available soil sampling data from 1984 (CRA, 1984a and 1984b) show that these areas had inorganic concentrations similar to background and minimal VOC contamination. If Buildings 502 (Source Area I) and 103 (Source Area K) were demolished to make way for new development, any VOCs in surface soil would be expected to volatilize during construction activities and therefore would not pose a threat under a residential scenario. The potential exposures faced by construction workers are difficult to estimate because the most recent sampling data are approximately 5 to 7 years old. Any volatilization during construction would be into the ambient air; the resulting air concentrations in the breathing zones of the workers would be expected to be very small. Furthermore, under the assumption that these areas might have low levels of VOC contamination in the soil, health and safety precautions could be taken to virtually eliminate any exposure.

For the remaining portion of each Class I exposure area [that portion not identified as a source area in the on-TCAAP RI report (ANL, 1990)] and for all Class II exposure areas, the degree of soil contamination and therefore the extent of exposure are not expected to be significant; these areas were not identified as potential source areas during a comprehensive review of historical records (ANL, 1990).

Children and adults living in residences developed on-TCAAP may be exposed to surface soil as a result of play activities, yard work, or gardening. Exposure to surface soil may occur via three exposure routes: (1) incidental ingestion, (2) inhalation of fugitive dusts, and (3) dermal contact. Exposure to surface soil will depend on two factors: (1) vegetation and (2) clean topsoil placed over native soil to facilitate growth of lawns.

The standard practice for residential lawns in the Minneapolis/St. Paul metropolitan area is to place a layer of topsoil (at least 6 inches deep) over native topsoil to facilitate lawn development. A grass lawn is assumed to virtually eliminate fugitive dusts (except when the lawn

is first seeded and possibly during gardening activities). Exposure to fugitive dusts is therefore evaluated only for construction workers. However, vegetation will not eliminate surface soil contact for children playing in yards or for adults doing yard work or gardening. Because residences are assumed to have a layer of clean topsoil placed over native surface soil, exposure is assumed to be primarily to the clean topsoil. However, during such activities as gardening or planting trees and shrubs, native surface soil may be brought to the surface and contacted directly. The assumed layer of clean topsoil may also be reduced or absent at some residences. For the purposes of evaluating exposure under RME conditions, it is assumed that all exposure is to native surface soils. This assumption may greatly overestimate actual exposure doses. This issue is discussed further in Chapter 5.

Exposures to surface and subsurface soils via ingestion and dermal contact are calculated as described in Section 3.4.2.1.2. Exposures for construction workers via inhalation of fugitive dusts are calculated using Equation 3-4 (see Section 3.4.2.1.3). The calculation of air concentrations is described in Appendix G.

3.4.3.1.3 On-TCAAP Surface Water and Sediment Exposures

TCAAP contains several large surface water bodies, including Rice Creek, Sunfish Lake, and Marsden Lake, as well as several small, miscellaneous surface water bodies. Future residents may be exposed to surface water and sediment in these surface water bodies through recreational activities. Exposure to surface water may occur via incidental ingestion (RME only) or dermal contact. Exposure to sediment may occur via dermal contact. Future development may eliminate some of the surface water bodies (probably the small, miscellaneous surface water bodies). However, because it is not possible to determine which surface water bodies might be eliminated, exposures are estimated for all of them. As stated earlier, it is assumed that only fish from Rice Creek and Round Lake will be caught and ingested.

Exposure doses associated with incidental ingestion of and dermal contact with surface water and dermal contact with sediment are calculated as described in Section 3.4.2.1.4. Exposure doses associated with ingestion of fish are also calculated as described in Section 3.4.2.2.3. Contaminant concentrations in fish are calculated by multiplying surface water concentrations by chemical-specific bioconcentration factors (BCF). Table 3-1 presents chemical-specific BCFs for organic chemicals of potential concern; BCFs for inorganic chemicals of potential concern were obtained from a single source (Callahan and others, 1979). The BCF used for silver (the only chemical of potential concern for which a hazard quotient is reported in Appendix D) is 3,080 L/kg.

3.4.3.1.4 On-TCAAP Air Exposures

As discussed earlier, VOC emissions were modeled from a series of on-TCAAP point sources using the ISCLT model and Turner (1974) (see Appendix F). Air concentrations were modeled to points throughout TCAAP under the assumption that residential, commercial, and industrial development could take place anywhere within current TCAAP boundaries. The exposure points are shown in Figures F-2 and F-3 in Appendix F. As stated earlier, estimated air concentrations are made up entirely of trichloroethene for evaluating carcinogenic risks and entirely of 1,1,1-trichloroethane for evaluating noncarcinogenic risks. This is a conservative approach that may overestimate the actual risks associated with inhalation of VOCs.

Exposures via inhalation of volatile emissions are calculated as described in Section 3.4.2.1.3.

3.4.3.1.5 On-TCAAP Soil Gas Exposures

The on-TCAAP RI team collected soil gas samples from 3 feet below the land surface and analyzed them for certain halogenated and aromatic hydrocarbons. However, the values reported are in a "relative" unit. Information available to PRC is not sufficient to estimate environmental soil gas levels. Therefore, PRC is unable to quantify exposure to contaminants in soil gas.

3.4.3.1.6 On-TCAAP Homegrown Vegetable and Fruit Exposures

Future residents are assumed to plant gardens that produce a mixture of vegetables and fruits, including root crops, leafy vegetables, and garden fruits, for home consumption. These vegetables and fruits may take up and accumulate compounds present in the soil. The degree to which specific compounds are taken up and concentrated depends on the particular plant and compound. Factors used to calculate specific concentrations were obtained from two sources: (1) Baes and others, 1984 (inorganic compounds) and (2) U.S. EPA Region 10, 1990 (PAHs). The factor for PAHs assumes that PAHs are taken up and concentrated to a similar extent as PCBs.

The methodology used to calculate produce-specific concentrations is presented in Appendix K. In brief, produce-specific concentrations are calculated by multiplying soil concentrations by produce-specific uptake factors. An overall vegetation concentration is then calculated by summing weighted produce-specific concentrations.

Exposure doses are calculated using Equation 3-9:

$$ED = \frac{CF \times IR \times FI \times EF \times YE}{BW \times AT} \quad (3\text{-}9)$$

The parameters are the same as those defined previously with the following exceptions:

CF = Contaminant concentration in food (mg/kg)
IR = Ingestion rate (kg/day)

3.4.3.2 Off-TCAAP Quantification of Exposure (Future Land Use)

Potential off-TCAAP exposures are associated with five media: ground water, surface soil, air, surface water, and sediment. Exposure doses for these media are assumed to be the same as those discussed for current land use. Results of exposure dose calculations are presented in Appendix D.

3.5 UNCERTAINTIES IN EXPOSURE ASSESSMENT

Exposure estimates calculated in this risk assessment are subject to varying degrees of uncertainty. Uncertainty is inherent in selection of exposure pathways and in parameters used to estimate exposure doses. The degree of uncertainty generally depends on the amount of site-specific data available. This section identifies the most significant of uncertainties for the exposure assessment (with several specific examples) and evaluates the potential impact of each uncertainty. However, the magnitude or degree of impact (e.g., exposure overestimated by an order of magnitude) will not be quantified for any of the uncertainties.

The following sources of uncertainty are discussed:

- Exposure pathway identification (assumption of RME future land use)
- Exposure parameters and assumptions
- Assumption of steady-state conditions
- Environmental chemical characterization
- Modeling procedures

3.5.1 Exposure Pathway Identification

Exposure pathways for this risk assessment were identified based on observed and assumed activity patterns of the local population. To the degree that actual activity patterns are not represented by those observed and assumed, uncertainty is introduced into the risk assessment.

In particular, exposure pathways associated with current and probable future land use have less uncertainty than exposure pathways associated with RME future land use. In general, current activity patterns can be estimated with a good degree of accuracy. To a lesser degree, activity patterns of homeowners and employees associated with future residential, commercial, and industrial development can also be estimated based on existing off-TCAAP conditions. However, the biggest specific area of uncertainty lies in the assumption of RME future land use itself. In fact, RME future land use (especially residential development on-TCAAP) is relatively unlikely considering community awareness of TCAAP's status as a Superfund site and the U.S. Army's internal requirement that an environmental baseline study be performed before any real property transactions occur. The results of such a study could lead to a restriction of development or remediation prior to development. Therefore, all exposure estimates developed under RME future land use must be considered in light of the uncertainty associated with RME future land use.

3.5.2 Exposure Parameters and Assumptions

Standard assumptions for population characteristics, such as body weight, surface area, life expectancy, and period of exposure, and assumptions for exposure characteristics, such as frequency, duration, amount of intake or contact, and degree of absorption or soil adherence, may not be representative of actual exposure conditions.

The impact of population characteristic differences will probably be small when considering the entire potentially exposed population because population characteristics used in the risk assessment are based on national averages or large sample populations. However, these characteristics may not accurately represent individuals who are exposed. Therefore, actual exposure may be overestimated or underestimated.

Exposure characteristics depend largely on activity patterns that are not easy to generalize. For example, the proposed frequency of exposure to surface water assumes that the surface water bodies evaluated in this risk assessment are not used for regular swimming; however, swimming could conceivably occur in Sunfish Lake, Rice Creek, and Round Lake. Swimming may take

place more regularly than assumed if these surface water bodies are identified as recreational areas near a future on-TCAAP residential development. A second specific example involves the assumed exposure to Unit 1 ground water both on- and off-TCAAP. As described in Section 3.1.6, the ground water in Unit 1 is perched and discontinuous and is unlikely to provide a long-term source of potable water. Therefore, the assumption of daily long-term use of Unit 1 ground water almost certainly overestimates the actual exposure to Unit 1 ground water.

Uncertainties are inherent in remaining exposure characteristics to various degrees. Therefore, exposure doses based on the selected exposure parameters may overestimate or underestimate actual exposure doses.

3.5.3 Assumption of Steady-State Conditions

The estimated exposure doses are based on an assumption of steady-state conditions. Chemical concentrations used to estimate exposure doses are based primarily on data presented in the on-TCAAP RI report (ANL, 1990) and off-TCAAP RI report (CDM, 1991). The inherent assumption is that current and future chemical concentrations are the same as those measured in the RIs. This assumption ignores the effects of various fate and transport mechanisms that will alter the composition and distribution of chemicals present in the various media. Also ignored is the impact of existing remedial measures (such as the BGRS/TGRS and ISV systems) that reduce chemical concentrations in the ground water. A baseline risk assessment normally evaluates the no-action alternative involving no remedial action. However, significant remedial actions have already been taken at TCAAP. Therefore, for the purposes of this risk assessment, no-action is defined as including existing remedial actions as of January 1991.

In general, the assumption of steady-state conditions probably results in overestimation of chemical concentrations and exposure doses.

3.5.4 Environmental Chemical Characterization

It is impossible to completely characterize the nature and extent of chemicals in the environment on- and off-TCAAP. Instead, the various environmental media were sampled to estimate environmental chemical concentrations and to estimate which chemicals originate from chemical releases at TCAAP. Because no sampling effort can completely and accurately characterize environmental conditions, exposure dose calculations are somewhat uncertain.

Uncertainties are introduced into exposure dose calculations in the course of collection, analysis, and evaluation of environmental chemical data. Six potentially significant areas of

uncertainty are discussed below: (1) seasonal variations in environmental concentrations, (2) nonrandom sample collection, (3) sample size, (4) types of sample analysis, (5) treatment of nondetect (ND) results, (6) high detection limits, and (7) comparison to background levels.

3.5.4.1 Seasonal Variations

This risk assessment is based primarily on data collected as part of the on-TCAAP RI (ANL, 1990) and off-TCAAP RI (CDM, 1991). Although these data represent the most thorough and complete sampling efforts, samples from a single season cannot reflect seasonal variations. This is not a concern for soil concentrations, which are unlikely to vary seasonally, but could affect results for surface water and ground water. Use of single-season sampling data may overestimate or underestimate actual environmental concentrations and corresponding exposure doses.

3.5.4.2 Nonrandom Sample Collection

Sampling both on- and off-TCAAP was not conducted in a random fashion. Generally, on-TCAAP or downgradient sampling points were selected to identify the magnitude of environmental chemical contamination, not to identify representative concentrations. For example, on-TCAAP soil sampling trench locations were chosen based on geophysical survey results as well as historical information as the areas most likely to have soil contamination. Therefore, exposure doses based on these soil samples as well as other nonrandom samples may overestimate actual exposure doses.

3.5.4.3 Sample Size

The total number of samples collected during the on-TCAAP RI (ANL, 1990) and the off-TCAAP RI (CDM, 1991) is quite large. However, the number of samples collected at particular exposure areas may be quite small. For example, surface water at several exposure areas, including Exposure Areas A, D, I, and K, is represented with only one or two samples; on-TCAAP Unit 4 ground water in Exposure Areas X2 and X4 were sampled only once each; off-TCAAP Unit 4 ground water was sampled for inorganics only once in Exposure Areas 4W, 4X, 4Y, and 4Z; and five or fewer surface soil or subsurface soil samples were collected at several exposure areas including B, C, G, I, and 129-5 in the on-TCAAP RI (ANL, 1990).

The nature and extent of chemical contamination cannot be accurately represented with an insufficient number of samples. Furthermore, comparisons with background data may be

misleading because of the large standard deviations resulting from small sample numbers (see also Section 3.5.4.6). In summary, the small number of samples of specific media at certain exposure areas introduces uncertainty both in terms of environmental characterization and statistical comparison. Additional samples may be especially important for on- and off-TCAAP Unit 4 ground water and on-TCAAP surface soil and subsurface soil.

3.5.4.4 Types of Sample Analysis

Samples collected as part of the on-TCAAP RI (ANL, 1990) were analyzed for organics using two methodologies: (1) GC/MS and (2) non-GC/MS. The data quality of the results of the two methodologies was reviewed and discussed with the U.S. Army laboratory. Results from the non-GC/MS methodology were determined to provide lower detection limits for wider range of chemicals than GC/MS methodologies. When a chemical at a particular sampling point had been analyzed for using both GC/MS and non-GC/MS methodologies, only non-GC/MS results were used. If the only available results were GC/MS results, these results were used. Because the two methodologies do not produce the same results, use of primarily non-GC/MS results may overestimate or underestimate actual environmental concentrations.

3.5.4.5 Treatment of Nondetect Results

In producing environmental statistics, ND results were replaced with a value equal to one-half the sample quantification limit. This procedure introduces uncertainty because the actual sample result could be less than or greater than the substituted value. However, the procedure is more protective of health than replacing ND results with zero.

The degree of uncertainty introduced is roughly proportional to the frequency of ND results within a particular sample set. Statistics calculated from a sample set that contains a single ND result are less uncertain than statistics calculated from a sample set in which most results are ND results.

3.5.4.6 High Detection Limits

As discussed in Section 3.5.4.5, in producing environmental statistics, ND results were replaced with a value equal to one-half the sample quantification limit. However, this approach was utilized only in those instances in which at least one sample result from a sample set for a particular medium and a particular exposure area was reported as a measured or estimated value. Environmental statistics were not produced for sample sets in which all results were reported as below sample detection limits.

Sample detection limits for soil and sediment are often relatively high becasuse of matrix factors. There may be instances in which a chemical is present in soils or sediment at concentrations associated with a significant risk to human health, but below sample detection limits. As a result, environmental statistics, exposures, and ultimately quantitative risks are not calculated for a particular media and exposure area, and the total estimated risk for that media and exposure area is underestimated.

3.5.4.7 Comparison to Background Levels

The statistical comparison of potentially affected or downgradient samples to background samples was a significant step in identifying chemicals of potential concern. Selecting appropriate background samples is critical to the accuracy and usefulness of such a comparison. For some media such as ground water, appropriate site-specific background samples were more easily identified (such as the Unit 3 and 4 wells along the far eastern boundary of TCAAP) than for others. Background soil samples, for example, were identified from "Urban Minnesota frontyard" samples collected from around the State of Minnesota or from point estimates collected from the Twin Cities metropolitan area. Surface water samples, including those from lakes and swamp areas, were compared to upgradient Rice Creek samples because more appropriate background samples were not available.

Results of the statistical comparison were not accepted at face value. The nature of the background samples was also considered in selecting chemicals of potential concern. However, a degree of uncertainty is introduced when the most appropriate background samples cannot be identified and a less appropriate set of samples must be used. This uncertainty may result in misrepresentation of chemicals of potential concern. Specifically, too few or too many chemicals of potential concern may be identified.

3.5.5 Modeling Procedures

As described above and in Appendix F, for evaluation of carcinogenic risks, the ISCLT model was used to estimate on- and off-TCAAP air concentrations of VOCs emitted from several on-TCAAP remedial activities. Numerous assumptions are included in the model. For example, the model assumes that no transformation processes such as photodegradation affect the emitted VOCs. In the environment, such processes almost certainly impact VOCs as they travel downwind. Assumption of no such impact may lead to overestimation of the concentration of VOCs at receptor points.

Uncertainty was further introduced when it was assumed for an evaluation of carcinogenic risks that all VOC emissions represented trichloroethene. This was a conservative assumption that may result in overestimation of risks from inhalation of VOCs. On the other hand, trichloroethene present in ground water may transform to vinyl chloride, a more toxic compound. PRC's estimates of air concentrations are based on current levels of contamination. This may lead to underestimation of the risk if a significant amount of trichloroethene is transformed to vinyl chloride sometime in the future.

Similar uncertainties are associated with the use of the Turner model (1974) to calculate air concentrations for chronic and acute exposures and the associated noncarcinogenic risks and the assumption that air concentrations consist entirely of 1,1,1-trichloroethane.

Finally, additional uncertainty is introduced with the use of meteorological data from 1982 to 1986 to represent existing conditions. Although it is unlikely that wind patterns will have changed dramatically in the last five years, some discrepancies can be expected.

3.5.6 Summary of Uncertainties

Table 3-5 summarizes the major sources of uncertainty in the exposure assessment. The impact of many of the uncertainties can be gauged by comparing results for current and probable future land use with results for RME future land use and by comparing results for probable case exposure conditions with results for RME conditions. In general, current and probable future land use conditions are more certain than RME future land use conditions, and probable case exposure conditions are more certain than RME conditions. Various uncertainties are inherent even in exposure estimates under the more certain conditions, although the degree of uncertainty is likely to be smaller.

3.6 EXPOSURE ASSESSMENT SUMMARY

This chapter describes the exposure setting and potentially exposed populations, identifies exposure pathways, and quantifies exposures under current and future land use, probable, and RME conditions. Tables 3-2 and 3-3 summarize potential human health exposure pathways evaluated under this risk assessment. Parameter values used in quantification of exposure are presented and discussed in Appendix C. Exposure dose estimates are presented in Appendix D.

TABLE 3-5

AREAS OF UNCERTAINTY AND EFFECTS ON EXPOSURE ESTIMATES

Area of Uncertainty	May Overestimate Exposure	May Underestimate Exposure	May Overestimate or Underestimate Exposure
Exposure Pathway Identification			
Assumption of RME future land use (residential, commercial, and industrial development within TCAAP boundaries)	X		
Assumption that certain pathways such as inhalation of fugitive dusts are insignificant and fact that these pathways were not evaluated (except for construction workers)		X	
Inability to calculate exposure doses for certain pathways such as inhalation of VOCs released into ambient air from the ground surface or released into basements of current and future buildings		X	
Exposure Parameters and Assumptions			
Assumptions regarding population characteristics, such as body weight, surface area, and life expectancy, and exposure characteristics, such as frequency, duration, and amount of intake, may not be representative of actual exposure conditions.			X
Assumption of Steady-State Conditions			
Chemical concentrations measured in or estimated from the on-TCAAP RI or off-TCAAP RI are assumed to remain constant and to represent current and future environmental conditions.	X		
Environmental Chemical Characterization			
Potential seasonal variations ignored			X
Nonrandom sample collection	X		
Sample Size			X
Types of sample analysis (non-GC/MS versus GC/MS)			X
Replacement of ND results with a value equal to one-half the sample detection limit			X
High detection limits		X	
Comparison to background levels			X
Modeling Procedures			
Potential transformation processes are not evaluated.			X
Assumption that all VOCs emitted are trichloroethene (carcinogenic risks) or 1,1,1-trichloroethane (noncarcinogenic risks)			X

TABLE 3-6

AREAS OF UNCERTAINTY AND EFFECTS ON RISK ESTIMATES

Area of Uncertainty	May Overestimate Exposure	May Underestimate Exposure	May Over-or Underestimate Exposure
Risk Factors			
– Extrapolation Most risk factors are extrapolated from animal test results. Extrapolations may be made for species, exposure dose, and exposure period; extrapolations are generally conservative.	X		
– Adjustment of Oral Risk Factors In order to characterize risks from dermal exposures, generally expressed as absorbed doses, oral risk factors are adjusted to account for oral absorption efficiency.	X		
– Slope Factors (SF) SFs represent upper 95-percent confidence limit values; carcinogenic risks calculated using SFs generally represent upper-bound estimates.	X		
– Lack of Risk Factors Risks from exposure to chemicals with no available chemical-specific or substitute risk factors cannot be quantitatively characterized.		X	
Risk Summations			
Risks from chemical mixtures are characterized by summing the individual chemical risks. This procedure assumes that chemicals have the same toxic end points and mechanisms of action and do not interact, either synergistically or antagonistically. These assumptions may be incorrect.			X
Exposure Periods			
Acute exposures are characterized by comparison to subchronic risk factors. Evaluating exposures using risk factors based on a longer exposure period is conservative.	X		

CHAPTER 4

TOXICITY ASSESSMENT

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CHAPTER 4
TOXICITY ASSESSMENT

This chapter provides information for assessing biological effects of contaminants at the New Brighton/Arden Hills site. The purpose of this chapter is to provide the reader with quantitative and qualitative information required to assess the risks from the various contaminants at the site. Section 4.1 gives quantitative data in the form of exposure standards, criteria, and guidelines. Section 4.2 presents discussion on the qualitative toxicity assessment. Section 4.3 provides toxicological profiles for the various chemicals. Section 4.4 presents discussion on the uncertainties associated with toxicity assessment.

4.1 EXPOSURE STANDARDS, CRITERIA, AND GUIDELINES

Federal and state regulatory agencies have established acceptable or quantifiable levels of risk for exposure to contaminants in various media. Standards, criteria and guidelines, for various chemicals are listed in Table 4-1. Some of these standards, criteria, and guidelines are not strictly risk based. Noncarcinogenic and carcinogenic toxicity factors such as RfDs and SFs are listed in Tables 4-2 through 4-5. Applicable standards, criteria and guidelines are discussed below.

Under the Safe Drinking Water Act, U.S. EPA established three types of standards for public water systems: maximum contaminant level goals (MCLG), MCLs, and secondary MCLs. MCLGs are nonenforceable health goals set at levels that result in no known adverse health effects, and that include an adequate margin of safety. MCLs are enforceable drinking water standards set as close to MCLGs as is feasible after accounting for analytical, technical, and economic considerations. MCLs and MCLGs are listed in 40 CFR Part 141. Secondary MCLs, nonenforceable goals based on aesthetic qualities such as taste and color, are listed in 40 CFR Part 143.

U.S. EPA has also established ambient water quality criteria (AWQC) as directed by Section 304 of the Clean Water Act. These criteria are intended to serve as guidelines for protecting human health and aquatic life from the effects of pollution. To protect human health, AWQCs identify maximum concentrations for safe exposure by direct ingestion, such as drinking water, and by indirect ingestion, such as consuming aquatic organisms present in ambient water. Many of the aquatic life criteria for organic chemicals are in fact observed minimal toxic concentrations because insufficient data are available to establish a reliable AWQC.

TABLE 4-1

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Parameter	Antimony	Arsenic	Cadmium	Chromium[g]	Cobalt	Copper
Maximum Contaminant Level (MCL) (µg/L)[a]	(10/5)[h]	50[b]	(5)[h]	(100)[h]	—	(1,300)[h]
MCL Goal (µg/L)[a]	(3)[h]	(0)[h]	(5)[h]	(100)[h]	—	(1,300)[h]
Secondary MCL (µg/L)[a]	—	—	—	—	—	1,000
Acute Health Advisory (1-day)(µg/L)[a]	15	—	40	1,000	—	—
Lifetime Health Advisory (µg/L)[a]	3	—	5	100	—	—
Water Quality Criterion, Consumption of Aquatic Organisms and Water (µg/L)[b]	146	0.0022	1.0	170,000	—	1,000
Water Quality Criterion, Consumption of Aquatic Organisms Only (µg/L)[b]	45,000	0.0175	—	3,433,000	—	—
Aquatic Water Quality Criterion, Chronic (µg/L)[b]	1,600	190	1.1[i]	120	—	5.0[i]
Threshold Limit Value (mg/m^3)[c]	0.5	0.2	0.05	0.05	0.05	0.2-1
Permissible Exposure Limit (mg/m^3)[d]	0.5	0.01	0.1-0.2	0.5	0.1	0.1-1
Minnesota Recommended Allowable Limit (RAL) (µg/L)[e]	1.0	0.2	4.0	100.0	1.0	1,000
Minnesota Water Quality Standard (WQS) (µg/L)[f]	—	10	10	50[j]	—	1,000

TABLE 4-1 (Continued)

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Parameter	Lead	Manganese	Mercury	Nickel	Silver	Thallium	Vanadium
Maximum Contaminant Level (MCL) (µg/L)[a]	(5)[h]	—	(2)[h]	(100)[h]	—	(2/1)[h]	—
MCL Goal (µg/L)[a]	(0)[h]	—	(2)[h]	(100)[h]	—	(0.5)[h]	—
Secondary MCL (µg/L)[a]	—	50	—	—	(90)[h]	—	—
Acute Health Advisory (1-day)(µg/L)[a]	—	—	—	1,000	200	7	80
Lifetime Health Advisory (µg/L)[a]	—	—	2	100	100	0.4	20
Water Quality Criterion, Consumption of Aquatic Organisms and Water (µg/L)[b]	50	50	0.144	632	50	13	—
Water Quality Criterion, Consumption of Aquatic Organisms Only (µg/L)[b]	—	—	—	—	—	—	—
Aquatic Water Quality Criterion, Chronic (µg/L)[b]	3.2[i]	—	—	—	0.12[i]	—	—
Threshold Limit Value (mg/m^3)[c]	0.15	5	0.05-0.10	0.1-1.0	0.01-0.10	0.1[k]	0.05
Permissible Exposure Limit (mg/m^3)[d]	—	1	0.05	0.1-1.0	0.01	0.1[k]	0.05
Minnesota Recommended Allowable Limit (RAL) (µg/L)[e]	20	300	1.0	70	10	0.3	20
Minnesota Water Quality Standard (WQS) (µg/L)[f]	50	50	—	—	50	—	—

TABLE 4-1 (Continued)

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Parameter	Zinc	Cyanide	Acetone	Benzene	Benzoic Acid	Bromodichloro-methane	2-Butanone
Maximum Contaminant Level (MCL) (µg/L)[a]	—	(200)[h]	—	5	—	—	—
MCL Goal (µg/L)[a]	—	(200)[h]	—	0	—	—	—
Secondary MCL (µg/L)[a]	5,000	—	—	—	—	—	—
Acute Health Advisory (1-day)(µg/L)[a]	4,000	200	—	200	—	7,000	80,000
Lifetime Health Advisory (µg/L)[a]	4,000	200	—	—	—	—	200
Water Quality Criterion, Consumption of Aquatic Organisms and Water (µg/L)[b]	5,000	200	—	0.66[l]	—	0.19	—
Water Quality Criterion, Consumption of Aquatic Organisms Only (µg/L)[b]	— 110[i]	—	—	40[l]	—	15.7	—
Aquatic Water Quality Criterion, Chronic (µg/L)[b]	1-10	5.2	—	—	—	—	—
Threshold Limit Value (mg/m^3)[c]	10	5	1,780	32	—	—	590
Permissible Exposure Limit (mg/m^3)[d]	—	5	—	32	—	—	—
Minnesota Recommended Allowable Limit (RAL) (µg/L)[e]	700	100	700	10	30,000	3.0	300
Minnesota Water Quality Standard (WQS) (µg/L)[f]	5,000	10	—	—	—	—	—

TABLE 4-1 (Continued)

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Parameter	Carbon Tetrachloride	Chloroform	1,1-Dichloro-ethane	1,2-Dichloro-ethane	1,1-Dichloro-ethene	1,2-Dichloro-ethene	2,4-Dinitro-toluene
Maximum Contaminant Level (MCL) (µg/L)[a]	5	—	—	5	7	(70, 100)[h,n]	—
MCL Goal (µg/L)[a]	0	—	—	0	7	(70, 100)[h,n]	—
Secondary MCL (µg/L)[a]	—	—	—	—	—	—	—
Acute Health Advisory (1-day)(µg/L)[a]	4,000	4,000	—	700	2,000	4,000-20,000[n]	—
Lifetime Health Advisory (µg/L)[a]	—	—	—	—	7	70-100[n]	—
Water Quality Criterion, Consumption of Aquatic Organisms and Water (µg/L)[b]	0.4[l]	0.19[l]	—	0.94[l]	0.033[l]	—	0.11
Water Quality Criterion, Consumption of Aquatic Organisms Only (µg/L)[b]	6.94	15.7[l]	—	243[l]	1.85[l]	—	—
Aquatic Water Quality Criterion, Chronic (µg/L)[b]	—	1,240[m]	—	20,000[m]	—	—	—
Threshold Limit Value (mg/m^3)[c]	31	49	810	40	20	793	1.5
Permissible Exposure Limit (mg/m^3)[d]	62	9.7	400	4	4	790	1.5
Minnesota Recommended Allowable Limit (RAL) (µg/L)[e]	3.0	60.0	70	4.0	6	70	1.0
Minnesota Water Quality Standard (WQS) (µg/L)[f]	—	—	—	—	—	—	—

TABLE 4-1 (Continued)

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Parameter	Ethyl-benzene	Methylene Chloride	N-Nitrosodi-phenylamine	Phenol	Phthalate Esthers: Bis(2-ethyl-hexyl)	Phthalate Esthers: Butyl-benzyl	Phthalate Esthers: Di-n-butyl
Maximum Contaminant Level (MCL) (µg/L)[a]	(700)[h]	(5)[h]	---	---	---	(4)	(4)[h]
MCL Goal (µg/L)[a]	(700)[h]	(0)[h]	---	---	---	(0)	(0)[h]
Secondary MCL (µg/L)[a]	(30)[h]	---	---	---	---	---	---
Acute Health Advisory (1-day)(µg/L)[a]	30,000	10,000	—	6,000	—	—	—
Lifetime Health Advisory (µg/L)[a]	700	---	---	4,000	---	---	---
Water Quality Criterion, Consumption of Aquatic Organisms and Water (µg/L)[b]	1,400	0.19	4.9	300	15,000	---	34,000
Water Quality Criterion, Consumption of Aquatic Organisms Only (µg/L)[b]	3,280	15.7	—	2,560	50,000	—	154,000
Aquatic Water Quality Criterion, Chronic (µg/L)[b]	—	—	—	19	3	---	3
Threshold Limit Value (mg/m^3)[c]	434	174	—	19	5	—	5
Permissible Exposure Limit (mg/m^3)[d]	435	1,740	—	—	5	—	5
Minnesota Recommended Allowable Limit (RAL) (µg/L)[e]	700	50.0	70	4000.0	20.0	100.0	700.0
Minnesota Water Quality Standard (WQS) (µg/L)[f]	—	—	---	1	---	—	---

TABLE 4-1 (Continued)

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Parameter	Di-n-octyl	Polychlorinated Biphenyls	Polycyclic Aromatic Hydrocarbons[o]	Tetrachloro-ethene	Toluene	1,1,1-Tri-chloroethane
Maximum Contaminant Level (MCL) (µg/L)[a]	—	(0.5)[h]	(0.2)[h]	(5)[h]	(2,000)[h]	200
MCL Goal (µg/L)[a]	—	(0)[h]	(0)[h]	(0)[h]	(2,000)[h]	200
Secondary MCL (µg/L)[a]	—	—	—	—	(40)[h]	—
Acute Health Advisory (1-day)(µg/L)[a]	—	—	—	2,000	20,000	100,000
Lifetime Health Advisory (µg/L)[a]	—	—	—	—	1,000	200
Water Quality Criterion, Consumption of Aquatic Organisms and Water (µg/L)[b]	—	0.000079[l]	0.0028	0.8	14,300	18,400
Water Quality Criterion, Consumption of Aquatic Organisms Only (µg/L)[b]	—	—	—	8.85	424,000	1,030,000
Aquatic Water Quality Criterion, Chronic (µg/L)[b]	—	—	—	840[m]	—	—
Threshold Limit Value (mg/m^3)[c]	—	—	0.2[p]	339	377	1,910
Permissible Exposure Limit (mg/m^3)[d]	—	0.5-1.0	0.2[p]	170	375	1,900
Minnesota Recommended Allowable Limit (RAL) (µg/L)[e]	—	0.05	0.3, 0.03[r]	7.0[q]	1000.0	600
Minnesota Water Quality Standard (WQS) (µg/L)[f]	—	—	—	—	—	—

TABLE 4-1 (Continued)

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Parameter	1,1,2-Tri-chloroethane	Trichloro-ethene	Vinyl Chloride	Xylene
Maximum Contaminant Level (MCL) (μg/L)[a]	(5)[h]	5	2	(10,000)[h]
MCL Goal (μg/L)[a]	(3)[h]	0	0	(10,000)[h]
Secondary MCL (μg/L)[a]	—	—	—	(20)[h]
Acute Health Advisory (1-day)(μg/L)[a]	600	—	3,000	40,000
Lifetime Health Advisory (μg/L)[a]	3	—	—	10,000
Water Quality Criterion, Consumption of Aquatic Organisms and Water (μg/L)[b]	0.6	2.7	2.0[l]	—
Water Quality Criterion, Consumption of Aquatic Organisms Only (μg/L)[b]	418	81	525	—
Aquatic Water Quality Criterion, Chronic (μg/L)[b]	9,400[m]	—	—	—
Threshold Limit Value (mg/m^3)[c]	55	269	13	434
Permissible Exposure Limit (mg/m^3)[d]	45	270	2.5	435
Minnesota Recommended Allowable Limit (RAL) (μg/L)[e]	3.0	31	0.10	10,000
Minnesota Water Quality Standard (WQS) (μg/L)[f]	—	—	—	—

TABLE 4-1 (Continued)

REGULATORY STANDARDS AND GUIDELINES FOR CHEMICALS
PRESENT AT NEW BRIGHTON/ARDEN HILLS SITE

Notes:

--- No value available.
[a] Drinking Water Regulations and Health Advisories, U.S. EPA, 1990d.
[b] U.S. Environmental Protection Agency, 1990f. Integrated Risk Information System (IRIS), On-line Database.
[c] American Conference of Governmental Industrial Hygienists (1990).
[d] 29 CFR 1910.1000.
[e] Recommended Allowable Limits for Drinking Water Contaminants, Release No. 3; Minnesota Department of Health; January, 1991.
[f] Minnesota Rules, Chapter 7050 for Rice Creek (Classes 1C, 2B, and 3B).
[g] For hexavalent chromium only, unless otherwise noted.
[h] Parenthetical values are proposed.
[i] Hardness dependent; cited value is 100 mg/L for $CaCO_3$.
[j] Hexavalent chromium (Classes 1C and 2B) and total chromium (Class 2B).
[k] Soluble compounds.
[l] Carcinogen; given number represents 10^{-6} estimated risks.
[m] This is a "lowest effect concentration;" insufficient data exist to derive a water quality criterion.
[n] Values are for cis- and trans- isomers, respectively.
[o] For benzo(a)pyrene, unless otherwise specified.
[p] Coal tar pitch volatiles, benzene-soluble fraction; include anthracene, benzo(a)pyrene, phenanthrene, acridine, chrysene, and pyrene.
[q] Value is for 1,1,2,2-Tetrachloroethene.
[r] Values are for total noncarcinogenic and total carcinogenic PAHs, respectively.

TABLE 4-2

NONCARCINOGENIC CONTAMINANT INHALATION REFERENCE DOSES (RfDs)

Chemical Parameter	Chronic/ Subchronic (mg/kg/day)	Critical Effect	RfD Basis/Source	Combined Uncertainty Factors
Acetone	1E-1[a,b]/ NA[a,b]	Increased liver and kidney weight, nephrotoxicity	HEAST[c] HEAST	1,000 100
2-Butanone	9E-02[d]/ 9E-01	Central Nervous System (CNS) effects CNS effects	HEAST HEAST	1,000 100
1,1-Dichloroethane	1E-01/ 1E+00	Kidney damage Kidney damage	HEAST HEAST	1,000 100
Manganese	3E-04/ 3E-04	CNS effects CNS effects	HEAST HEAST	100 100
Methylene Chloride	9E-01[e,f]/ 9E-01[e,f]	None observed None observed	HEAST HEAST	100 100
Toluene	6E-01[e,f]/ 6E-01[e,f]	CNS effects, eye and nose irritation CNS effects, eye and nose irritation	HEAST HEAST	100 100
1,1,1-Trichloroethane	3E-01[g]/ 3E+00[g]	Hepatotoxicity Hepatotoxicity	HEAST HEAST	1,000 100
Xylene	9E-02[e,f]/ 9E-02[e,f]	CNS effects, nose and throat irritation CNS effects, nose and throat irritation	HEAST HEAST	100 100

Notes:

[a] Developmental effects have been used as the basis of calculation.

[b] Carcinogen Risk Assessment Verification Endeavor (CRAVE) verified as Carcinogenic Assessment Group (CAG) group D substance.

[c] Health Effects Assessment Summary Tables, U.S. EPA, 1990c.

[d] Under review by RfD workshop.

[e] Verified, Work Group concurrence on final database file and IRIS input pending.

[f] Values derived from reference concentrations identified in HEAST.

[g] These values differ from those in U.S. EPA (1984) because the study chosen as the basis for inhalation RfD values was changed to conform to the inhalation study chosen as the basis for oral RfDs derived on IRIS.

TABLE 4-3

NONCARCINOGENIC CONTAMINANT ORAL REFERENCE DOSES (RfDs)

Chemical Parameter	Chronic/ Subchronic (mg/kg/day)	Conf.* Level	Critical Effect	RfD Basis/Source	Combined Uncertainty Factors
Anthracene	3E-01[m,f]/	NA	No effects	Gavage/HEAST[b]	3,000
	3E+00		No effects	Gavage/HEAST	300
Antimony	4E-04[a]/	L	Reduced life span, altered blood chemistries	Water/HEAST	1,000
	4E-04		Reduced life span, altered blood chemistries	Water/HEAST	1,000
Arsenic	1E-03[c]/	NA	Keratosis, hyperpigmentation[d]	Oral/HEAST	1
	1E-03		Keratosis, hyperpigmentation	Oral/HEAST	1
Benzoic Acid	4E+00[a]/	M	Irritation, malaise	Diet/HEAST	1
	4E+00		Irritation, malaise	Diet/HEAST	1
Bis(2-ethylhexyl)phthalate	2E-02[a]/	M	Increased relative liver weight[d]	Diet/HEAST	1,000
	2E-02		Increased relative liver weight	Diet/HEAST	1,000
Bromodichloromethane	2E-02[a]/	M	Renal cytomegaly[d]	Gavage/HEAST	1,000
	2E-02		Renal cytomegaly	Gavage/HEAST	1,000
2-Butanone	5E-02[f,g,h,i]/	M	Fetotoxicity	Oral/HEAST	1,000
	5E-01[g,h]		Fetotoxicity	Oral/HEAST	100
Cadmium	5E-04/	H	Renal damage	Water/HEAST	10
	ND		NA	NA	NA
Carbon Tetrachloride	7E-04[a]/	H	Liver lesions[d]	Oral/HEAST	1,000
	7E-03		Liver lesions	Oral/HEAST	100

TABLE 4-3 (Continued)

NONCARCINOGENIC CONTAMINANT ORAL REFERENCE DOSES (RfDs)

Chemical Parameter	Chronic/ Subchronic (mg/kg/day)	Conf. Level	Critical Effect	RfD Basis/Source	Combined Uncertainty Factors
Chloroform	1E-02[a]/ 1E-02	M	Liver lesions[d] Liver lesions	Oral/HEAST Oral/HEAST	1,000 1,000
Chromium	1E+00[a,j]/ 1E+01[j]	L	None observed None observed	Diet/IRIS[a] Diet/IRIS	1,000 1,000
Copper	4E-02[k]/ 4E-02[k]	M	Local Gastro intestinal (GI) irritation Local GI irritation	Oral/IRIS Oral/IRIS	1,000 1,000
Cyanide	2E-02[a]/ 2E-02	M	Weight loss, thyroid effects, and myelin degeneration Weight loss, thyroid effects, and myelin degeneration	Diet/HEAST Diet/HEAST	500 500
1,1-Dichloroethane	1E-01[c]/ 1E+00	NA	None observed[d] None observed	Diet/HEAST Diet/HEAST	1,000 100
1,1-Dichloroethene	9E-03[i]/ 9E-03	M	Liver lesions[d] Liver lesions	Water/HEAST Water/HEAST	1,000 1,000
1,2-Dichloroethene	2E-02[a,l]/ 2E-01	L	Increased serum alkaline phosphatase Increased serum alkaline phosphatase	Water/HEAST Water/HEAST	1,000 100
Di-n-butylphthalate	1E-01/ 1E+00[a]	L	Mortality Mortality	Diet/IRIS Diet/IRIS	1,000 1,000
Di-n-octylphthalate	2E-02/ 2E-02	NA	Elevated liver and kidney weights; increased serum glutamic-oxaloacetic transaminase (SGOT) and serum glutamic-pyruvic transaminase (SGPT). Elevated liver and kidney weights; increased SGOT and SGPT.	Diet/HEAST Diet/HEAST	1,000 1,000

TABLE 4-3 (Continued)

NONCARCINOGENIC CONTAMINANT ORAL REFERENCE DOSES (RfDs)

Chemical Parameter	Chronic/ Subchronic (mg/kg/day)	Conf. Level	Critical Effect	RfD Basis/Source	Combined Uncertainty Factors
Ethylbenzene	1E-01[a,f]/	L	Hepatotoxicity, nephrotoxicity	Oral/HEAST	1,000
	1E+00		Hepatotoxicity, nephrotoxicity	Oral/HEAST	100
Manganese	2E-01[m]/	NA	CNS	Water/HEAST	100
	5E-01		Reproduction	Gestation/HEAST	100
Mercury	3E-04[m]/	M	Kidney effects	Oral/HEAST	1,000
	3E-04		Kidney effects	Oral/HEAST	1,000
Methylene Chloride	6E-02[a]/	M	Liver toxicity[d]	Water/IRIS	100
	6E-02		Liver toxicity	Water/IRIS	100
Nickel	2E-02[i]/	M	Reduced body/organ weight	Diet/HEAST	300
	2E-02		Reduced body/organ weight	Diet/HEAST	300
Phenol	6E-01[a,f,g]/	L	Reduced fetal body weight	Gavage/HEAST	100
	6E-01[g]		Reduced fetal body weight	Gavage/HEAST	100
Pyrene	3E-02[m]/	NA	Renal effects	Gavage/HEAST	3,000
	3E-01		Renal effects	Gavage/HEAST	300
Selenium	3E-03[m,n]/	H	Hair/nail loss, dermatitis	Diet/HEAST	15
	3E-03[l]		Hair/nail loss, dermatitis	Diet/HEAST	15
Silver	3E-03[a]/	M	Argyria	Therapeutic/IRIS	2
	3E-03		Argyria	Therapeutic/IRIS	2
Tetrachloroethene	1E-02[a]/	M	Hepatotoxicity[d]	Oral/HEAST	1,000
	1E-01		Hepatotoxicity	Oral/HEAST	100

TABLE 4-3 (Continued)

NONCARCINOGENIC CONTAMINANT ORAL REFERENCE DOSES (RfDs)

Chemical Parameter	Chronic/ Subchronic (mg/kg/day)	Conf. Level	Critical Effect	RfD Basis/Source	Combined Uncertainty Factors
Thallium	7E-05[o]/	NA	Increased SGOT and serum lactic dehydrogenase (LDH) level, alopecia	Oral/HEAST	3,000
	7E-04[o]		Increased SGOT and serum LDH level, alopecia	Oral/HEAST	300
Toluene	3E-01[e,f,h]/	M	CNS effects	Oral/HEAST	100
	4E-01		CNS effects	Gavage/HEAST	100
1,1,1-Trichloroethane	9E-02[a,h]/	M	Hepatotoxicity	Oral/HEAST	1,000
	9E-01[h]		Hepatotoxicity	Oral/HEAST	100
1,1,2-Trichloroethane	4E-03[a]/	M	Clinical chemistry alterations[d]	Water/HEAST	1,000
	4E-02		Clinical chemistry alterations	Water/HEAST	100
Vanadium	9E-03[c]/	L	Decreased hair cystine	Oral/IRIS	100
	9E-03		Decreased hair cystine	Oral/IRIS	100
Xylene	2E+00[p]/	M	Hyperactivity, decreased body weight, increased mortality	Oral/HEAST	100
	4E+00[p]		None observed	Oral/HEAST	100
Zinc	2E-01[c]/	NA	Anemia	Therapeutic/HEAST	10
	2E-01		Anemia	Therapeutic/HEAST	10

TABLE 4-3 (Continued)

NONCARCINOGENIC CONTAMINANT ORAL REFERENCE DOSES (RfDs)

Notes:

* Confidence level: L = low, M = medium, and H = high.

[a] Verified, available on IRIS.
[b] Health Effects Assessment Summary Tables, U.S. EPA, 1990c.
[c] Under review by RfD Work Group.
[d] Also see Table 4-5.
[e] A new RfD will be verified, and the old number on IRIS will be changed.
[f] CRAVE-verified as a CAG Group D substance.
[g] Developmental effects have been used as the basis of calculation.
[h] Based on route-to-route extrapolation.
[i] The oral RfD, although still available on IRIS, is being reconsidered by the RfD Work Group.
[j] Values for trivalent chromium as a soluble salt.
[k] Estimated from drinking water standard of 1.3 mg/L.
[l] Values are for 1,2-t-dichloroethene; data for 1,2-c-Dichloroethene are not adequate.
[m] Verified, Work Group concurrence on final database file and IRIS input pending.
[n] Value for selenious acid.
[o] Value for thallium in soluble salts.
[p] Value for o-xylene.
[q] U.S. Environmental Protection Agency, 1990f. Integrated Risk Information System (IRIS), On-line Database.

NA Not applicable or not available.
ND Not determined.

TABLE 4-4

CARCINOGENIC CONTAMINANT INHALATION SLOPE FACTORS (SF)

Compound	SF $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification*	Type of Cancer	SF Basis/Source
Arsenic	5.0E+01[a,b]	A	Respiratory tract[c]	Air/HEAST[d]
Benzene	2.9E-02[a]	A	Leukemia	Occupational/HEAST
Cadmium	6.1E+00[a]	B1	Respiratory tract[c]	Occupational/HEAST
Carbon Tetrachloride	1.3E-01[g]	B2	Liver[c]	Gavage/HEAST
Chloroform	8.1E-02[a]	B2	Liver[c]	Water/HEAST
Chromium	4.1E+01[a,e]	A	Lung[c]	Occupational/HEAST
1,2-Dichloroethane	9.1E-02[a,g]	B2	Circulatory system	Gavage/HEAST
1,1-Dichloroethene	1.2E+00[a,h]	C	Kidney[c]	Air/HEAST
Methylene Chloride	1.4E-02[i]	B2	Lung, liver[c]	Air/HEAST
Nickel	1.7E+00[a,f]	A	Respiratory tract[c]	Occupational/HEAST
Tetrachloroethene	3.3E-03	B2	Leukemia, liver[c]	Air/HEAST
1,1,2-Trichloroethane	5.7E-02[a,g]	C	Liver[c]	Gavage/HEAST
Trichloroethene	1.7E-02[b,j]	B2	Lung	Air/HEAST
Vinyl Chloride	3.0E-01[h,j]	A	Liver	Air/HEAST

Notes:

[a] Verified, available on IRIS.
[b] An absorption factor of 30 percent is used in calculation of the unit risk.
[c] Also see Table 4-2.
[d] Health Effects Assessment Summary Tables, U.S. EPA, 1990c.
[e] Values are for hexavalent chromium.
[f] Values are for nickel subsulfide.
[g] Based on route-to-route extrapolation.
[h] Based on metabolized dose.
[i] Still available on IRIS, but under review by Work Group.
[j] Verified, Work Group concurrence on final database file and IRIS input pending.
[*] U.S. EPA weight of evidence classification.

TABLE 4-4 (Continued)

CARCINOGENIC CONTAMINANT INHALATION SLOPE FACTORS (SF)

Group A	Human Carcinogen (sufficient evidence of carcinogenicity in humans)
Group B	Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or no evidence of carcinogenicity in humans)
Group C	Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or no human data)
Group D	Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)
Group E	Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

TABLE 4-5

CARCINOGENIC CONTAMINANT ORAL SLOPE FACTORS (SF)

Compound	SF $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification*	Type of Cancer	SF Basis/Source
Arsenic	1.8E+00[b]	A	Skin	Water/HEAST[d]
Benzene	2.9E-02[a,e]	A	Leukemia	Occupational/HEAST
Bis(2-ethylhexyl)phthalate	1.4E-02[a]	B2	Liver[c]	Diet/HEAST
Bromodichloromethane	1.3E-01[f]	B2	Liver	Gavage/HEAST
Carbon Tetrachloride	1.3E-01[a]	B2	Liver[c]	Gavage/HEAST
Chloroform	6.1E-03[a]	B2	Kidney[c]	Water/HEAST
1,1-Dichloroethane	9.1E-02[f]	C	Hemangiosarcoma	Gavage/HEAST
1,2-Dichloroethane	9.1E-02[a]	B2	Circulatory system	Gavage/HEAST
1,1-Dichloroethene	6.0E-01[a]	C	Adrenal	Gavage/HEAST
2,4-Dinitrotoluene	6.8E-01[f,h]	B2	NA	Diet/HEAST
Methylene Chloride	7.5E-03[g]	B2	Liver[c]	Air, Water/HEAST
N-Nitrosodiphenylamine	4.9E-03[a]	B2	Urinary bladder	Diet/HEAST
Polychlorinated biphenyls	7.7E+00[a]	B2	Liver	Diet/HEAST
Polycyclic Aromatic Hydrocarbons	1.15E+01[i]	B2	Stomach	Diet/HEAST
Tetrachloroethene	5.1E-02[j]	B2	Liver[c]	Gavage/HEAST
1,1,2-Trichloroethane	5.7E-02[a]	C	Liver[c]	Gavage/HEAST

TABLE 4-5 (Continued)

CARCINOGENIC CONTAMINANT ORAL SLOPE FACTORS (SF)

Compound	SF $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification*	Type of Cancer	SF Basis/Source
Trichloroethene	1.1E-02[f,k]	B2	Liver	Gavage/HEAST
Vinyl Chloride	2.3E+00[j]	A	Lung	Diet/HEAST

Notes:

[a] Verified, available on IRIS.
[b] Slope factor derived from unit risk proposed by Risk Assessment Forum and noted in HEAST, U.S. EPA, 1990c.
[c] Also see Table 4-3.
[d] Health Effects Assessment Summary Tables, U.S. EPA, 1990c.
[e] Based on route-to-route extrapolation.
[f] Verified, Work Group concurrence on final database file and IRIS input pending.
[g] The slope factor, although still available on IRIS, is being reconsidered by CRAVE Work Group.
[h] This value applies to a mixture of 2,4- and 2,6-dinitrotoluene isomers.
[i] Value for benzo(a)pyrene is used for the carcinogenic PAHs benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene as directed in memorandum from P.F. Hurst, Environmental Criteria and Assessment Office, U.S. EPA, August 8, 1990.
[j] Under review by CRAVE.
[k] Based on metabolized dose.
[*] U.S. EPA weight of evidence classification.

Group A Human Carcinogen (sufficient evidence of carcinogenicity in humans)

Group B Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or no evidence of carcinogenicity in humans)

Group C Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or no human data)

Group D Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)

Group E Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

Threshold limit values (TLV) are criteria set by the American Conference of Governmental Industrial Hygienists at levels expected to have negligible adverse effects on almost all workers exposed 8 hours per day, 40 hours per week. The Occupational Safety and Health Administration (OSHA) issues regulations prescribing Permissible Exposure Limits (PEL), which are time-weighted averages as TLVs. The list of PELs was updated in January 1989 (29 CFR 1910.1000). Although revised values are being phased in through "transitional limits," Table 4-1 lists the "final limits," which reflect OSHA's conclusions regarding appropriate exposure limits.

To maintain the quality of both surface and ground water, Chapter 7050 of the Minnesota Rules prescribes Water Quality Standards (WQS) that vary according to class of water; the portion of Rice Creek on and near TCAAP is designated 1C (domestic consumption, Class C); 2B (fisheries and recreation, Class B); and 3B (industrial consumption, Class B). Minnesota Recommended Allowable Limits (RALs) and Minnesota Water Quality Standards (WQSs) are included in Table 4-1.

The U.S. EPA Office of Drinking Water has developed health advisories (HA). The levels in these advisories are based on noncarcinogenic health effects. Synergistic health effects of other noncarcinogenic chemicals are not considered, but each HA has a margin of safety. Acute HAs are calculated for a child weighing 10 kilogram (kg) consuming 1 liter of water per day; lifetime exposure HAs are calculated for an adult weighing 70 kg consuming 2 liters of water per day for 70 years.

The RfDs are an estimate of the daily exposure that is likely to cause no appreciable risk of deteriorative effects to humans, including sensitive populations. RfDs are expressed in mg/kg/day and are used to evaluate noncarcinogenic health effects.

The carcinogenic potency or slope factor (SF) of a chemical is calculated by U.S. EPA's Carcinogen Advisory Group (CAG). This factor, multiplied by the exposed person's intake (in the proper dosage units), is used to estimate the probability of developing cancer in a lifetime after exposure to a chemical. Evidence of carcinogenicity is CAG's evaluation of the likelihood that the agent is a carcinogen in humans.

Most standards for radioactive materials, such as the occupational standards of the NRC, are specific to a radioisotope or other source of radiation. Radioisotope specific data are not available for TCAAP samples. However, less specific regulations exist for drinking water, promulgated both as primary MCLs under the federal Safe Drinking Water Act (SDWA) and as Minnesota RALs. For alpha radiation, the limits are as follows:

- 5 pCi/L for combined radium-226 and radium-228.
- 15 pCi/L for gross alpha, including radium-226 but excluding radon and uranium.

For beta and gamma (photon) activity, the basic limit is the concentration of manmade radionuclides in drinking water that would give an annual dose to the whole body or any internal organ not greater than 4 millirem/year. Specific limits for tritium and strontium-90 are 20,000 and 8 pCi/L, respectively.

Two soil criteria have been set for lead and PCBs. The Centers for Disease Control (1985) concluded that lead in soil and dust is a significant hazard to children if its concentration exceeded 500 to 1,000 mg/kg. U.S. EPA requires cleanup of soil containing 25 mg/kg of PCBs in restricted areas and 10 mg/kg of PCBs in unrestricted areas (40 CFR 761.125).

4.2 QUALITATIVE TOXICITY ASSESSMENT

Quantitative risk assessment is not possible for chemicals such as aluminum, calcium, cobalt, lead, magnesium, potassium, iron, sodium, chloroethane, gross alpha and gross beta because SF or RfD values are not available. Although these chemicals are considered chemicals of potential concern, PRC eliminated them from further quantitative risk evaluation. However, lead is a relatively toxic chemical, and the Centers for Disease Control (CDC) (1985) has issued guidance on lead levels in soils. Specifically, CDC has concluded that lead in soil and dust is a significant hazard to children if the concentration of lead exceeds 500 to 1,000 mg/kg. PRC therefore qualitatively assessed the risk posed by lead in surface soils. Furthermore, gross alpha and gross beta risks were qualitatively assessed. Inorganics such as aluminum, calcium, cobalt, magnesium, potassium, iron, and sodium were identified as chemicals of potential concern in only off-TCAAP exposure areas in ground water. All of these compounds are relatively nontoxic. Furthermore, samples from background ground-water locations were not analyzed for these compounds. It is probable that these inorganics are present in off-TCAAP ground water at levels comparable to the background. Therefore, risks from exposure to these chemicals, except cobalt, are not further discussed in this report. A brief toxicological profile is presented in Chapter 4 for chloroethane and cobalt which are known to be toxic. Considering the large number of chemicals of potential concern for which quantitative risk assessments were conducted, contribution to the total risk due to exposure to chemicals eliminated from quantitative risk assessments is not expected to be significant.

For some chemicals, risk factors may be available for one potential route of exposure but not another. For example, an oral RfD was identified for 1,1,2-trichloroethane, but an inhalation

RfD for the same chemical was not available. The implication is that the risk of adverse health effects resulting from ingestion of 1,1,2-trichloroethane is accounted for but any risk resulting from inhalation of 1,1,2-trichloroethane is not accounted for quantitatively.

1,2-dichloroethene exists as cis and trans isomers. The data available to PRC were reported sometimes as 1,2-dichloroethene, while at other occasions cis-1,2-dichloroethene and trans-1,2-dichloroethene were identified. Risk factors are available for only 1,2-dichloroethene. PRC used the risk factors for 1,2-dichloroethene for cis- and trans-1,2-dichloroethene.

Chemicals of potential concern present in an exposure area that are not considered in the quantification of risk are presented in Appendix B. They are labeled with an asterisk to differentiate them from chemicals of potential concern for which quantitative risk evaluation was possible.

Of the chemicals for which no risk factors are identified, lead is recognized to have potentially severe toxic effects. The unique properties of lead make it impossible to quantify toxicity values (U.S. EPA, 1990b). Therefore, this section presents a qualitative evaluation of the risk associated with lead concentrations present at the New Brighton/Arden Hills site. The risk associated with lead exposure varies according to the individual, depending on nutritional status, age, and total lead body burden (from all sources). These and other factors prevent the use of numerical estimates to quantitatively assess the health risks of lead (U.S. EPA, 1990b).

One possible approach to assessing the risk associated with lead concentrations present at the TCAAP site is to compare these concentrations to lead concentrations known to cause adverse health effects and to regulatory standards. A concentration as low as 1 mg/L of lead in drinking water has been reported to cause lead poisoning in Scotland (NLM, 1990). U.S. EPA has determined that the adverse effects of lead may result from levels so low as to be without a minimum threshold (IRIS, U.S. EPA, 1990). Lead concentrations in TCAAP ground water can be compared to the MCLs promulgated under SDWA (see Table 4-1).

Studies suggest that workers inhaling 1 $\mu g/m^3$ of lead for 11 to 37 years had mean blood lead (PbB) levels of 32 $\pm$ 14 $\mu g/dL$; lead-related effects such as decreased serum phosphorus and abnormal urine-concentrating ability have also been shown (NLM, 1990). Adverse effects on reproductive ability have also been demonstrated in men with PbB levels above 41 $\mu g/dL$ (NLM, 1990). The risk of lead poisoning has been established at PbB levels above 60 $\mu g/dL$ according to the National Institute of Occupational Safety and Health (NLM, 1990).

The potential for significant lead exposure to children is of particular concern because the neurobehavioral effects of lead may occur at very low exposure levels in children (U.S. EPA, 1990b). A PbB level of 10 to 15 μg/dL has been cited as a threshold for adverse effects in children (Environmental Reporter, 1990). Studies indicate that children may absorb lead at a rate five times greater than that of adults following ingestion and may retain five times the dose in a form that can produce toxic effects (NLM, 1990). If this information is used to develop a rough conversion factor (5 x 5 = 25) for converting the exposure of a child to an "adult-equivalent dose," then the exposure of an on-TCAAP resident child 0 to 6 years old would be the estimated dose multiplied by the conversion factor (25) to equal an adult-equivalent dose.

The nutritional status of an exposed child also influences the effects of lead through such factors as levels of calcium, Vitamin D, iron, zinc, fats, proteins, and phosphate as well as hormonal influences (Gilman and others, 1980; Doull and others, 1980). The baseline lead body burden also determines whether additional exposure will result in unacceptable PbB levels and corresponding adverse effects. As stated previously, U.S. EPA has determined that there may be no minimum threshold for the adverse effects of lead, particularly for the neurobehavioral effects seen in children (U.S. EPA, 1990b).

Women are generally more sensitive to the hematopoietic (blood) system effects of lead than men (NLM, 1990). A fetus may be particularly sensitive to the effects of lead because of transfer of lead from the mother through the placenta and the resulting potential for pre-term birth, reduced birth weight, and decreased intelligence quotient (IQ) in the infant (NLM, 1990). Also at a greater risk from exposure to lead are persons with genetic disorders such as renal tubular dysfunction, glucose-6-phosphate dehydrogenase deficiency, sickle-cell anemia, and hemoglobin S or O thalassemia (NLM, 1990). Finally, children exhibiting pica behavior could consume much greater quantities of contaminated soil than is estimated in the exposure assessment and would, therefore, be at greater risk (NLM, 1990).

4.3 TOXICOLOGICAL PROFILES

The contaminants at the New Brighton/Arden Hills site have varying effects on humans. Brief summaries of the known effects of these contaminants are provided below. More detailed information, including a glossary of toxicological terminology and references, is given in Appendix H.

It is never possible to predict with complete certainty the effect that a given concentration of a chemical will have on a given individual because everyone reacts differently. For some chemicals, certain classes of persons are known to be more susceptible. Furthermore, the

standard values given in Tables 4-2 through 4-5 generally involve two extrapolations: from animals to humans, and from a high dose (giving adverse effects) to a low dose. Uncertainty factors and similar devices are used to account for errors in extrapolation. Finally, the most difficult factor to estimate is the interaction among contaminants and between contaminants and other factors. If particular uncertainties and interactions are known, they are pointed out in the following individual summaries.

Inorganics

Antimony. Antimony acts both as a metal (in lead alloys, for instance) and as a nonmetal. Its primary effect is irritation at the site of contact, leading in some cases to lung lesions and gastrointestinal ulcers. It also increases the risk of heart disease and damage to the liver.

Arsenic. Arsenic has been known as a toxicant for many centuries. It is an essential trace mineral in some animals. Acutely toxic doses are rare and cause gastrointestinal upset. Repeated low-dose exposure from inhalation and ingestion (in medicines or drinking water) causes characteristic skin lesions that can eventually turn into cancers. The nervous system, the blood, and other systems are sometimes affected.

Cadmium. Cadmium leaching in acute doses from ceramic containers into food and drink has been known to cause severe gastrointestinal toxicity. Repeated small doses accumulate in the body and may cause severe kidney lesions. This leads to loss of calcium; weak, easily broken bones; and severe joint and muscle pains. Inhalation of cadmium produces lung tumors in animals.

Chromium. Chromium is an essential trace mineral. Acute toxicity is extremely rare. Repeated doses cause many lesions, primarily at the site of contact but also in the liver and kidneys. Inhalation of hexavalent chromium (but not trivalent) causes lung tumors in workers.

Cobalt. Cobalt is a relatively rare element that has been shown to be toxic in high concentrations. Extreme concentrations have produced acute effects on gastrointestinal and nervous systems and have caused goiters and skin rashes. Chronic exposure can result in loss of sense of smell and gastrointestinal effects leading to weight loss.

Copper. Copper is an essential trace mineral that rarely affects humans adversely. Toxic effects, usually seen in persons with an inborn metabolic defect, include lesions in the liver and nervous system. Copper is highly toxic to aquatic animals, but water hardness decreases its potency.

Cyanide. Massive doses of cyanide can be fatal within seconds. Lesser doses act more slowly. Cyanide blocks the use of oxygen by cells, so its effects are seen in virtually every system. Very low repeated doses have no effect because the body incorporates some cyanide into cyanocobalamin (Vitamin B_{12}) and detoxifies the rest. Slightly higher repeated doses lead to mild toxic effects, primarily on the nervous system; breathlessness during exertion; and occasional thyroid toxicity from detoxified cyanide.

Lead. Lead has long been known as a toxicant. Acute doses affect the nervous and gastrointestinal systems. Repeated small doses accumulate, causing a wide variety of lesions and functional problems in the same systems. Lead is carcinogenic (to the kidneys) in animals. Children are extremely susceptible to lead toxicity from conception to the end of postpubertal growth. A recent study has found that dosing for a short, preschool period leads to severe behavioral and learning disorders that persist into adulthood.

Manganese. Manganese is an essential trace mineral with relatively low toxicity. The main effect of acute doses is irritation at contact sites. Repeated doses can result in brain lesions, behavioral disorders, and even Parkinson's Disease. Children seem to be particularly susceptible.

Mercury. Mercury toxicity has long been known. Acute toxicity is rare and results primarily in irritation at contact. Repeated doses accumulate, producing a characteristic syndrome of nervous system disturbances along with lesions in the kidneys and elsewhere. Children are particularly sensitive both before and after birth, especially to methylmercury, which readily crosses the placenta.

Nickel. Nickel is an essential trace mineral in some animals. Acute doses are irritating to humans; repeated contact often causes allergic sensitization. Chronic dosing causes lung tumors (after inhalation) and adverse effects on the blood and reproductive systems.

Silver. Silver has little toxicity. Repeated doses lead to deposits of silver in connective tissue throughout the body, causing a gray-blue pigmentation.

Thallium. Most uses of thallium have ceased because of its high cumulative toxicity. Repeated doses may result in generalized hair loss and atrophy of the optic nerve as well as less specific effects on the nervous system, liver, kidneys, and other organs.

Vanadium. Vanadium is a widely distributed element that is essential in some animals. It produces irritation at contact and some kidney and central nervous system effects.

Zinc. Zinc is a vital part of numerous enzyme systems. Zinc deficiency is seen more frequently than zinc toxicity because normal internal control measures minimize overdosing. Toxic effects include fever and gastrointestinal symptoms.

Organic Compounds

Acetone. Acetone is a natural constituent of the body that is produced during metabolism; it is normally found in the blood and urine. The main acute toxic effect is central nervous system depression, but irritation also occurs, especially in the eyes.

Benzene. Large acute doses of benzene produce central nervous system depression, while repeated doses produce effects ranging from local irritation to effects on the hematopoietic system. Hematopoietic effects themselves range from clotting defects to leukemia, in some cases.

Benzoic Acid. Benzoic acid is generally recognized as a safe food additive. Large doses cause irritation and decreased blood pH. Benzoic acid also causes allergic reactions in some people.

Bromodichloromethane. Bromodichloromethane causes central nervous system depression and liver and kidney lesions. It is most frequently found in chlorine-treated drinking water.

2-Butanone. A widely used solvent, 2-butanone is also called methyl ethyl ketone. The only toxic effect on humans is local irritation.

Carbon Tetrachloride. Carbon tetrachloride has been replaced in most of its uses because of its high toxicity. Single doses produce central nervous system depression and gastrointestinal irritation. Repeated doses also cause severe liver degeneration and kidney lesions. Simultaneous dosing with many chemicals, including ethanol, greatly increases the liver toxicity of carbon tetrachloride. Carbon tetrachloride is a potent liver carcinogen in many animals.

Chloroethane. In high concentrations, chloroethane has been shown to have narcotic effects, while exposure to extremely high concentrations has been associated with lack of coordination, a weak analgesia, stupor, stomach cramps and possible cardiac arrythmias. It also vaporizes quickly and can cause mild irritation of the eyes and mucos membranes.

Chloroform. Chloroform produces central nervous system depression and was widely used as a general anesthetic before it was found to cause cardiac arrest. Repeated doses cause liver and

kidney lesions; great variations in susceptibility exist. For instance, chloroform-induced kidney lesions are rare in humans but are common in some strains of mice. Chloroform causes kidney tumors in some animals, but human (epidemiological) studies are inconclusive.

1,1-Dichloroethane. Acute doses of 1,1-dichloroethane produce central nervous system depression and irritation at contact; very high doses produce liver and kidney lesions. The few repeated-dose animal studies have found only nonspecific effects such as decreased weight gain.

1,2-Dichloroethane. Acute doses of 1,2-dichloroethane produce central nervous system depression and local irritation; high doses also cause lesions in the liver, kidneys, and adrenal glands. Because repeated doses cause similar effects in animals, with some lesions developing into tumors, 1,2-dichloroethane is considered a probable human carcinogen.

1,1-Dichloroethene. Acute doses of 1,1-dichloroethene cause central nervous system depression and irritation at contact. Repeated doses cause liver and kidney lesions. Although most animal carcinogenicity studies have been inadequate, a few have shown 1,1-dichloroethene to be carcinogenic; therefore, 1,1-dichloroethene is considered a possible human carcinogen.

1,2-Dichloroethene. The compound 1,2-dichloroethene is comprised of two isomers that are practically identical toxicologically. Single doses cause central nervous system depression and some irritation. Repeated doses also cause liver and kidney lesions.

2,4-Dinitrotoluene. The compound 2,4-dinitrotoluene is used in making explosives and urethane foams. Single doses affect the hemoglobin of the blood, preventing it from carrying oxygen. In animals, repeated doses lead to various cancers; 2,4-dinitrotoluene is therefore considered a probable human carcinogen.

Ethylbenzene. Single doses of ethylbenzene are irritating (especially to the lungs) and cause central nervous system depression. Repeated doses also cause bone marrow and liver lesions in humans.

Methylene Chloride. Methylene chloride is a widely used solvent that causes central nervous system depression. Repeated doses affect the nervous system and, in animals, cause tumors. Methylene chloride is therefore considered a probable human carcinogen.

N-Nitrosodiphenylamine. N-Nitrosodiphenylamine is used in the manufacture of rubber and is formed spontaneously by nitrite and diphenylamine. Evidence exists that it is absorbed through

the skin as well as through the gastrointestinal tract. Repeated dosing of animals causes cancers, especially of the bladder. It is considered a probable human carcinogen.

Phenol. Phenol is now used as a chemical intermediate; formerly it was used as an antiseptic. It is well absorbed by all routes, including the skin. Phenol's effects include irritation, central nervous system stimulation, and liver and kidney toxicity. It is more toxic to fish than to aquatic invertebrates and micro-organisms.

Phthalate Esters. Phthalate esters are ubiquitous in the environment because of their use as plasticizers. Although most have very little toxicity, the most common, bis(2-ethylhexyl) phthalate, is carcinogenic to animals. It is therefore considered a probable human carcinogen.

Polychlorinated Biphenyls. The main toxic effect of single doses of PCBs is chloracne, a severe form of acne that may persist for decades. Repeated doses of PCBs also cause skin lesions (hyperpigmentation), visual disturbances, gastrointestinal effects (including liver lesions), lethargy, and reproductive toxicity in humans. Some researchers ascribe many of these effects to polychlorinated dibenzofurans, the thermal degradation products of PCBs. PCBs have been found to be carcinogenic in animal studies, but human results are not conclusive.

Polycyclic Aromatic Hydrocarbons. PAHs are a large group of chemicals often found as a mixture in the products of incomplete combustion. They are absorbed after inhalation and ingestion but are probably not absorbed through the skin. Over a dozen PAHs are known to be carcinogenic to animals and are considered probable human carcinogens. PAHs are believed to the main carcinogenic ingredients in mixtures such as coal soot, coal tar, and cigarette smoke. Extensive interactions occur among PAHs and between PAHs and other chemicals. In most cases, PAHs increase the toxicity of other chemicals; the role of PAHs in increasing the carcinogenicity of asbestos in cigarette smoke is a well studied example.

Tetrachloroethene. Single doses of tetrachloroethene cause central nervous system depression, irritation, and lesions in the liver and kidneys. Repeated doses cause similar lesions, primarily in the liver and kidneys. Tetrachloroethene has been found to be carcinogenic in animal studies.

Toluene. Single doses of toluene are irritating (especially to the lungs) and cause central nervous system depression. Repeated doses also cause liver and kidney lesions.

1,1,1-Trichloroethane. Acute doses of 1,1,1-trichloroethane cause central nervous system depression and mild local irritation. The compound also sensitizes the heart to normal control

measures and can produce sudden death by cardiac arrest. Repeated doses cause liver and kidney lesions.

1,1,2-Trichlorethane. The compound 1,1,2-trichloroethane is a more potent toxicant than other, closely related chemicals. Single doses cause central nervous system depression, irritation on contact, and liver lesions. Repeated doses cause liver lesions and some kidney lesions.

Trichloroethene. Acute doses of trichloroethene cause central nervous system depression and some irritation. It was used as a surgical anesthetic until some patients suffered cardiac arrest and others developed liver lesions, even after a single dose. Repeated doses produce liver, kidney, and nervous system lesions. Trichloroethene is carcinogenic to animals.

Vinyl Chloride. Single doses of vinyl chloride produce central nervous system depression as well as disturbances of the heart and circulatory system. Repeated doses to workers result in a characteristic syndrome that includes liver lesions, circulatory effects (Raynaud's disease), skin and bone lesions, lack of platelets, and chromosome abnormalities. Much of the current interest in chemically induced tumors began when vinyl chloride was discovered to cause an extremely rare tumor (hemangiosarcoma) in workers.

Xylene. Xylene has three isomers that are practically identical toxicologically. Single doses are irritating (especially to the lungs) and cause central nervous system depression. Repeated doses also cause liver lesions in some workers.

Radiation

Ionizing radiation produces disrupting effects on chemical bonds when it interacts with matter. The amount and type of damage depend on (1) the type and amount of radiation, which determine the extent of damage, and (2) the chemical characteristics of the radiation species, which define where the radiation starts.

4.4 UNCERTAINTIES IN TOXICITY ASSESSMENT

Uncertainties exist in the toxicity assessment as a result of the methodology used to quantify various chemicals' toxicological effects and difficulties encountered in identifying the toxicological effects of certain chemicals. In some instances these uncertainties may result in overestimation of risk, and in others risk may be underestimated. Each area of uncertainty is discussed below.

4.4.1 Development of Risk Factors

In development of risk factors, U.S. EPA makes several assumptions that may tend to overestimate the actual risk of adverse health effects to humans resulting from exposure to a specific chemical. Use of data from animal studies involves extrapolation from high doses administered to laboratory animals to much lower doses expected to be experienced by humans. The dose-response relationship may not be the same at these lower doses and may, therefore, result in overestimation of risk.

Overestimation may also result from the assumption that humans are more sensitive to adverse health effects of exposure to a chemical than the animals used in a study. Under this assumption, safety factors are included when a risk factor is developed using results of animal studies to predict adverse health effects in humans. In some cases, data from a study of adverse health effects resulting from exposure via a particular route (ingestion, inhalation, or dermal contact) are used to predict adverse health effects resulting from exposure via a different route. This route-to-route extrapolation introduces uncertainty that may result in underestimation or overestimation of adverse health effects, depending on the particular chemical involved and the particular route that has been extrapolated to.

In development of a risk factor, the 95-percent upper-bound estimate of the dose-response relationship is calculated and used as the final risk factor. This produces a risk factor designed to predict the maximum response that can be expected from a given dose based on the study data. Using the average response could result in underprediction of some responses, but using the 95-percent upper-bound estimate should avoid underprediction for 95 percent of the responses.

4.4.2 Lack of Risk Factors

Risk factors for all potential routes of exposure are available for some of the chemicals of potential concern, but other chemicals' risk factors are available only for particular routes (for example, for inhalation but not ingestion). This may result in underestimation or overestimation of risk, depending on how the risk assessor chooses to evaluate the risk of a chemical in the absence of a readily identifiable risk factor. The risk assessor may choose to use a substitute risk factor or may attempt to evaluate the risk qualitatively.

When substitute risk factors are used, additional uncertainty is introduced into the estimation of risk from exposure to a given chemical. This does, however, allow the risk from exposure to that chemical to be included in the final quantification of risk, which is desirable.

For example, although several PAHs are identified as B2 carcinogens under U.S. EPA's weight-of-evidence classification system, no current SF can be identified for them. Approval was obtained, however, from U.S. EPA's Environmental Criteria and Assessment Office to use a previously developed CSF for benzo(a)pyrene for all PAHs with weight-of-evidence classifications of B2 (memorandum from P.F. Hurst, Environmental Criteria and Assessment Office, U.S. EPA, August 8, 1990). This may lead to overestimation of the total risk.

Risk factors were also substituted to allow consideration of adverse health effects resulting from short-term (acute) exposures. Acute risk factors were not identified for the chemicals of potential concern, so subchronic risk factors were used. This may tend to overestimate the actual risk, but it allows consideration of the risk of adverse health effects resulting from acute exposures, which are likely to occur more frequently than long-term (chronic) exposures.

In attempting to assess the risk from exposure to particular chemicals qualitatively, uncertainty is introduced by the research data available for these chemicals. In some cases, only limited data are available; in others a greater volume is available but is to some degree contradictory. PRC relied primarily on data provided by IRIS (U.S. EPA, 1990f) and the National Library of Medicine Database; both are frequently updated on-line databases. If necessary, these data were supplemented by U.S. EPA documents, including the Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1990c); various Health Assessment Documents prepared by the Office of Health and Environmental Assessment; and various Toxicological Profiles prepared by the Agency for Toxic Substances and Disease Registry. Several of these documents are in draft form and are subject to revision.

CHAPTER 5

RISK CHARACTERIZATION

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CHAPTER 5
RISK CHARACTERIZATION

In this chapter, PRC quantifies the risks from each current and future land use exposure pathway described in Chapter 3. Risks are quantified and evaluated for individual chemicals, for multiple chemicals within specific exposure pathways, and across multiple exposure pathways, as appropriate. Carcinogenic effects are evaluated for average lifetime exposures, and noncarcinogenic effects are evaluated for short-term (acute/subchronic) and long-term (chronic) exposures. Risks under current land use conditions are evaluated first, followed by risks under future land use conditions. The chapter concludes with a discussion of the uncertainties involved in risk characterization.

5.1 RISK CHARACTERIZATION METHODOLOGY

The methodologies used to characterize carcinogenic and noncarcinogenic risks are discussed separately below.

5.1.1 Carcinogenic Risks

For a carcinogen, a risk estimate represents the incremental probability that an individual will develop cancer over a lifetime as a result of exposure to that carcinogen (U.S. EPA, 1989a). The risks are termed excess lifetime cancer risks and are calculated using Equation 5-1:

$$\text{Upper-bound Excess Lifetime Cancer Risk (Risk)} = \text{CDI} \times \text{SF} \qquad (5\text{-}1)$$

where

CDI = Chronic daily intake (mg/kg/day)

SF = Slope factor $(\text{mg/kg/day})^{-1}$

Risk is expressed as a probability: for example, 1E-06 translates to one additional cancer in an exposed population of one million. The SF in almost all cases represents an upper 95th percent confidence limit of the probability of a carcinogenic response, based on experimental animal data used in a multistage model. Therefore, the resulting risk estimate represents an upper-bound estimate of the carcinogenic risk; the actual risk will probably not exceed the estimate and is likely to be less.

U.S. EPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as belonging to one of six groups: Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A chemicals are agents for which sufficient

data exist to support a causal association between exposure to the agents and the inducement of cancer in humans. Group B1 and B2 chemicals are agents for which limited (B1) or inadequate or no (B2) evidence of carcinogenicity exists from human exposure studies, but sufficient evidence of carcinogenicity exists from animal studies. Group C chemicals are agents for which limited evidence of carcinogenicity exists from animal studies, and inadequate or no evidence exists from human studies. Group D chemicals are characterized by an inadequate carcinogenicity database. Chemicals exhibiting no evidence of carcinogenic response in humans or animals are assigned to Group E. The U.S. EPA weight-of-evidence classifications for carcinogens involved in this risk assessment are presented in Table 4-4.

Carcinogenic risks in this risk assessment are evaluated for chemicals with weight-of-evidence classifications of A, B1, B2, and C. Most available SFs have been derived from experiments in which the route of exposure was ingestion. The resulting oral SFs relate to the amount of substance administered per unit of time and unit of body weight. When dermal routes of exposure are considered, chronic daily intake (CDI) are expressed as absorbed rather than administered doses. To estimate carcinogenic risks for dermal routes of exposure, SFs must also be expressed in terms of absorbed doses. SFs are adjusted to account for oral absorption efficiency. The SFs were adjusted as follows for dermal absorption scenarios (U.S. EPA, 1989a):

$$\text{Adjusted SF} = \frac{\text{Oral SF}}{\text{Oral absorption efficiency}} \qquad (5\text{-}2)$$

Table 5-1 presents chemical-specific oral absorption efficiencies and the adjusted SFs used to evaluate dermal exposures.

Estimating risks from dermal exposure involves making several additional assumptions that do not apply to total exposures. Therefore, the uncertainty associated with dermal risk estimates is greater.

Because of the high degree of uncertainty involved in estimating risks from dermal exposure to contaminants and the conservative nature of the assumptions involved, the risks estimated for dermal exposures may overestimate the actual risks. This issue is discussed for specific exposure pathways below.

According to the revised NCP (U.S. EPA, 1990b), carcinogenic risks from exposures at a Superfund site after remediation may range from 1E-04 (one cancer in an exposed population of ten thousand) to 1E-06 (one cancer in an exposed population of one million). A risk level greater than 1E-04 is considered to present a significant risk, and a level less than 1E-06 is considered

TABLE 5-1

ORAL SLOPE FACTORS ADJUSTED FOR DEGREE OF ORAL ABSORPTION EFFICIENCY FOR USE IN EVALUATING DERMAL EXPOSURES

Compound	Oral SF[a] $(mg/kg/day)^{-1}$	% Oral Absorption	Adjusted SF[b] $(mg/kg/day)^{-1}$	Reference[c]
Arsenic	1.75E+00	95	1.8E+00	ATSDR, 1987a
Benzene	2.9E-02	100	3.2E-02	Owen, 1990
Benzo(a)pyrene	1.15E+01	50	2.30E+01	Owen, 1990
Bis(2-ethylhexyl)phthalate	1.4E-02	15	9.3E-02	ATSDR, 1987d
Bromodichloromethane	1.3E-01	90	1.4E-01	Default
Carbon Tetrachloride	1.3E-01	80	1.6E-01	U.S. EPA, 1982a
Chloroform	6.1E-03	100	6.1E-03	ATSDR, 1987c
1,1-Dichloroethane	9.1E-02	70	1.3E-01	ATSDR, 1989c
1,2-Dichloroethane	9.1E-02	70	1.3E-01	ATSDR, 1989c
1,1-Dichloroethene	6E-01	93	6.5E-01	Owen, 1990
2,4-Dinitrotoluene	6.8E-01	90	7.6E-01	Default
Methylene Chloride	7.5E-03	100	7.5E-03	Owen, 1990
N-Nitrosodiphenylamine	4.9E-03	40	1.2E-02	Default
PCB (Aroclor 1260)	7.7E+00	90	8.6E+00	ATSDR, 1987g
Tetrachloroethene	5.1E-02	90	5.7E-02	Default
1,1,2-Trichloroethane	5.7E-02	90	6.3E-02	Default
Trichloroethene	1.1E-02	90	1.2E-02	ATSDR, 1988b
Vinyl Chloride	2.3E+00	90	2.6E+00	Owen, 1990

Notes:

[a] References for specific oral CSFs are presented in Table 4-4.

[b] Oral SFs were adjusted as follows: oral SF ÷ % oral absorptions = adjusted SF (U.S. EPA, 1989a).

[c] References are listed for the % oral absorption: Default absorption values were adopted as follows: volatiles -- 90%; semivolatiles -- 40%; and inorganics -- 5%. These default values were determined based on a review of available oral absorption values for volatile, semivolatile, and inorganic chemicals.

insignificant. Risk levels between 1E-04 and 1E-06 are within the target range. The terms "significant" and "insignificant" are not meant to imply acceptability; however, they help put the numerical estimates developed in this risk assessment into context. In general, a potential upper-bound excess lifetime cancer risk of 1E-06 is used by U.S. EPA as a point of departure or benchmark.

Within a given exposure pathway, individuals may be exposed to more than one substance. To estimate the overall carcinogenic potential for each exposure pathway, PRC followed the procedures outlined in Guidelines for the Health Risk Assessment of Chemical Mixtures (U.S. EPA, 1986b). The total upper-bound excess lifetime cancer risk for each exposure pathway is estimated using Equation 5-3:

$$Risk_T = Risk1 + Risk2 + ... + Riski \quad (5\text{-}3)$$

where

$Risk_T$ = Total cancer risk for a given exposure pathway

$Risk_i$ = Risk estimate for the i^{th} substance

The risk summation methodology is based on two primary assumptions: (1) intakes of individual substances are small and (2) the independent action of each substance is summed (no synergistic or antagonistic chemical interactions exist, and each substance causes the same effect--cancer). To the extent that these assumptions are not valid, the estimated total risk may overestimate or underestimate the actual risk.

Finally, at particular exposure points, receptors may be exposed via a number of exposure pathways. For example, under RME future land use conditions, receptors may be exposed to ground water via a private well, to ambient air via inhalation, and to surface soil via incidental ingestion and dermal contact. The total exposure for a receptor equals the sum of the exposures via the various exposure pathways to which the receptor is exposed at a particular exposure point. Under each land use condition, exposure pathway combinations are developed for receptors both on- and off-TCAAP. The total incremental carcinogenic risk posed to a receptor via a combination of pathways is calculated using Equation 5-4:

$$\text{Total Exposure Point Cancer Risk} = \text{Risk (exposure pathway}_1\text{)} + \text{Risk (exposure pathway}_2\text{)} + ... + \text{Risk (exposure pathway}_i\text{)} \quad (5\text{-}4)$$

The nature, development, and risks of each exposure pathway combination are discussed in Sections 5.2 and 5.3.

5.1.2 Noncarcinogenic Risks

For noncarcinogens, the potential for individuals to develop noncancer effects is evaluated by comparing an exposure dose developed over a specific exposure period to an RfD developed over a similar exposure period. This comparison takes the form of a ratio called a hazard quotient (HQ), and is expressed in Equation 5-5:

$$\text{Noncancer HQ} = \text{E} / \text{RfD} \qquad (5\text{-}5)$$

where

HQ = Hazard Quotient
E = Exposure dose (or intake)
RfD = Reference dose

and

ED and RfD are expressed in the same units and represent the same exposure period.

For most compounds, the RfD is expressed as an administered dose. Hazard calculations are based on the assumption that both the RfD and exposure dose are expressed as an administered dose. Exposure doses for dermal routes of exposure are expressed as absorbed doses. Thus, oral RfDs are adjusted to account for oral absorption efficiencies so as to be expressed in terms of absorbed doses. Oral RfDs are adjusted for dermal routes of exposure as follows (U.S. EPA, 1989a):

Hazard Quotient (HQ) = Oral RfD x Oral Absorption Efficiency

Table 5-2 presents chemical-specific oral absorption efficiencies and the adjusted chronic oral RfDs. Adjusted subchronic oral RfDs are presented only for chemicals whose subchronic RfD is different from the chronic RfD.

An HQ exceeding one indicates the potential for noncarcinogenic health effects. The sum of individual HQs associated with the same target organ (described below) may exceed one even if no single HQ exceeds one.

In this risk assessment, exposure doses are developed and evaluated for acute (1 day) exposure periods and chronic exposure periods for a series of age groups within each exposure pathway. Because RfDs are not readily available for acute exposure periods, acute exposure doses are evaluated using subchronic RfDs. This approach was adopted in order to present a complete risk assessment. However, in some instances the approach is overly conservative

TABLE 5-2

ORAL REFERENCE DOSES ADJUSTED FOR DEGREE OF ORAL ABSORPTION EFFICIENCY FOR USE IN EVALUATING DERMAL EXPOSURES

Compound	Chronic Oral RfD[a] (mg/kg/day)	Subchronic Oral RfD[a] (mg/kg/day)	% Oral Abs.	Adjusted Chronic RfD[b] (mg/kg/day)	Adjusted Subchronic RfD[b] (mg/kg/day)	Reference[c]
Acetone	1E-01	NA	90	9E-02	NA	Default
Antimony	4E-04	4E-04	5	2E-05	2E-05	Default
Arsenic	1E-03	1E-03	95	1E-03	1E-03	ATSDR, 1987a
Barium	5E-02	5E-02	10	5E-03	5E-03	Owen, 1990
Benzoic Acid	4E+00	4E+00	40	2E+00	2E+00	Default
Bis(2-ethylhexyl)phthalate	2E-02	2E-02	15	3E-03	3E-03	ATSDR, 1987d
Bromodichloromethane	2E-02	2E-02	90	2E-02	2E-02	Default
2-Butanone	5E-02	5E-01	90	5E-02	5E-01	Default
N-butylbenzyl phthalate	2E-01	2E+00	15	3E-02	3E-01	ATSDR, 1987e
Cadmium	5E-04	NA	6	3E-05	NA	ATSDR, 1987b
Carbon Tetrachloride	7E-04	7E-03	80	6E-04	6E-03	U.S. EPA, 1982a
Chloroform	1E-02	1E-02	100	1E-02	1E-02	ATSDR, 1987c
Chromium	1E+00	1E+01	1	1E-02	1E-01	U.S. EPA, 1984a
Cyanide	2E-02	2E-02	45	9E-03	9E-03	ATSDR, 1988a
1,1-Dichloroethane	1E-01	1E+00	70	7E-02	7E-01	ATSDR, 1989c
1,1-Dichloroethene	9E-03	9E-03	93	8E-03	8E-03	Owen, 1990
1,2-Dichloroethene	2E-02	2E-01	90	2E-02	2E-01	Default
Di-n-butylphthalate	1E-01	1E+00	15	2E-02	2E-01	ATSDR, 1987e
Di-n-octylphthalate	2E-02	2E-02	15	3E-03	3E-03	ATSDR, 1987e
Ethylbenzene	1E-01	1E+00	82	8E-02	8E-01	Owen, 1990
Fluoranthene	4E-02	4E-01	50	2E-02	2E-01	Owen, 1990
Manganese	2E-01	5E-01	5	1E-02	2E-02	Default
Mercury	3E-04	3E-04	10	3E-05	3E-05	U.S. EPA, 1980
Methylene Chloride	6E-02	6E-02	100	6E-02	6E-02	Owen, 1990
Nickel	2E-02	2E-02	3	6E-04	6E-04	ATSDR, 1987f
Phenol	6E-01	6E-01	90	5E-01	5E-01	Default
Pyrene	3E-02	3E-01	50	2E-02	2E-01	Owen, 1990
Selenium	3E-03	3E-03	60	2E-03	2E-03	Owen, 1990
Silver	3E-03	3E-03	5	2E-04	2E-04	Default
Tetrachloroethene	1E-02	1E-01	90	9E-03	9E-02	Default
Thallium	7E-05	7E-04	5	4E-06	4E-05	Default
Toluene	3E-01	4E-01	100	3E-01	4E-01	U.S. EPA, 1981
1,1,1-Trichloroethane	9E-02	9E-01	90	8E-02	8E-01	Default
1,1,2-Trichloroethane	4E-03	4E-02	90	4E-03	4E-02	ATSDR, 1989c
Vanadium	9E-03	9E-03	5	5E-04	5E-04	Default
Xylene	2E+00	4E+00	100	2E+00	4E+00	Owen, 1990
Zinc	2E-01	2E-01	50	1E-01	1E-01	U.S. EPA, 1984b

Notes:

[a] Reference for specific chronic/subchronic oral RfDs is presented in Table 4-3.

[b] Chronic/subchronic oral RfDs were adjusted as follows:
RfD x % oral absorption = Adjusted RfD (U.S. EPA, 1989a)

[c] References are listed for the % oral absorption = default absorption values were adopted as follows:
Volatiles 90%
Semivolatiles 40%
Inorganics 5% (best professional judgement)

because subchronic and chronic RfD values are the same. Thus, calculations may indicate that the potential for adverse health effects exists for acute conditions but not for chronic exposures. These instances are artifacts resulting from the methodology used; the risks from acute exposure are overestimated, and the actual acute HQs are less than one, indicating no potential for adverse health effects. These instances are noted within the text, as appropriate.

The age groups evaluated differ for each exposure pathway, and exposure periods range in duration from 1 to 53 years (53 years corresponds to the period of time during which a person is considered to be an adult, assuming a 70-year lifetime and that adulthood begins at age 18). Normally, U.S. EPA guidance states that chronic exposures for humans range in duration from 7 years to a lifetime (1989a). In this risk assessment, most age group exposure periods for children are less than 7 years in length. However, these individual age group exposure periods are part of a longer total exposure period. Under probable exposure conditions, residents are assumed to live at a given location on- or off-TCAAP for 30 years (the national average upper-bound time at one residence (U.S. EPA, 1989a)) and for 70 years (the estimated length of a human life) under RME conditions. Therefore, rather than evaluating each age group exposure period separately as a subchronic exposure, a chronic exposure is developed as appropriate for each age group. This approach assumes exposure at the estimated frequency for the length of each age group exposure period. Each chronic exposure is evaluated using chronic RfDs.

As with carcinogenic substances, within a given exposure pathway, individuals may be exposed to multiple substances with noncarcinogenic health effects. To estimate the overall noncarcinogenic potential for each exposure pathway, PRC followed the procedures outlined in Guidelines for the Health Risk Assessment of Chemical Mixtures (U.S. EPA, 1986b). The total noncarcinogenic risk for each exposure pathway is estimated using Equation 5-7:

$$\text{Hazard Index (HI)} = ED_1 / RfD_1 + ED_2 / RfD_2 + \ldots + ED_i / RfD_i \qquad (5\text{-}7)$$

where

E_i = Exposure dose (or intake) for the i^{th} substance: for acute exposure periods, E_i is calculated as a 1-day dose; for a chronic exposure period, E_i is calculated as a chronic daily intake averaged over the length of each age group. In each case, E_i is presented in mg/kg/day.

AL_i = Maximum acceptable level for the i^{th} substance [for the purposes of this risk assessment, AL equals the RfD for the i^{th} substance (U.S. EPA, 1989a)].

This summation methodology assumes that the various substances to which a receptor is exposed cause the same health effect by the same mechanism. If this assumption is incorrect, the

estimated total exposure point HI may overestimate the total noncarcinogenic risk for a given exposure pathway. This methodology also assumes that when the mechanism of interaction is unknown, the assumption of additivity predicts reasonably well the toxicities of mixtures. If this assumption is incorrect, the HI may overestimate or underestimate the noncarcinogenic risk.

In accordance with U.S. EPA guidance (1989a), all HIs are further evaluated. Based on this evaluation, all HIs greater than one are grouped into one of three categories and distinctly footnoted in the risk characterization summary tables.

The first group of HIs include those HIs that are driven by one or more chemical-specific HQ greater than one; these HIs indicate the potential for adverse noncarcinogenic health effects. The second and third groups of HIs include those HIs that are not driven by one or more chemical-specific HQ greater than one. For each of these HIs, chemical-specific HQs associated with the same target organ(s) or chemical effect(s) (as indicated in Chapter 4) are summed.

The second group of HIs include those HIs for which no target organ- or chemical-effect-specific HQ sums are greater than one; these HI are not associated with potential noncarcinogenic health effects. Finally, the third group of HIs include those HIs for which one or more target organ- or chemical-effect-specific HQ sums are greater than one; these HI indicate the potential for adverse noncarcinogenic health effects.

As discussed above for carcinogenic effects, exposure pathway combinations are developed for receptors both on- and off-TCAAP. The total noncarcinogenic risk posed to a receptor via a combination of pathways may be calculated using Equation 5-8:

$$\text{Total Exposure Point HI} = \text{HI (exposure pathway}_1\text{)} + \text{HI (exposure pathway}_2\text{)} + \ldots + \text{HI (exposure pathway}_i\text{)} \quad (5\text{-}8)$$

Because of the complexity of evaluating noncarcinogenic effects associated with similar target organs or chemical effects, total exposure point HI were not calculated for the risk characterization summary tables. However, any combination of exposure pathways which include chemical-specific HQ greater than one or including target organ or chemical effect HQ sums greater than one are assumed to be associated with adverse noncarcinogenic health effects.

5.2 CURRENT LAND USE CONDITIONS

Risks under current land use conditions associated with each of the exposure pathways described in Chapter 3 are discussed below. Risks are first discussed for on-TCAAP exposures, followed by off-TCAAP exposures.

Risks are evaluated under both current and future land use conditions and under both probable exposure and RME conditions. For each exposure pathway, carcinogenic risks are discussed first, followed by noncarcinogenic risks. Summary tables listing pathway-specific risks are presented in Appendix D. In Tables D-1 through D-158, for media other than ground water, chemical-specific results are presented only for chemicals that contribute most of the risk. For carcinogenic risks, chemical-specific results are presented only for chemicals whose individual upper-bound excess lifetime cancer risks are greater than or equal to 1E-07. However, the pathway-specific totals include all individual chemical-specific risks associated with a given pathway. Similarly, for noncarcinogenic risks, chemical-specific risks are generally presented only for chemicals whose individual HQs are greater than or equal to 1E-01 under acute exposure conditions. However, the pathway-specific HIs include all chemical-specific HQs associated with a given pathway. If no chemical-specific risks are greater than or equal to 1E-07 (upper-bound excess lifetime cancer risk) or 1E-01 (HQ), then the results for the exposure areas with the greatest risks are presented.

In contrast, for exposure to ground water, all chemical-specific results are presented for both carcinogenic and noncarcinogenic risks. This approach is used because ground water is the most contaminated medium associated with TCAAP and because ground water will be the focus of remediation efforts both on- and off-TCAAP.

5.2.1 On-TCAAP -- Current Land Use Conditions

Potential on-TCAAP exposures under current land use conditions are associated with the following media: surface soil, air, and surface water and sediment. Pathway-specific risks for these media are discussed below.

5.2.1.1 Surface Soil -- On-TCAAP (Current Land Use Conditions)

On-TCAAP employees (primarily maintenance workers) may be exposed to surface soil via incidental ingestion or dermal contact. The carcinogenic risks for these pathways are discussed below, followed by the noncarcinogenic risks.

Carcinogenic Risks

The carcinogenic risks associated with exposures to surface soil under probable exposure and RME conditions, respectively, are presented in Appendix D, Tables D-1 (incidental ingestion) and D-2 (dermal contact). Potential carcinogens were identified only in Exposure Areas C, E, and 129-3. Exposure to surface soil within remaining exposure areas presents no incremental carcinogenic risks.

Under probable exposure conditions, all chemical-specific upper-bound excess lifetime cancer risks (risks) associated with exposure to surface soil via ingestion are less than 1E-07. The greatest chemical-specific risk is 8E-08 for benzo(b)fluoranthene in Exposure Area C. The total pathway risks associated with the exposure areas range from 7E-10 in Exposure Area E to 3E-07 in Exposure Area C. Under RME conditions, all chemical-specific risks for soil ingestion are less than 1E-06; the greatest risk (8E-07) is associated with benzo(b)fluoranthene in Exposure Area C. The total pathway risks range from 2E-08 in Exposure Area E to 3E-06 in Exposure Area C.

Also under probable exposure conditions, chemical-specific risks associated with exposure to surface soil via dermal contact are less than 1E-06 except for benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene in Exposure Area C. Chemical-specific risks in Exposure Area C range from 6E-06 to 1E-05. The total pathway risks associated with the exposure areas range from 6E-09 in Exposure Area F to 4E-05 in Exposure Area C. Under RME conditions, all chemical-specific risks for direct soil contact are less than 1E-06 except for five PAHs in Exposure Area C. Chemical-specific risks for these PAHs range from 9E-06 to 2E-05. The total pathway risks range from 3E-08 in Exposure Area F to 6E-05 in Exposure Area C.

Noncarcinogenic Risks

Results for acute exposure to surface soil under probable exposure and RME conditions are presented in Tables D-3 (incidental ingestion) and D-4 (dermal contact). Results for chronic exposure to surface soil are presented in Tables D-5 (incidental ingestion) and D-6 (dermal contact). Acute exposures are discussed first, followed by chronic exposures.

For acute exposures under probable exposure conditions, chemical-specific HQs associated with ingestion are less than 1E-01 except for Exposure Area A, where the HQ for antimony is 1.8E-01. The total pathway HIs range from 3.2E-05 in Exposure Area 129-5 to 1.8E-01 in Exposure Area A. Under RME conditions, the chemical-specific HQ for antimony

and the total HI exceed one only in Exposure Areas A (HI = 5.9E+00) and 129-3 (HI = 1.3E+00). The minimum total pathway HI is estimated as 5.7E-04 for Exposure Area 129-15.

For dermal contact under probable exposure conditions, the chemical-specific HQ for antimony exceeds one in Exposure Areas A (HQ = 4.1E+00) and 129-3 (HQ = 1.6E+00). Total pathway HIs exceed one in Exposure Areas A and 129-3 and range from 1.2E-03 in Exposure Area 129-5 to 4.1E+00 in Exposure Area A. Under RME conditions, chemical-specific HQs equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, (ranging from 1.0E+00 to 3.6E+01). The total pathway HIs range from 5.9E-03 in Exposure Area 129-5 to 3.7E+01 in Exposure Area A.

For chronic exposures under probable exposure conditions, all chemical-specific HQs and the total pathway HI associated with incidental ingestion are less than 1E-02, with a maximum of 5.0E-03 for antimony in Exposure Area A. Total pathway HIs range from 9.1E-07 in Exposure Area 129-5 to 5.0E-03 in Exposure Area A. Under RME conditions, all chemical-specific HQs and the total pathway HI are less than one, with the greatest HQ equal to 1.6E-01 (antimony) in Exposure Area A. Total pathway HIs range from 1.1E-05 in Exposure Area B to 1.6E-01 in Exposure Area A.

Under probable exposure conditions, all chemical-specific HQs and the total pathway HI associated with dermal contact are less than one, with a maximum of 1.1E-01 for antimony in Exposure Area A. Total pathway HIs range from 3.6E-05 in Exposure Area 129-5 to 1.1E-01 in Exposure Area A. Under RME conditions, the HQ associated with antimony and the total pathway HI in Exposure Area A are estimated as 1.0E+00, indicating the potential for noncarcinogenic health effects. All other chemical-specific HQs and total pathway HIs are less than one.

As discussed in Chapter 3, carcinogenic and noncarcinogenic risks associated with exposure to surface soil may be overestimated because the assumed exposure parameters, primarily frequency of exposure and degree of absorption, may be greater than under actual exposure conditions. Furthermore, carcinogenic risks in Source Area C are associated with chemical concentrations (PAHs) measured at a single sampling point. PAHs may not be widely distributed in Source Area C, and receptors may be exposed less frequently than assumed.

5.2.1.2 Air -- On-TCAAP (Current Land Use Conditions)

As discussed in Chapter 3, for evaluating carcinogenic risks associated with inhaling ambient air, it is assumed that all VOC emissions from on-TCAAP remedial actions are

trichloroethene. For evaluating noncarcinogenic risks, it is assumed that all VOC emissions capable of causing noncarcinogenic effects are 1,1,1-trichloroethane. Risks are evaluated for 47 receptor locations, 37 on-TCAAP and 10 off-TCAAP. The selection of these locations is described in Appendix F, and receptor locations are shown in Figures F-2 and F-3. On-TCAAP housing is located along the northwestern boundary of TCAAP between receptor locations BD2 and BD3. Therefore, exposures and risks to persons living in this housing can be estimated based on results for receptor locations BD2 and BD3.

Carcinogenic Risks

The risks associated with inhalation of ambient air are presented in Tables D-7 and D-8 for probable exposure and RME conditions, respectively. Under probable exposure conditions, the risks for on-TCAAP workers are all less than 1E-06. The maximum risk (7E-07) was calculated for receptor location 116 South. These risk estimates assume 8 hours of exposure per day over 12 years, although workers are realistically expected to be present 8 hours per day only in exposure areas where manufacturing or office buildings are located. Therefore, the risk calculated for location 116 South overestimates the true risk to workers, most of whose time will be spent in Building 116 (2E-09) rather than south of the building. The risk for persons living in on-TCAAP Army housing is estimated as ranging from 2E-07 (BD3) to 6E-07 (BD2).

Under RME conditions, the risks to workers are greater than 1E-06 in only two receptor locations (116 South and 116 East-Southeast); a maximum risk of 2E-06 was calculated for both locations. The risk estimates may overestimate actual risks because workers are more likely to be located in Building 116 (9E-09) rather than some distance from the building. Because employees are assumed to work at a single location, risks are not summed for multiple areas. The risk to persons living in on-TCAAP Army housing is estimated as ranging from 5E-07 (BD3) to 2E-06 (BD2).

Risks for the U.S. Army housing are calculated based on 24-hour-per-day exposure. However, some persons may work on-TCAAP and live in on-TCAAP Army housing. Separate risks are not calculated for such individuals. Because estimated air concentrations vary up to an order of magnitude throughout TCAAP, and because inhalation risks vary between working and home activities, risks faced by persons who both live and work on-TCAAP may be somewhat lower or higher than those faced by persons who only live on-TCAAP.

Noncarcinogenic Risks

Noncarcinogenic risks associated with acute exposures to ambient air under probable exposure and RME conditions are presented in Tables D-7a and D-8a, respectively. Noncarcinogenic risks associated with chronic exposures under probable and RME conditions are presented in Tables D-7b and D-8b, respectively. Acute exposures are discussed first, followed by chronic exposures.

For acute exposures to ambient air under probable conditions, all HQs and total pathway HIs are less than 2E-04. The greatest total pathway HI for on-TCAAP workers is 1.4E-04 for receptor locations 116 North and 116 South. Similarly, the greatest risk for persons living in on-TCAAP Army housing is estimated as 1.4E-04 for receptor location BD2 (children 0 to 6 years old). Under RME conditions, all HQs and total pathway HIs are less than 6E-04. The greatest total pathway HI for on-TCAAP workers is 5.0E-04 for receptor locations 116 North and 116 South. Similarly, the greatest risk for persons living in on-TCAAP Army housing is estimated as 2.4E-04 for receptor location BD2 (children 0 to 6 years old).

For chronic exposures to ambient air under probable conditions, all HQs and total pathway HIs are less than 2E-03. The greatest total pathway HI for on-TCAAP workers is 1.4E-03 for receptor locations 116 North and 116 South. Similarly, the greatest risk for persons living in on-TCAAP Army housing is estimated as 1.4E-03 for receptor location BD2. Under RME conditions, all HQs and total pathway HIs are less than 6E-03. The greatest HI for on-TCAAP workers is 5.0E-03 for receptor locations 116 North and 116 South. Similarly, the greatest risk for persons living in on-TCAAP Army housing is 2.4E-03 (children 0 to 6 years old) for receptor location BD2.

5.2.1.3 Surface Water and Sediment -- On-TCAAP (Current Land Use Condition)

On-TCAAP employees (primarily maintenance workers) may be exposed to surface water via dermal contact or incidental ingestion and to sediment via dermal contact. Carcinogenic risks for these pathways are discussed first, followed by noncarcinogenic risks.

Carcinogenic Risks

Carcinogenic risks associated with exposure to surface water under probable exposure and RME conditions are presented in Tables D-9 (dermal contact) and D-10 (incidental ingestion).

Under probable exposure conditions, risks associated with dermal contact with surface water are evaluated only for Exposure Area K because potential carcinogens were not measured above background levels in surface water bodies in other areas. Chemical-specific risks are all less than or equal to 2E-09; the total pathway risk is 2E-09. Under RME conditions, chemical-specific risks are all less than or equal to 2E-08; the total pathway risk is 2E-08.

Incidental ingestion of surface water is assumed to take place only under RME conditions. Again, risks are evaluated only for Exposure Area K. Chemical-specific risks are all less than 1E-09; the total pathway risk is 3E-10.

Noncarcinogenic Risks

Noncarcinogenic risks associated with acute exposures to surface water and sediment under probable exposure and RME conditions are presented in Tables D-11 (dermal contact--surface water), D-12 (incidental ingestion--surface water), and D-13 (dermal contact--sediment). Noncarcinogenic risks associated with chronic exposures are presented in Tables D-14 (dermal contact--surface water), D-15 (incidental ingestion--surface water), and D-16 (dermal contact--sediment). Acute exposures for the exposure pathways are discussed first, followed by chronic exposures.

For acute exposure to surface water via dermal contact under probable exposure conditions, all chemical-specific HQs and total pathway HIs are less than 1E-01. The maximum chemical-specific HQ is 9.2E-03 for thallium in Exposure Area C, and the maximum total pathway HI is 1.7E-02 in Exposure Area C. Under RME conditions, all chemical-specific HQs and total pathway HIs are less than one. The maximum chemical-specific HQ is 1.1E-01 for thallium in Round Lake, and the maximum total pathway HI is 1.1E-01 at Round Lake.

Acute exposure to surface water via incidental ingestion is assumed to occur only under RME conditions. Results show that all chemical-specific HQs and the total pathway HI are less than 1E-01. The maximum total pathway HI is 1.1E-02 in Exposure Area C.

For dermal contact with sediment, all chemical-specific HQs and the total pathway HI are less than 1E-01 under probable exposure conditions and are less than one under RME conditions. The maximum total pathway HIs are 8.5E-02 and 5.3E-01 at Sunfish Lake under probable exposure and RME conditions, respectively.

For chronic exposure to surface water via dermal contact under probable exposure conditions, all chemical-specific HQs and total pathway HIs are less than 1E-03. The maximum

chemical-specific HQ is 2.5E-04 for thallium in Exposure Area C, and the maximum total pathway HI is 3.4E-04 in Exposure Area C. Under RME conditions, all chemical-specific HQs and total pathway HIs are less than 1E-02. The maximum chemical-specific HQ is 5.9E-03 for thallium at Round Lake, and the maximum total pathway HI is 5.9E-03 at Round Lake.

For incidental ingestion of surface water under RME conditions, all chemical-specific HQs and the total pathway HI are less than 1E-03. The maximum total pathway HI is 6.2E-04 at Round Lake.

For dermal contact with sediment, all chemical-specific HQs and the total pathway HIs are less than 1E-03 under probable exposure conditions and are less than 1E-02 under RME conditions. The maximum total pathway HIs are 2.3E-04 and 2.9E-03 at Sunfish Lake under probable exposure and RME conditions, respectively.

5.2.2 Off-TCAAP -- Current Land Use Condition

Potential off-TCAAP exposures under current land use conditions are associated with the following media: ground water, air, and surface water and sediment. For each of these media, carcinogenic risks are discussed first, followed by noncarcinogenic risks.

5.2.2.1 Ground Water -- Off-TCAAP (Current Land Use Conditions)

Most residents living off-TCAAP are assumed to drink water from municipal sources. However, a small number of residents may rely on private drinking water wells for their potable water. Residents may be exposed to ground water via ingestion, dermal contact, and inhalation of volatiles released during showering. Risks associated with these pathways are discussed below, first for exposures associated with Unit 1 ground water and then for exposures associated with Unit 3 and Unit 4 ground water. Carcinogenic risks are discussed first, followed by noncarcinogenic risks.

Carcinogenic Risks - Unit 1

Risks associated with exposures to Unit 1 ground water are evaluated only for Exposure Area S. Estimated upper-bound excess lifetime cancer risks under probable exposure and RME conditions, respectively, are presented in Tables D-17 and D-18 (ingestion), D-19 and D-20 (dermal contact), and D-21 and D-22 (inhalation of volatiles).

For ingestion of Unit 1 ground water under probable exposure conditions, all chemical-specific risks are less than 1E-06, with a maximum of 4E-08 for chloroform. The total pathway risk is 4E-08. Under RME conditions, all chemical-specific risks are less than 1E-06, with a maximum of 3E-07 for chloroform. The total pathway risk is 2E-07.

Risks associated with dermal contact are slightly lower than those associated with ingestion. Under probable exposure conditions, all chemical-specific risks are less than 1E-07, with a maximum of 6E-08 for chloroform. The total pathway risk is 6E-08. Under RME conditions, all chemical-specific risks are less than 1E-06, with a maximum of 3E-07 for chloroform. The total pathway risk is 3E-07.

Results for inhalation of volatiles indicate that the risks are approximately in the same order of magnitude as those for ingestion. Specifically, under probable exposure conditions, all chemical-specific risks are less than 1E-06, with a maximum of 2E-07 for chloroform. The total pathway risk is 2E-07. Under RME conditions, the maximum chemical-specific risk is 2E-06 for chloroform. The total pathway risk is 2E-06.

Carcinogenic Risks - Unit 3

Carcinogenic risks associated with exposures to Unit 3 ground water under probable exposure and RME conditions, respectively, are presented in Tables D-23 and D-24 (ingestion), D-25 and D-26 (dermal contact), and D-27 and D-28 (inhalation of volatiles).

For ingestion of Unit 3 ground water under probable exposure conditions, chemical-specific risks equal or exceed the U.S. EPA bench mark of 1E-06 in Exposure Areas 3Z, 3Y, 3X, 3W, and 3V, with a maximum of 3E-04 for 1,1-dichloroethene in Exposure Areas 3Y and 3Z and for trichloroethene in Exposure Area 3Z. Total pathway risks exceed 1E-06 in Exposure Areas 3Z, 3Y, 3X, 3W, and 3V and range from 4E-06 in Exposure Areas 3W and 3V to 6E-04 in Exposure Area 3Z. Under RME conditions, individual chemical-specific risks equal or exceed 1E-05 in Exposure Areas 3Z, 3Y, 3X, 3W, and 3V, with a maximum of 1E-03 for 1,1-dichloroethene in Exposure Areas 3Y and 3Z and for trichloroethene in Exposure Area 3Z. Total pathway risks range from 2E-05 in Exposure Areas 3V and 3W to 2E-03 in Exposure Areas 3Y and 3Z.

Risks associated with dermal contact are slightly lower than those associated with ingestion. Under probable exposure conditions, individual chemical-specific risks equal or exceed 1E-06 in Exposure Areas 3V, 3W, 3X, 3Y, and 3Z. The maximum chemical-specific risk is 4E-04 for 1,1-dichloroethene in Exposure Areas 3Y and 3Z and for trichloroethene in

Exposure Area 3Z. All total pathway risks exceed 1E-06, with a maximum of 9E-04 in Exposure Area 3Z. Under RME conditions, individual chemical-specific risks exceed 1E-06 in Exposure Areas 3V, 3W, 3X, 3Y, and 3Z, with a maximum of 3E-03 for 1,1-dichloroethene in Exposure Areas 3Y and 3Z. All total pathway risks exceed 1E-05, with a maximum of 6E-03 in Exposure Area 3Z.

Risks for inhalation of volatiles are approximately in the same order of magnitude as those for ingestion. Specifically, under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas 3V, 3W, 3X, 3Y, and 3Z, with a maximum of 3E-04 for 1,1-dichloroethene in Exposure Area 3Z. Total pathway risks exceed 1E-06 in the same exposure areas and range from 2E-06 in Exposure Areas 3V and 3W to 5E-04 in Exposure Area 3Z. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas 3V, 3W, 3X, 3Y, and 3Z, with a maximum of 2E-03 for 1,1-dichloroethene in Exposure Areas 3Y and 3Z. Total pathway risks exceed 1E-06 in the same exposure areas and range from 2E-05 in Exposure Areas 3V and 3W to 4E-03 in Exposure Area 3Z.

Carcinogenic Risks - Unit 4

Carcinogenic risks associated with exposures to Unit 4 ground water under probable exposure and RME conditions, respectively, are presented in Tables D-29 and D-30 (ingestion), D-31 and D-32 (dermal contact), and D-33 and D-34 (inhalation of volatiles).

For ingestion of Unit 4 ground water under probable exposure conditions, individual chemical-specific risks equal or exceed 1E-06 in Exposure Areas 4W, 4X, 4Y, and 4Z, with a maximum of 2E-04 for 1,1-dichloroethene in Exposure Area 4Z. Total pathway risks exceed 1E-05 in Exposure Areas 4W, 4X, 4Y, and 4Z and range from 2E-05 in Exposure Areas 4W and 4Y to 3E-04 in Exposure Area 4Z. Similarly, under RME conditions, individual chemical-specific risks equal or exceed 1E-05 in Exposure Areas 4W, 4X, 4Y, and 4Z, with a maximum of 1E-03 for 1,1-dichloroethene in Exposure Area 4Z. Total pathway risks equal or exceed 1E-04 in Exposure Areas 4W and 4Z and range from 4E-05 in Exposure Areas 4X and 4Y to 1E-03 in Exposure Area 4Z.

Under probable exposure conditions, individual chemical-specific risks associated with dermal contact with Unit 4 ground water exceed 1E-06 in Exposure Areas 4W, 4Y, and 4Z, with a maximum of 6E-05 for 1,1-dichloroethane and trichloroethene in Exposure Area 4Z. Total pathway risks equal or exceed 1E-05 in Exposure Areas 4W, 4Y, and 4Z and exceed 1E-06 in Exposure Area 4X, with a maximum of 2E-04 in Exposure Area 4Z. Under RME conditions, individual chemical-specific risks exceed 1E-06 in Exposure Areas 4W, 4X, 4Y, and 4Z, with a

maximum of 4E-04 for 1,1-dichloroethane in Exposure Area 4Z. Total pathway risks equal or exceed 1E-04 in Exposure Areas 4W, 4Y, and 4Z and exceed 1E-05 in Exposure Area 4X, with a maximum of 3E-03 in Exposure Area 4Z.

Risks for inhalation of volatiles are similar to those for ingestion. Specifically, under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas 4W, 4Y, and 4Z, with a maximum of 2E-04 for 1,1-dichloroethene in Exposure Area 4Z. Total pathway risks equal or exceed 1E-06 in Exposure Areas 4W, 4X, 4Y, and 4Z and range from 1E-06 in Exposure Area 4X to 2E-04 in Exposure Area 4Z. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas 4W, 4X, 4Y, and 4Z, with a maximum of 1E-03 for 1,1-dichloroethene in Exposure Area 4Z. Total pathway risks exceed 1E-06 in the same exposure areas and range from 1E-05 in Exposure Area 4X to 1E-03 in Exposure Area 4Z.

Noncarcinogenic Risks -- Unit 1

Noncarcinogenic risks associated with acute exposures under probable exposure and RME conditions, respectively, are presented in Tables D-35 and D-36 (ingestion) and D-37 and D-38 (dermal contact). Noncarcinogenic risks associated with chronic exposures are presented in Tables D-39 and D-40 (ingestion), and D-41 and D-42 (dermal contact). Acute exposures are discussed first, followed by chronic exposures.

For acute exposure to Unit 1 ground water via ingestion under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 2.9E-03 for chloroform (children 2 to 4 years old). Total pathway HIs are all less than one and range from 1.3E-03 (adults) to 3.7E-03 (children 2 to 4 years old). Under RME conditions, all chemical-specific HQs are less than one with a maximum of 5.6E-03 for chloroform (children 2 to 4 years old). Total pathway HIs are less than one and range from 2.5E-03 (children 15 to 19 years old) to 7E-03 (children 2 to 4 years old).

For acute exposure to Unit 1 ground water via dermal contact under probable exposure conditions, all chemical-specific HQs are less than 1E-02, with a maximum of 3.1E-03 for chloroform (children 0 to 6 years old) in Exposure Area S. All total pathway HIs are less than 1E-02, with a maximum of 3.1E-03 (children 0 to 6 years old). Under RME conditions, all chemical-specific HQs are less than 1E-02, with a maximum of 9.8E-03 for chloroform (children 0 to 6 years old). Total pathway HIs are less than 1E-01, with a maximum of 1.0E-02 (children 0 to 6 years old).

For chronic exposures to Unit 1 ground water via ingestion under probable exposure conditions, all chemical-specific HQs are less than one, with a maximum of 2.9E-03 for chloroform (children 2 to 4 years old). Total pathway HIs are less than one and range from 1.3E-03 (adults) to 3.7E-03 (children 2 to 4 years old). Under RME conditions, all chemical-specific HQs are less than one, with a maximum of 5.6E-03 for chloroform (children 2 to 4 years old). Total pathway HIs are less than one and range from 2.5E-03 (children 15 to 19 years old) to 7.0E-03 (children 2 to 4 years old).

Under probable exposure conditions, all chemical-specific HQs associated with chronic exposure via dermal contact with Unit 1 ground water are less than 1E-02, with a maximum of 3.1E-03 for chloroform (children 0 to 6 years old). Total pathway HIs are less than 1E-02, with a maximum of 4.0E-03 (children 0 to 6 years old). Under RME conditions, all chemical-specific HQs are less than 1E-02, with a maximum of 9.8E-03 for chloroform (children 0 to 6 years old). Total pathway HIs are less than 1E-01, with a maximum of 1.2E-02 (children 0 to 6 years old).

Results for chronic exposures to Unit 1 ground water via inhalation cannot be quantitatively calculated because inhalation RfDs are not available for the identified chemicals of potential concern, chloroform and 1,2-dichloroethene; therefore, Tables D-43 and D-44 which were set aside for inhalation results do not appear in this report. Refer to Chapter 4 and Appendix I for discussion of the toxicity of these chemicals.

Noncarcinogenic Risks -- Unit 3

Noncarcinogenic risks associated with acute exposures under probable exposure and RME conditions, respectively, are presented in Tables D-45 and D-46 (ingestion) and D-47 and D-48 (dermal contact). Noncarcinogenic risks associated with chronic exposures are presented in Tables D-49 and D-50 (ingestion), D-51 and D-52 (dermal contact), and D-53 and D-54 (inhalation). Acute exposures are discussed first, followed by chronic exposures.

For acute exposure to Unit 3 ground water via ingestion under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 2.4E-01 for 1,1-dichloroethene (children 2 to 4 years old) in Exposure Area 3Z. Total pathway HIs are all less than one in all exposure areas and range from 7.1E-04 (adults) in Exposure Area 3W to 6.8E-01 (children 2 to 4 years old) in Exposure Area 3Z. Under RME conditions, all chemical-specific HQs are less than one, with a maximum of 5.0E-01 for 1,1-dichloroethene (children 2 to 4 years old) in Exposure Area 3Z. Total pathway HIs equal or exceed one only in Exposure Area 3Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HI is less

than one) and range from 2.0E-03 (children 15 to 19 years old) in Exposure Area 3W to 1.1E+00 (children 2 to 4 years old) in Exposure Area 3Z.

For acute exposure to Unit 3 ground water via dermal contact under probable exposure conditions, all chemical-specific HQs are less than one, with a maximum of 3.0E-01 for 1,1-dichloroethene (children 0 to 6 years old) in Exposure Area 3Z. All total pathway HIs are less than one, with a maximum of 4.9E-01 (children 0 to 6 years old) in Exposure Area 3Y. Similarly, under RME conditions, all chemical-specific HQs are less than one with a maximum of 9.9E-01 for 1,1-dichloroethene (children 0 to 6 years old) in Exposure Area 3Z. Total pathway HIs exceed one in Exposure Areas 3Y and 3Z, with a maximum of 1.3E+00 in Exposure Area 3Y (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for both Exposure Area 3Y and Exposure Area 3Z are less than one).

For chronic exposures to Unit 3 ground water via ingestion under probable exposure conditions, all chemical-specific HQs are less than one, with a maximum of 7.4E-01 for 1,1,2-trichloroethane in Exposure Area 3Y. Total pathway HIs exceed one only in Exposure Areas 3Y and 3Z and range from 2.0E-03 (children 15-19 years old and adults) in Exposure Area 3W to 1.2E+00 (children 2 to 4 years old) in Exposure Area 3Y (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for both Exposure Area 3Y and Exposure Area 3Z are less than one). Under RME conditions, individual chemical-specific HQs equal or exceed one only in Exposure Area 3Y, with a maximum of 2.2E+00 for 1,1,2-trichloroethane (children 2 to 4 years old). Total pathway HIs exceed one in Exposure Areas 3Y and 3Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HI for Exposure Area 3Z is less than one), and range from 5.6E-03 (children 15 to 19 years old) in Exposure Area 3W to 3.0E+00 (children 2 to 4 years old) in Exposure Area 3Y.

Under probable exposure conditions, all chemical-specific HQs associated with dermal contact with Unit 3 ground water are less than one, with a maximum of 8.2E-01 for 1,1,2-trichloroethane (children 0 to 6 years old) in Exposure Area 3Y. Total pathway HIs exceed one only in Exposure Area 3Y (1.3E+00) (children 0 to 6 years old) (evaluation of target organ- and chemical effect-specific HQs indicate that the true HI for Exposure Area 3Y is less than one). Under RME conditions, chemical-specific HQs exceed one only in Exposure Area 3Y, with a maximum of 3.8E+00 for 1,1,2-trichloroethane (children 0 to 6 years old). Total pathway HIs exceed one in Exposure Areas 3Y and 3Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area 3Z are less than one) and range from 1.6E-02 (adults) in Exposure Area 3W to 5.3E+00 (children 0 to 6) in Exposure Area 3Y.

For chronic exposures to Unit 3 ground water via inhalation under probable exposure conditions, all chemical-specific HQs are less than one, with a maximum of 1.9E-02 for 1,1-dichloroethene in Exposure Area 3Y. Total pathway HIs are less than one and range from 1.6E-05 (adults) in Exposure Area 3V to 3.1E-02 (children 0 to 6 years old) in Exposure Area 3Y. Under RME conditions, all chemical-specific HQs are less than one, with a maximum of 9.0E-02 for 1.1-dichloroethene in Exposure Area 3Y. Total pathway HIs are all less than one and range from 1.2E-04 (adults) in Exposure Area 3V to 1.3E-01 (children 0 to 6 years old) in Exposure Area 3Z.

Noncarcinogenic Risks -- Unit 4

Noncarcinogenic risks associated with acute exposures under probable and RME conditions, respectively, are presented in Tables D-55 and D-56 (ingestion) and D-57 and D-58 (dermal contact). Noncarcinogenic risks associated with chronic exposures under probable and RME conditions, respectively, are presented in Tables D-59 and D-60 (ingestion), D-61 and D-62 (dermal contact), and D-63 and D-64 (inhalation). Acute exposures for each of the exposure pathways are discussed first, followed by chronic exposures.

For acute exposure to Unit 4 ground water via ingestion under probable exposure conditions, chemical-specific HQs equal or exceed one only for antimony and only in Exposure Area 4X, with a maximum of 5.2E+00 (children 2 to 4 years old). Total pathway HIs exceed one in Exposure Areas 4X and 4Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area 4Z are less than one), and range from 5.4E-03 (adults) in Exposure Area 4Y to 6.5E+00 (children 2 to 4 years old) in Exposure Area 4X. Under RME conditions, chemical-specific HQs equal or exceed one only for antimony and only in Exposure Area 4X, with a maximum of 5.5E+00 (children 2 to 4 years old). Total pathway HIs exceed one in Exposure Areas 4X and 4Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area 4Z are less than one) and range from 7.3E-03 (children 15 to 19 years old) in Exposure Area 4Y to 6.2E+00 (children 2 to 4 years old) in Exposure Area 4X.

Noncarcinogenic risks via dermal contact are slightly less than those for ingestion. Under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 2.0E-01 for 1,1-dichloroethene (children 0 to 6 years old) in Exposure Area 4Z. All total pathway HIs are less than one, with a maximum of 2.4E-01 (children 0 to 6 years old) in Exposure Area 4Z. Under RME conditions, all chemical-specific HQs are less than one, with a maximum of 6.9E-01 for 1,1,-dichloroethene (children 0 to 6 years old) in Exposure Area 4Z.

All total pathway HIs are less than one, with a maximum of 8.4E-01 (children 0 to 6 years old) in Exposure Area 4Z.

For chronic exposures to Unit 4 ground water via ingestion under probable exposure conditions, chemical-specific HQs equal or exceed one only for antimony and only in Exposure Area 4X, with a maximum of 5.2E+00 (children 2 to 4 years old). Total pathway HIs equal or exceed one in Exposure Areas 4X and 4Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area 4Z are less than one) with a maximum of 6.7E+00 (children 2 to 4 years old) in Exposure Area 4X. Under RME conditions, chemical-specific HQs equal or exceed one only in Exposure Area 4X, with a maximum of 5.5E+00 for antimony (children 2 to 4 years old). Total pathway HIs exceed one in Exposure Areas 4X and 4Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area 4Z are less than one), with a maximum of 7.4E+00 (children 2 to 4 years old) in Exposure Area 4X.

In contrast, for chronic exposures to Unit 4 ground water via dermal contact under probable exposure conditions, all chemical-specific HQs are less than 1E-01, with a maximum of 9.1E-02 for antimony (children 2 to 4 years old) in Exposure Area 4X. Total pathway HIs are all less than 1.0 and range from 9.2E-06 (adults) in Exposure Area 4Y to 1.1E-02 (children 0 to 6 years old) in Exposure Area 4X. Under RME conditions, all chemical-specific HQs are less than one with a maximum of 3.3E-01 for 1,2-dichloroethane (children 0 to 6 years old) in Exposure Area 4Z. Total pathway HIs exceed one only in Exposure Area 4Z (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area 4Z are less than one), with a maximum of 1.2E+00 (children 0 to 6 years old).

Under probable exposure conditions, all chemical-specific HQs associated with chronic inhalation of volatiles are less than 1E-01, with a maximum of 1.0E-02 for 1,1,1-trichloroethane in Exposure Area 4Z. All total pathway HIs are less than 1.0E-01, with a maximum of 1.9E-02 (children 0 to 6 years old) in Exposure Area 4Z. Under RME conditions, all chemical-specific HQs are less than 1.0E-01, with a maximum of 5.1E-02 for 1,1,1-trichloroethane (children 0 to 6 years old) in Exposure Area 4Z. Total pathway HIs are less than one with a maximum of 1.0E-01 (children 0 to 6 years old) in Exposure Area 4Z.

5.2.2.2 Air -- Off-TCAAP (Current Land Use Conditions)

As discussed in Section 5.2.1.2, for evaluating carcinogenic risks associated with inhalation of ambient air, all VOC emissions from on-TCAAP remedial actions are assumed to be

trichloroethene. For evaluating noncarcinogenic risks, all VOC emissions capable of causing noncarcinogenic effects are assumed to be 1,1,1-trichloroethane.

Carcinogenic Risks

Carcinogenic risks associated with inhalation of ambient air under probable exposure and RME conditions, respectively, are presented in Tables D-7 and D-8. Under probable exposure conditions, risks are all less than 1E-06 at off-TCAAP receptor locations and range from 2E-08 (Silver Lake) to 2E-07 (Snelling Ave., Shoreview, and Triangle).

Under RME conditions, risks are all less than 1E-06 at off-TCAAP receptor locations and range from 5E-08 (Silver Lake) to 7E-07 (Snelling Ave.). Some residents may live and work off-TCAAP. However, as described earlier, risks at exposure points are calculated based on 24-hour-per-day exposure at home.

Noncarcinogenic Risks

Noncarcinogenic risks associated with acute exposures to ambient air under probable exposure and RME conditions are presented in Tables D-7a and D-8a, respectively. Noncarcinogenic risks associated with chronic exposures under probable exposure and RME conditions are presented in Tables D-7b and D-8b, respectively. Acute exposures are discussed first, followed by chronic exposures.

For acute exposures to ambient air under probable conditions, HQs and total pathway HIs are all less than 2E-04 at off-TCAAP receptor locations and range from 1.5E-06 (adults) at Silver Lake to 1.3E-04 (children 0 to 6 years old) at the triangle immediately southwest of TCAAP. Under RME conditions, HQs and total pathway HIs are all less than 3E-04 and range from 3.0E-06 (adults) at Silver Lake to 2.2E-04 (children 0 to 6 years old) at the triangle.

For chronic exposures to ambient air under probable conditions, HQs and total pathway HIs are all less than 2E-03 at off-TCAAP receptor locations and range from 1.5E-05 (adults) at Silver Lake to 1.3E-03 (children 0 to 6 years old) at the triangle. Under RME conditions, HQs and total pathway HIs are all less than 3E-03 and range from 3.0E-05 (adults) at Silver Lake to 2.2E-03 (children 0 to 6 years old) at the triangle.

5.2.2.3 Surface Water and Sediment -- Off-TCAAP (Current Land Use Conditions)

Off-TCAAP residents may be exposed to chemicals in surface water via dermal contact, incidental ingestion, and ingestion of fish that have bioaccumulated the chemicals. Residents may also be exposed to sediment via dermal contact. As discussed in Chapter 3, under current conditions, off-TCAAP exposures are evaluated only for Round Lake and the portion of Rice Creek from the western boundary of TCAAP to the point where the creek enters Long Lake. Ingestion of fish is evaluated only for Rice Creek. Carcinogenic risks for these pathways are discussed first, followed by noncarcinogenic risks.

Carcinogenic Risks

No carcinogenic chemicals were measured in surface water and sediment above background concentrations at the potential off-TCAAP exposure points described above. Therefore, no upper-bound excess lifetime cancer risks are associated with off-TCAAP exposure to surface water and sediment.

Noncarcinogenic Risks

Noncarcinogenic risks associated with acute exposures to surface water under probable exposure conditions and RME conditions are presented in Tables D-65 and D-66 (dermal contact), D-67 (incidental ingestion; evaluated only under RME conditions), and D-68 (ingestion of fish). Noncarcinogenic risks associated with acute exposures to sediment under probable and RME conditions, respectively, are presented in Tables D-69 and D-70 (dermal contact). Noncarcinogenic risks associated with chronic exposures to surface water under probable and RME conditions, respectively, are presented in Tables D-71 and D-72 (dermal contact), D-73 (incidental ingestion; evaluated only under RME conditions), and D-74 (ingestion of fish). Noncarcinogenic risks associated with chronic exposures to sediment under probable and RME conditions, respectively, are presented in Tables D-75 and D-76 (dermal contact). Acute exposures for each of the exposure pathways are discussed first, followed by chronic exposures.

Under probable exposure conditions, all chemical-specific HQs and total pathway HIs associated with acute exposure to surface water via dermal contact are less than 1E-01; under RME conditions, all chemical-specific HQs and total pathway HIs are less than one. The maximum total pathway HIs are 2.8E-02 (children 0 to 6 years old) in Exposure Area C and 2.1E-01 (children 0 to 6 years old) at Round Lake under probable and RME conditions, respectively.

For acute exposure to surface water via incidental ingestion, all chemical-specific HQs and the total pathway HIs are less than 1E-01. Maximum chemical-specific HQs and total pathway HIs are 1.2E-02 (children 0 to 18 years old) at Round Lake. For exposures via ingestion of fish from Rice Creek, the chemical-specific HQ and total pathway HI are less than one under probable conditions for all age groups, with a maximum HQ and total pathway HI of 9.4E-01 (silver; children 0 to 9 years old). Under RME conditions, the chemical-specific HQ and total pathway HI exceed one only for children 0 to 9 years old, with a maximum HQ and total pathway HI of 1.3E+00 (silver).

For dermal contact with sediment under probable exposure conditions, all chemical-specific HQs and the total pathway HI are less than one, with a maximum of 1.6E-01 for antimony (children 0 to 6 years old) at Sunfish Lake. For dermal contact with sediment under RME conditions, chemical-specific HQs and total pathway HIs exceed one for antimony at Sunfish Lake with values of 1.6E+00 and 1.4E+00 for children 0 to 6 and 7 to 12 years old, respectively.

For chronic exposure to surface water via dermal contact, all chemical-specific HQs and total pathway HIs are less than 1E-02 under probable exposure conditions and are less than 1E-01 under RME conditions. The maximum chemical-specific HQ (thallium) and total pathway HI (children 0 to 6 years old) are 5.4E-03 in Exposure Area C and 4.0E-02 at Round Lake under probable exposure and RME conditions, respectively.

For exposure to surface water via incidental ingestion, all chemical-specific HQs and the total pathway HI are less than 1E-02. The maximum chemical-specific HQ (thallium) and total pathway HI (children 0 to 18 years old) are 2.3E-03 at Round Lake. Similarly, for chronic exposure via ingestion of fish, all chemical-specific HQs and the total pathway HI are less than 1E-01 under probable exposure conditions and are less than one under RME conditions. The maximum chemical-specific HQ (silver) and total pathway HI (children 0 to 9 years old) are 9.5E-02 and 2.5E-01 under probable exposure and RME conditions, respectively.

For dermal contact with sediment, all chemical-specific HQs and the total pathway HIs are less than 1E-02 under probable exposure conditions. The maximum chemical-specific HQ (antimony) and total pathway HI (children 0 to 6 years old) are 3.1E-03 at Sunfish Lake. Under RME conditions, all chemical-specific HQs and total pathway HIs are less than 1E-01. The maximum chemical-specific HQ (antimony) and total pathway HI (children 0 to 6 years old) are 3.1E-02 at Sunfish Lake.

5.3 FUTURE LAND USE CONDITIONS

Risks under future land use conditions associated with each of the exposure pathways described in Chapter 3 are discussed below for on-TCAAP and off-TCAAP exposures.

Risks are evaluated under both current and future land use conditions and under both probable exposure and RME conditions. For each exposure pathway, carcinogenic risks are discussed first, followed by noncarcinogenic risks. Summary tables listing pathway-specific risks are presented in Appendix D. In Tables D-1 through D-158, for media other than ground water, chemical-specific results are presented only for chemicals that contribute most of the risk. For carcinogenic risks, chemical-specific results are presented only for chemicals whose individual upper-bound excess lifetime cancer risks are greater than or equal to 1E-07. However, the pathway-specific totals include all individual chemical-specific risks associated with a given pathway. Similarly, for noncarcinogenic risks, chemical-specific risks are generally presented only for chemicals whose individual HQs are greater than or equal to 1E-01 under acute exposure conditions. However, the pathway-specific HIs include all chemical-specific HQs associated with a given pathway. If no chemical-specific risks are greater than or equal to 1E-07 (upper-bound excess lifetime cancer risk) or 1E-01 (HQ), then the results for the exposure areas with the greatest risks are presented.

In contrast, for exposure to ground water, all chemical-specific results are presented for both carcinogenic and noncarcinogenic risks. This approach is used because ground water is the most contaminated medium associated with TCAAP and because ground water will be the focus of remediation efforts both on- and off-TCAAP.

5.3.1 On-TCAAP -- Future Land Use Conditions

Potential on-TCAAP exposures under future land use conditions are associated with the following media: ground water, surface and subsurface soils, surface water and sediment, air, soil gas, and home-grown vegetables and fruits.

5.3.1.1 Ground Water -- On-TCAAP (Future Land Use Conditions)

Future land uses include residential and commercial or industrial development within current TCAAP boundaries. In this scenario, at least some residences obtain potable water from private wells completed in Unit 1, 3, or 4. In reality, such private wells are unlikely for three reasons: (1) municipal water is readily available; (2) the Village of Arden Hills prohibits use of private wells as drinking water sources; and (3) residents will almost certainly be aware of any

ground-water contamination in their area. Private wells may be installed and used if municipal water becomes unavailable, current village ordinances change, or individual residents choose to violate the ordinances. In any case, the following risk estimates probably represent upper-bound conditions.

Residents may be exposed to ground water via ingestion, dermal contact, and inhalation of volatiles released during showering. Risks associated with these pathways are discussed for exposures associated with Unit 1, 3, and 4 ground water. Carcinogenic risks are discussed first, followed by noncarcinogenic risks.

Carcinogenic Risks -- Unit 1

Carcinogenic risks associated with exposures to Unit 1 ground water under probable exposure and RME conditions, respectively, are presented in Tables D-77 and D-78 (ingestion), D-79 and D-80 (dermal contact), and D-81 and D-82 (inhalation of volatiles). Each of these exposure pathways is discussed below.

For exposure via ingestion under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas A, C, H, I, J, and K, with a maximum of 2E-03 for trichloroethene in Exposure Area K. Total pathway risks exceed 1E-06 in the same exposure areas and range from 4E-06 in Exposure Areas C and J to 2E-03 in Exposure Area K. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas A, C, H, I, J, and K, with a maximum of 2E-02 for trichloroethene in Exposure Area K. Total pathway risks exceed 1E-06 in the same exposure areas, and range from 1E-05 in Exposure Area C to 2E-02 in Exposure Area K.

For dermal contact with Unit 1 ground water under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 only in Exposure Areas A, I, J, and K, with a maximum of 3E-03 for trichloroethene in Exposure Area K. Total pathway risks exceed 1E-06 in Exposure Areas A, I, J, and K. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas A, C, H, I, and K, with a maximum of 7E-03 for trichloroethene in Exposure Area K. Total pathway risks exceed 1E-06 in the same exposure areas, with a maximum of 7E-03 in Exposure Area K.

For inhalation of volatiles from Unit 1 ground water, risks are approximately in the same order of magnitude as those for ingestion. Under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas A, I, and K, with a maximum of 1E-03 for trichloroethene in Exposure Area K. Total pathway risks exceed 1E-06 in Exposure Areas A,

I, and K, with a maximum of 1E-03 in Exposure Area K. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas A, I, J, and K, with a maximum of 2E-02 for trichloroethene in Exposure Area K. Total pathway risks exceed 1E-06 in the same exposure areas and range from 1E-06 in Exposure Area J to 2E-02 in Exposure Area K.

Carcinogenic Risks -- Unit 3

Carcinogenic risks associated with exposures to Unit 3 ground water under probable exposure and RME conditions, respectively, are presented in Tables D-83 and D-84 (ingestion), D-85 and D-86 (dermal contact), and D-87 and D-88 (inhalation of volatiles).

For exposure via ingestion under probable exposure conditions, individual chemical-specific risks equal or exceed 1E-06 in Exposure Areas D, E, F, G, I, K, 129-5, 129-15, X3, and X4, with a maximum of 2E-03 for trichloroethene in Exposure Area D. Total pathway risks equal or exceed 1E-06 in Exposure Areas D, E, F, G, I, K, 129-5, 129-15, X3, and X4 and range from 5E-08 in Exposure Area C to 2E-03 in Exposure Areas D, G, and X3. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas D, E, F, G, H, I, K, 129-5, 129-15, X3, and X4 and equal or exceed 1E-05 in Exposure Areas D, F, G, I, 129-15, X3, and X4, with a maximum of 2E-02 for trichloroethene in Exposure Area D. Total pathway risks exceed 1E-06 in Exposure Areas D, E, F, G, H, I, K, 129-5, 129-15, X3, and X4 and range from 2E-07 in Exposure Area C to 2E-02 in Exposure Area D.

For exposures via dermal contact under probable exposure conditions, individual chemical-specific risks equal or exceed 1E-06 in Exposure Areas D, E, F, G, I, 129-15, and X3, with a maximum of 4E-03 for trichloroethene in Exposure Area D. Total pathway risks exceed 1E-06 in Exposure Areas D, E, F, G, I, 129-15, and X3, with a maximum of 4E-03 in Exposure Area D. Under RME conditions, individual chemical-specific risks exceed 1E-06 in Exposure Areas D, E, F, G, H, I, 129-3, 129-5, 129-15, X2, X3, and X4, with a maximum of 4E-02 for trichloroethene in Exposure Area D. Total pathway risks exceed 1E-06 in Exposure Areas D, E, F, G, H, I, 129-3, 129-5, 129-15, X2, X3, and X4, with a maximum of 4E-02 in Exposure Area D.

For exposures via inhalation of volatiles, the risks are approximately in the same order of magnitude as those for ingestion. Specifically, under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas D, F, G, I, 129-15, and X3, with a maximum of 2E-03 for trichloroethene in Exposure Area D. Total pathway risks exceed 1E-06 in the same exposure areas and range from 2E-08 in Exposure Area E to 2E-03 in Exposure Area D. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas D,

F, G, H, I, 129-5, 129-15, and X3, with a maximum of 2E-02 for trichloroethene in Exposure Area D. Total pathway risks exceed 1E-06 in the same exposure areas and range from 5E-08 in Exposure Area E to 2E-02 in Exposure Area D.

Carcinogenic Risks -- Unit 4

Carcinogenic risks associated with exposures to Unit 4 ground water under probable exposure and RME conditions, respectively, are presented in Tables D-89 and D-90 (ingestion), D-91 and D-92 (dermal contact), and D-93 and D-94 (inhalation of volatiles). On-TCAAP Unit 4 ground water in exposure Area X3 was divided into upper, middle, and deep sections to address stratification of contaminant concentrations and to separately evaluate the vertical portion of the aquifer pumped by SC wells.

For exposure via ingestion under probable exposure conditions, individual chemical-specific risks equal or exceed 1E-06 within Exposure Areas X3-Upper, X3-Middle, and X3-Deep, with a maximum of 2E-04 for arsenic, 1,1-dichloroethane, and trichloroethene in Exposure Area X3-Upper. Total pathway risks exceed 1E-06 in Exposure Areas X3-Upper, X3-Middle, and X3-Deep and range from 2E-07 in Exposure Area I Upper to 7E-04 in Exposure Area X3-Upper. Under RME conditions, individual chemical-specific risks equal or exceed 1E-06 in Exposure Areas I, X3-Upper, X3-Middle, and X3-Deep, with a maximum of 1E-03 for arsenic in Exposure Area X3-Upper. Total pathway risks exceed 1E-06 in Exposure Areas I, X3-Upper, and X3-Deep and range from 6E-07 in Exposure Area I to 3E-03 in Exposure Area X3-Upper.

For exposures via dermal contact under probable exposure conditions, individual chemical-specific risks equal or exceed 1E-06 in Exposure Areas X3-Upper, X3-Middle, and X3-Deep, with a maximum of 2E-04 for 1,1-dichloroethene, 1,1-dichloroethane, and trichloroethene in Exposure Area X3-Upper. Total pathway risks exceed 1E-06 in the same exposure areas, with a maximum of 6E-04 in Exposure Area X3-Upper. Under RME conditions, individual chemical-specific risks exceed 1E-06 in Exposure Areas I, X3-Upper, X3-Middle, and X3-Deep, with a maximum of 2E-03 for 1,1-dichloroethene in Exposure Area X3-Upper. Total pathway risks exceed 1E-06 in the same exposure areas and range from 5E-06 in Exposure Area I to 4E-03 in Exposure Area X3-Upper.

For exposures via inhalation of volatiles, risks are approximately in the same order of magnitude as those for ingestion. Specifically, under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas X3-Upper, X3-Middle, and X3-Deep, with a maximum of 5E-04 for 1,1-dichloroethene in Exposure Area X3-Upper. Total pathway

risks exceed 1E-06 in the same exposure areas and range from 4E-07 in Exposure Area I to 6E-04 in Exposure Area X3-Upper. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas I, X3-Upper, X3-Middle, and X3-Deep, with a maximum of 1E-03 for 1,1-dichloroethene in Exposure Area X3-Upper. Total pathway risks exceed 1E-06 in the same exposure areas and range from 2E-06 in Exposure Area I to 2E-03 in Exposure Area X3-Upper.

Noncarcinogenic Risks -- Unit 1

Noncarcinogenic risks associated with acute exposure under probable exposure and RME conditions, respectively, are presented in Tables D-95 and D-96 (ingestion) and D-97 and D-98 (dermal contact). Noncarcinogenic risks associated with chronic exposure under probable exposure and RME conditions, respectively, are presented in Tables D-99 and D-100 (ingestion), D-101 and D-102 (dermal contact), and D-103 and D-104 (inhalation). Acute exposure for the exposure pathways is discussed first, followed by chronic exposure.

For acute exposure via ingestion under probable conditions, all chemical-specific HQs are less than one, with a maximum of 9.5E-01 for antimony (children 2 to 4 years old) in Exposure Area A. Total pathway HIs exceed one only in Exposure Area A (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area A are less than one) and range from 1.5E-03 (adults) in Exposure Area B to 9.9E-01 (children 2 to 4 years old) in Exposure Area A. Under RME conditions, chemical-specific HQs equal or exceed one in Exposure Areas A and K, with a maximum of 1.5E+00 for 1,2-dichloroethene (children 2 to 4 years old) in Exposure Area K. Total pathway HIs equal or exceed one in Exposure Areas A, C, and K and range from 3.2E-03 (children 15 to 19 years old) in Exposure Area B to 1.7E+00 (children 2 to 4 years old) in Exposure Area K (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area C are less than one).

For acute exposure via dermal contact under probable exposure conditions, all chemical-specific HQs are less than 1E-01, with a maximum of 7.5E-02 (children 0 to 6 years old) for 1,2-dichloroethane in Exposure Area K. Total pathway HIs are less than 1E-01 and range from 2.3E-05 (adults) in Exposure Area B to 7.6E-02 (children 0 to 6 years old) in Exposure Area K. Under RME conditions, all chemical-specific HQs are less than one, with a maximum of 2.5E-01 for 1,2-dichloroethene (children 0 to 6 years old) in Exposure Area K. Total pathway HIs are less than one and range from 1.2E-03 (adults) in Exposure Area X3 to 2.6E-01 (children 0 to 6 years old) in Exposure Area K.

Risks associated with chronic exposure to Unit 1 ground water are generally somewhat greater than those associated with acute exposure. For exposure via ingestion under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 9.5E-01 for antimony (children 2 to 4 years old) in Exposure Area A. Total pathway HIs equal or exceed one in Exposure Areas A and I, and range from 3.9E-02 (adults) in Exposure Area 129-5 to 1.5E+00 (children 2 to 4 years old) in Exposure Area A (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Areas A and I are less than one). Under RME conditions, chemical-specific HQs equal or exceed one in Exposure Areas A, I, J, and K, with a maximum of 1.5E+00 (children 2 to 4 years old) for manganese in Exposure Area J and for 1,2-dichloroethene in Exposure Area K. Total pathway HIs exceed one in Exposure Areas A, C, I, J, and K and range from 1.6E-02 (children 15 to 19 years old) in Exposure Area 129-5 to 2.7E+00 in Exposure Area A (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area C are less than one).

For exposure via dermal contact under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 7.5E-01 for 1,2-dichloroethene (children 0 to 6 years old) in Exposure Area K. Total pathway HIs are less than one and range from 1.1E-03 (adults) in Exposure Area 129-5 to 8.7E-01 (children 0 to 6 years old) in Exposure Area A. Under RME conditions, chemical-specific HQs equal or exceed one in Exposure Areas A and K, with a maximum of 2.5E+00 for 1,2-dichloroethene (children 0 to 6 years old) in Exposure Area K. Total pathway HIs exceed one in the same exposure areas and range from 2.0E-03 (adults) in Exposure Area 129-5 to 2.5E+00 (children 0 to 6 years old) in Exposure Area K.

For exposure via inhalation under probable exposure conditions, all chemical-specific HQs are less than 1E-03, with a maximum of 9.4E-04 for xylene (children 0 to 6 years old) in Exposure Area B. Total pathway HIs are less than 1E-03 and range from 8.6E-06 (adults) in Exposure Area J to 9.4E-04 (children 0 to 6 years old) in Exposure Area B. Under RME conditions, all chemical-specific HQs are less than 1E-02, with a maximum of 3.0E-03 for toluene (children 0 to 6 years old) in Exposure Area H. Total pathway HIs are less than 1E-02 and range from 3.4E-05 (adults) in Exposure Area J to 3.0E-03 (children 0 to 6 years old) in Exposure Area H.

Noncarcinogenic Risks -- Unit 3

Noncarcinogenic risks associated with acute exposure under probable exposure and RME conditions, respectively, are presented in Tables D-105 and D-106 (ingestion) and D-107 and D-108 (dermal contact). Noncarcinogenic risks associated with chronic exposure under probable

exposure and RME conditions, respectively, are presented in Tables D-109 and D-110 (ingestion), D-111 and D-112 (dermal contact), and D-113 and D-114 (inhalation).

For acute exposure via ingestion under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 3.6E-01 for 1,1-dichloroethene (children 2 to 4 years old) in Exposure Area X3. Total pathway HIs are all less than one and range from 4.7E-05 (adults) in Exposure Area C to 9.8E-01 (children 2 to 4 years old) in Exposure Area G. Under RME conditions, individual chemical-specific HQs equal or exceed one only in Exposure Area G, with a maximum of 5.3E+00 for methylene chloride (children 2 to 4 years old). Total pathway HIs exceed one in Exposure Areas G and X3 and range from 4.4E-02 (children 15 to 19 years old) in Exposure Area C to 6.7E+00 (children 2 to 4 years old) in Exposure Area G (evaluation of target organ- and chemical-effect-specific HQs indicate that the true HIs for Exposure Area X3 are less than one).

For acute exposure via dermal contact under probable exposure conditions, chemical-specific HQs exceed one only in Exposure Area G, with a maximum of 2.2E+00 for methylene chloride (children 0 to 6 years old) in Exposure Area G. Total pathway HIs exceed one only in Exposure Area G and range from 7.3E-05 (adults) in Exposure Area C to 3.0E+00 (children 0 to 6 years old) in Exposure Area G. Under RME conditions, chemical-specific HQs exceed one in Exposure Area G and X3, with a maximum of 9.3E+00 for methylene chloride (children 0 to 6 years old) in Exposure Area G. Total pathway HIs exceed 1.0 only in Exposure Areas G and X3, and range from 2.5E-04 (adults) in Exposure Area C to 1.2E+01 (children 0 to 6 years old) in Exposure Area G.

Risks associated with chronic exposure to Unit 3 ground water are generally somewhat greater than those associated with acute exposure. For exposure via ingestion under probable exposure conditions, individual chemical-specific HQs equal or exceed one in Exposure Areas D and G, with a maximum of 3.5E+00 for 1,2-dichloroethene in Exposure Area G. Total pathway HIs exceed one in Exposure Areas D, G, and X3 and range from 6.2E-05 (adults) in Exposure Area C to 9.0E+00 (children 2 to 4 years old) in Exposure Area G (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area X3 are less than one). Under RME conditions, chemical-specific HQs equal or exceed one in Exposure Areas D and G, with a maximum of 6.8E+00 for 1,2-dichloroethene (children 2 to 4 years old) in Exposure Area G. Total pathway HIs exceed one in Exposure Areas D, G, and X3 and range from 1.4E-04 (children 15 to 19 years old) in Exposure Area C to 1.9E+01 (children 2 to 4 years old) in Exposure Area G (evaluation of target organ- and chemical effect-specific HQs indicate that the true HIs for Exposure Area X3 are less than one).

For exposure via dermal contact under probable exposure conditions, chemical-specific HQs exceed one only in Exposure Areas D and G, with a maximum of 4.0E+00 for 1,1,1-trichloroethane (children 0 to 6 years old) in Exposure Area G. Total pathway HIs exceed one in Exposure Areas D, G, and X3 and range from 1.0E-04 (adults) in Exposure Area C to 1.0E+01 (children 0 to 6 years old) in Exposure Area G (evaluation of target organ- and chemical effect-specific HQs indicate that the true HI for Exposure X3 are less than one). Under RME conditions, chemical-specific HQs exceed one in Exposure Areas D, G, and X3 with a maximum of 1.2E+01 for 1,1,1-trichloroethane and 1,2-dichloroethane (children 0 to 6 years old) in Exposure Area G. Total pathway HIs exceed one in Exposure Areas D, F, G, and X3 and range from 3.4E-04 (adults) in Exposure Area C to 3.5E+01 (children 0 to 6 years old) in Exposure Area G (evaluation of target organ- and chemical effect-specific HQ indicates that the true HIs for Exposure Area F are less than one).

For exposure via inhalation under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 5.0E-01 for 1,1,1-trichloroethane (children 0 to 6 years old) in Exposure Area G. Total pathway HIs are all less than one and range from 7.8E-06 (adults) in Exposure Area C to 6.9E-01 (children 0 to 6 years old) in Exposure Area G. Under RME conditions, chemical-specific HQs equal or exceed one in Exposure Areas D, G, and X3, with a maximum of 3.5E+00 for 1,1,1-trichloroethane (children 0 to 6 years old) in Exposure Area X3. Total pathway HIs exceed one in the same exposure areas and range from 3.0E-05 (adults) in Exposure Areas H and 129-5 to 3.7E+00 (children 0 to 6 years old) in Exposure Area X3.

Noncarcinogenic Risks -- Unit 4

Noncarcinogenic risks associated with acute exposure to Unit 4 ground water under probable exposure and RME conditions, respectively, are presented in Tables D-115 and D-116 (ingestion) and D-117 and D-118 (dermal contact). Noncarcinogenic risks associated with chronic exposures under probable and RME conditions, respectively, are presented in Tables D-119 and D-120 (ingestion), D-121 and D-122 (dermal contact), and D-123 and D-124 (inhalation).

For acute exposure via ingestion under probable exposure conditions, all chemical-specific HQs are less than one, with a maximum of 4.0E-01 for arsenic (children 2 to 4 years old) in Exposure Area X3-Upper. Total pathway HIs are less than one and range from 2.2E-05 (adults) in Exposure Area I to 5.7E-01 (children 2 to 4 years old) in Exposure Area X3-Upper. Under RME conditions, chemical-specific HQs equal or exceed one only in Exposure Area X3-Upper, with a maximum of 1.3E+00 for arsenic. Total pathway HIs exceed one only in Exposure

Area X3 Upper and range from 2.6E-05 (children 15 to 19 years old) in Exposure Area I to 1.9E+00 (children 2 to 4 years old) in Exposure Area X3-Upper.

For acute exposure via dermal contact under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 1.8E-01 for 1,1-dichloroethene (children 0 to 6 years old) in Exposure Area X3-Upper. Total pathway HIs are all less than one and range from 3.9E-05 (adults) in Exposure Area I to 2.0E-01 (children 0 to 6 years old) in Exposure Area X3-Upper. Under RME conditions, all chemical-specific HQs are less than one with a maximum of 5.9E-01 for 1,1-dichloroethene (children 0 to 6 years old) in Exposure Area X3-Upper. Total pathway HIs are all less than one and range from 7.3E-05 (adults) in Exposure Area I to 6.8E-01 (children 0 to 6 years old) in Exposure Area X3-Upper.

Risks associated with chronic exposure to Unit 4 ground water are generally somewhat greater than those associated with acute exposure. For exposure via ingestion under probable exposure conditions, all chemical-specific HQs are less than one with a maximum of 4.0E-01 for arsenic (children 2 to 4 years old) in Exposure Area X3-Upper. Total pathway HIs are less than one and range from 1.5E-04 (adults) in Exposure Area X3-Deep to 7.4E-01 (children 2 to 4 years old) in Exposure Area X3-Upper. Under RME conditions, chemical-specific HQs equal or exceed one only in Exposure Area X3-Upper, with a maximum of 1.3E+00 for arsenic (children 2 to 4 years old). Total pathway HIs exceed one only in Exposure Area X3-Upper and range from 6.8E-02 (adults) in Exposure Area X3-Deep to 2.0E+00 (children 2 to 4 years old) in Exposure Area X3-Upper.

For exposure via dermal contact under probable exposure conditions, all chemical-specific HQs are less than one, with a maximum of 1.8E-01 for 1,1,1-trichloroethane and 1,1-dichloroethene (children 0 to 6 years old) in Exposure Area X3-Upper. Total pathway HIs are all less than one, and range from 3.9E-04 (adults) in Exposure Area I to 4.2E-01 (children 0 to 6 years old) in Exposure Area X3-Upper. Under RME conditions, all chemical-specific HQs are less than one, with a maximum of 6.3E-01 for 1,1,1-trichloroethane (children 0 to 6 years old) in Exposure Area X3-Upper. Total pathway HIs exceed one only in Exposure Area X3-Upper and range from 7.3E-04 (adults) in Exposure Area I to 1.4E+00 (children 0 to 6 years old) in Exposure Area X3-Upper (evaluation of target organ- and chemical effect-specific HQs indicates that the true HIs for Exposure Area X3-Upper are less than one).

For exposure via inhalation under probable exposure conditions, all chemical-specific HQs are less than 1E-01, with a maximum of 2.3E-02 for 1,1,1-trichloroethane and 1,1-dichloroethane (children 0 to 6 years old) in Exposure Area X3-Upper. Total pathway HIs are all less than 1.0E-01 and range from 1.5E-05 (adults) in Exposure Area I to 4.6E-02 (children 0 to 6

years old) in Exposure Area X3-Upper. Under RME conditions, all chemical-specific HQs are less than one, with a maximum of 3.8E-01 for 1,1,1-trichloroethane (children 0 to 6 years old) in Exposure Area X3-Upper. Total pathway HIs are less than one, and range from 1.0E-04 (adults) in Exposure Area I to 4.8E-01 (children 0 to 6 years old) in Exposure Area X3-Upper.

5.3.1.2 Surface and Subsurface Soils -- On-TCAAP (Future Land Use Conditions)

Children and adults living in residences on-TCAAP may be exposed to surface soil as a result of play activities, yard work, or gardening. Construction workers building these residences may also be exposed to surface soil. The same individuals may be exposed to subsurface soil that has been brought to the surface as a result of construction activities and has in effect become surface soil. As discussed in Chapter 3, exposure to soils may occur via incidental ingestion, dermal contact, and inhalation of fugitive dusts (construction workers only). However, any exposure is expected to be greatly reduced as a result of two factors: (1) clean top soil placed over native soils to facilitate lawn growth and (2) the lawn itself.

Because of difficulties in differentiating between exposure to native soils and to clean topsoil, all exposure is assumed to be to native soils. This assumption almost certainly results in overestimation of exposure doses and corresponding risks. Therefore, risks discussed in this section represent upper-bound estimates of potential risks. Actual risks are expected to be much less than those presented and may in fact be insignificant.

Each pathway described above is discussed below, first for surface soil and then for subsurface soil. (Exposure to fugitive dusts is evaluated for subsurface soil only.) Carcinogenic risks are discussed first, followed by noncarcinogenic risks.

Carcinogenic Risks -- Surface Soil

Carcinogenic risks associated with exposures to surface soil under probable exposure and RME conditions, respectively, are presented in Tables D-125 and D-126 (incidental ingestion) and D-127 and D-128 (dermal contact).

For exposures via incidental ingestion under probable exposure conditions, chemical-specific risks equal or exceed the U.S. EPA bench mark of 1E-06 in Exposure Areas C (residents and construction workers) and 129-3 (residents only), with a maximum of 6E-05 for benzo(b)fluoranthene in Exposure Area C for residents and a maximum of 2E-06 for benzo(a)pyrene, benzo(b)fluoranthene, and chrysene in Exposure Area C for construction workers. Total pathway risks exceed 1E-06 in Exposure Areas C and 129-3 for residents and in

Exposure Area C for construction workers. (Potential carcinogens were measured in surface soil only in these two exposure areas.) Total pathway risks range from 5E-07 in Exposure Area E to 2E-04 in Exposure Area C for residents and range from 8E-09 in Exposure Area 129-3 to 9E-06 in Exposure Area C for construction workers.

Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas C, E, and 129-3 for residents, with a maximum of 4E-04 for benzo(b)fluoranthene in Exposure Area C, and equal or exceed 1E-06 in Exposure Area C for construction workers, with a maximum of 2E-05 for benzo(b)fluoranthene and benzo(a)pyrene. Total pathway risks for residents equal or exceed 1E-06 in Exposure Areas C, E, and 129-3 and range from 9E-06 in Exposure Area E to 2E-03 in Exposure Area C. Total pathway risks for construction workers equal or exceed 1E-06 in Exposure Area C and range from 8E-08 in Exposure Area 129-3 to 7E-05 in Exposure Area C.

For exposures via dermal contact under probable exposure conditions, chemical-specific risks for residents exceed 1E-06 in Exposure Areas C and 129-3, with a maximum of 4E-04 for benzo(b)fluoranthene in Exposure Area C. Chemical-specific risks for construction workers equal or exceed 1E-06 only in Exposure Area C, with a maximum of 1E-05 for three PAHs. Total pathway risks for residents exceed 1E-06 in Exposure Areas C and 129-3 and range from 5E-07 in Exposure Area E to 2E-03 in Exposure Area C. Total pathway risks for workers equal or exceed 1E-06 only in Exposure Area C and range from 1E-08 in Exposure Area E to 5E-05 in Exposure Area C.

Under RME conditions, chemical-specific risks for residents exceed 1E-06 in Exposure Areas C, E, and 129-3, with a maximum of 2E-03 for three PAHs in Exposure Area C. Chemical-specific risks for construction workers exceed 1E-06 only in Exposure Area C, with a maximum of 4E-05 for benzol(b)fluoranthene and benzo(a)pyrene. Total pathway risks for residents equal or exceed 1E-06 in Exposure Areas C, E, and 129-3 and range from 7E-06 in Exposure Area E to 8E-03 in Exposure Area C. Total pathway risks for construction workers exceed 1E-06 only in Exposure Area C and range from 8E-08 in Exposure Area E to 2E-04 in Exposure Area C.

Carcinogenic Risks -- Subsurface Soil

Carcinogenic risks associated with exposures to subsurface soil under probable exposure and RME conditions, respectively, are presented in Tables D-129 and D-130 (incidental ingestion), D-131 and D-132 (dermal contact), and D-133 and D-134 (inhalation). Potential carcinogens were measured above background concentrations only in Exposure Areas C, E, and

129-3. Exposure to subsurface soil in other exposure areas is associated with no incremental carcinogenic risks.

For exposures via incidental ingestion under probable exposure conditions, chemical-specific risks for residents equal or exceed the U.S. EPA bench mark of 1E-06 in Exposure Areas C and 129-3, with a maximum of 6E-05 for benzo(b)fluoranthene in Exposure Area C. Chemical-specific risks for construction workers exceed 1E-06 only in Exposure Area C, with a maximum of 2E-06 for three PAHs. Total pathway risks for residents range from 4E-07 in Exposure Area E to 2E-04 in Exposure Area C. Total pathway risks for construction workers exceed 1E-06 only in Exposure Area C and range from 8E-09 in Exposure Areas E and 129-3 to 9E-06 in Exposure Area C.

Under RME conditions, chemical-specific risks for residents equal or exceed 1E-06 in Exposure Areas C, E, and 129-3, with a maximum of 4E-04 for benzo(b)fluoranthene in Exposure Area C. Chemical-specific risks for construction workers exceed 1E-06 only in Exposure Area C, with a maximum of 2E-05 for benzo(b)fluoranthene and benzo(a)pyrene. Total pathway risks for residents range from 7E-06 in Exposure Area E to 2E-03 in Exposure Area C. Total pathway risks for construction workers equal or exceed 1E-06 only in Exposure Area C and range from 7E-08 in Exposure Area 129-3 to 7E-05 in Exposure Area C.

For exposures via dermal contact under probable exposure conditions, chemical-specific risks for residents equal or exceed 1E-06 in Exposure Areas C and 129-3, with a maximum of 4E-04 for benzo(b)fluoranthene in Exposure Area C. Chemical-specific risks for construction workers equal or exceed 1E-06 only in Exposure Area C, with a maximum of 1E-05 for three PAHs. Total pathway risks for residents exceed 1E-06 in Exposure Areas C and 129-3 and range from 3E-07 in Exposure Area E to 2E-03 in Exposure Area C. Total pathway risks for workers exceed 1E-06 only in Exposure Area C and range from 7E-09 in Exposure Area E to 5E-05 in Exposure Area C.

Under RME conditions, chemical-specific risks for residents exceed 1E-06 in Exposure Areas C, E, and 129-3, with a maximum of 2E-03 for three PAHs in Exposure Area C. Chemical-specific risks for construction workers equal or exceed 1E-06 only in Exposure Area C, with a maximum of 4E-05 for benzo(a)pyrene and benzo(b)fluoranthene. Total pathway risks for residents exceed 1E-06 in Exposure Areas C, E, and 129-3, and range from 5E-06 in Exposure Area E to 8E-03 in Exposure Area C. Total pathway risks for construction workers equal or exceed 1E-06 only in Exposure Area C, and range from 6E-08 in Exposure Area E to 2E-04 in Exposure Area C.

Results for exposures via inhalation of fugitive dusts by construction workers indicate that under probable exposure conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas A, E, F, G, H, J, 129-5, and 129-15, with a maximum of 7E-06 for nickel in Exposure Area J. Total pathway risks exceed 1E-06 in the same exposure areas and range from 3E-07 in Exposure Area 129-3 to 7E-06 in Exposure Area J. Under RME conditions, chemical-specific risks equal or exceed 1E-06 in Exposure Areas A, B, C, E, F, G, H, J, 129-3, 129-5, and 129-15, with a maximum of 2E-03 for chromium in Exposure Area A. Total pathway risks exceed 1E-06 in the same exposure areas and range from 6E-06 in Exposure Area G to 2E-03 in Exposure Area A.

Noncarcinogenic Risks -- Surface Soil

Noncarcinogenic risks associated with acute exposures to surface soil under probable exposure and RME conditions, respectively, are presented in Tables D-135 and D-136 (incidental ingestion) and D-137 and D-138 (dermal contact). Noncarcinogenic risks associated with chronic exposures under probable exposure and RME conditions, respectively, are presented in Tables D-139 and D-140 (ingestion) and D-141 and D-142 (dermal contact). Because no noncarcinogenic compounds with inhalation toxicity factors were measured in surface soil, noncarcinogenic risks for exposure to surface soil are not quantitatively evaluated. Acute exposures for the exposure pathways are discussed first, followed by chronic exposures.

Acute exposures to surface soil are discussed below. For exposure via incidental ingestion under probable exposure conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 1.8E+01 for children 0 to 6 years old in Exposure Area A. Chemical-specific risks for construction workers exceed one only for antimony in Exposure Area A, with a maximum of 3.6E+00. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3 and range from 3.2E-04 for adults in Exposure Area 129-5 to 1.8E+01 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one only in Exposure Areas A and 129-3 and range from 3.2E-04 in Exposure Area C to 3.6E+00 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 2.3E+02 for antimony (children 0 to 6 years old) in Exposure Area A. Chemical-specific risks for construction workers exceed one only for antimony in Exposure Areas A, F, H, and 129-3 with a maximum of 4.7E+01 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3 and range from 1.5E-04 for adults in Exposure Area C to 2.3E+02 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one in Exposure Areas A, F, H, and 129-3 and range from 1.2E-03 in Exposure Area C to 4.7E+01 in Exposure Area A.

For exposure via dermal contact under probable exposure conditions, chemical-specific HQs equal or exceed one only for antimony in Exposure Areas A, 129-3, and H, with a maximum of 1.1E+01 for children 0 to 6 years old in Exposure Area A. Chemical-specific HQs equal or exceed one only for antimony in Exposure Areas A and 129-3, with a maximum of 4.1E+00 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, H, 129-3, and range from 1.2E-03 for adults in Exposure Area 129-5 to 1.1E+01 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one in Exposure Areas A and 129-3 and range from 1.2E-03 in Exposure Area 129-5 to 4.1E+00 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 1.4E+02 for children 0 to 6 years old in Exposure Area A. Chemical-specific HIs for construction workers equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 3.6E+01 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3 and range from 4.1E-03 for adults in Exposure Area C to 1.4E+02 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers equal or exceed one in Exposure Areas A, F, H, and 129-3 and range from 2.4E-03 in Exposure Area C to 3.7E+01 in Exposure Area A.

Results for chronic exposures to on-TCAAP surface soil are discussed below. For exposures via incidental ingestion under probable exposure conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A and 129-3, with a maximum of 5.2E+00 for children 0 to 6 years old in Exposure Area A. All chemical-specific HQs for construction workers are less than one, with a maximum of 7.5E-01 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A and 129-3 and range from 2.7E-05 for adults in Exposure Area 129-5 to 5.2E+00 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers are all less than one and range from 8.2E-05 in Exposure Area 129-5 to 7.6E-01 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 1.4E+02 for antimony (children 0 to 6 years old) in Exposure Area A. Chemical-specific HQs for construction workers equal or exceed one for antimony in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3 and range from 6.6E-05 for adults in Exposure Area B to 1.4E+02 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one only in Exposure Area A and range from 5.8E-04 in Exposure Area 129-5 to 9.9E+00 in Exposure Area A.

For exposures via dermal contact under probable exposure conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A and H, with a maximum of 3.3E+00 for children 0 to 6 years old in Exposure Area A. All chemical-specific HQs for construction workers are less than one, with a maximum of 8.6E-01 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A and H and range from 1.1E-04 for adults in Exposure Area 129-5 to 3.3E+00 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers are all less than one and range from 1.6E-04 in Exposure Area 129-5 to 8.6E-01 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 8.0E+01 for children 0 to 6 years old in Exposure Area A. Chemical-specific HQs for construction workers exceed one only for antimony in Exposure Area A. Total pathway HIs exceed one in Exposure Areas A, F, H, and 129-3 and range from 1.2E-03 for adults in Exposure Area B to 8.0E+01 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one only for antimony in Exposure Area A and range from 7.7E-04 in Exposure Area 129-5 to 7.6E+00 in Exposure Area A.

Noncarcinogenic Risks -- Subsurface Soil

Noncarcinogenic risks associated with acute exposures to subsurface soil under probable exposure and RME conditions, respectively, are presented in Tables D-143 and D-144 (incidental ingestion) and D-145 and D-146 (dermal contact). Noncarcinogenic risks associated with chronic exposures under probable exposure and RME conditions, respectively, are presented in Tables D-147 and D-148 (ingestion) and D-149 and D-150 (dermal contact). No noncarcinogenic compounds with inhalation toxicity factors were detected in subsurface soil. Acute exposures for the exposure pathways are discussed first, followed by chronic exposures.

For acute exposures via incidental ingestion under probable exposure conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 1.3E+01 for children 0 to 6 years old in Exposure Area A. Chemical-specific HQs for construction workers exceed one only for antimony in Exposure Areas A and 129-3, with a maximum of 2.7E+00 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3, and range from 1.5E-06 for adults in Exposure Area B to 1.3E+01 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one in Exposure Areas A and 129-3 and range from 2.9E-06 in Exposure Area B to 2.7E+00 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 1.5E+02 for antimony (children 0 to 6 years old) in Exposure Area A. Chemical-specific HQs for construction workers exceed one only for antimony in Exposure Areas

A, F, H, and 129-3, with a maximum of 3.0E+01 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3 and range from 2.0E-06 for adults in Exposure Area B to 1.5E+02 in Exposure Area A. Total pathway HIs for construction workers exceed one in Exposure Areas A, F, H, and 129-3 and range from 1.6E+05 in Exposure Area B to 3.0E+01 in Exposure Area A.

For acute exposure via dermal contact under probable exposure conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, H, and 129-3, with a maximum of 8.3E+00 for children 0 to 6 years old in Exposure Area A. Chemical-specific HQs for construction workers exceed one only for antimony in Exposure Areas A and 129-3, with a maximum of 3.0E+00 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, H, and 129-3 and range from 1.3E-05 for adults in Exposure Area B to 8.3E+00 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one in Exposure Areas A and 129-3 and range from 1.7E+05 in Exposure Area B to 3.0E+00 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 8.5E+01 for children 0 to 6 years old in Exposure Area A. Chemical-specific HQs for construction workers exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 2.3E+01 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3, and range from 1.0E-04 for adults in Exposure Area B to 8.5E+01 for children 0 to 6 in Exposure Area A. Total pathway HIs for construction workers exceed one only for antimony in Exposure Areas A, F, H, and 129-3 and range from 6.1E-05 in Exposure Area B to 2.3E+01 in Exposure Area A.

For chronic exposures via incidental ingestion under probable exposure conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A and 129-3, with a maximum of 3.9E+00 for children 0 to 6 years old in Exposure Area A. All chemical-specific HQs for construction workers are less than one with a maximum of 5.6E-01 in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A and 129-3 and range from 1.2E-06 for adults in Exposure Area B to 3.9E+00 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers are all less than one and range from 6.5E-06 in Exposure Area B to 5.6E-01 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 8.6E+01 (children 0 to 6 years old) in Exposure Area A. Chemical-specific HQs for construction workers exceed one only for antimony in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H and 129-3 and range from 3.2E-06 for adults in Exposure Area B to 8.6E+01 for children 0 to 6 years old in Exposure

Area A. Total pathway HIs for construction workers exceed one in Exposure Area A and range from 3.5E-05 in Exposure Area B to 6.2E+00 in Exposure Area A.

For chronic exposures via dermal contact under probable exposure conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A and 129-3, with a maximum of 2.4E+00 for children 0 to 6 years old in Exposure Area A. All chemical-specific HQs for construction workers are less than one with a maximum of 6.3E-01 for antimony in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A and 129-3 and range from 1.4E-05 for adults in Exposure Area B to 2.4E+00 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers are all less than one and range from 3.7E-05 in Exposure Area B to 6.3E-01 in Exposure Area A. Under RME conditions, chemical-specific HQs for residents equal or exceed one only for antimony in Exposure Areas A, F, H, and 129-3, with a maximum of 5.0E+01 for children 0 to 6 years old in Exposure Area A. Chemical-specific HQs for construction workers exceed one only for antimony in Exposure Area A. Total pathway HIs for residents exceed one in Exposure Areas A, F, H, and 129-3 and range from 1.7E-04 for adults in Exposure Area B to 5.0E+01 for children 0 to 6 years old in Exposure Area A. Total pathway HIs for construction workers exceed one only in Exposure Area A and range from 1.4E-04 in Exposure Area B to 4.8E+00 in Exposure Area A.

5.3.1.3 Surface Water and Sediment -- On-TCAAP (Future Land Use Conditions)

On-TCAAP residents or individuals visiting on-TCAAP may be exposed to chemicals in surface water via dermal contact, incidental ingestion, and ingestion of fish that have bioaccumulated the chemicals. Residents may also be exposed to sediment via dermal contact. Exposures may take place in the on-TCAAP portion of Rice Creek, Marsden Lake, Sunfish Lake, miscellaneous surface water bodies located throughout TCAAP (identified by source area), and nearby off-TCAAP surface water bodies such as Round Lake and the off-TCAAP portion of Rice Creek. Carcinogenic risks for each pathway are discussed first, followed by noncarcinogenic risks.

Carcinogenic Risks

Carcinogenic risks associated with exposures to surface water under probable exposure and RME conditions, respectively, are presented in Tables D-151 (dermal contact) and D-152 (incidental ingestion). Carcinogenic risks associated with exposures to sediments under probable and PME conditions are presented in Table D-152B.

Potential carcinogens [bis(2-ethylhexyl)phthalate and trichloroethene] were detected in surface water at concentrations above background only in Exposure Area K. For exposure via dermal contact, the maximum chemical-specific risks are associated with trichloroethene; these are estimated as 5E-08 and 4E-07 under probable exposure and RME conditions, respectively. The total pathway risks are 6E-08 and 5E-07 under probable exposure and RME conditions, respectively.

Exposure via incidental ingestion is assumed to take place only under RME conditions. The maximum chemical-specific risk is associated with bis(2-ethylhexyl)phthalate and is estimated as 4E-09. The total pathway risk is estimated as 5E-09. For exposures via ingestion of fish, no upper-bound excess lifetime cancer risks exist because no potentially carcinogenic chemicals were detected above background concentrations in either Rice Creek or Round Lake.

Carcinogenic compounds were measured above background in sediments only in Exposure Area 129-15. The total pathway risks under probable and RME conditions are 3E-09 and 4E-08, respectively.

Noncarcinogenic Risks

Noncarcinogenic risks associated with acute exposures to surface water under probable exposure and RME conditions, are presented in Tables D-65 and D-66 (dermal contact), respectively, D-67 (incidental ingestion; evaluated only under RME conditions), and D-68 (ingestion of fish). Noncarcinogenic risks associated with acute exposures to sediment under probable and RME conditions are presented in Tables D-69 and D-70, respectively. Noncarcinogenic risks associated with chronic exposures under probable and RME conditions are presented in Tables D-71 and D-72 (dermal contact), respectively, D-73 (incidental ingestion), and D-74 (ingestion of fish). Noncarcinogenic risks associated with chronic exposures to sediment under probable and RME conditions are presented in Tables D-75 and D-76, respectively. Acute and chronic noncarcinogenic risks are the same as those discussed in Section 5.2.2.3 and are not repeated here.

5.3.1.4 Air -- On-TCAAP (Future Land Use Conditions)

As discussed in Section 5.2.1.2, for evaluating carcinogenic risks associated with inhalation of ambient air, all VOC emissions from on-TCAAP remedial actions are assumed to be trichloroethene. For evaluating noncarcinogenic risks, all VOC emissions capable of causing noncarcinogenic effects are assumed to be 1,1,1-trichloroethane. Risks are evaluated for each of

the 18 on-TCAAP Class I and Class II exposure areas as well as for 13 additional on-TCAAP receptor locations. All on-TCAAP receptor locations are shown in Figure F-2 in Appendix F.

Carcinogenic Risks

Risks associated with inhalation of ambient air are presented in Tables D-7 and D-8 for probable exposure and RME conditions, respectively. Under probable exposure conditions, risks range from 9E-08 (Building 116) to 2E-05 (receptor locations 116 South and 116 East-Southeast); risks equal or exceed 1E-06 in Exposure Areas D, E, F, J, 129-3, 129-15, and X3 and at receptor locations D North, D South, D Northwest, D East-Southeast, 116 North, 116 South, 116 Northwest, and 116 East-Southeast. Under RME conditions, risks range from 9E-07 (Exposure Area H) to 7E-05 (receptor location 116 South); risks exceed 1E-06 at all receptor locations except receptor locations A and B, Building 116, and I South.

Noncarcinogenic Risks

Noncarcinogenic risks associated with acute exposures to ambient air under probable exposure and RME conditions are presented in Tables D-7a and D-8a, respectively. Noncarcinogenic risks associated with chronic exposures under probable exposure and RME conditions are presented in Tables D-7b and D-8b, respectively. Acute exposures are discussed first, followed by chronic exposures.

For acute exposures to ambient air under probable exposure conditions, all HQs and HIs are less than 3E-03. For residents, risks range from 3.6E-06 (adults) at receptor location BD4 to 2.5E-03 (children 0 to 6 years old) at receptor location 116 North. For workers, risks range from 1.0E-06 at receptor location BD4 to 1.4E-04 at receptor locations 116 North and 116 South. Under RME conditions, all HQs and HIs are less than 5E-03. For residents risks range from 7.2E-06 (adults) at receptor location BD4 to 4.3E-03 at receptor location 116 North. For workers, risks range from 3.6E-06 at receptor location BD4 to 5.0E-04 at receptor locations 116 North and 116 South.

For chronic exposures to ambient air under probable exposure conditions, all HQs and HIs are less than 3.0E-02. For residents, risks range from 3.6E-05 (adults) at receptor location BD4 to 2.5E-02 (children 0 to 6 years old) at receptor location 116 North. For workers, risks range from 1.0E-05 at receptor location BD4 to 1.4E-03 at receptor locations 116 North and 116 South. Under RME conditions, all HQs and HIs are less than 5.0E-02. For residents, risks range from 7.2E-05 (adults) at receptor location BD4 to 4.3E-02 (children 0 to 6 years old) at receptor

location 116 North. For workers, risks range from 3.6E-05 at receptor location BD4 to 5.0E-03 at receptor locations 116 North and 116 South.

5.3.1.5 Soil Gas -- On-TCAAP (Future Land Use Conditions)

As discussed in Chapter 3, it is not possible to accurately quantify possible exposure to chemicals in soil gas present in basements of homes constructed on-TCAAP under RME future land use conditions. Contaminated soil gas in soil adjacent to basements of future on-TCAAP residences is expected to make its way into these buildings.

Residents may be exposed to volatile contaminants via inhalation within their homes. Chemical-specific and total pathway upper-bound excess lifetime cancer risks equaling or exceeding 1E-06 or chemical-specific HQs and total pathway HIs exceeding unity are likely, although quantification is not possible. This pathway may present carcinogenic and noncarcinogenic risks that will contribute to the total risks for on-TCAAP residents under RME future land use conditions.

5.3.1.6 Home-Grown Vegetables and Fruits -- On-TCAAP (Future Land Use Conditions)

Future on-TCAAP residents may be exposed to chemicals that have bioconcentrated in home-grown vegetables and fruits that residents ingest as part of their daily diets. Exposures are evaluated for each of the 18 on-TCAAP Class I and Class II exposure areas. Carcinogenic risks associated with these exposures are presented in Tables D-153 (probable exposure conditions) and D-154 (RME conditions). Noncarcinogenic risks associated with acute exposure under probable and RME conditions are presented in Tables D-155 and D-156, respectively. Noncarcinogenic risks associated with chronic exposure under probable and RME conditions are presented in Tables D-157 and D-158, respectively.

Carcinogenic Risks

Potentially carcinogenic chemicals of potential concern were identified only in Exposure Areas C, E and 129-3. Only volatile carcinogens were measured in Exposure Area 129-3; volatile chemicals are not expected to be taken up and accumulated in vegetables and fruits. Therefore, carcinogenic risks are evaluated only for Exposure Areas C and E. Under probable exposure conditions, chemical-specific risks in these areas range from 1E-06 (PCBs in Exposure Area E) to 8E-05 [benzo(b)fluoranthene in Exposure Area C]. Total pathway risks are estimated as 1E-06 (Exposure Area E) and 3E-04 (Exposure Area C). Under RME conditions, chemical-specific

risks range from 7E-06 (PCBs in Exposure Area E) to 3E-04 [benzo(b)fluoranthene, benzo(a)pyrene, and chrysene in Exposure Area C]. Total pathway risks are estimated as 7E-06 (Exposure Area E) and 1E-03 (Exposure Area C).

Noncarcinogenic Risks

For acute exposures under probable exposure conditions, chemical-specific HQs range from 6.0E-07 (chromium, adults, Exposure Area 129-15) to 3.9E+01 (antimony, children 0 to 11 months old, Exposure Area A) and exceed one only for antimony in Exposure Areas A, F, and 129-3. Total pathway HIs range from 6.0E-07 for adults in Exposure Area 129-15 to 3.9E+01 for children 0 to 11 months old in Exposure Area A. Under RME conditions, chemical-specific HQs range from 6.3E-07 (chromium, adults, Exposure Area 129-15) to 1.3E+02 (antimony, children 0 to 11 months old, Exposure Area A) and exceed one for antimony in Exposure Areas A, F, and 129-3. Total pathway HIs range from 6.3E-07 for adults in Exposure Area 129-15 to 1.3E+02 for children 0 to 11 months old in Exposure Area A.

For chronic exposures under probable exposure conditions, chemical-specific HQs range from 1.5E-06 (chromium, adults, Exposure Area 129-15) to 9.6E+00 (antimony, children 0 to 11 months old, Exposure Area A) and exceed one only for antimony in Exposure Areas A and 129-3. Total pathway HIs range from 6.0E-06 for adults in Exposure Area 129-15 to 9.7E+00 for children 0 to 11 months old in Exposure Area A. Under RME conditions, chemical-specific HQs range from 3.2E-06 (chromium, adults, Exposure Area 129-15) to 6.3E+01 (antimony, children 0 to 11 months old, Exposure Area A) and exceed one for antimony in Exposure Areas A, F, 129-3, and H. Total pathway HIs range from 3.2E-06 for adults in Exposure Area 129-15 to 6.3E+01 for children 0 to 11 months old in Exposure Area A.

5.3.2 Off-TCAAP -- Future Land Use Conditions

As discussed in Chapter 3, potential off-TCAAP exposures under future land use conditions are associated with the following media: ground water, air, and surface water and sediment. Risks associated with these media are assumed to be the same as those for off-TCAAP exposures under current land use conditions (see Section 5.2.2).

5.4 QUALITATIVE RISK ASSESSMENT

As discussed in Chapters 2 and 4, risks associated with several chemicals of potential concern cannot be evaluated quantitatively because risk factors (RfDs or SFs) are not available. In some cases, risk factors are unavailable for any routes of exposure (for example, for lead and

copper); in other cases risk factors are available for one or more routes of exposure but not for others (for example, for chloroform). Risks associated with exposure to chemicals in soil gas cannot be quantified even though inhalation risk factors are available, primarily because chemical concentrations in soil gas were presented in relative and not absolute units in the on-TCAAP RI report (ANL, 1990).

As suggested by U.S. EPA (1989a), qualitative discussion of risks is sufficient when quantitative discussion of risks is not possible. Some of the chemicals for which no risk factors are available are not expected to pose any risk to human health at the concentrations measured on- and off-TCAAP; these chemicals include magnesium, potassium, and sodium. Exposure to these chemicals in addition to chemicals for which risks are quantified will not increase the actual risks to human receptors above the estimates presented.

Other chemicals, such as chloroform, may in fact pose some risk to human health. Although the magnitude of that risk can be quantified for some exposure pathways, it cannot be quantified for others because risk factors are not available. Refer to Chapter 4 and Appendix H for toxicological summaries and toxicological evaluations, respectively, of these chemicals. If possible, toxicological information is presented in Chapter 4 and Appendix H pertaining to the routes for which risk cannot be quantified.

Finally, three areas require more complete qualitative discussion: exposure to lead, exposure to gross alpha and gross beta radiation, and exposure to volatile chemicals in soil gas. Each area is discussed below.

5.4.1 Exposure to Lead

Section 4.2.1 presents a qualitative evaluation of lead toxicity (also, see Appendix H). The risk of health effects related to lead exposure varies according to the individual, depending on his or her nutritional status, age, and total lead body burden from all sources. Women are generally more sensitive to the effects of lead on the blood system than are men. Also, fetuses may be at particular risk.

U.S. EPA (1990) has determined that there may be no threshold for the adverse effects of lead, particularly for neurobehavioral effects found in children. A concentration of lead as low as 1 mg/L in drinking water has been demonstrated to produce clinical lead poisoning (NLM, 1990). However, concentrations of lead in ground water both on- and off-TCAAP are well below this level; generally, average lead concentrations both on- and off-TCAAP are less than 10

μg/L; maximum concentrations of 91 μg/L and 32 μg/L have been measured on- and off-TCAAP, respectively.

Although lead poisoning may not occur as a result of exposure to lead in ground water, lead has been measured at above-background concentrations in Units 1, 3, and 4 on-TCAAP and in Units 3 and 4 off-TCAAP. Exposure to lead via ground water ingestion will add to total body burdens and may itself or in combination with other routes of exposure cause adverse health effects in human receptors.

Lead has also been measured in surface and subsurface soils on-TCAAP. In particular, lead has been measured at above-background concentrations in Exposure Areas F, I, and K.

CDC (1985) has published guidance for lead concentrations in residential soils that CDC associates with an acceptable level of risk. Specifically, CDC concluded that adverse clinical and health affects (elevated blood lead levels) may result from exposure to levels in soils and dust at concentrations exceeding 500 - 1,000 mg/kg. Exposure to soils with lead concentrations less than 500 mg/kg is generally not expected to result in adverse health effects. However, the risk of adverse health effects varies according to the individual.

Only the 95-percent upper-bound confidence limit (UCL) of the arithmetic mean lead concentration for Exposure Area F, 681 mg/kg in surface soil, exceeds the lower limit of the cleanup range. This indicates that exposure to lead in surface soil in Exposure Area F may present some additional risk to exposed populations. Exposure to lead in soils in other exposure areas is not expected to result in additional risk.

5.4.2 Exposure to Gross Alpha and Gross Beta Radiation

To assess the risk from exposure to radioisotopes, the identity and activity of each radioisotope must be known. Methods for assessing such risks are available in U.S. EPA (1989a). However, the only available data for TCAAP are gross alpha and gross beta activities for selected soil and water samples, (see Appendix A). Risks from exposure to gross alpha and gross beta radiation are discussed qualitatively below; first for ground water and then for surface and subsurface soils.

Ground Water

The only standards applicable to the available nonspecific ground-water results are the MCLs for drinking water. Therefore, a quantitative risk assessment based on the methods

discussed in U.S. EPA (1989a) is not possible. Instead, gross alpha and gross beta levels measured in both on- and off-TCAAP ground-water samples are compared to MCLs.

The MCL for alpha radiation (40 CFR 141.15) has two parts:

- 15 pCi/L for gross alpha activity (including radium-228 but excluding radon and uranium)
- 5 pCi/L for combined radium-226 and radium-228

The individual isotopes presenting low total activities cannot be identified (especially if more than one or two are present). Gross alpha activities for ground-water samples from TCAAP range from 1.5 to 4.2 pCi/L, and are therefore well below the more restrictive MCL.

The MCL for beta radiation (40 CFR 141.16) (and for gamma radiation, often measured simultaneously with beta radiation) is 4 millirem/year (average annual dose to the total body or to any internal organ). The specific radioisotopes present must be known in order to apply this MCL. The regulation includes specific activities for two radioisotopes: 20,000 pCi/L for tritium and 8 pCi/L for strontium-90. Observed beta activities in TCAAP ground-water samples range from 1.4 to 6.4 pCi/L, well below the lower of the two regulation values.

Surface and Subsurface Soils

No existing standards describe allowable concentrations of gross alpha or gross beta radiation in soil. However, the Uranium Mill Tailings Radiation Control Act of 1978 Standards (U.S. EPA, 1990c) limit radium-226 concentrations in soil to 5 pci/g for the top 15 cm and to 15 pci/g below a depth of 15 cm. Radium-226, which emits alpha and other radiations, is one of the most radiotoxic nuclides, especially because it is deposited in the bones.

The maximum gross alpha concentration measured on-TCAAP is 4.7 pci/g in Exposure Area A. This concentration is below the more restrictive surface soil limit for radium-226. Though qualitative, comparison of gross alpha concentrations measured on-TCAAP to radium-226 limits for soils suggests that gross alpha concentrations measured on-TCAAP will not be especially harmful to human receptors.

No applicable standards were identified for comparison with gross beta concentrations measured on-TCAAP. Thus, risks to human health presented by gross beta concentrations measured in soil on-TCAAP cannot be qualitatively evaluated in this risk assessment.

5.4.3 Exposure to Volatiles in Soil Gas

As discussed in Section 5.3.1.5, volatile chemicals in soil gas are expected to make their way into basements of future on-TCAAP residences to some extent. In the on-TCAAP RI (ANL, 1990), soil gas samples were analyzed for five volatile chemicals: 1,1,1-trichloroethane, toluene, and xylene (noncarcinogenic via inhalation) and trichloroethene and benzene (potential carcinogens via inhalation).

If these chemicals make their way into future on-TCAAP residences and commercial buildings, exposure to them via inhalation may result in additional noncarcinogenic and carcinogenic health effects. The magnitude of the additional risks cannot be estimated based on existing information.

5.5 UNCERTAINTIES IN RISK CHARACTERIZATION

Risk estimates calculated in this risk assessment are subject to varying degrees of uncertainty from a variety of sources. In contrast to the uncertainties involved in estimation of exposure, the uncertainties inherent in risk characterization depend less on availability of site-specific information and more on availability and use of chemical-specific toxicity information. This section identifies the most significant sources of uncertainty for the risk characterization and assesses the potential impact of the uncertainty.

The following sources of uncertainty are discussed:

- Risk factors
  - -- Extrapolations (related to species, exposure dose, and exposure period)
  - -- Adjustment of risk factors
  - -- Slope factors
  - -- Lack of risk factors
- Risk summations
- Exposure periods

Table 5-2A summarizes these sources of uncertainty and expresses the likely impact of each uncertainty on the estimated risks by indicating if the effect of the uncertainty will be to (1) overestimate the risk, (2) underestimate the risk, or (3) over- or underestimate the risk.

TABLE 5-2A

AREAS OF UNCERTAINTY AND EFFECTS ON RISK ESTIMATES

Area of Uncertainty	May Overestimate Exposure	May Underestimate Exposure	May Over-or Underestimate Exposure
Risk Factors			
– Extrapolation Most risk factors are extrapolated from animal test results. Extrapolations may be made for species, exposure dose, and exposure period; extrapolations are generally conservative.	X		
– Adjustment of Oral Risk Factors In order to characterize risks from dermal exposures, generally expressed as absorbed doses, oral risk factors are adjusted to account for oral absorption efficiency.	X		
– Slope Factors (SF) SFs represent upper 95-percent confidence limit values; carcinogenic risks calculated using SFs generally represent upper-bound estimates.	X		
– Lack of Risk Factors Risks from exposure to chemicals with no available chemical-specific or substitute risk factors cannot be quantitatively characterized.		X	
Risk Summations			
Risks from chemical mixtures are characterized by summing the individual chemical risks. This procedure assumes that chemicals have the same toxic end points and mechanisms of action and do not interact, either synergistically or antagonistically. These assumptions may be incorrect.			X
Exposure Periods			
Acute exposures are characterized by comparison to subchronic risk factors. Evaluating exposures using risk factors based on a longer exposure period is conservative.	X		

5.5.1 Risk Factors

Risk factors, such as SFs and RfDs are used to characterize risks associated with estimated exposures. However, uncertainty is involved in development and use of risk factors. Four specific sources of uncertainty are discussed below.

5.5.1.1 Extrapolations

Risk factors (SFs and RfDs) used in evaluating human health risks are developed using several types of extrapolations. Extrapolations are made for species, exposure dose, and exposure period. These are discussed below.

Most risk factors are based on animal test results. However, human beings may differ from test animals in uptake, metabolism, distribution, and elimination of chemicals. Risk factors are generally developed under the assumption that a human being is as sensitive or more sensitive to a chemical than the test animal, even though results for the most sensitive test species are generally used as the basis for the risk factors. An uncertainty factor (usually 10, but sometimes up to 1,000) is incorporated into the risk factor to account for any greater human sensitivity. To the extent that human beings are more or less sensitive than the test animals, results may under estimate or (more likely) overestimate the true risks to human beings.

In the laboratory, test animals are usually exposed for less than 2 years to high chemical dose levels on a regular schedule. In contrast, humans are likely to be exposed to much lower chemical doses on a less regular basis for widely varying exposure periods. Limited human data exists for many chemicals characterized as carcinogenic in this risk assessment. Most of the evidence used to characterize these chemicals as carcinogenic is from animal studies. Presently, chemicals that are found to be carcinogenic in laboratory animals (under appropriate experimental protocols) are considered to be potential human carcinogens. To the extent that particular chemicals are ultimately shown <u>not</u> to be carcinogenic to humans, carcinogenic risks presented in this risk assessment may overestimate actual carcinogenic risks associated with TCAAP.

However, many noncarcinogenic health effects may have thresholds, meaning that they are not observed under low-dose or infrequent exposure conditions. If actual human exposures are below chemical-specific thresholds, use of risk factors based on laboratory exposures may result in overestimation of actual risks.

In general, risk factors are very conservative, in order to protect human health. In the risk characterization, therefore, estimated risks may overestimate true risks.

5.5.1.2 Adjustment of Risk Factors

This risk assessment presents carcinogenic and noncarcinogenic risks for chemicals with available risk factors (RfDs and SFs). Most available risk factors are derived from experiments in which the route of exposure was ingestion. The resulting oral risk factors are related to the amount of substance administered per unit of time and unit of body weight. When dermal routes of exposure are considered, exposures are expressed as absorbed rather than administered doses. To estimate risks for dermal routes of exposure, risk factors must also be expressed in terms of absorbed doses. Therefore, risk factors are adjusted to account for oral absorption efficiency.

Estimating risks from dermal exposure involves making several additional assumptions that do not apply to risks from oral exposure. Therefore, the uncertainty associated with estimating dermal risks is greater. Because of the high degree of uncertainty involved in estimating risks from dermal exposure to chemicals and because of the conservative nature of the assumptions involved, risks estimated for dermal exposures may overestimate actual risks.

The oral SF for trichloroethene has been removed from IRIS and is footnoted in HEAST (U.S. EPA, 1990c) as being based on a metabolized dose. U.S. EPA's Environmental Criteria and Assessment Office (ECAO) has recently indicated that trichloroethene's SF was originally derived in terms of a metabolized dose: 1.3E-02 (mg metabolized dose/kg/day)$^{-1}$ (Hurst, 1991). This value was then converted to an administered dose by applying a conversion factor of 0.85 (the approximate extent to which trichloroethene has been metabolized in laboratory studies of mice and rats) (Hurst, 1991). The resulting risk factor, 1.1E-02 (mg administered dose/kg/day)$^{-1}$, is listed in HEAST (U.S. EPA, 1990c) and is used in this risk assessment.

The derivation and use of the SF for trichloroethene therefore involve a degree of uncertainty, in terms of both the derivation of the original SF (see Section 5.5.1.3) and the conversion of this SF to an administered dose.

The inhalation SF for trichloroethene, 1.7 (mg/kg/day)$^{-1}$, listed in HEAST is also presented in units of (mg metabolized TCE/kg/day)$^{-1}$. The metabolism of trichloroethene appears to vary somewhat among species. Various researchers have reported the percentage of a trichloroethene dose metabolized as being between 40 and 75 percent of the retained dose (ATSDR, 1988b). Stutt and others (as reported in ATSDR, 1988b) have studied metabolism of trichloroethene in mice and rats. Almost 100 percent of the dose was metabolized in mice, and approximately 79 to 98 percent of the dose was metabolized in rats. (The percentage of metabolism decreased with increased doses).

The inhalation SF for trichloroethene reported in HEAST is based on studies using mice. Because mice apparently metabolize 100 percent of the administered dose, the SF presented in units of (mg administered dose/kg/day)$^{-1}$ also equals 1.7. To be conservative, this risk assessment uses an inhalation SF for trichloroethene equal to 1.7 (mg administered dose/kg/day)$^{-1}$. To the extent that trichloroethene is metabolized to a lesser degree in human beings, use of this SF may result in overestimation of the actual risks to human health from exposure via inhalation by approximately a factor of two (less than an order of magnitude).

5.5.1.3 Slope Factors

SFs represent the upper 95-percent confidence limit values, based on the linearized, multistage carcinogenesis model. The estimated carcinogenic risks calculated using SF generally represent upper-bound estimates of the true risks. Therefore, the use of these SFs may result in an overestimation of the true risks. Specifically, true risks are unlikely to be greater than the estimated values, and are likely to be less.

5.5.1.4 Lack of Risk Factors

Uncertainty is introduced by the lack of risk factors for some chemicals for which appropriate substitute are not available. In not evaluating the risks from potential exposures to these chemicals, true risks may be underestimated. For example, high levels of lead have been measured in Exposure Area F on-TCAAP. However, no risk factors are available for lead; the only guidance presents levels of lead in soils and dust (500 to 1000 mg/kg) developed by CDC (U.S. Department of Health and Human Services, 1985) that may be associated with adverse non carcinogenic health effects (elevated blood lead levels above background). Without chemical-specific risk factors, quantitative risks for lead and other chemicals cannot be developed. The true risks associated with exposure to these chemicals must be evaluated qualitatively.

5.5.2 Risk Summations

Risks from mixing chemicals found at TCAAP are calculated by summing individual chemical risks. This procedure is recommended by U.S. EPA (1986 and 1989a) and assumes that all chemicals have the same toxic endpoints and mechanisms of action. However, this assumption may be incorrect; chemicals may in fact have different toxic endpoints and mechanisms of action. Furthermore, chemicals in a mixture may act synergistically or antagonistically once they enter the human body. Little information is currently available on synergistic or antagonistic actions

within chemical mixtures. Interactions between chemicals in a mixture may form new toxic components or may cause changes in the bioavailability of the existing chemicals. Summation of individual chemical risks within and across exposure pathways may overestimate or underestimate true risks.

5.5.3 Exposure Periods

Exposure periods over which exposure doses are calculated should be similar to exposure periods for risk factors used to assess risks associated with the exposure doses. For example, chronic exposure doses should be evaluated using chronic risk factors. For this risk assessment, acute exposure doses are evaluated using subchronic risk factors (RfDs). Because of lack of appropriate test data, subchronic RfDs for some chemicals are the same as their chronic RfDs. Evaluating exposure doses using risk factors based on longer exposure periods is conservative and generally results in overestimation of true risks.

5.6 RISK CHARACTERIZATION SUMMARY

This chapter describes procedures used to quantitatively estimate risks to human health associated with acute and chronic exposures; it also presents chemical-specific risks associated with each exposure pathway. This section discusses total upper-bound excess lifetime carcinogenic risks and noncarcinogenic risks for each exposure area; it also identifies the chemicals of potential concern contributing most to these risks. Total risks associated with each of the exposure pathways in each exposure area are summarized in Tables 5-3 through 5-26. These tables are presented at the end of Chapter 5.

Risks are summarized under three sets of exposure conditions. Risks associated with exposures on-TCAAP under current and probable future land use conditions are summarized in Tables 5-3 and 5-4. Risks associated with exposures off-TCAAP under current and probable and RME future land use conditions are summarized in Tables 5-5 and 5-6. (Risks associated with exposures off-TCAAP under RME future land use conditions are assumed to be identical to those under probable future land use conditions.) Risks associated with exposures on-TCAAP under RME future land use conditions are summarized in Tables 5-7 through 5-25. In addition, Table 5-26 summarizes risks associated with on-TCAAP exposures to ground water from Units 1 and 4 under RME future land use conditions. (Risks summarized for the third set of exposure conditions include risks associated with exposure to ground water from Unit 3.)

One set of footnotes that applies to Tables 5-3 through 5-26 is presented immediately following Table 5-26. The most important of these footnotes relate to the HIs presented in the

tables. As discussed in Section 5.1.2, within each exposure pathway, all chemical-specific HQs are summed and expressed as an HI. Initially, all HIs greater than one are assumed to indicate the potential for noncarcinogenic adverse health effects. The extent to which an HI exceeds one does not matter.

This approach is conservative because not all chemicals affect the same target organ(s) or have the same chemical effect(s). Therefore, in accordance with the most recent U.S. EPA guidance (U.S. EPA, 1989c), all HIs greater than one are further evaluated. Specifically, each HI greater than one is reviewed to determine whether the total is driven by one or more chemical-specific HQs greater than one; those HIs driven by one or more chemical-specific HQ are footnoted as such, and the exposure is assumed to have the potential to result in an adverse noncarcinogenic health effect. If no chemical-specific HQ greater than 1.0 is identified, chemical-specific HQs associated with the same target organ(s) or chemical effect(s) are summed as separate HIs. If none of these target organ- or chemical effect-specific HIs is greater than one, the overall HI is footnoted as such; exposure via the pathway is not associated with any adverse noncarcinogenic health effect(s). Finally, if one or more of the target organ- or chemical effect-specific HIs exceed one, the overall HI is footnoted as such and exposure via the pathway may be associated with adverse noncarcinogenic health effects.

Risks are discussed according to exposure area for each of the exposure conditions described above. Receptors are assumed to be exposed within a single exposure area. For example, under RME future land use conditions, a receptor living in a home located in Exposure Area A is assumed to be exposed to surface soil, subsurface soil, ground water, air, and vegetables and fruits only in Exposure Area A. The single exception to this assumption involves exposures associated with surface water and sediment.

A second assumption is made: under each exposure condition, receptors may be exposed to surface water and sediment from any of the surface water bodies for which risks are evaluated under the exposure condition. Therefore, exposure area-specific risks are summarized separately from surface water and sediment risks. The reader may determine which surface water bodies a receptor may be exposed to; the reader may then consider the risks associated with those surface water bodies in addition to exposure area-specific risks.

5.6.1 On-TCAAP Risks Under Current and Probable Future Land Use Conditions

Risks for on-TCAAP maintenance workers associated with exposure to surface soil and surface water and sediment are summarized in Tables 5-3 and 5-4, respectively. Risks associated with excavation activities on-TCAAP under current and probable future land use conditions are

assumed to be equal to or less than those under RME future land use conditions and are summarized in Section 5.6.3. Risks for on-TCAAP office or manufacturing area workers associated with the inhalation of VOCs from remedial activities are assumed to be equal to those under RME future land use conditions and are summarized in Section 5.6.3. Finally, exposure to ground water is assumed to be an incomplete pathway and is not evaluated under current or probable future land use conditions.

5.6.1.1 Surface Soil Risks

Risks associated with on-TCAAP exposures to surface soil under current and probable future land use conditions are summarized in Table 5-3.

Exposure Area A

All upper-bound excess lifetime cancer risks associated with exposure to surface soil via ingestion and dermal contact are less than 1E-07. Noncarcinogenic HQs exceed one for exposure via ingestion only for acute exposure under RME conditions. HQs exceed one for acute exposure via dermal contact under both probable and RME conditions and for chronic exposure via dermal contact only under RME conditions. The major contributor to total risks is antimony in all cases.

Exposure Area C

The total upper-bound excess cancer risks associated with exposure to surface soil via ingestion and dermal contact are 2E-05 and 3E-05 under probable and RME conditions, respectively. The major contributors to total risks are five PAHs: benzo(a)anthracene, benzo(b)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene. All noncarcinogenic HQs are less than one.

Exposure Area F

All upper-bound excess lifetime cancer risks are less than 1E-07. Noncarcinogenic HQs exceed one only for acute exposure to surface soil via dermal contact. The major contributor to risks is total antimony.

Exposure Area H

The total upper-bound excess lifetime cancer risks are 1E-08 and 1E-07 under probable and RME conditions, respectively. Noncarcinogenic HQs exceed one only for acute exposure to surface soil via dermal contact. The major contributor to total risks is antimony.

Exposure Area 129-3

The total upper-bound excess lifetime cancer risks are 3E-07 and 5E-07 under probable and RME conditions, respectively. The major contributor to total risks is 2,4-dinitrotoluene. Noncarcinogenic HQs exceed one only for acute exposure via ingestion under RME conditions and via dermal contact under probable and RME conditions. The major contributor to total risks is antimony in all cases.

Exposure Areas B, D, E, G, J, 129-5, and 129-15

All upper-bound excess cancer risks associated with exposure to surface soil via ingestion and dermal contact are less than 1E-07. No noncarcinogenic HQ is greater than one.

Exposure Areas I and K

Risks are not evaluated for these areas because surface soil in Exposure Areas I and K was not sampled during the on-TCAAP RI (ANL, 1990).

5.6.1.2 Surface Water and Sediment Risks

Risks associated with on-TCAAP exposures to surface water and sediment under current and probable future land use conditions are summarized in Table 5-4. All upper-bound excess cancer risks are less than 1E-07. No noncarcinogenic HQ is greater than one.

5.6.2 Off-TCAAP Risks Under Current and Probable and RME Future Land Use Conditions

Risks associated with off-TCAAP exposures to ground water via ingestion, inhalation, and dermal contact are summarized in Table 5-5. Risks associated with off-TCAAP exposures to VOCs via inhalation are summarized in Table 5-6. Risks associated with exposures related to surface water and sediment are equal to those under on-TCAAP RME future land use (see

Section 5.6.3). Under current and probable future land use conditions, off-TCAAP residents are assumed to be exposed only at surface water bodies located off-TCAAP. Under RME future land use conditions, off-TCAAP residents may be exposed at surface water bodies located both on- and off-TCAAP.

5.6.2.1 Ground-Water Risks

Risks associated with off-TCAAP exposure to ground water are summarized in Table 5-5. Risks are discussed according to exposure area: first Unit 1 Exposure Area S, then Unit 3 Exposure Areas (3V, 3W, 3X, 3Y, and 3Z), and finally Unit 4 Exposure Areas (4W, 4X, 4Y, and 4Z). Unit 4 exposure areas do not entirely underlie Unit 3 exposure areas of similar designation.

Exposure Area S

Exposure Area S is the only off-TCAAP exposure area evaluated for Unit 1. The total upper-bound excess lifetime cancer risks are 3E-07 and 3E-06 under probable and RME conditions, respectively. The major contributor to total risks is chloroform. All noncarcinogenic HQs associated with both acute and chronic exposures are less than one.

Exposure Area 3V

The total upper-bound excess lifetime cancer risks are 1E-05 and 5E-05 under probable and RME conditions, respectively. Exposures via ingestion, inhalation, and dermal contact contribute similarly to total risks. The major contributors to total risks are 1,1-dichloroethane, 1,1-dichloroethene, and bis(2-ethylhexyl)phthalate. All noncarcinogenic HQs associated with both acute and chronic exposures are less than one.

Exposure Area 3W

The total upper-bound excess lifetime cancer risks are 1E-05 and 1E-04 under probable and RME conditions, respectively. The major contributors to total risks are 1,1-dichloroethane, 1,1-dichloroethene, and trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures in both Unit 3 and Unit 4 are less than one.

Exposure Area 3X

The total upper-bound excess lifetime cancer risks are 6E-05 and 4E-04 under probable and RME conditions, respectively. The major contributors to total risks are 1,1-dichloroethane, 1,1-

dichloroethene, and 1,1,2-trichloroethane. All noncarcinogenic HQs associated with acute and chronic exposures via ingestion, inhalation, and dermal contact are less than one.

Exposure Area 3Y

The total upper-bound excess lifetime cancer risks are 1E-03 and 8E-03 under probable and RME conditions, respectively. The major contributors to total risks are 1,1-dichloroethane, 1,1-dichloroethene, 1,1,2-trichloroethane, and trichloroethene. All noncarcinogenic HQs associated with acute exposures via ingestion, inhalation, and dermal contact are less than one for both children and adults. Noncarcinogenic HQs associated with chronic exposures exceed one for exposures via ingestion and dermal contact under RME conditions for both children and adults. The major contributor to total noncarcinogenic risks via both pathways is 1,1,2-trichloroethane.

Exposure Area 3Z

The total upper-bound excess lifetime cancer risks are 2E-03 and 1E-02 under probable and RME conditions, respectively. The major contributors to the total risks are trichloroethene, 1,1-dichloroethene, 1,1-dichloroethane, and 1,2-dichloroethane. All noncarcinogenic HQs associated with acute and chronic exposures via ingestion, inhalation, and dermal contact are less than one.

Exposure Area 4W

The total upper-bound excess lifetime cancer risks are 4E-05 and 4E-04 under probable and RME conditions, respectively. The major contributors to total risks are 1,1-dichloroethene, 1,1-dichloroethane, and trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures via ingestion, inhalation, and dermal contact are less than one.

Exposure Area 4X

The total upper-bound excess lifetime cancer risks are 8E-05 and 2E-04 under probable and RME conditions, respectively. The major contributors to total risks are bis(2-ethylhexyl)phthalate, 1,1-dichloroethene, trichloroethene, and 1,1-dichloroethane. Noncarcinogenic HQs exceed one for acute and chronic exposures via ingestion for both children and adults under both probable and RME conditions. The major contributor to total risks is antimony in all cases. All noncarcinogenic HQs associated with acute and chronic exposures via inhalation and dermal contact are less than one.

Exposure Area 4Y

The total upper-bound excess lifetime cancer risks are 6E-05 and 2E-04 under probable and RME conditions, respectively. The major contributors to total risks are 1,1-dichloroethene, trichloroethene, and 1,1-dichloroethane. All noncarcinogenic HQs associated with acute and chronic exposures via ingestion, inhalation, and dermal contact are less than one.

Exposure Area 4Z

The total upper-bound excess lifetime cancer risks are 7E-04 and 5E-03 under probable and RME conditions, respectively. The major contributors to the total risks are 1,1-dichloroethene, trichloroethene, and 1,1-dichloroethane. All noncarcinogenic HQs associated with acute and chronic exposures via ingestion, inhalation, and dermal contact are less than one.

5.6.2.2 Air Risks

Risks associated with off-TCAAP exposure to VOCs via inhalation are summarized in Table 5-6. Upper-bound excess lifetime cancer risks are evaluated under the assumption that all VOC emissions consist of trichloroethene. Noncarcinogenic risks are evaluated under the assumption that all VOC emissions consist of 1,1,1-trichloroethane. Risks are estimated for receptor points in the following off-TCAAP locations: Shoreview, the triangle area immediately southwest of TCAAP, the area south of the triangle area, Long Lake, New Brighton, Silver Lake, Mounds View, Spring Lake, and Snelling Avenue.

Upper-bound excess lifetime cancer risks are less than 1E-06 at all receptor points. The greatest risk under probable conditions is 2E-07 at Shoreview, the triangle area, and Snelling Avenue. The greatest risk under RME conditions is 7E-07 at Snelling Avenue. All noncarcinogenic HQs associated with acute and chronic exposures for children and adults are less than 1E-02.

5.6.3 On-TCAAP Risks Under RME Future Land Use Conditions

Risks for future on-TCAAP residents, construction workers, and industrial or manufacturing workers are summarized according to exposure area in Tables 5-7 through 5-25. For the purposes of this risk assessment, future on-TCAAP residents are assumed to use ground water from Unit 3. (Additional risks associated with exposure to on-TCAAP Unit 1 and Unit 4 ground water under RME future land use conditions are summarized in Section 5.6.4).

5.6.3.1 Exposure Area-Specific Risks

For each exposure area, total upper-bound excess lifetime cancer risks are discussed first, followed by noncarcinogenic risks.

Exposure Area A

The total upper-bound excess lifetime cancer risks are 2E-07 and 6E-07 for residents, 2E-06 and 2E-03 for construction workers, and 6E-09 and 2E-08 for manufacturing or industrial workers under probable and RME conditions, respectively. Total risks for residents and industrial or manufacturing workers are associated with inhalation of trichloroethene. The major contributors to total risks for construction workers are cadmium and nickel under probable conditions and hexavalent chromium under RME conditions (haxavalent chromium was assumed to be present only under RME conditions).

Noncarcinogenic HQs associated with acute exposures under probable conditions exceed one for children, adults, and construction workers via ingestion of and dermal contact with surface and subsurface soils for children and adults via ingestion of vegetables and fruits. The major contributor to total risks is antimony in all cases.

Noncarcinogenic HQs associated with chronic exposures exceed one for children via ingestion of and dermal contact with surface and subsurface soils and ingestion of vegetables and fruits under both probable and RME conditions. Noncarcinogenic HQs associated with chronic exposures for adults exceed one via dermal contact with surface and subsurface soils under RME conditions and ingestion of vegetables and fruits under both probable and RME conditions. Noncarcinogenic HQs associated with chronic exposures for construction workers exceed one via ingestion of and dermal contact with surface and subsurface soils under both probable and RME conditions. The major contributor to total risks is antimony in all cases.

Noncarcinogenic HQs associated with acute and chronic exposures to ground water and air are less than one.

Exposure Area B

All total upper-bound excess lifetime cancer risks are less than 1E-06 with one exception. Exposures to subsurface soil for construction workers via inhalation under RME conditions present an upper-bound excess lifetime cancer risk of 1E-04. This risk is driven almost entirely by hexavalent chromium (hexavalent chromiium was assumed to be present only under RME

conditions). All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area C

The total upper-bound excess lifetime cancer risks are 5E-03 and 2E-02 for residents, 1E-04 and 8E-04 for construction workers, and 3E-08 and 9E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene for surface and subsurface soils and trichloroethene for ground water, and for vegetables and fruits, and air. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area D

The total upper-bound excess lifetime cancer risks are 8E-03 and 8E-02 for residents and 4E-08 and 1E-07 for industrial or manufacturing workers. The major contributor to total risks for residents via exposure to ground water is trichloroethene. Total risks associated with exposure to VOCs in air are due entirely to trichloroethene.

All noncarcinogenic HQs associated with acute exposures are less than one. Noncarcinogenic risks associated with chronic exposures exceed one only for exposure to ground water. HQs exceed one for children via ingestion and dermal contact under both probable and RME conditions and via inhalation under RME conditions. HQs exceed one for adults via dermal contact under both probable and RME conditions and via ingestion under RME conditions. The major contributor to total risks is 1,1,1-trichloroethane in all cases.

Exposure Area E

The total upper-bound excess lifetime cancer risks are 8E-06 and 5E-05 for residents, 3E-06 and 6E-04 for construction workers, and 3E-08 and 1E-07 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are PCBs for surface and subsurface soils; tetrachloroethene and bis(2-ethylhexyl)phthalate for ground water; and PCBs for vegetables and fruits. Risks associated with inhalation of VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area F

The total upper-bound excess lifetime cancer risks are 4E-04 and 2E-03 for residents, 2E-06 and 2E-04 for construction workers, and 3E-08 and 1E-07 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are 1,1-dichloroethene, bis(2-ethylhexyl)phthalate, and trichloroethene for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene.

Noncarcinogenic HQs associated with acute exposures exceed one only for children--via ingestion of surface and subsurface soils under probable and RME conditions; via dermal contact with surface and subsurface soils under RME conditions; and via ingestion of vegetables and fruits under probable and RME conditions. Under RME conditions, HQs exceed one for children and construction workers via ingestion of surface and subsurface soils; for children, adults, and construction workers via dermal contact with surface and subsurface soils; and for children and adults via ingestion of vegetables and fruits.

Noncarcinogenic HQs associated with chronic exposures exceed one only for children under RME conditions via ingestion of and dermal contact with surface and subsurface soils and via ingestion of vegetables and fruits. The major contributor to total noncarcinogenic risks for both acute and chronic exposures is antimony in all cases.

Exposure Area G

The total upper-bound excess lifetime cancer risks are 6E-03 and 4E-02 for residents, 3E-06 and 6E-06 for construction workers, and 3E-08 and 9E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are nickel for subsurface soil and 1,1-dichloroethane, methylene chloride, and trichloroethene for ground water. Risks via inhalation of VOCs are due entirely to trichloroethene.

Noncarcinogenic HQs exceed one only for exposures to ground water for children and adults. For acute exposures, HQs exceed one via ingestion under RME conditions and via dermal contact under probable and RME conditions for both children and adults. For chronic exposures, HQs exceed one via ingestion and dermal contact under probable and RME conditions for both children and adults and via inhalation under RME conditions for children. The major contributors to total noncarcinogenic risks are methylene chloride, 1,1,1-trichloroethane, and 1,2-dichloroethene.

Exposure Area H

The total upper-bound excess lifetime cancer risks are 1E-06 and 1E-05 for residents, 6E-06 and 1E-03 for construction workers, and 1E-08 and 3E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are nickel and cadmium under probable conditions and hexavalent chromium under RME conditions for subsurface soil (hexavalent chromium was assumed to be present only under RME conditions) and trichloroethene for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene.

Noncarcinogenic HQs associated with acute exposures exceed one for children via ingestion of and dermal contact with surface and subsurface soils under probable and RME conditions. HQs exceed one for adults via dermal contact with surface and subsurface soils under RME conditions. Similarly, HQs exceed one for construction workers via ingestion and dermal contact with surface and subsurface soils under RME conditions. The major contributor to total risks is antimony in all cases. HQs associated with chronic exposures exceed one only for children via ingestion of and dermal contact with surface and subsurface soils under RME conditions. The major contributor to total risks is antimony.

Exposure Area I

The total upper-bound excess lifetime cancer risks are 8E-04 and 1E-02 for residents and 1E-08 and 5E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are trichloroethene, tetrachloroethene, bis(2-ethylhexyl)phthalate, 1,1-dichloroethene, 1,1-dichloroethane, and 1,1,2-trichloroethane for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area J

The total upper-bound excess lifetime cancer risks are 2E-06 and 6E-06 for residents, 7E-06 and 3E-04 for construction workers, and 6E-08 and 2E-07 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are nickel under probable conditions and hexavalent chromium under RME conditions for surface and subsurface soils (hexavalent chromium was assumed to be present only under RME conditions). Risks associated with inhalation of VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area K

The total upper-bound excess lifetime cancer risks are 3E-06 and 9E-06 for residents and 2E-08 and 9E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributor to total risks is bis(2-ethylhexyl)phthalate for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area 129-3

The total upper-bound excess lifetime cancer risks are 3E-05 and 2E-04 for residents, 4E-07 and 2E-04 for construction workers, and 5E-08 and 2E-07 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are 2,4-dinitrotoluene for surface and subsurface soils and trichloroethene for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene.

Noncarcinogenic HQs associated with acute exposures via ingestion of and dermal contact with surface and subsurface soils exceed one for children and construction workers under probable and RME conditions. For adults, HQs exceed one for exposures via ingestion under RME conditions and via dermal contact under probable and RME conditions. HQs also exceed one for exposures via ingestion of vegetables and fruits for children and adults under probable and RME conditions.

Noncarcinogenic HQs associated with chronic exposures exceed one only for children and adults: for children via ingestion of and dermal contact with surface and subsurface soils and via ingestion of vegetables and fruits under both probable and RME conditions; for adults via dermal contact with surface and subsurface soils under RME conditions and via ingestion of vegetables and fruits under probable and RME conditions. The major contributor to total risks associated with both acute and chronic exposures is antimony in all cases.

Exposure Area 129-5

The total upper-bound excess lifetime cancer risks are 4E-06 and 2E-05 for residents, 1E-06 and 6E-05 for construction workers, and 1E-08 and 4E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are nickel under probable conditions and hexavalent chromium under RME conditions for surface and subsurface soils (hexavalent chromium was assumed to be present only under RME conditions) and bis(2-ethylhexyl)phthalate for ground water. Risks associated with inhalation of

VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area 129-15

The total upper-bound excess lifetime cancer risks are 7E-06 and 2E-05 for residents, 1E-06 and 7E-05 for construction workers, and 6E-08 and 2E-07 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are nickel under probable conditions and hexavalent chromium under RME conditions for surface and subsurface soils (hexavalent chromium was assumed to be present only under RME conditions) and trichloroethene and chloroform for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area X1

The total upper-bound excess lifetime cancer risks are 4E-07 and 1E-06 for residents and 1E-08 and 4E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributor to total risks is trichloroethene associated with inhalation of VOCs. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area X2

The total upper-bound excess lifetime cancer risks are 9E-07 and 5E-06 for residents and 1E-08 and 4E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributor to total risks is trichloroethene for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

Exposure Area X3

The total upper-bound excess lifetime cancer risks are 6E-03 and 2E-02 for residents and 1E-07 and 4E-07 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributors to total risks are vinyl chloride, 1,1-dichloroethene, trichloroethene, and 1,1-dichloroethane for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene. Noncarcinogenic HQs exceed one only for children for both acute and chronic exposures to ground water via dermal contact under RME conditions.

Exposure Area X4

The total upper-bound excess lifetime cancer risks are 8E-06 and 2E-05 for residents and 1E-08 and 5E-08 for industrial or manufacturing workers under probable and RME conditions, respectively. The major contributor to total risks is bis(2-ethylhexyl)phthalate for ground water. Risks associated with inhalation of VOCs are due entirely to trichloroethene. All noncarcinogenic HQs associated with acute and chronic exposures are less than one.

5.6.3.2 Surface Water and Sediment Risks

Most potential exposures to surface water and sediment on- and off-TCAAP present little risk to human health. The maximum upper-bound excess lifetime cancer risks, 5E-07 is associated with exposure to surface water via dermal contact under RME conditions in Exposure Area K. Noncarcinogenic HQs exceeded one in only two instances both involving children under RME conditions: (1) acute exposure to Sunfish Lake sediment via dermal contact and (2) acute ingestion of fish from Rice Creek.

Therefore, exposure to surface water and sediment on- or off-TCAAP will add little to total carcinogenic and noncarcinogenic risks for off-TCAAP residents under all exposure conditions and for on-TCAAP residents under RME future land use conditions.

5.6.4 Additional On-TCAAP Ground-Water Risks (Units 1 and 4) Under RME Future Land Use Conditions

As discussed in Section 5.6.3, for the purposes of summarizing on-TCAAP risks under RME future land use conditions, it is assumed that residents will be exposed to Unit 3 ground water. In general, exposures to Unit 3 ground water are associated with greater risks than exposures to Unit 1 or Unit 4 ground water. However, because on-TCAAP residents under RME future land use conditions may be exposed to ground water from Unit 1 or Unit 4 instead of Unit 3, risks associated with Unit 1 and 4 ground water are summarized in this section. Risks associated with exposure to ground water from Unit 1 or 4 may be substituted for those previously described for Unit 3 in assessing risks for a particular exposure area.

Rather than summarize risks for each exposure area, risks are summarized according to unit. Risks associated with Unit 1 ground water are discussed first, followed by risks associated with Unit 4 ground water.

5.6.4.1 Unit 1 Risks

The total upper-bound excess lifetime cancer risks (for exposure areas with total carcinogenic risks greater than 1E-07) range from 7E-07 to 6E-03 under probable conditions and from 9E-06 to 8E-02 under RME conditions. The major contributors to total risks are vinyl chloride, 1,1-dichloroethene, trichloroethene, and bis(2-ethylhexyl)phthalate.

Noncarcinogenic HQs exceed one for children in Exposure Areas A, I, and J and for children and adults in Exposure Area K under RME conditions. Specifically, HQs associated with ingestion exceed one in at least one of the exposure areas listed above for both acute and chronic exposures. HQs associated with dermal contact exceed one in at least one of the exposure areas listed above, but only for chronic exposures. The major contributors to total risks are antimony, 1,2-dichloroethene, and manganese.

5.6.4.2 Unit 4 Risks

The total upper-bound excess lifetime cancer risks (for exposure areas with total carcinogenic risks greater than 1E-07) range from 7E-07 to 2E-03 under probable conditions and from 9E-06 to 9E-03 under RME conditions. The major contributors to total risks are 1,1-dichloroethene, trichloroethene, arsenic, and 1,1-dichloroethane.

Noncarcinogenic HQs exceed one in Exposure Area X3-Upper, for acute and chronic exposure via ingestion by children under RME conditions. The major contributor to total risks is arsenic.

TABLE 5-3

SUMMARY OF RISKS FOR ON-TCAAP WORKERS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices	Chronic Hazard Indices
				Worker	Worker	Worker
A	Surface Soil	Ingestion	Probable[b]	--	1.8E-01	5.0E-03
			RME[c]	--	5.9E+00[d]	1.6E-01
		Dermal Contact	Probable	--	4.1E+00[d]	1.1E-01
			RME	--	3.7E+01[d]	1.0E+00[d]
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND
B	Surface Soil	Ingestion	Probable	--	3.9E-05	1.1E-06
			RME	--	3.9E-04	1.1E-05
		Dermal Contact	Probable	--	1.5E-03	4.4E-05
			RME	--	4.1E-03	1.2E-04
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND
C	Surface Soil	Ingestion	Probable	3E-07	1.5E-05	4.2E-06
			RME	3E-06	1.5E-04	4.2E-05
		Dermal Contact	Probable	2E-05	1.7E-03	4.3E-04
			RME	3E-05	2.8E-03	6.6E-04
	TOTAL		Probable	2E-05	ND	ND
			RME	3E-05	ND	ND

TABLE 5-3 (Continued)

SUMMARY OF RISKS FOR ON-TCAAP WORKERS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices	Chronic Hazard Indices
				Worker	Worker	Worker
E	Surface Soil	Ingestion	Probable	7E-10	1.6E-03	6.0E-05
			RME	2E-08	7.9E-03	6.3E-04
		Dermal Contact	Probable	1E-08	2.1E-02	8.6E-04
			RME	5E-08	3.8E-02	3.2E-03
	TOTAL		Probable	1E-08	ND	ND
			RME	7E-08	ND	ND
F	Surface Soil	Ingestion	Probable	5E-09	1.6E-02	4.4E-04
			RME	1E-07	2.0E-01	5.3E-03
		Dermal Contact	Probable	6E-09	3.5E-01	9.6E-03
			RME	3E-08	1.1E+00[d]	3.0E-02
	TOTAL		Probable	1E-08	ND	ND
			RME	1E-07	ND	ND
H	Surface Soil	Ingestion	Probable	6E-09	2.5E-02	7.0E-04
			RME	8E-08	2.5E-01	7.4E-03
		Dermal Contact	Probable	7E-09	5.5E-01	1.6E-02
			RME	3E-08	1.5E+00[d]	4.4E-02
	TOTAL		Probable	1E-08	ND	ND
			RME	1E-07	ND	ND

TABLE 5-3 (Continued)

SUMMARY OF RISKS FOR ON-TCAAP WORKERS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices	Chronic Hazard Indices
				Worker	Worker	Worker
J	Surface Soil	Ingestion	Probable	--	3.1E-04	8.4E-06
			RME	--	6.1E-03	1.7E-04
		Dermal Contact	Probable	--	8.0E-03	2.2E-04
			RME	--	3.8E-02	1.1E-03
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND
129-3	Surface Soil	Ingestion	Probable	3E-09	7.2E-02	2.0E-03
			RME	4E-08	1.3E+00[d]	3.6E-02
		Dermal Contact	Probable	3E-07	1.7E+00[d]	4.9E-02
			RME	5E-07	8.1E+00[d]	2.3E-01
	TOTAL		Probable	3E-07	ND	ND
			RME	5E-07	ND	ND
129-5	Surface Soil	Ingestion	Probable	--	3.2E-05	9.1E-07
			RME	--	5.7E-04	1.6E-05
		Dermal Contact	Probable	--	1.2E-03	3.6E-05
			RME	--	5.9E-03	1.7E-04
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND

TABLE 5-3 (Continued)

SUMMARY OF RISKS FOR ON-TCAAP WORKERS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices	Chronic Hazard Indices
				Worker	Worker	Worker
129-15	Surface Soil	Ingestion	Probable	--	3.6E-05	1.0E-06
			RME	--	1.1E-03	3.0E-05
		Dermal Contact	Probable	--	1.4E-03	4.2E-05
			RME	--	1.1E-02	3.2E-04
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-4

SUMMARY OF FOR ON-TCAAP WORKERS RISKS FROM EXPOSURE TO SURFACE WATER AND SEDIMENTS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices	Chronic Hazard Indices
				Worker	Worker	Worker
C	Surface Water	Ingestion	Probable[b]	NA	NA	NA
			RME[c]	--	8.5E-03	--
		Dermal Contact	Probable	--	1.7E-02	3.4E-04
			RME	NA	1.0E-01	3.4E-03
	Sediments	Dermal Contact	Probable	--	--	--
			RME	--	--	--
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND
K	Surface Water	Ingestion	Probable	NA	NA	NA
			RME	3E-10	--	--
		Dermal Contact	Probable	2E-09	--	--
			RME	2E-08	--	--
	Sediments	Dermal Contact	Probable	--	--	--
			RME	--	--	--
	TOTAL		Probable	2E-09	ND	ND
			RME	2E-08	ND	ND
Round Lake	Surface Water	Ingestion	Probable	NA	NA	NA
			RME	--	1.1E-02	6.2E-04
		Dermal Contact	Probable	--	8.5E-03	2.3E-04
			RME	--	1.1E-01	5.9E-03
	Sediments	Dermal Contact	Probable	--	--	--
			RME	--	--	--
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND

TABLE 5-4 (Continued)

SUMMARY OF FOR ON-TCAAP WORKERS RISKS FROM EXPOSURE TO SURFACE WATER AND SEDIMENTS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices	Chronic Hazard Indices
				Worker	Worker	Worker
Sunfish Lake	Surface Water	Ingestion	Probable	NA	NA	NA
			RME	--	--	--
		Dermal Contact	Probable	--	--	--
			RME	NA	--	--
	Sediments	Dermal Contact	Probable	--	8.5E-02	2.3E-04
			RME	--	5.3E-01	2.9E-03
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND
Marsden Lake	Surface Water	Ingestion	Probable	NA	NA	NA
			RME	--	--	--
		Dermal Contact	Probable	--	8.1E-03	1.7E-04
			RME	NA	5.8E-02	2.2E-03
	Sediments	Dermal Contact	Probable	--	--	--
			RME	--	--	--
	TOTAL		Probable	--	ND	ND
			RME	--	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-5

SUMMARY OF RISKS FOR EXPOSURE TO OFF-TCAAP GROUND WATER
PROBABALE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE & RME FUTURE LAND USE CONDITIONS

Exposure Area/Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indices	
			Resident	Child[a]	Adult	Child[a]	Adult
1S Unit 1	Ingestion	Probable[b]	4E-08	3.7E-03	1.3E-03	3.7E-03	1.3E-03
		RME[c]	2E-07	7.0E-03	3.4E-03	7.0E-03	3.4E-03
	Inhalation	Probable	2E-07	--	--	--	--
		RME	2E-06	--	--	--	--
	Dermal Contact	Probable	6E-08	3.1E-03	1.6E-03	4.0E-03	2.1E-03
		RME	3E-07	1.0E-02	5.1E-03	1.2E-02	6.2E-03
TOTAL		Probable	3E-07	ND	ND	ND	ND
		RME	3E-06	ND	ND	ND	ND
3V Unit 3	Ingestion	Probable	4E-06	3.3E-01	1.1E-01	3.3E-01	1.2E-01
		RME	2E-05	5.6E-01	2.5E-01	5.3E-01	2.6E-01
	Inhalation	Probable	2E-06	NA	NA	1.0E-04	1.6E-05
		RME	2E-05	NA	NA	7.5E-04	1.2E-04
	Dermal Contact	Probable	4E-06	1.8E-02	8.6E-03	1.3E-02	5.8E-03
		RME	5E-05	3.3E-02	1.7E-02	4.4E-02	2.3E-02
TOTAL		Probable	1E-05	ND	ND	ND	ND
		RME	9E-05	ND	ND	ND	ND
3W Unit 3	Ingestion	Probable	4E-06	2.0E-03	7.1E-04	5.5E-03	2.0E-03
		RME	2E-05	5.6E-03	2.7E-03	1.5E-02	7.5E-03
	Inhalation	Probable	2E-06	NA	NA	9.2E-04	1.4E-04
		RME	2E-05	NA	NA	6.1E-03	9.3E-04
	Dermal Contact	Probable	6E-06	2.5E-03	1.3E-03	7.0E-03	3.6E-03
		RME	6E-05	1.1E-02	5.7E-03	3.2E-02	1.6E-02
TOTAL		Probable	1E-05	ND	ND	ND	ND
		RME	1E-04	ND	ND	ND	ND

TABLE 5-5 (Continued)

SUMMARY OF RISKS FOR EXPOSURE TO OFF-TCAAP GROUND WATER
PROBABALE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE & RME FUTURE LAND USE CONDITIONS

Exposure Area/Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indices	
			Resident	Child[a]	Adult	Child[a]	Adult
3X Unit 3	Ingestion	Probable	2E-05	1.6E-02	5.6E-03	8.3E-02	3.0E-02
		RME	1E-04	4.8E-02	2.3E-02	2.8E-01	1.3E-01
	Inhalation	Probable	1E-05	NA	NA	4.8E-04	7.3E-05
		RME	1E-04	NA	NA	2.5E-03	3.8E-04
	Dermal Contact	Probable	3E-05	1.8E-02	9.5E-03	9.4E-02	4.8E-02
		RME	2E-04	8.9E-02	4.5E-02	4.9E-01	2.5E-01
TOTAL		Probable	6E-05	ND	ND	ND	ND
		RME	4E-04	ND	ND	ND	ND
3Y Unit 3	Ingestion	Probable	4E-04	3.3E-01	7.4E-02	1.2E+00[b]	3.8E-01
		RME	2E-03	8.9E-01	4.2E-01	3.0E+00[c]	1.5E+00[d]
	Inhalation	Probable	5E-05	NA	NA	3.2E-02	5.0E-03
		RME	2E-03	NA	NA	1.2E-01	1.9E-02
	Dermal Contact	Probable	5E-04	4.9E-01	2.6E-01	1.3E+00[b]	6.9E-01
		RME	4E-03	1.3E+00[c]	6.5E-01	5.3E+00[c]	2.7E+00[d]
TOTAL		Probable	1E-03	ND	ND	ND	ND
		RME	8E-03	ND	ND	ND	ND
3Z Unit 3	Ingestion	Probable	6E-04	6.8E-01	2.4E-01	1.1E+00[b]	4.9E-01
		RME	2E-03	1.0E+00[c]	4.7E-01	1.8E+00[c]	8.4E-01
	Inhalation	Probable	5E-04	NA	NA	2.4E-02	3.7E-03
		RME	4E-03	NA	NA	1.3E-01	1.9E-02
	Dermal Contact	Probable	9E-04	4.3E-01	2.1E-01	9.1E-01	4.6E-01
		RME	6E-03	1.2E+00[c]	6.1E-01	2.6E+00[c]	1.3E+00[d]
TOTAL		Probable	2E-03	NA	ND	ND	ND
		RME	1E-02	NA	ND	ND	ND

TABLE 5-5 (Continued)

SUMMARY OF RISKS FOR EXPOSURE TO OFF-TCAAP GROUND WATER
PROBABALE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE & RME FUTURE LAND USE CONDITIONS

Exposure Area/Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indices	
			Resident	Child[a]	Adult	Child[a]	Adult
4W Unit 4	Ingestion	Probable	2E-05	8.8E-01	3.2E-01	8.3E-01	3.0E-01
		RME	1E-04	8.8E-01	4.2E-01	9.0E-01	4.4E-01
	Inhalation	Probable	1E-05	NA	NA	1.0E-03	1.6E-04
		RME	1E-04	NA	NA	7.5E-03	1.1E-03
	Dermal Contact	Probable	1E-05	1.6E-02	8.3E-03	3.0E-02	1.6E-02
		RME	2E-04	6.1E-02	3.2E-02	1.1E-01	5.7E-02
TOTAL		Probable	4E-05	ND	ND	ND	ND
		RME	4E-04	ND	ND	ND	ND
4X Unit 4	Ingestion	Probable	8E-05	6.0E+00[a]	2.2E+00[a]	6.7E+00[a]	2.4+00[a]
		RME	2E-04	6.2E+00[a]	2.9E+00[a]	7.4E+00[a]	3.6E+00[a]
	Inhalation	Probable	1E-06	NA	NA	1.1E-03	1.7E-04
		RME	1E-05	NA	NA	8.4E-03	1.2E-03
	Dermal Contact	Probable	3E-06	1.5E-01	1.0E-01	2.4E-01	1.3E-01
		RME	2E-05	3.4E-01	1.8E-01	4.4E-01	2.3E-01
TOTAL		Probable	8E-05	ND	ND	ND	ND
		RME	2E-04	ND	ND	ND	ND
4Y Unit 4	Ingestion	Probable	2E-05	1.5E-02	5.4E-03	2.6E-02	9.5E-03
		RME	4E-05	2.1E-02	1.0E-02	3.7E-02	1.8E-02
	Inhalation	Probable	1E-05	NA	NA	1.8E-03	2.8E-04
		RME	7E-05	NA	NA	8.2E-03	1.2E-03
	Dermal Contact	Probable	3E-05	1.8E-02	9.2E-03	4.4E-02	2.3E-02
		RME	1E-04	3.8E-02	1.9E-02	5.8E-02	3.0E-02
TOTAL		Probable	6E-05	ND	ND	ND	ND
		RME	2E-04	ND	ND	ND	ND

TABLE 5-5 (Continued)

SUMMARY OF RISKS FOR EXPOSURE TO OFF-TCAAP GROUND WATER
PROBABALE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE & RME FUTURE LAND USE CONDITIONS

Exposure Area/Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indices	
			Resident	Child[a]	Adult	Child[a]	Adult
4Z Unit 4	Ingestion	Probable	3E-04	1.1E+00[e]	4.0E-01	1.3+00[e]	4.7E-01
		RME	1E-03	1.4E+00[e]	6.5E-01	1.9E+00[e]	8.6E-01
	Inhalation	Probable	2E-04	NA	NA	1.9E-02	3.0E-03
		RME	1E-03	NA	NA	1.0E-01	1.5E-02
	Dermal Contact	Probable	2E-04	2.4E-01	1.2E-01	5.1E-01	2.6E-01
		RME	3E-03	8.4E-01	4.3E-01	1.2E+00[e]	6.1E-01
TOTAL		Probable	7E-04	ND	ND	ND	ND
		RME	5E-03	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-6

SUMMARY OF OFF-TCAAP RISKS FROM INHALATION OF TICHLOROETHENE
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
CURRENT AND PROBABLE FUTURE & RME LAND USE CONDITIONS

Location	Pathway	Exposure	Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indicies	
			Resident	Child[a]	Adult	Child[a]	Adult
Shoreview	Inhalation	Probable[b]	2E-07	3.8E-05	7.8E-06	3.8E-04	7.8E-05
		RME[c]	5E-07	6.6E-05	1.6E-05	6.6E-04	1.6E-04
Triangle	Inhalation	Probable	2E-07	1.3E-04	2.6E-05	1.3E-03	2.6E-04
		RME	6E-07	2.2E-04	5.1E-05	2.2E-03	5.1E-04
South of Triangle	Inhalation	Probable	8E-08	5.1E-05	1.0E-05	5.1E-04	1.0E-04
		RME	2E-07	8.8E-05	2.1E-05	8.8E-04	2.1E-04
Long Lake	Inhalation	Probable	6E-08	3.3E-05	6.6E-06	3.3E-04	6.6E-05
		RME	2E-07	5.6E-05	1.3E-05	5.6E-04	1.3E-04
New Brighton	Inhalation	Probable	4E-08	3.5E-05	7.2E-06	3.5E-04	7.2E-05
		RME	1E-07	6.1E-05	1.4E-05	6.1E-04	1.4E-04
Silver Lake	Inhalation	Probable	2E-08	7.5E-06	1.5E-06	7.5E-05	1.5E-05
		RME	5E-08	1.3E-05	3.0E-06	1.3E-04	3.0E-05
Mounds View	Inhalation	Probable	1E-07	3.8E-05	7.8E-06	3.8E-04	7.8E-05
		RME	4E-07	6.6E-05	1.6E-05	6.6E-04	1.6E-04
Spring Lake	Inhalation	Probable	1E-07	3.1E-05	6.3E-06	3.1E-04	6.3E-05
		RME	4E-07	5.3E-05	1.3E-05	5.3E-04	1.3E-04
Snelling Avenue	Inhalation	Probable	2E-07	1.1E-04	2.2E-05	1.1E-03	2.2E-04
		RME	7E-07	1.9E-04	4.5E-05	1.9E-03	4.5E-04

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-7

SUMMARY OF RISKS FOR EXPOSURE AREA A
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	–	–	1.8E+01[d]	1.8E+00[d]	3.6E+00[d]	5.2E+00[d]	1.5E-01	7.5E-01
		RME[c]	–	–	2.3E+02[d]	5.9E+00[d]	4.7E+01[d]	1.4E+02[d]	9.7E-01	9.9E+00[d]
	Dermal Contact	Probable	–	–	1.1E+01[d]	4.1E+00[d]	4.1E+00[d]	3.3E+00[d]	3.4E-01	8.6E-01
		RME	–	–	1.4E+02[d]	6.2E+01[d]	3.7E+01[d]	8.0E+01[d]	1.0E+01[d]	7.6E+00[d]
Subsurface Soil	Ingestion	Probable	–	–	1.3E+01[d]	1.3E+00[d]	2.7E+00[d]	3.9E+00[d]	1.1E-01	5.6E-01
		RME	–	–	1.5E+02[d]	3.7E+00[d]	3.0E+01[d]	8.6E+01[d]	6.1E-01	6.2E+00[d]
	Inhalation	Probable	–	2E-06	NA	NA	NA	NA	NA	NA
		RME	–	2E-03	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	–	–	8.3E+00[d]	3.0E+00[d]	3.0E+00[d]	2.4E+00[d]	2.5E-01	6.3E-01
		RME	–	–	8.5E+01[d]	3.9E+01[d]	2.3E+01[d]	5.0E+01[d]	6.4E+00[d]	4.8E+00[d]
Ground Water Unit 3	Ingestion	Probable	–	NA	–	–	NA	3.4E-02	1.2E-02	NA
		RME	–	NA	–	–	NA	6.6E-02	3.2E-02	NA
	Inhalation	Probable	–	NA	NA	NA	NA	NA	NA	NA
		RME	–	NA	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	–	NA	–	–	NA	9.3E-04	4.7E-04	NA
		RME	–	NA	–	–	NA	2.9E-03	3.1E-03	NA
Air	Inhalation	Probable	2E-07	6E-09	8.3E-05	1.7E-05	4.8E-06	8.3E-04	1.7E-04	4.8E-05
		RME	6E-07	2E-08	1.4E-04	3.4E-05	1.7E-05	1.4E-03	3.4E-04	1.7E-04
Fruit and Vegetables	Ingestion	Probable	–	NA	3.9E+01[d]	1.1E+01[d]	NA	9.7E+00[d]	2.7E+00[d]	NA
		RME	–	NA	1.3E+02[d]	3.6E+01[d]	NA	6.3E+01[d]	1.8E+01[d]	NA
TOTAL		Probable	2E-07	2E-06	ND	ND	ND	ND	ND	ND
		RME	6E-07	2E-03	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-8

SUMMARY OF RISKS FOR EXPOSURE AREA B
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	--	--	3.9E-03	3.9E-04	7.8E-04	1.2E-03	3.3E-05	1.8E-04
		RME[c]	--	--	1.5E-02	3.9E-04	3.1E-03	9.3E-03	6.6E-05	7.2E-04
	Dermal Contact	Probable	--	--	4.1E-03	1.5E-03	1.5E-03	1.3E-03	1.3E-04	3.6E-04
		RME	--	--	1.5E-02	6.9E-03	4.1E-03	9.5E-03	1.2E-03	9.7E-04
Subsurface Soil	Ingestion	Probable	--	--	1.4E-05	1.5E-06	2.9E-06	4.2E-05	1.2E-06	6.5E-06
		RME	--	--	7.8E-05	2.0E-06	1.6E-05	4.6E-04	3.2E-06	3.5E-05
	Inhalation	Probable	NA	--	NA	NA	,A	NA	NA	NA
		RME	NA	1E-04	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	--	--	4.5E-05	1.7E-05	1.7E-05	1.3E-04	1.4E-05	3.7E-05
		RME	--	--	2.3E-04	1.0E-04	6.1E-05	1.3E-03	1.7E-04	1.4E-04
Air	Inhalation	Probable	2E-07	6E-09	4.7E-05	9.6E-06	2.7E-06	4.7E-04	9.6E-05	2.7E-05
		RME	6E-07	2E-08	8.1E-05	1.9E-05	9.6E-06	8.1E-04	1.9E-04	9.6E-05
TOTAL		Probable	2E-07	6E-09	ND	ND	ND	ND	ND	ND
		RME	6E-07	1E-04	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-9

SUMMARY OF RISKS FOR EXPOSURE AREA C
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	2E-04	9E-06	1.5E-03	1.5E-04	3.2E-04	4.3E-03	1.2E-04	1.4E-03
		RME[c]	2E-03	7E-05	6.0E-03	1.5E-04	1.2E-03	3.5E-02	2.5E-04	5.4E-03
	Dermal Contact	Probable	2E-03	5E-05	4.3E-03	1.6E-03	1.6E-03	1.2E-02	1.3E-03	7.1E-03
		RME	8E-03	2E-04	9.0E-03	4.1E-03	2.4E-03	5.3E-02	6.7E-03	1.1E-02
Subsurface Soil	Ingestion	Probable	2E-04	9E-06	1.5E-03	1.5E-04	3.0E-04	4.4E-03	1.3E-04	1.3E-03
		RME	2E-03	7E-05	6.0E-03	1.5E-04	1.2E-03	3.5E-02	2.5E-04	5.5E-03
	Inhalation	Probable	NA	--	NA	NA	NA	NA	NA	NA
		RME	NA	3E-04	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	2E-03	5E-05	4.3E-03	1.6E-03	1.6E-03	1.3E-02	1.3E-03	7.0E-03
		RME	8E-03	2E-04	9.0E-03	4.0E-03	2.5E-03	5.3E-02	6.7E-03	1.1E-02
Ground Water Unit 3	Ingestion	Probable	5E-08	NA	1.3E-04	4.7E-05	NA	1.7E-04	6.2E-05	NA
		RME	2E-07	NA	2.9E-04	1.4E-04	NA	3.8E-04	1.8E-04	NA
	Inhalation	Probable	4E-08	NA	NA	NA	NA	5.1E-05	7.8E-06	NA
		RME	2E-07	NA	NA	NA	NA	2.5E-04	3.8E-05	NA
	Dermal Contact	Probable	8E-08	NA	1.4E-04	7.3E-05	NA	1.9E-04	1.0E-04	NA
		RME	5E-07	NA	5.0E-04	2.5E-04	NA	6.6E-04	3.4E-04	NA
Air	Inhalation	Probable	9E-07	3E-08	4.3E-04	8.8E-05	2.5E-05	4.3E-03	8.8E-04	2.5E-04
		RME	3E-06	9E-08	7.4E-04	1.8E-04	8.8E-05	7.4E-03	1.8E-03	8.8E-04
Fruit and Vegetables	Ingestion	Probable	3E-04	NA	--	--	NA	--	--	NA
		RME	1E-03	NA	--	--	NA	--	--	NA
TOTAL		Probable	5E-03	1E-04	ND	ND	ND	ND	ND	ND
		RME	2E-02	8E-04	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-10

SUMMARY OF RISKS FOR EXPOSURE AREA D
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Ground Water Unit 3	Ingestion	Probable	2E-03	NA	1.7E-01	5.8E-02	NA	1.8E+00[d]	6.1E-01	NA
		RME	2E-02	NA	5.1E-01	2.4E-01	NA	5.3E+00[d]	2.4E+00[d]	NA
	Inhalation	Probable	2E-03	NA	NA	NA	NA	2.6E-01	4.1E-02	NA
		RME	2E-02	NA	NA	NA	NA	1.8E+00[d]	2.7E-01	NA
	Dermal Contact	Probable	4E-03	NA	2.1E-01	1.1E-01	NA	2.1E+00[d]	1.1E+00[d]	NA
		RME	4E-02	NA	9.9E-01	4.0E-01	NA	9.8E+00[d]	4.9E+00[d]	NA
Air	Inhalation	Probable	1E-06	4E-08	1.8E-04	3.6E-05	1.0E-05	1.8E-03	3.6E-04	1.0E-04
		RME	4E-06	1E-07	3.0E-04	7.2E-05	3.6E-05	3.0E-03	7.2E-04	3.6E-04
TOTAL		Probable	8E-03	4E-08	ND	ND	ND	ND	ND	ND
		RME	8E-02	1E-07	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-11

SUMMARY OF RISKS FOR EXPOSURE AREA E
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	5E-07	1E-08	1.7E-01	1.6E-02	3.3E-02	6.3E-02	1.8E-03	1.2E-02
		RME[c]	9E-06	2E-07	3.1E-01	8.0E-03	6.4E-02	6.0E-01	4.0E-03	4.0E-02
	Dermal Contact	Probable	5E-07	1E-08	2.5E-02	9.0E-03	9.0E-03	1.6E-02	1.6E-03	5.0E-03
		RME	7E-06	8E-08	1.4E-01	6.4E-02	3.8E-02	2.6E-01	3.2E-02	2.9E-02
Subsurface Soil	Ingestion	Probable	4E-07	8E-09	6.0E-02	6.1E-03	1.2E-02	2.8E-02	8.0E-04	4.5E-03
		RME	7E-06	2E-07	3.0E-01	7.0E-03	6.2E-02	4.5E-01	3.2E-03	3.8E-02
	Inhalation	Probable	NA	3E-06	NA	NA	NA	NA	NA	NA
		RME	NA	6E-04	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	3E-07	7E-09	2.4E-02	9.3E-03	9.3E-03	1.3E-02	1.3E-03	4.0E-03
		RME	5E-06	6E-08	1.3E-01	6.0E-02	3.5E-02	2.1E-01	2.7E-02	2.4E-02
Ground Water Unit 3	Ingestion	Probable	2E-06	NA	1.2E-01	2.3E-02	NA	9.1E-02	3.3E-02	NA
		RME	6E-06	NA	1.1E-01	5.4E-02	NA	1.3E-01	6.4E-02	NA
	Inhalation	Probable	2E-08	NA	NA	NA	NA	NA	NA	NA
		RME	5E-08	NA	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	2E-06	NA	3.2E-03	1.7E-03	NA	1.7E-02	8.6E-03	NA
		RME	3E-06	NA	5.7E-03	2.9E-03	NA	1.6E-02	8.3E-03	NA
Air	Inhalation	Probable	1E-06	3E-08	2.4E-04	4.8E-05	1.4E-05	2.4E-03	4.8E-04	1.4E-04
		RME	3E-06	1E-07	4.1E-04	9.6E-05	4.8E-05	4.1E-03	9.6E-04	4.8E-04
Fruit and Vegetables	Ingestion	Probable	1E-06	NA	5.7E-01	1.7E-01	NA	2.4E-01	7.0E-02	NA
		RME	7E-06	NA	6.1E-01	1.8E-01	NA	8.2E-01	2.5E-01	NA
TOTAL		Probable	8E-06	3E-06	ND	ND	ND	ND	ND	ND
		RME	5E-05	6E-04	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-12

SUMMARY OF RISKS FOR EXPOSURE AREA F
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	–	–	1.6E+00[d]	1.6E-01	3.3E-01	4.7E-01	1.4E-02	9.1E-02
		RME[c]	–	–	7.6E+00[d]	1.9E-01	1.5E+00[d]	4.5E+00[d]	3.2E-02	4.2E-01
	Dermal Contact	Probable	–	–	9.5E-01	3.5E-01	3.5E-01	2.8E-01	2.9E-02	9.7E-02
		RME	–	–	4.1E+00[d]	1.8E+00[d]	1.1E+00[d]	2.4E+00[d]	3.1E-01	3.0E-01
Subsurface Soil	Ingestion	Probable	–	–	1.6E+00[d]	1.6E-01	3.3E-01	4.9E-01	1.4E-02	9.2E-02
		RME	–	–	7.9E+00[d]	2.0E-01	1.6E+00[d]	4.6E+00[d]	3.3E-02	4.5E-01
	Inhalation	Probable	NA	2E-06	NA	NA	NA	NA	NA	NA
		RME	NA	2E-04	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	–	–	9.9E-01	3.6E-01	3.6E-01	2.9E-01	3.0E-02	1.0E-01
		RME	–	–	4.5E+00[d]	2.0E+00[d]	1.2E+00[d]	2.6E+00[d]	3.3E-01	3.3E-01
Ground Water Unit 3	Ingestion	Probable	6E-05	NA	2.3E-01	8.1E-02	NA	3.1E-01	1.1E-01	NA
		RME	5E-04	NA	4.0E-01	2.0E-01	NA	8.2E-01	4.0E-01	NA
	Inhalation	Probable	6E-05	NA	NA	NA	NA	1.8E-02	2.8E-03	NA
		RME	7E-04	NA	NA	NA	NA	1.5E-01	2.3E-02	NA
	Dermal Contact	Probable	3E-04	NA	9.7E-02	5.0E-02	NA	2.2E-01	1.1E-01	NA
		RME	1E-03	NA	4.7E-01	2.4E-01	NA	1.2E+00[e]	6.2E-01	NA
Air	Inhalation	Probable	1E-06	3E-08	4.3E-04	8.8E-05	2.5E-05	4.3E-03	8.8E-04	2.5E-04
		RME	3E-06	1E-07	7.4E-04	1.8E-04	8.8E-05	7.4E-03	1.8E-03	8.8E-04
Fruit and Vegetables	Ingestion	Probable	–	NA	3.2E+00[d]	9.0E-01	NA	1.7E-01	2.2E-02	NA
		RME	–	NA	3.6E+00[d]	1.0E+00[d]	NA	1.8E+00[d]	5.1E-01	NA
TOTAL		Probable	4E-04	2E-06	ND	ND	ND	ND	ND	ND
		RME	2E-03	2E-04	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-13

SUMMARY OF RISKS FOR EXPOSURE AREA G
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Subsurface Soil	Ingestion	Probable	--	--	4.8E-02	2.2E-03	4.3E-03	6.1E-03	1.8E-04	5.6E-04
		RME	--	--	8.0E-02	2.2E-03	1.7E-02	5.0E-02	3.5E-04	2.2E-03
	Inhalation	Probable	NA	3E-06	NA	NA	NA	NA	NA	NA
		RME	NA	6E-06	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	--	--	2.2E-02	8.2E-03	8.8E-03	6.7E-03	6.9E-04	1.1E-03
		RME	--	--	8.3E-02	3.9E-02	2.2E-02	5.0E-02	6.4E-03	3.0E-03
Ground Water Unit 3	Ingestion	Probable	2E-03	NA	9.8E-01	3.3E-01	NA	9.0E+00[d]	3.2E+00[d]	NA
		RME	9E-03	NA	6.7E+00[d]	3.4E+00[d]	NA	1.8E+01[d]	9.6E+00[d]	NA
	Inhalation	Probable	1E-03	NA	NA	NA	NA	7.0E-01	1.1E-01	NA
		RME	7E-03	NA	NA	NA	NA	3.2E+00[d]	4.8E-01	NA
	Dermal Contact	Probable	3E-03	NA	3.0E+00[d]	1.5E+00[d]	NA	1.0E+01[d]	5.3E+00[d]	NA
		RME	2E-02	NA	1.2E+01[d]	6.0E+00[d]	NA	3.5E+01[d]	1.7E+01[d]	NA
Air	Inhalation	Probable	9E-07	3E-08	3.4E-04	6.9E-05	2.0E-05	3.4E-03	6.9E-04	2.0E-04
		RME	3E-06	9E-08	5.8E-04	1.4E-04	6.9E-05	5.8E-03	1.4E-03	6.9E-04
Fruit and Vegetables	Ingestion	Probable	--	NA	--	--	NA	--	--	NA
		RME	--	NA	--	--	NA	--	--	NA
TOTAL		Probable	6E-03	3E-06	ND	ND	ND	ND	ND	ND
		RME	4E-02	6E-06	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-14

SUMMARY OF RISKS FOR EXPOSURE AREA H
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	--	--	2.5E+00[d]	2.4E-01	4.9E-01	7.3E-01	2.1E-02	1.3E-01
		RME[c]	--	--	9.4E+00[d]	2.5E-01	2.0E+00[d]	6.5E+00[d]	4.4E-02	5.8E-01
	Dermal Contact	Probable	--	--	1.5E+00[d]	5.5E-01	5.5E-01	4.5E-01	4.6E-02	1.6E-01
		RME	--	--	5.6E+00[d]	2.5E+00[d]	1.5E+00[d]	3.5E+00[d]	4.5E-01	4.4E-01
Subsurface Soil	Ingestion	Probable	--	--	2.4E+00[d]	2.3E-01	4.8E-01	7.3E-01	2.0E-02	1.3E-01
		RME	--	--	1.0E+01[d]	2.4E-01	2.0E+00[d]	6.1E+00[d]	4.3E-02	5.8E-01
	Inhalation	Probable	NA	6E-06	NA	NA	NA	NA	NA	NA
		RME	NA	1E-03	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	--	--	1.5E+00[d]	5.4E-01	5.4E-01	4.4E-01	4.5E-02	1.5E-01
		RME	--	--	5.6E+00[d]	2.6E+00[d]	1.5E+00[d]	3.4E+00[d]	4.4E-01	4.3E-01
Ground Water Unit 3	Ingestion	Probable	3E-07	NA	4.0E-02	1.4E-02	NA	5.0E-02	1.9E-02	NA
		RME	3E-06	NA	7.0E-02	3.0E-02	NA	8.0E-02	4.0E-02	NA
	Inhalation	Probable	2E-07	NA	NA	NA	NA	5.2E-05	8.3E-06	NA
		RME	2E-06	NA	NA	NA	NA	2.0E-04	3.0E-03	NA
	Dermal Contact	Probable	4E-07	NA	1.4E-03	7.0E-02	NA	4.8E-03	2.6E-03	NA
		RME	5E-06	NA	4.0E-03	2.2E-03	NA	2.8E-02	1.1E-02	NA
Air	Inhalation	Probable	3E-07	1E-08	8.3E-05	1.7E-05	4.8E-06	8.3E-04	1.7E-04	4.8E-05
		RME	1E-06	3E-08	1.4E-04	3.4E-05	1.7E-05	1.4E-03	3.4E-04	1.7E-04
Fruit and Vegetables	Ingestion	Probable	--	NA	4.6E-02	1.3E-02	NA	1.4E-01	4.1E-02	NA
		RME	--	NA	1.1E-01	3.4E-02	NA	3.2E+00[d]	9.2E-01	NA
TOTAL		Probable	1E-06	6E-06	ND	ND	ND	ND	ND	ND
		RME	1E-05	1E-03	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-15

SUMMARY OF RISKS FOR EXPOSURE AREA I
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Ground Water Unit 3	Ingestion	Probable	3E-04	NA	3.6E-01	1.3E-02	NA	6.1E-01	2.1E-01	NA
		RME	1E-03	NA	4.2E-01	2.0E-01	NA	7.6E-01	3.6E-01	NA
	Inhalation	Probable	1E-04	NA	NA	NA	NA	5.1E-03	8.0E-04	NA
		RME	1E-03	NA	NA	NA	NA	2.4E-02	3.7E-03	NA
	Dermal Contact	Probable	4E-04	NA	1.7E-01	8.9E-02	NA	4.6E-01	2.3E-01	NA
		RME	9E-03	NA	3.0E-01	1.6E-01	NA	9.6E-01	4.8E-01	NA
Air	Inhalation	Probable	5E-07	1E-08	1.7E-04	3.4E-05	9.6E-06	1.7E-03	3.4E-04	9.6E-05
		RME	1E-06	5E-08	2.8E-04	6.7E-05	3.4E-05	2.8E-03	6.7E-04	3.4E-04
TOTAL		Probable	8E-04	1E-08	ND	ND	ND	ND	ND	ND
		RME	1E-02	5E-08	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-16

SUMMARY OF RISKS FOR EXPOSURE AREA J
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	–	–	3.1E-02	3.1E-03	6.2E-03	8.7E-03	2.5E-04	3.5E-03
		RME[c]	–	–	2.4E-01	6.1E-03	4.9E-02	1.5E-01	9.9E-04	2.7E-02
	Dermal Contact	Probable	–	–	2.1E-02	8.0E-03	8.0E-03	6.4E-03	6.6E-04	4.4E-03
		RME	–	–	1.4E-01	6.4E-02	3.8E-02	8.4E-02	1.1E-02	2.2E-02
Subsurface Soil	Ingestion	Probable	–	–	2.0E-02	2.1E-03	4.1E-03	5.9E-03	1.7E-04	2.3E-03
		RME	–	–	1.7E-01	4.3E-03	3.5E-02	1.0E-01	7.2E-04	1.9E-02
	Inhalation	Probable	NA	7E-06	NA	NA	NA	NA	NA	NA
		RME	NA	3E-04	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	–	–	1.5E-02	5.7E-03	5.7E-03	4.6E-03	4.8E-04	3.2E-03
		RME	–	–	1.1E-01	4.9E-02	2.9E-02	6.5E-02	8.3E-03	1.7E-02
Air	Inhalation	Probable	2E-06	6E-08	4.7E-04	9.6E-05	2.7E-05	4.7E-03	9.6E-04	2.7E-04
		RME	6E-06	2E-07	8.1E-04	1.9E-04	9.6E-05	8.1E-03	1.9E-03	9.6E-04
Fruit and Vegetables	Ingestion	Probable	NA	NA	8.9E-02	2.5E-02	NA	2.2E-02	6.6E-03	NA
		RME	NA	NA	2.2E-01	5.9E-02	NA	1.0E-01	3.0E-02	NA
TOTAL		Probable	2E-06	7E-06	ND	ND	ND	ND	ND	ND
		RME	6E-06	3E-04	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-17

SUMMARY OF RISKS FOR EXPOSURE AREA K
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Ground Water Unit 3	Ingestion	Probable[b]	2E-06	NA	2.7E-02	9.5E-03	NA	2.7E-02	9.5E-03	NA
		RME[c]	6E-06	NA	4.1E-02	2.0E-02	NA	4.1E-02	2.0E-02	NA
	Inhalation	Probable	--	NA	--	--	NA	--	--	NA
		RME	--	NA	--	--	NA	--	--	NA
	Dermal Contact	Probable	8E-08	NA	9.6E-04	4.9E-04	NA	9.6E-04	4.9E-04	NA
		RME	4E-07	NA	2.4E-03	1.2E-03	NA	2.4E-03	1.2E-03	NA
Air	Inhalation	Probable	9E-07	2E-08	2.4E-04	4.9E-05	1.4E-05	2.4E-03	4.9E-04	1.4E-04
		RME	3E-06	9E-08	4.1E-04	9.8E-05	4.9E-05	4.1E-03	9.8E-04	4.9E-04
TOTAL		Probable	3E-06	2E-08	ND	ND	ND	ND	ND	ND
		RME	9E-06	9E-08	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-18

SUMMARY OF RISKS FOR EXPOSURE AREA 129-3
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	3E-06	8E-09	7.1E+00[d]	7.2E-01	1.4E+00[d]	2.1E+00[d]	6.0E-02	5.6E-02
		RME[c]	2E-05	8E-08	5.1E+01[d]	1.3E+00[d]	1.0E+01[d]	3.1E+01[d]	2.2E-01	4.1E-01
	Dermal Contact	Probable	1E-05	3E-08	4.6E+00[d]	1.7E+00[d]	1.7E+00[d]	1.4E+00[d]	1.5E-01	6.9E-02
		RME	7E-05	1E-07	3.0E+01[d]	1.4E+01[d]	8.1E+00[d]	1.9E+01[d]	2.4E+00[d]	3.3E-01
Subsurface Soil	Ingestion	Probable	2E-06	8E-09	7.2E+00[d]	7.3E-01	1.4E+00[d]	2.1E+00[d]	6.0E-02	5.6E-02
		RME	2E-05	7E-08	5.1E+01[d]	1.3E+00[d]	1.0E+01[d]	3.1E+01[d]	2.2E-01	4.0E-01
	Inhalation	Probable	NA	3E-07	NA	NA	NA	NA	NA	NA
		RME	NA	2E-04	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	1E-05	5E-08	4.5E+00[d]	1.7E+00[d]	1.7E+00[d]	1.4E+00[d]	1.4E-01	6.7E-02
		RME	6E-05	1E-07	3.0E+01[d]	1.4E+01[d]	8.1E+00[d]	1.9E+01[d]	2.4E+00[d]	3.3E-01
Ground Water Unit 3	Ingestion	Probable	2E-07	NA	2.7E-02	1.0E-02	NA	2.7E-02	1.0E-02	NA
		RME	9E-07	NA	4.0E-02	1.9E-02	NA	3.3E-02	1.9E-02	NA
	Inhalation	Probable	2E-07	NA	NA	NA	NA	NA	NA	NA
		RME	9E-07	NA	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	3E-07	NA	1.4E-03	7.3E-04	NA	7.1E-04	3.6E-04	NA
		RME	2E-06	NA	1.5E-03	7.7E-04	NA	1.6E-03	8.1E-04	NA
Air	Inhalation	Probable	2E-06	5E-08	6.7E-04	1.4E-04	3.9E-05	6.7E-03	1.4E-03	3.9E-04
		RME	5E-06	2E-07	1.1E-03	2.7E-04	1.4E-04	1.1E-02	2.7E-03	1.4E-03
Fruit and Vegetables	Ingestion	Probable	--	NA	1.5E+01[d]	4.3E+00[d]	NA	4.0E+00[d]	1.1E+00[d]	NA
		RME	--	NA	2.8E+01[d]	7.8E+00[d]	NA	1.5E+01[d]	4.1E+00[d]	NA
TOTAL		Probable	3E-05	4E-07	ND	ND	ND	ND	ND	ND
		RME	2E-04	2E-04	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-19

SUMMARY OF RISKS FOR EXPOSURE AREA 129-5
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	–	NA	3.2E-03	3.2E-04	6.5E-04	9.6E-04	2.7E-05	8.2E-05
		RME[c]	–	NA	2.3E-02	5.7E-04	4.6E-03	1.4E-02	9.6E-05	5.8E-04
	Dermal Contact	Probable	–	NA	3.4E-03	1.2E-03	1.2E-03	1.1E-03	1.1E-04	1.6E-04
		RME	–	NA	2.2E-02	1.0E-02	5.9E-03	1.4E-02	1.7E-03	7.7E-04
Subsurface Soil	Ingestion	Probable	–	NA	6.8E-03	6.6E-04	1.4E-03	4.7E-03	1.4E-04	4.0E-04
		RME	–	NA	5.6E-02	1.4E-03	1.1E-02	5.5E-02	3.9E-04	2.3E-03
	Inhalation	Probable	NA	1E-06	NA	NA	NA	NA	NA	NA
		RME	NA	6E-05	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	–	NA	7.1E-03	2.6E-03	2.6E-03	3.6E-03	3.7E-04	5.6E-04
		RME	–	NA	5.5E-02	2.5E-02	1.5E-02	1.4E-01	1.8E-02	8.1E-03
Ground Water Unit 3	Ingestion	Probable	2E-06	NA	2.0E-02	1.0E-02	NA	8.0E-01	3.0E-02	NA
		RME	8E-06	NA	3.3E-02	1.6E-02	NA	2.0E-01	1.0E-01	NA
	Inhalation	Probable	4E-07	NA	NA	NA	NA	5.4E-05	8.5E-06	NA
		RME	3E-06	NA	NA	NA	NA	2.0E-04	3.0E-05	NA
	Dermal Contact	Probable	9E-07	NA	8.0E-04	4.0E-04	NA	2.8E-03	1.4E-03	NA
		RME	6E-06	NA	2.0E-03	1.0E-03	NA	1.0E-02	5.7E-03	NA
Air	Inhalation	Probable	4E-07	1E-08	4.7E-05	9.6E-06	2.7E-06	4.7E-04	9.6E-05	2.7E-05
		RME	1E-06	4E-08	8.1E-05	1.9E-05	9.6E-06	8.1E-04	1.9E-04	9.6E-05
TOTAL		Probable	4E-06	1E-06	ND	ND	ND	ND	ND	ND
		RME	2E-05	6E-05	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-20

SUMMARY OF RISKS FOR EXPOSURE AREA 129-15
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Surface Soil	Ingestion	Probable[b]	–	–	3.6E-03	3.6E-04	7.3E-04	1.1E-03	3.1E-05	1.3E-04
		RME[c]	–	–	4.3E-02	1.1E-03	8.7E-03	2.6E-02	1.8E-04	1.6E-03
	Dermal Contact	Probable	–	–	3.7E-03	1.4E-03	1.4E-03	1.2E-03	1.3E-04	2.7E-04
		RME	–	–	4.2E-02	1.9E-02	1.1E-02	2.6E-02	3.2E-03	2.1E-03
Subsurface Soil	Ingestion	Probable	–	–	4.8E-03	4.7E-04	1.0E-03	3.9E-03	1.1E-04	4.8E-04
		RME	–	–	4.3E-02	1.1E-03	8.7E-03	4.5E-02	3.2E-04	2.8E-03
	Inhalation	Probable	NA	1E-06	NA	NA	NA	NA	NA	NA
		RME	NA	7E-05	NA	NA	NA	NA	NA	NA
	Dermal Contact	Probable	–	–	5.2E-03	1.9E-03	1.9E-03	2.9E-03	3.0E-04	6.5E-04
		RME	–	–	4.2E-02	1.9E-02	1.1E-02	3.5E-02	4.4E-03	2.8E-03
Ground Water Unit 3	Ingestion	Probable	1E-06	NA	4.2E-02	2.1E-02	NA	6.9E-02	3.2E-02	NA
		RME	5E-05	NA	5.7E-02	2.8E-02	NA	1.1E-01	5.1E-02	NA
	Inhalation	Probable	2E-06	NA	NA	NA	NA	8.7E-04	1.4E-04	NA
		RME	9E-06	NA	NA	NA	NA	3.7E-03	5.7E-04	NA
	Dermal Contact	Probable	2E-06	NA	1.8E-02	9.4E-03	NA	4.7E-02	2.2E-02	NA
		RME	1E-05	NA	3.8E-02	1.9E-02	NA	1.0E-01	5.3E-02	NA
Air	Inhalation	Probable	2E-06	6E-08	4.7E-04	9.6E-05	2.7E-05	4.7E-03	9.6E-04	2.7E-04
		RME	6E-06	2E-07	8.1E-04	1.9E-04	9.6E-05	8.1E-03	1.9E-03	9.6E-04
TOTAL		Probable	7E-06	1E-06	ND	ND	ND	ND	ND	ND
		RME	8E-05	7E-05	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-21

SUMMARY OF RISKS FOR EXPOSURE AREA X1
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Ground Water Unit 3	Ingestion	Probable[b]	--	NA	--	--	NA	--	--	NA
		RME[c]	--	NA	--	--	NA	--	--	NA
	Inhalation	Probable	--	NA	--	--	NA	--	--	NA
		RME	--	NA	--	--	NA	--	--	NA
	Dermal Contact	Probable	--	NA	--	--	NA	--	--	NA
		RME	--	NA	--	--	NA	--	--	NA
Air	Inhalation	Probable	4E-07	1E-08	1.3E-04	2.7E-05	7.8E-06	1.3E-03	2.7E-04	7.8E-05
		RME	1E-06	4E-08	2.3E-04	5.4E-05	2.7E-05	2.3E-03	5.4E-04	2.7E-04
TOTAL		Probable	4E-07	1E-08	ND	ND	ND	ND	ND	ND
		RME	1E-06	4E-08	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-22

SUMMARY OF RISKS FOR EXPOSURE AREA X2
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Ground Water Unit 3	Ingestion	Probable	2E-07	NA	–	–	NA	9.9E-03	3.5E-03	NA
		RME	8E-07	NA	–	–	NA	2.0E-02	9.4E-03	NA
	Inhalation	Probable	1E-07	NA	NA	NA	NA	–	–	NA
		RME	8E-07	NA	NA	NA	NA	–	–	NA
	Dermal Contact	Probable	3E-07	NA	–	–	NA	2.7E-04	1.4E-04	NA
		RME	2E-06	NA	–	–	NA	8.4E-04	4.3E-04	NA
Air	Inhalation	Probable	4E-07	1E-08	3.7E-05	7.4E-06	2.1E-06	3.7E-04	7.4E-05	2.1E-05
		RME	1E-06	4E-08	6.3E-05	1.5E-05	7.4E-06	6.3E-04	1.5E-04	7.4E-05
TOTAL		Probable	9E-07	1E-08	ND	ND	ND	ND	ND	ND
		RME	5E-06	4E-08	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-23

SUMMARY OF RISKS FOR EXPOSURE AREA X3
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Ground Water Unit 3	Ingestion	Probable	2E-03	NA	7.1E-01	2.5E-01	NA	2.0E+00[e]	7.1E-01	NA
		RME	5E-03	NA	1.2E+00[e]	5.7E-01	NA	3.1E+00[e]	1.5E+00[e]	NA
	Inhalation	Probable	7E-04	NA	NA	NA	NA	1.2E-01	1.9E-02	NA
		RME	4E-03	NA	NA	NA	NA	3.7E+00[d]	5.6E-01	NA
	Dermal Contact	Probable	3E-03	NA	8.4E-01	4.8E-01	NA	2.2E+00[e]	1.1E+00[e]	NA
		RME	8E-03	NA	1.9E+00[d]	1.0E+00[e]	NA	5.4E+00[d]	2.8E+00[e]	NA
Air	Inhalation	Probable	4E-06	1E-07	8.7E-04	1.8E-04	5.0E-05	8.7E-03	1.8E-03	5.0E-04
		RME	1E-05	4E-07	1.5E-03	3.5E-04	1.8E-04	1.5E-02	3.5E-03	1.8E-03
TOTAL		Probable	6E-03	1E-07	ND	ND	ND	ND	ND	ND
		RME	2E-02	4E-07	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-24

SUMMARY OF RISKS FOR EXPOSURE AREA X4
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Medium	Pathway	Exposure	Upperbound Excess Cancer Risks		Acute Hazard Indices			Chronic Hazard Indices		
			Resident	Worker	Child[a]	Adult	Worker	Child[a]	Adult	Worker
Ground Water Unit 3	Ingestion	Probable[b]	7E-06	NA	1.3E-01	4.9E-02	NA	1.3E-01	4.9E-02	NA
		RME[c]	2E-05	NA	1.6E-01	8.0E-02	NA	1.6E-01	8.0E-02	NA
	Inhalation	Probable	–	NA	–	–	NA	–	–	NA
		RME	–	NA	–	–	NA	–	–	NA
	Dermal Contact	Probable	3E-07	NA	4.9E-03	2.3E-03	NA	6.1E-03	3.0E-03	NA
		RME	1E-06	NA	8.4E-03	4.4E-03	NA	1.2E-02	6.6E-03	NA
Air	Inhalation	Probable	5E-07	1E-08	1.3E-04	2.6E-05	7.3E-06	1.3E-03	2.6E-04	7.3E-05
		RME	1E-06	5E-08	2.2E-04	5.1E-05	2.6E-05	2.2E-03	5.1E-04	2.6E-04
TOTAL		Probable	8E-06	1E-08	ND	ND	ND	ND	ND	ND
		RME	2E-05	5E-08	ND	ND	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-25

SUMMARY OF RISKS FROM EXPOSURE TO SURFACE WATER AND SEDIMENTS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indices	
				Resident	Child[a]	Adult	Child[a]	Adult
C	Surface Water	Ingestion	Probable[b]	NA	NA	NA	NA	NA
			RME[c]	--	--	--	--	--
		Dermal Contact	Probable	--	2.8E-02	9.3E-03	5.4E-03	1.8E-03
			RME	--	9.0E-02	4.6E-02	1.7E-02	8.8E-03
	Sediments	Dermal Contact	Probable	--	--	--	--	--
			RME	--	--	--	--	--
	TOTAL		Probable	--	ND	ND	ND	ND
			RME	--	ND	ND	ND	ND
K	Surface Water	Ingestion	Probable	NA	NA	NA	NA	NA
			RME	5E-09	--	--	--	--
		Dermal Contact	Probable	6E-08	--	--	--	--
			RME	5E-07	--	--	--	--
	Sediments	Dermal Contact	Probable	--	--	--	--	--
			RME	--	--	--	--	--
	TOTAL		Probable	6E-08	ND	ND	ND	ND
			RME	5E-07	ND	ND	ND	ND
Round Lake	Surface Water	Ingestion	Probable	NA	NA	NA	NA	NA
			RME	--	1.2E-02	1.1E-02	2.3E-03	2.2E-03
		Dermal Contact	Probable	--	2.6E-02	8.5E-03	4.9E-03	1.6E-03
			RME	--	2.1E-01	1.1E-01	4.0E-02	2.0E-02
	Sediments	Dermal Contact	Probable	--	--	--	--	--
			RME	--	--	--	--	--
	TOTAL		Probable	--	ND	ND	ND	ND
			RME	--	ND	ND	ND	ND

TABLE 5-25 (Continued)

SUMMARY OF RISKS FROM EXPOSURE TO SURFACE WATER AND SEDIMENTS
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Exposure Area	Medium	Pathway	Exposure	Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indices	
				Resident	Child[a]	Adult	Child[a]	Adult
Sunfish Lake	Surface Water	Ingestion	Probable	NA	NA	NA	NA	NA
			RME	–	–	–	–	–
		Dermal Contact	Probable	–	–	–	–	–
			RME	–	–	–	–	–
	Sediments	Dermal Contact	Probable	–	1.6E-01	8.5E-02	3.1E-03	1.6E-03
			RME	–	1.6E+00[d]	5.3E-01	3.1E-02	1.0E-02
	TOTAL		Probable	–	ND	ND	ND	ND
			RME	–	ND	ND	ND	ND
Marsden Lake	Surface Water	Ingestion	Probable	NA	NA	NA	NA	NA
			RME	–	–	–	–	–
		Dermal Contact	Probable	–	–	–	–	–
			RME	–	8.0E-02	4.1E-02	1.5E-02	7.8E-03
	Sediments	Dermal Contact	Probable	–	–	–	–	–
			RME	–	–	–	–	–
	TOTAL		Probable	–	ND	ND	ND	ND
			RME	–	ND	ND	ND	ND
Rice Creek	Surface Water	Ingestion	Probable	NA	NA	NA	NA	NA
			RME	–	–	–	–	–
		Dermal Contact	Probable	–	–	–	–	–
			RME	–	–	–	–	–
		Ingestion of Fish	Probable	–	7.4E-01	5.5E-01	4.5E-02	5.6E-02
			RME	–	1.3E+00[d]	7.4E-01	2.5E-01	1.5E-01
	Sediments	Dermal Contact	Probable	–	–	–	–	–
			RME	–	–	–	–	–
	TOTAL		Probable	–	ND	ND	ND	ND
			RME	–	ND	ND	ND	ND

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

TABLE 5-26

SUMMARY OF RISKS FROM EXPOSURE TO ON-TCAAP GROUND WATER
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Exposure Area Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Indices		Chronic Hazard Indices	
			Resident	Child[a]	Adult	Child[a]	Adult
Area A Unit 1	Ingestion	Probable[b]	1E-05	9.9E-01	3.7E-01	1.5E+00[e]	5.1E-01
		RME[c]	9E-05	1.6E+00[d]	7.7E-01	2.7E+00[d]	1.3E+00[e]
	Inhalation	Probable	1E-06	NA	NA	7.2E-04	1.1E-04
		RME	1E-05	NA	NA	2.4E-03	3.6E-04
	Dermal Contact	Probable	1E-05	5.3E-02	2.8E-02	8.7E-01	2.5E-01
		RME	1E-04	2.0E-01	9.9E-02	2.2E+00[d]	1.1E+00[e]
TOTAL		Probable	2E-05	ND	ND	ND	ND
		RME	2E-04	ND	ND	ND	ND
Area B Unit 1	Ingestion	Probable	--	4.2E-03	1.5E-03	7.0E-02	2.6E-02
		RME	--	8.9E-03	4.0E-03	1.4E-01	6.6E-02
	Inhalation	Probable	--	NA	NA	9.4E-04	1.4E-04
		RME	--	NA	NA	1.0E-03	1.5E-04
	Dermal Contact	Probable	--	4.5E-03	2.3E-03	4.7E-02	2.5E-02
		RME	--	1.6E-02	7.9E-03	1.6E-01	9.0E-02
TOTAL		Probable	--	ND	ND	ND	ND
		RME	--	ND	ND	ND	ND
Area C Unit 1	Ingestion	Probable	4E-06	3.4E-01	5.0E-02	7.0E-01	2.6E-01
		RME	1E-05	3.7E-01	1.7E-01	7.0E-01	2.6E-01
	Dermal Contact	Probable	2E-07	1.3E-02	6.6E-03	2.3E-02	1.1E-02
		RME	6E-07	2.1E-02	1.1E-02	4.5E-02	2.0E-02
TOTAL		Probable	4E-06	ND	ND	ND	ND
		RME	1E-05	ND	ND	ND	ND

TABLE 5-26 (Continued)

SUMMARY OF RISKS FROM EXPOSURE TO ON-TCAAP GROUND WATER
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Exposure Area Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Quotients		Chronic Hazard Quotients	
			Resident	Child[a]	Adult	Child[a]	Adult
Area H Unit 1	Ingestion	Probable	1E-05	3.2E-01	1.1E-01	3.7E-01	1.3E-01
		RME	3E-05	3.8E-01	1.9E-01	4.6E-01	2.0E-01
	Inhalation	Probable	--	NA	NA	6.7E-04	1.0E-04
		RME	--	NA	NA	3.0E-03	4.6E-04
	Dermal Contact	Probable	7E-07	9.5E-03	6.8E-03	1.4E-02	7.9E-03
		RME	2E-06	2.7E-02	1.4E-02	3.2E-02	1.6E-02
TOTAL		Probable	1E-05	ND	ND	ND	ND
		RME	3E-05	ND	ND	ND	ND
Area I Unit 1	Ingestion	Probable	6E-05	4.0E-01	1.5E-01	1.1E+00[e]	3.9E-01
		RME	4E-04	6.2E-01	3.0E-01	1.9E+00[d]	8.8E-01
	Inhalation	Probable	2E-05	NA	NA	4.4E-04	6.9E-05
		RME	1E-04	NA	NA	1.7E-03	2.5E-04
	Dermal Contact	Probable	1E-04	4.1E-02	2.1E-02	1.9E-01	1.0E-01
		RME	7E-04	1.5E-01	7.6E-02	9.0E-01	4.5E-01
TOTAL		Probable	2E-04	ND	ND	ND	ND
		RME	1E-03	ND	ND	ND	ND
Area I Unit 4	Ingestion	Probable	2E-07	6.1E-05	2.2E-05	6.1E-04	2.2E-04
		RME	2E-06	7.3E-05	3.5E-05	7.3E-04	3.5E-04
	Inhalation	Probable	4E-07	NA	NA	9.5E-05	1.5E-05
		RME	2E-06	NA	NA	2.6E-04	3.9E-05
	Dermal Contact	Probable	9E-08	7.5E-05	3.9E-05	7.5E-04	3.9E-04
		RME	5E-06	1.4E-04	7.3E-05	1.4E-03	7.3E-04
TOTAL		Probable	7E-07	ND	ND	ND	ND
		RME	9E-06	ND	ND	ND	ND

TABLE 5-26 (Continued)

SUMMARY OF RISKS FROM EXPOSURE TO ON-TCAAP GROUND WATER
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Exposure Area Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Quotients		Chronic Hazard Quotients	
			Resident	Child[a]	Adult	Child[a]	Adult
Area J Unit 1	Ingestion	Probable	4E-06	1.2E-01	4.1E-02	5.8E-01	2.1E-01
		RME	2E-05	2.0E-01	1.0E-01	1.8E+00[d]	8.5E-01
	Inhalation	Probable	2E-07	NA	NA	5.4E-05	8.6E-06
		RME	1E-06	NA	NA	2.2E-04	3.4E-05
	Dermal Contact	Probable	2E-06	3.1E-03	1.6E-03	5.3E-03	2.7E-03
		RME	3E-06	8.7E-03	4.5E-03	9.2E-02	4.6E-02
TOTAL		Probable	6E-06	ND	ND	--	--
		RME	2E-05	ND	ND	--	--
Area K Unit 1	Ingestion	Probable	2E-03	1.6E-01	5.8E-02	8.0E-01	2.9E-01
		RME	2E-02	1.7E+00[d]	8.3E-01	1.8E+00[d]	8.3E-01
	Inhalation	Probable	1E-03	NA	NA	--	--
		RME	2E-02	NA	NA	--	--
	Dermal Contact	Probable	3E-03	7.6E-02	3.8E-02	7.5E-01	3.8E-01
		RME	4E-02	2.6E-01	1.3E-01	2.5E+00[d]	1.3E+00[d]
TOTAL		Probable	6E-03	ND	ND	--	--
		RME	8E-02	ND	ND	--	--
Area 129-5 Unit 1	Ingestion	Probable	--	4.1E-02	1.5E-02	4.1E-02	1.5E-02
		RME	--	4.4E-02	2.1E-02	4.4E-02	2.1E-02
	Dermal Contact	Probable	--	2.2E-03	1.1E-03	2.2E-03	1.1E-03
		RME	--	3.8E-03	2.0E-03	3.9E-03	2.0E-03
TOTAL		Probable	--	ND	ND	--	--
		RME	--	ND	ND	--	--

TABLE 5-26 (Continued)

SUMMARY OF RISKS FROM EXPOSURE TO ON-TCAAP GROUND WATER
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Exposure Area Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Quotients		Chronic Hazard Quotients	
			Resident	Child[a]	Adult	Child[a]	Adult
Area X3 Unit 1	Ingestion	Probable	--	6.0E-02	2.1E-02	1.5E-01	5.3E-02
		RME	--	6.3E-02	3.0E-02	1.4E-01	6.9E-02
	Inhalation	Probable	--	NA	NA	--	--
		RME	--	NA	NA	--	--
	Dermal Contact	Probable	--	1.5E-03	7.6E-04	3.7E-03	1.9E-03
		RME	--	2.4E-03	1.2E-03	6.0E-03	3.0E-03
TOTAL		Probable	--	ND	ND	ND	ND
		RME	--	ND	ND	ND	ND
Area X3 Unit 4 (Upper)	Ingestion	Probable	7E-04	5.7E-01	1.6E-01	7.4E-01	2.2E-01
		RME	3E-03	1.9E+00[d]	9.1E-01	2.0E+00[d]	9.5E-01
	Inhalation	Probable	6E-04	NA	NA	4.6E-02	7.0E-03
		RME	2E-03	NA	NA	4.8E-01	7.3E-02
	Dermal Contact	Probable	6E-04	2.0E-01	1.1E-01	4.2E-01	2.2E-01
		RME	4E-03	6.8E-01	3.4E-01	1.4E+00[e]	7.2E-01
TOTAL		Probable	2E-03	ND	ND	ND	ND
		RME	9E-03	ND	ND	ND	ND
Area X3 Unit 4 (Middle)	Ingestion	Probable	2E-04	3.1E-01	1.0E-01	3.7E-01	1.6E-01
		RME	1E-03	5.6E-01	2.8E-01	6.6E-01	3.2E-01
	Inhalation	Probable	1E-04	NA	NA	1.2E-02	2.0E-03
		RME	2E-04	NA	NA	4.1E-02	6.2E-03
	Dermal Contact	Probable	2E-04	1.1E-01	5.6E-02	1.9E-01	1.0E-01
		RME	1E-03	3.1E-01	1.6E-01	5.3E-01	2.7E-01
TOTAL		Probable	5E-04	ND	ND	ND	ND
		RME	2E-03	ND	ND	ND	ND

TABLE 5-26 (Continued)

SUMMARY OF RISKS FROM EXPOSURE TO ON-TCAAP GROUND WATER
PROBABLE AND REASONABLE MAXIMUM EXPOSURES
RME FUTURE LAND USE CONDITIONS

Exposure Area Unit	Pathway	Exposure	Upperbound Excess Cancer Risks	Acute Hazard Quotients		Chronic Hazard Quotients	
			Resident	Child[a]	Adult	Child[a]	Adult
Area X3 Unit 4 (Deep)	Ingestion	Probable	4E-05	3.0E-02	1.0E-02	4.2E-02	1.5E-02
		RME	4E-04	1.0E-01	4.9E-02	1.4E-01	6.8E-02
	Inhalation	Probable	4E-05	NA	NA	3.0E-03	4.7E-04
		RME	5E-04	NA	NA	2.4E-02	3.5E-03
	Dermal Contact	Probable	7E-05	3.8E-02	2.0E-02	5.3E-02	2.8E-02
		RME	8E-04	2.0E-01	1.0E-01	2.8E-01	1.4E-01
TOTAL		Probable	2E-04	ND	ND	ND	ND
		RME	2E-03	ND	ND	–	–

Notes regarding Tables 5-3 through 5-26 appear following Table 5-26.

NOTES FOR TABLES 5-3 THROUGH 5-26

[a] The risk estimates listed under this heading are for the child age group most at risk.

[b] Probable = Probable exposure conditions

[c] RME = Reasonable maximum exposure

[d] Hazard index (HI) greater than 1, including at least one individual chemical with a hazard quotient (HQ) greater than 1. This HI indicates the potential for adverse noncarcinogenic health effects via the associated exposure pathway.

[e] HI greater than 1 with no chemical-specific HQ greater than 1, and no sum of chemical-specific HQs (effect-specific HIs) associated with similar target organs or chemical effect are greater than 1. Because all effect-specific HIs are less than 1, exposures via the associated pathway are not expected to result in adverse noncarcinogenic health effects.

[f] HI greater than 1 with no chemical-specific HQ greater than 1, but at least one sum of chemical-specific HQs (effect-specific HI) associated with similar target organs or chemical effect is greater than 1. Because at least one effect-specific HI is greater than 1, exposure via the associated pathway has the potential to cause adverse health effects.

-- = Used to represent upperbound excess cancer risks less than 1E-07 or noncarcinogenic risks (HQ and HI) less than 1E-02.

ND = Not determined; the sum of chemical specific HQ across exposure pathways was not estimated due to the complexity of evaluating noncarcinogenic effects associated with similar target organs or chemical effects. However, any combination of exposure pathways which include chemical-specific HQ greater than 1 (footnoted d as discussed above) or including target organs or chemical effect sums greater than 1 (footnoted f as discussed above) is associated with the potential for adverse noncarcinogenic health effects.

NA = Not assessed; risks were not evaluated for these particular exposure pathways. (See discussion in Chapter 3).

CHAPTER 6

SUMMARY AND CONCLUSION

TABLE OF CONTENTS

CHAPTER 6
SUMMARY AND CONCLUSIONS

This chapter summarizes the results of the risk assessment for the New Brighton/Arden Hills Superfund site. As discussed in Chapter 1, the Superfund site includes on- and off-TCAAP areas affected by contamination from TCAAP. The site is divided into smaller exposure areas for risk assessment purposes.

6.1 CHEMICALS OF POTENTIAL CONCERN

The site contains a wide variety of chemicals of potential concern. These chemicals are listed according to exposure area in Appendix B. The most widespread of the chemicals are the following:

- Heavy metals, including antimony, cadmium, chromium, nickel, and silver
- Volatile halogenated organic chemicals, including 1,1-dichloroethane, chloroform, 1,1-dichloroethene, 1,2-dichloroethene, 1,1,1-trichloroethane, and trichloroethene
- A semivolatile organic chemical, bis(2-ethylhexyl)phthalate

Chemicals present at the site but less widespread include the following:

- Toxic metals, such as arsenic, lead, and thallium
- Cyanide
- Volatile organic chemicals, including 1,2-dichloroethane, vinyl chloride, tetrachloroethene, toluene, and xylene
- Other organic chemicals, including benzoic acid, 2,4-dinitrotoluene, PCBs, and several PAHs
- Gross alpha and gross beta radioactivity

In accordance with U.S. EPA guidance (1989a), risks are assessed for all chemicals present at levels exceeding background concentrations as well as for several additional chemicals. Refer to Chapter 2 for details.

6.2 EXPOSURE ASSESSMENT

The potential for exposure varies among the exposure areas studied. Exposures are detailed in Chapter 3 and Appendix C and are summarized in this section. Exposure scenarios are classified as follows:

- On-TCAAP or off-TCAAP
- Current use or future use (including residential, commercial, or industrial development of TCAAP)
- Probable exposure concentrations or RME concentrations

Each exposure area has one or more associated exposure pathways. For residents, these include exposure to ground water by ingestion, inhalation (during showering), and dermal contact; exposure to surface soil by incidental ingestion, inhalation of fugitive dust, and dermal contact; and eating vegetables and fruits grown in contaminated soil in a home garden. Residents and visitors may be exposed to contaminated surface water and sediment in Rice Creek, Round Lake, Marsden Lake, and Sunfish Lake (these surface water bodies are designated as separate exposure areas for risk assessment purposes) and in several Class I exposure areas. Workers in an exposure area being remediated or developed may be exposed to relatively intense but short-term doses of subsurface soil contaminants as a result of maintenance or construction activities.

Some exposures are considered minimal and are not explicitly assessed. For instance, on-TCAAP drinking water is effectively treated to remove volatile organic chemicals, so the risk for current use by on-TCAAP persons is considered negligible. For off-TCAAP areas, ground water is the major contaminated medium assessed. Chapter 3 details exposures and exposure calculation methods for each exposure area.

6.3 TOXICITY ASSESSMENT

The potential adverse effects of each of the chemicals of potential concern are summarized in Chapter 4 and are detailed in Appendix H. For a few chemicals, such as chloroethane, no accepted risk factors (RfDs or SFs) are available for assessing risk. However, many of these chemicals have relatively low toxicity. Exposures to these chemicals will generally contribute negligibly to the total risks for receptors.

6.4 RISK CHARACTERIZATION

Chapter 5 combines the exposure pathways defined in Chapter 3 with the toxicity data summarized in Chapter 4 to assess the risk for each exposure scenario. Tables 5-3 through 5-26 summarize the significant risks for each exposure area. Tables 5-3 and 5-4 summarize risks for on-TCAAP workers exposed under current and probable future land use conditions. Tables 5-5 and 5-6 summarize risks associated with off-TCAAP exposures under current, probable future, and RME future land use conditions. Tables 5-7 through 5-25 summarize risks associated with on-TCAAP exposures under RME future land use conditions. Finally, Table 5-26 summarizes risks associated with on-TCAAP exposures to Unit 1 and Unit 4 ground water.

Risks to human health from exposure to chemicals of potential concern at or released from TCAAP vary widely among exposure pathways in particular exposure areas. Risks associated with potential exposures to each medium are highlighted below for the major exposure conditions. As appropriate, maximum upper-bound excess lifetime cancer risks under RME conditions and chemicals contributing most to risks (both carcinogenic and noncarcinogenic) are identified.

6.4.1 On-TCAAP Risks Under Current and Probable Future Land Use Conditions

- Exposure to ground water present little or no risk. All ground water passes through an air stripper/GAC system that removes contaminants before the ground water is used as potable water on-TCAAP.
- Exposures to surface soil by maintenance workers present an upper-bound excess lifetime cancer risk greater than 1E-06 only in Exposure Area C (3E-05, PAHs) and HQs greater than one in Exposure Areas A, F, H, and 129-3 (antimony).
- Exposures to surface water and sediment are associated with upper-bound excess lifetime cancer risks less than 1E-07, and HQs are less than one.
- Exposures to VOCs released from on-TCAAP remedial actions are associated with upper-bound excess lifetime cancer risks less than 1E-06 and HQs less than 1E-02.

6.4.2 On-TCAAP Risks Under RME Future Land Use Conditions

- Exposures to ground water present upper-bound excess lifetime cancer risks greater than 1E-06 in many exposure areas in Units 1, 3, and 4. The greatest total upper-bound excess lifetime cancer risk is for Unit 3 ground water in Exposure Area D (8E-02; trichloroethene). HQs exceed one only in the following exposure areas: A, I, J, and K- Unit 1 (antimony, 1,2-dichloroethene, and manganese); D, G, and X3-Unit 3

(1,1,1-trichloroethane, methylene chloride, 1,2-dichloroethene, and 1,1-dichloroethene); and X3-Upper Unit 4 (arsenic).

- Exposures of residents to surface and subsurface soils present total upper-bound excess lifetime cancer risks greater than 1E-06 only in Exposure Areas C, E, and 129-3; the major contributors to risks in these exposure areas are PAHs, PCBs, and 2,4-dinitrotoluene, respectively. HQs exceed one for residents in Exposure Areas A, F, H, and 129-3; the major contributor to risks in these exposure areas is antimony.

- Exposures to surface water and sediment are associated with upper-bound excess lifetime cancer risks less than 1E-07. HQs exceed one only for acute exposure under RME conditions involving ingestion of fish from Rice Creek (silver) and dermal contact with Sunfish Lake sediment (antimony).

- Exposures to VOCs released from on-TCAAP remedial actions present upper-bound excess lifetime cancer risks greater than 1E-06 in all Class I and Class II exposure areas except Exposure Areas A and B. The greatest risks exist at a location south of Building 116 (7E-05) under RME conditions. All HQs are less than one.

- Exposures to home-grown vegetables and fruits present upper-bound excess lifetime cancer risks greater than 1E-06 only in Exposure Areas C (1E-03; PAHs) and E (7E-06; PCBs). HQs exceed one only in Exposure Areas A, F, and 129-3 (antimony).

6.4.3 Off-TCAAP Risks Under Current, Probable Future, and RME Future Land Use Conditions

- Exposures to ground water present upper-bound excess lifetime cancer risks greater than 1E-06 in all exposure areas for Units 1, 3, and 4 and present HQs greater than one in exposure areas for Units 3 and 4. The greatest upper-bound excess lifetime cancer risk is in Exposure Area 3Z (1E-02; trichloroethene, 1,1-dichloroethene, 1,1-dichloroethane, and 1,2-dichloroethane); the lowest risk is in Exposure Area S (3E-07). HQs exceed one only in Exposure Areas 3Y and 4X (1,1,2-trichloroethane and antimony, respectively).

- Exposures to surface water and sediment are associated with upper-bound excess lifetime cancer risks less than 1E-07. HQs exceed one only for acute ingestion of fish from Rice Creek by children (silver)

- Exposures to VOCs released from on-TCAAP remedial actions are associated with upper-bound excess lifetime cancer risks less than 1E-06 and HQs less than 1E-01.

6.5 UNCERTAINTIES

Characterization of risks to human health associated with a Superfund site is not an exact science. Uncertainties are introduced at various points throughout the risk characterization

process. Specific areas of uncertainty related to data evaluation, exposure assessment, toxicity assessment, and risk characterization for this risk assessment are discussed in Chapters 2, 3, 4, and 5, respectively.

The most significant areas of uncertainty involve (1) the assumption of mixed residential and commercial development on-TCAAP under RME future land use conditions and (2) possible use of private drinking water wells both on- and off-TCAAP. The assumption of mixed residential and commercial and industrial development was decided by U.S. EPA, MPCA, the U.S. Army, and TCAAP lessees. Such development, which is less likely than other future scenarios such as continuation of current operations or development of the site as a park or sports complex, represent upper-bound estimates of potential future on-TCAAP exposures and risks to human health.

In addition, extensive use of private drinking water wells off- and especially on-TCAAP is unlikely considering the availability of municipal water and community awareness of existing contamination. However, a small number of private wells may currently exist off-TCAAP within the plume southwest of TCAAP. (New Brighton, Columbia Heights, and Minneapolis do not have ordinances prohibiting use of private drinking water wells.) Furthermore, community awareness may diminish if the U.S. Army leaves TCAAP. For these reasons, use of on-TCAAP ground water as a drinking water source remains a possibility under future RME land use conditions (although Arden Hills currently prohibits use of private drinking water wells). Assumption of the existence of private drinking water wells, especially on-TCAAP, provides an upper-bound estimate of the risks to human health.

In general, many areas of uncertainty in this risk assessment are interpreted in such a way as to provide upper-bound risk estimates. Actual risks associated with various exposure pathways are unlikely to exceed the risk values estimated for RME conditions. However, risk values estimated in this risk assessment for probable exposure conditions should be interpreted cautiously; these values may underestimate actual risks.

6.6 GENERAL CONCLUSIONS

- Risks under current and probable future land use conditions are generally lower than risks under RME future land use conditions. Exposure to contaminated media is limited by existing institutional controls and interim remedial actions, such as restricted on-TCAAP access, the existence and use of uncontaminated public drinking water supplies, and the on-TCAAP drinking water system.
- Total on-TCAAP risks are greater than total off-TCAAP risks.

- Exposures to ground water and VOCs released from on-TCAAP remedial actions present the greatest risks under RME future land use condition. Exposure to contaminated ground water will probably be limited because of the availability of uncontaminated municipal drinking water supplies and, in some cities, requirements to use these supplies rather than private drinking water wells. However, a significant number of persons will be exposed to VOCs released from on-TCAAP remedial actions.

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