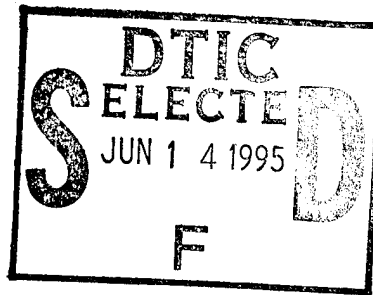




PROGRAM MANAGER RMA CONTAMINATION CLEANUP

U.S. ARMY
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RISK ASSESSMENT
SANITARY SEWER INTERIM RESPONSE ACTION
VERSION 2.1

January 1990
Contract No. DAAA15-88-D0024
RIFS6

Prepared by:

EBASCO SERVICES INCORPORATED
APPLIED ENVIRONMENTAL, INC.
CH2M HILL DATACHEM, INC.
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ROCKY MOUNTAIN ARSENAL CONTAMINATION CLEANUP

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TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	
1.0 <u>INTRODUCTION</u>	1-1
1.1 BACKGROUND AND RATIONALE	1-1
1.2 APPROACH	1-1
1.3 REPORT FORMAT	1-2
2.0 <u>SITE DESCRIPTION AND HISTORY</u>	2-1
2.1 SITE LOCATION AND USE	2-1
2.2 CONTAMINATION HISTORY	2-1
3.0 <u>SELECTED INTERIM ACTION TECHNOLOGY</u>	3-1
4.0 <u>CONTAMINANTS OF CONCERN</u>	4-1
4.1 ANALYTES DETECTED IN THE RI	4-1
4.2 SELECTION OF CONTAMINANTS OF CONCERN	4-4
5.0 <u>HUMAN HEALTH RISK ASSESSMENT</u>	5-1
5.1 EXPOSURE ASSESSMENT	5-1
5.1.1 <u>Population Distribution for Off-Post Area</u>	5-1
5.1.2 <u>Applicable Contaminant Migration Pathways</u>	5-4
5.1.3 <u>Applicable Off-Post Human Exposure Pathways</u>	5-4
5.1.4 <u>Computation of Ground Level Air Contaminant Concentrations</u>	5-6
5.1.5 <u>Computation of Contaminant Intake Rates</u>	5-15
5.2 TOXICITY ASSESSMENT	5-18
5.2.1 <u>Hazard Identification</u>	5-18
5.2.2 <u>Dose-Response Assessment</u>	5-19
5.3 RISK CHARACTERIZATION	5-22
5.3.1 <u>Noncarcinogenic Health Risks</u>	5-22
5.3.2 <u>Carcinogenic Health Risks</u>	5-23
5.4 UNCERTAINTY CONSIDERATIONS	5-24
5.4.1 <u>Toxicity Assessment</u>	5-25
5.4.2 <u>Exposure Assessment</u>	5-25

TABLE OF CONTENTS
(continued)

	<u>Page</u>
5.4.3 <u>Risk Characterization</u>	5-26
6.0 <u>ECOLOGICAL RISK ASSESSMENT</u>	6-1
6.1 <u>SPECIES AND HABITAT DISTRIBUTION</u>	6-1
6.1.1 <u>Vegetation Resources</u>	6-1
6.1.2 <u>Wildlife Resources</u>	6-2
6.2 <u>EXPOSURE ASSESSMENT</u>	6-6
6.2.1 <u>Potentially Exposed Biota Populations</u>	6-6
6.2.2 <u>Applicable Contaminant Transport Mechanisms</u>	6-7
6.2.3 <u>Evaluation of Exposure to Biota</u>	6-10
6.3 <u>TOXICITY ASSESSMENT</u>	6-10
6.4 <u>RISK CHARACTERIZATION</u>	6-11
6.4.1 <u>Qualitative Estimate of Risk</u>	6-11
6.4.2 <u>Uncertainty Considerations</u>	6-11
6.4.3 <u>Summary of Risks</u>	6-11
7.0 <u>SOCIAL IMPACTS</u>	7-1
7.1 <u>NOISE IMPACTS</u>	7-1
7.2 <u>ODOR IMPACTS</u>	7-2
7.3 <u>VISUAL IMPACTS</u>	7-2
7.4 <u>VEHICULAR IMPACTS</u>	7-2
8.0 <u>CONCLUSIONS AND RECOMMENDATIONS</u>	8-1
9.0 <u>REFERENCES</u>	9-1

APPENDIX A - SCREEN MODEL RESULTS

APPENDIX B - TOXICITY PROFILES

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
4.1-1	Analytes Detected in Soils Beneath the Sanitary Sewer	4-2
4.1-2	Analytes Detected in Soils at MH 4-3, MH 6-1, and Trench MKE 7 . . .	4-5
4.2-1	Contaminants of Concern Selected for Evaluation in the Risk Assessment	4-6
5.1-1	Parameter Values and Results of Volatile Emission Rate Calculations . .	5-10
5.1-2	Parameter Values and Results of Fugitive Dust Emission Calculations . .	5-13
5.1-3	Parameter Values and Results of Dispersion Modeling	5-14
5.1-4	Parameter Values and Results of Ambient Air Concentration Calculations at the Point of Exposure	5-14
5.1-5	Parameter Values Used in Contaminant Intake Rate Calculations	5-16
5.1-6	Estimated Contaminant Intake Rates	5-17
5.2-1	Dose-Response Estimates for Contaminants of Concern	5-21
5.3-1	Estimated Upperbound Individual Cancer Risk for Contaminants of Concern	5-24
6.2-1	RMA Terrestrial Species That May Potentially be Exposed to Contaminants	6-8

LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
2.1-1	Location Map for the Sanitary Sewer System	2-2
5.1-1	Regional Statistical Areas Used in Population Characterizations	5-2
5.1-2	Annual Wind Rose for RMA Vicinity	5-5
5.1-3	Location of Contaminant Source and Nearest Off-Post Residence	5-7
6.1-1	Biota Areas of Special Interest Near Sanitary Sewer IRA Area	6-3
6.1-2	September 1989 Prairie Dog Colonies and Sanitary Sewer Features	6-5

EXECUTIVE SUMMARY

The purpose of the Sanitary Sewer Interim Response Action (IRA) Risk Assessment Report is to quantitatively characterize potential health risks to off-post human populations, and to qualitatively characterize potential risks to on-post ecological receptors resulting from implementation of the Sanitary Sewer IRA. Technical procedures presented in the most recent EPA guidance documents, such as the Risk Assessment Guidance for Superfund and the Superfund Exposure Assessment Manual, were used to perform the risk assessment.

IRA activities, as presented in the Sanitary Sewers IRA Decision Document, were reviewed. Of these activities, only excavation was determined to result in the potential release of contaminants of concern, which were identified as aldrin, methylene chloride, and trichloroethylene. Applicable contaminant transport pathways were identified to be volatilization of contaminants and airborne transport of potentially contaminated particulates.

A conservative Gaussian plume model was used to estimate ground level air contaminant concentrations to human populations off-post. Contaminant intake rates, based on these concentrations, were compared to toxicological data to determine both carcinogenic and noncarcinogenic human health risks. The risk values were extremely low and led to the conclusion that no off-post human health risks will result from implementation of this IRA.

A qualitative assessment of the risk to ecologic receptors on-post was conducted. This assessment was qualitative in nature because information on biotic intake rates and chemical-specific allowable exposure rates was not available. The limited area of disturbance, the low concentrations of contaminants, and the short duration of excavation activities contributed to the conclusion that ecologic receptors will not be adversely affected by implementation of this IRA.

It should be noted that the activities associated with implementation of this IRA (i.e., excavating a trench and opening manholes) are similar to activities required for routine maintenance of utilities at RMA. Activities of this type have not been observed to impact

either on-post ecologic receptors or off-post humans, and the results of this risk assessment corroborate these observations.

1.0 INTRODUCTION

This section describes the purpose for conducting this risk assessment and the methodology employed. The contents of the remaining sections are also outlined.

1.1 BACKGROUND AND RATIONALE

The Army is currently undertaking a series of response actions at several sites on the Rocky Mountain Arsenal (RMA) that are known to be contaminated. These actions, known as Interim Response Actions (IRAs), are intended to prevent further migration of contaminants and/or to minimize the potential exposure of human and ecological receptors prior to the implementation of a final remedial response action for the entire RMA site.

The following risk assessment addresses the potential risks to off-post human health and short-term risks to on-post ecological receptors as a result of the implementation of the Sanitary Sewer IRA. The human health and ecologic risk assessments are addressed separately for the purposes of this report. Risks to workers involved in the IRA construction are not quantified in this assessment because their exposure is addressed through the use of appropriate health and safety measures as required in the site Health and Safety Plan.

1.2 APPROACH

The human health component of this IRA risk assessment is consistent with the procedures specified in the Risk Assessment Guidance (RAG) for Superfund (USEPA, 1989a). This approach consists of a series of analytical steps, which include the following:

- Identification of contaminants of concern (COCs)
- Analysis of contaminant releases
- Identification of exposed populations
- Identification of potential exposure pathways
- Estimation of exposure concentrations for the identified exposure pathways
- Estimation of contaminant intake rates
- Collection of quantitative and qualitative toxicity information
- Determination of approximate toxicity values

- Characterization of potential for adverse health effects to occur, resulting in estimated carcinogenic and noncarcinogenic risks
- Evaluation of the uncertainty in the analyses
- Summary of the risk

The ecological risk assessment is based on procedures specified in the EPA Region I Supplemental Risk Assessment Guidance for the Superfund Program - Part 2 (USEPA, 1989b). This risk assessment is qualitative in nature because information on biotic intake rates was not readily available nor were chemical-specific allowable exposure rates that would permit the quantification of risk to ecological receptors. Risks were evaluated based on the following steps:

- Identification of COCs
- Identification of contaminant transport pathways
- Development of toxicological profiles for COCs
- Characterization of potentially exposed populations and habitats and applicable exposure pathways
- Discussion of the potential for unacceptable exposures
- Identification and discussion of the major assumptions used in the assessment together with other sources of uncertainty.

1.3 REPORT FORMAT

Section 2.0 contains a brief description and history, followed by a description of the IRA technology in Section 3.0. Contaminants of concern for the human and ecological risk assessments are identified in Section 4.0. The human health risk assessment is developed in Section 5.0, and the ecological risk assessment is developed in Section 6.0. Section 7.0 contains a discussion of other potential impacts, including noise, odor, visual, and vehicular impacts. Conclusions are presented in Section 8.0 and references are found in Section 9.0. Results of the dispersion model are included as Appendix A and toxicity profiles for the COCs are included as Appendix B.

2.0 SITE DESCRIPTION AND HISTORY

The sanitary sewer is described and its current operating conditions are discussed in this section and relevant results from the Remedial Investigation (RI) are presented.

2.1 SITE LOCATION AND USE

The portions of the sanitary sewer system under consideration for this IRA include the collection systems in the North Plants and South Plants areas and the interceptor line connecting these areas to the Sewage Treatment Plant in Section 24. A map of the sanitary sewer system is presented in Figure 2.1-1.

The North Plants system is not currently used for sanitary wastewater transport, although it is used to carry effluent from the treatment system for the Building 1727 sump. The South Plants system services occupied buildings in South Plants and is currently operating far below its design capacity. The entire South Plants facility is being closed, and this portion of the sewer will be phased out as buildings that are currently in use are taken out of service. Two of the primary buildings remaining are the boilerhouse and the RMA laboratory. The interceptor line transports flow from South Plants north to the treatment plant. It picks up flow from the Administration Area and Motor Pool/Rail Classification Yard at Manhole 46 and possible flow from North Plants at Manhole 11.

2.2 CONTAMINATION HISTORY

Contamination associated with the sanitary sewer system was investigated under Task 10 as part of the RI and results have been presented in Contamination Assessment Reports (Ebasco, 1988a; 1988b; 1988c). Because the extensive size of the sanitary sewer prohibited an investigation of the entire system under the RI, samples were collected along segments of the sewer that were documented to be in poor condition. These samples were used to characterize a "worst case scenario" of contamination originating from the sewer, and this "worst case" contaminant distribution was then projected along the entire sewer system. Because the sewer is generally buried at least 5 feet (ft), analytes detected during the sanitary sewer investigation characterize soil conditions beneath the sewer rather than conditions at the surface.

Legend

Sanitary Sewer Main

Lift Station

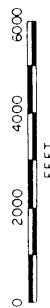
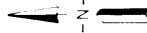
Manhole with Number

Section Number

Area Boundary

Approximate Location of New Sanitary Sewer Line Construction

Approximate Location of Potentially Contaminated Soils



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Rocky Mountain Arsenal Contamination
Cleanup

FIGURE 2.1-1

Location Map for the Sanitary Sewer System

Rocky Mountain Arsenal

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SEWAGE TREATMENT
PLANT

20

19

23

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NORTH
PLANTS
AREA

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The condition of the sanitary sewer in North Plants was generally good, and no target analytes were detected above their indicator levels in samples collected from soils beneath manholes. A sludge grab sample was collected from within Manhole S41 and showed elevated levels of several target analytes (dibromochloropropane, mercury, arsenic, chromium, copper, lead, and zinc). Seven connections were reportedly open due to demolition activities, and it is possible that these connections could collect surface runoff.

Analytes detected in soils beneath the interceptor line and sanitary sewer in South Plants were attributed to the sewer, to groundwater plumes, to previous spills, and to the chemical sewer, which parallels the sanitary sewer in some areas. Infiltration of groundwater into the sewer and exfiltration of water in the sewer to surrounding soils was documented to have occurred (Ebasco, 1988a; 1988b; 1988c) and the sewer appeared to be a potential contaminant transport pathway.

3.0 SELECTED INTERIM ACTION TECHNOLOGY

The purpose of this IRA is to prevent contaminated groundwater from entering the sanitary sewer system and flowing inside the sewer to possible exfiltration points downstream. The general implementation approach is described in the Sanitary Sewer IRA Decision Document (RMA, 1989).

In the North Plants, this will be achieved by capping exposed connections and leveling any catchment basins surrounding those connections. The connections will be capped with rubber compression plugs.

The interceptor line between South Plants and Manhole 46 will be grouted at selected manholes to prevent potential contaminant transport through this portion of the line. At each grouted manhole, sheet pile will be driven from the surface through the sewer pipe to prevent potential contaminant transport within the sewer trenches.

The South Plants collection system will be grouted at selected manholes to cut off flow in segments of the sewer that are not in use, and allow flow from occupied buildings to reach Manhole 97 (the southernmost manhole on the interceptor line, just north of December 7th Avenue). Sheet pile will again be used at each grouted manhole to prevent potential contaminant transport within the sewer trench. A temporary above-ground pressure line will be installed to carry flow from Manhole 97 west to the Firehouse. Installation of this pressure line will not involve excavation except at road crossings, where a culvert will be installed.

A new force main will be installed in a trench leading west from the Firehouse to the Administration Area. The dimensions of the trench will be approximately 5 ft deep and 3,000 ft long. The trench will not disturb contaminated soil, as determined by the RI, with the exception of an area where the new sewer will cross over an old chemical sewer trench. The chemical sewer was removed from this location in 1982, but potential contamination in the soil was not addressed at that time. During excavation, every bucket of soil removed from up to 10 ft on either side of the chemical sewer trench will be

checked with an OVA or HNu to monitor the possibility of harmful contaminants being released to the atmosphere. Total excavation activities are expected to last for approximately two weeks.

The activities required to implement the sanitary sewer IRA can be divided into two categories, invasive and noninvasive. Invasive activities will take place in Sections 35 and 36, and include excavation for the new sewer line and installation of culverts at road crossings to contain the temporary pressure line. Noninvasive activities will include capping, grouting, and driving sheet pile, and will occur along the sewer line in North Plants, South Plants, and the interceptor line in Section 36. Both invasive and noninvasive activities will include a minimal amount of surface soil disturbance due to transport of materials, equipment, and personnel to areas of activity.

4.0 CONTAMINANTS OF CONCERN

Analytes detected during the RI are discussed in this section. From these analytes, specific COCs were identified for evaluation in this IRA risk assessment.

4.1 ANALYTES DETECTED IN THE RI

Analytical data from the RI were reviewed to characterize potential contamination in the area where the IRA activities will occur. Only soils data collected in the vicinity of the sanitary sewer were considered in selecting COCs. Contaminant data from other environmental media, i.e., surface water, groundwater, sewer water, and air, were not considered in this risk assessment for the following reasons:

- Surface water does not exist along the sanitary sewer or the segment of the removed chemical sewer.
- Groundwater will not be encountered in areas of proposed activities.
- Water within the sanitary sewer line is not considered to be a source of exposure because it is isolated in the sewer line.
- The relationship of contaminants measured during the RMA Air Monitoring Program to those contaminants relevant to the Sanitary Sewer IRA cannot be established.

In the areas where noninvasive activities are planned, analytical data for the sanitary sewer were obtained from the Contamination Assessment Reports (CARs) for North Plants (Ebasco, 1988a), South Plants (Ebasco, 1988b), and the Sanitary Sewer Interceptor Line (Ebasco, 1988c). Analytical data represent samples collected from beneath portions of the sewer in South Plants and along the interceptor line, from beneath manholes in North Plants and the interceptor line, and from inside a manhole in North Plants. A brief summary of the analytes detected, the sample locations, the depth of the samples, and the analyte concentrations is presented in Table 4.1-1. All metals detected above their indicator ranges (accepted background levels) and all organic compounds detected are included in the table. Details of the investigations, including sample location maps, are contained in the CARs (Ebasco, 1988a; 1988b; 1988c). The sample locations are included in Table 4.1-1 to facilitate comparison with the sample location maps in the CARs.

Table 4.1-1 Analytes Detected in Soils Beneath the Sanitary Sewer*

Page 1 of 2

Analyte	Sample Location	Depth	Conc. (µg/g)
Aldrin	SS04 (boring 1)	7.5-8.5	7
	SS04 (boring 3)	7.5-8.5	1
	SS04 (boring 7)	7.5-8.5	2
Chloroform	SS02 (boring 8)	24.4-25.4	1
	SS02 (boring 8)	36.9-37.9	0.9
	SS02 (boring 8)	39.4-40.4	1
	SS03 (boring 1)	12-13	5
	SS03 (boring 2)	12-13	4
	SS03 (boring 6)	12.5-13.5	1
	SS03 (boring 7)	12-13	6
	SS03 (boring 7)	17-18	20
Chromium	SS01 (boring 6)	9.6-10.6	49
Copper	SS02 (boring 8)	24.4-25.4	37
	SS02 (boring 8)	36.9-37.9	64
	SS02 (boring 8)	39.4-40.4	94
	SS04 (boring 1)	7.5-8.5	37
	SS04 (boring 3)	7.5-8.5	38
	SS04 (boring 5)	7.5-8.5	37
	SS04 (boring 7)	7.5-8.5	39
	SS04 (boring 8)	7.5-8.5	52
	SS04 (boring 8)	12.5-13.5	40
	SS04 (boring 8)	16.5-17.5	35
	SS04 (boring 9)	7.5-8.5	38
	SS04 (boring 9)	16.5-17.5	36
Dibromochloropropane	MH S41	5.6	0.015
Dieldrin	SS01 (boring 4)	5.7-6.7	0.4
	SS02 (boring 1)	5.4-6.4	0.7
	SS02 (boring 6)	5.4-6.4	2
	SS02 (boring 6)	9.4-10.4	0.5
	SS04 (boring 4)	7.5-8.5	0.3
Diisopropylmethyl Phosphonate	SS01 (boring 11)	19.7-20.7	2
	SS01 (boring 12)	19.7-20.7	3
Mercury	MKE 12 (boring 1)	9.0-9.9	0.16
	MH S41	5.6	34

<u>Analyte</u>	<u>Sample Location</u>	<u>Depth</u>	<u>Conc. (µg/g)</u>
Methylene Chloride	SS01 (boring 6)	5.7-6.7	10
	SS01 (boring 6)	9.6-10.6	2
	SS01 (boring 6)	14.7-15.7	2
	SS01 (boring 7)	5.7-6.7	2
	SS01 (boring 8)	5.7-6.7	2
	SS01 (boring 9)	5.7-6.7	2
	SS01 (boring 10)	5.7-6.7	3
Zinc	SS02 (boring 8)	24.4-25.4	94
	SS02 (boring 8)	36.9-37.9	110
	SS02 (boring 8)	39.4-40.4	120
	SS02 (boring 8)	44.4-45.4	83
	SS02 (boring 8)	47.5-48.0	110
	SS04 (boring 1)	7.5-8.5	84
	SS04 (boring 2)	7.5-8.5	93
	SS04 (boring 3)	7.5-8.5	110
	SS04 (boring 4)	7.5-8.5	85
	SS04 (boring 5)	7.5-8.5	110
	SS04 (boring 6)	7.5-8.5	82
	SS04 (boring 7)	7.5-8.5	99
	SS04 (boring 8)	12.5-13.5	110
	SS04 (boring 8)	16.5-17.5	94
	SS04 (boring 9)	11.5-12.5	92
	SS04 (boring 9)	16.5-17.5	94

*Includes all organics detected and all metals detected above their indicator ranges.

Invasive activities will consist of trench excavation to a depth of 5 ft and a length of 3,000 ft between the Firehouse and the Administration Building, as well as installation of culverts at road crossings. The trench will not disturb areas of confirmed or inferred contamination except where it crosses a former chemical sewer line. Portions of the chemical sewer, both upstream and downstream of where the trench will be dug, are still in place and were investigated as part of the RI. The Chemical Sewer CAR (Ebasco, 1988d) presents sample results collected from beneath two manholes (6-1 and 4-3) south of December 7th Avenue and from a trench (MKE7) in Section 35. The analytes detected (i.e., all organics and all metals above indicator ranges), sample locations, sample depths, and analyte concentrations are summarized in Table 4.1-2. Sample location maps may be found in the Chemical Sewer CAR (Ebasco, 1988d). Again, the sample locations are included in Table 4.1-2 to facilitate comparison with the sample location maps found in the CAR.

4.2 SELECTION OF CONTAMINANTS OF CONCERN

Noninvasive IRA activities will involve minimal disturbances at the soil surface in areas along the sanitary sewer line. Analytes detected and attributed to the sanitary sewer were associated with samples collected from beneath the sewer at depths of 5 ft or more (see Table 4.1-1). Because these samples do not characterize soils that will be disturbed, analytes detected below a depth of 5 ft during the sanitary sewer investigation were not considered as COCs for this risk assessment. This eliminates virtually all of the analytical results from the sanitary sewer investigation.

Surface contamination may exist in areas of noninvasive activities in South Plants and along the interceptor line, as determined by other programs in the RI. As stated previously, surface soil disturbances due to noninvasive activities will result in only minimal disturbances in the immediate vicinity of the activities. Disturbance of these soils will not increase risks to biota in the vicinity, nor will it impact human populations off-post. Therefore, analytes detected or inferred in surface soils in South Plants and along the interceptor line in Section 36 were not considered as COCs for this risk assessment.

Table 4.1-2 Analytes Detected in Soils at MH 4-3, MH 6-1, and Trench MKE 7*

Page 1 of 1

<u>Analyte</u>	<u>Sample Location</u>	<u>Depth (ft)</u>	<u>Conc. (µg/g)</u>
Aldrin	MH 4-3	3.2-4.2	2
Carbon tetrachloride	MH 6-1	23.5-24.5	0.6
Copper	MH 6-1	12.5-13.5	47
		17.5-18.5	42
		23.5-24.5	46
Methylene chloride	MH 4-3	3.2-4.2	1
		8.2-9.2	1
		12.2-13.2	1
Tetrachloroethylene	MH 6-1	23.5-24.5	1
1,1,1-Trichloroethane	MH 6-1	23.5-24.5	0.5
1,1,2-Trichloroethane	MH 6-1	17.5-18.5	0.8
Trichloroethylene	MH 4-3	8.2-9.2	0.6
Zinc	MH 4-3	12.2-13.2	82
	MH 6-1	12.5-13.5	85
		17.5-18.5	110

*Includes all organics detected and all metals detected above their indicator ranges.

Invasive activities will occur to depths of 5 ft through a small section of potentially contaminated soil (see Table 4.1-2). To be conservative, maximum analyte concentrations to a depth of 10 ft (twice the excavation depth) were considered to be COCs in this section of potentially contaminated soil. Analytes detected at depths greater than 10 ft were not included as COCs because of their distance below the excavation activities.

Based on these considerations, all analytes detected along the removed chemical sewer trench except aldrin, methylene chloride, and trichloroethylene have been eliminated as COCs for this risk assessment. The analytes remaining and their maximum measured concentrations within the 0 to 10 ft depth interval are listed in Table 4.2-1.

Table 4.2-1 Contaminants of Concern Selected for Evaluation in the Risk Assessment

<u>Contaminant of Concern</u>	<u>Maximum Concentration (µg/g)</u>
Aldrin	2
Methylene chloride	1
Trichloroethylene	0.6

5.0 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment is developed in this section and includes an exposure assessment, a toxicity assessment, a risk characterization, and uncertainty considerations. Each of these elements is discussed in relation to the sanitary sewer IRA in the sections which follow.

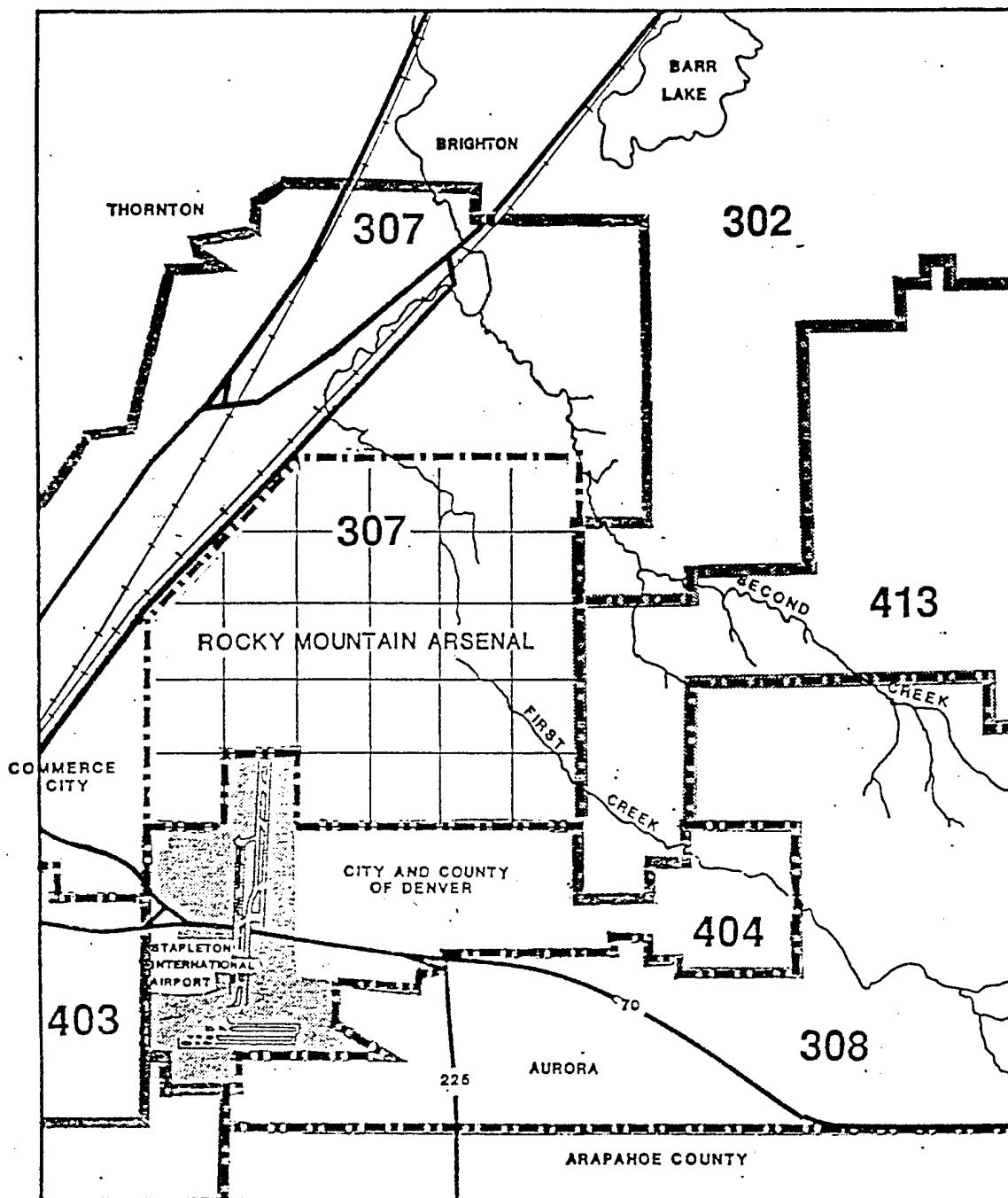
5.1 EXPOSURE ASSESSMENT

The human health exposure assessment requires an identification of populations that may potentially be exposed to contamination in environmental media as a result of implementation of the Sanitary Sewer IRA. Possible contaminant transport mechanisms to these receptors and applicable exposure pathways are identified. Contaminant concentrations at the point of exposure are then estimated and contaminant intake rates calculated.

5.1.1 Population Distribution for Off-Post Area

Data used to characterize human populations off-post of RMA were obtained from the Denver Regional Council of Government (DRCOG) Population and Employment Forecasts, as presented in the Exposure Assessment for RMA (Ebasco, 1989). These data are presented for the areas surrounding RMA as Regional Statistical Areas (RSAs). These RSAs are depicted in Figure 5.1-1, and include RSAs 302, 307, 308, 403, 404, and 413. The current (1990) population and employment estimates for these RSAs are presently unavailable; therefore, estimates are presented for 1985 with projected estimates for the year 2010, where available. The population density, employment populations, land use, and an approximate minimum distance to invasive activities undertaken as part of this IRA are presented for each RSA. Population density for each RSA was estimated by dividing population estimates by the approximate area of the RSA. Because RSA 307 includes RMA, this area has been subtracted from the RSA area in square miles for the determination of population density.

A small portion of RSA 302, known as the Adams-North Central RSA, borders RMA on the northeast. It is comprised of open space and agricultural lands. Its reported population



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 REGIONAL STATISTICAL AREAS (308)

Prepared for:
U.S. Army Program Manager
Rocky Mountain Arsenal Contamination Cleanup

Figure 5.1-1
Regional Statistical Areas
Used in Population Characterizations

density for 1985 was approximately 175 persons per square mile. Employment population for this RSA was 4,682 persons in 1985. The minimum distance from the construction site of the new sanitary sewer line to the border of this RSA is roughly 3 miles.

RSA 307, known as the Adams-South Central RSA, corresponds to Commerce City's planning area located on the north, northwest, and western borders of RMA. This RSA includes Commerce City industrial and residential zones, and had a reported population density of 680 persons per square mile in 1985. RSA 307 population density is projected to grow to roughly 1,110 persons per square mile by 2010. The employment population for this RSA was estimated at 34,900 persons in 1985. The closest boundary of RSA 307 to construction of the new sanitary sewer line is roughly 2.8 miles.

RSA 403, known as the Denver Park Hill RSA, does not actually share a border with RMA, but is located to the southwest and includes residential areas within Denver city limits. The population density was estimated at 4,725 persons per square mile in 1985, and is projected to diminish to 4,104 persons per square mile by 2010 due to the unavailability of land in this older section of Denver. The employment population of this RSA was estimated at 17,200 persons in 1985. The minimum distance to new sewer line construction is roughly 4.2 miles.

RSA 404, known as the Denver-Northeast RSA, borders RMA to the south and southeast. This RSA includes residential neighborhoods such as Montbello and light industrial zones in and around Stapleton International Airport. Population density estimates range from 1,110 persons per square mile in 1985 to 2,272 persons per square mile in 2010, with growth due to expansion of residential neighborhoods. Employment population estimates for 1985 indicate that roughly 32,000 persons were employed in this RSA. Of this estimate, Stapleton International Airport employs roughly 18,000 employees. The minimum distance from the RSA 404 border to the area of new sewer line construction is approximately 2 miles.

RSA 413, known as the Denver-New Airport RSA, includes areas designated as open space and a small portion of this RSA borders RMA to the east. The population density estimated for this RSA in 1985 was 57 persons per square mile, and 190 persons were employed in this RSA in 1985. The distance from the area of sanitary sewer line construction to the nearest border of RSA 314 is roughly 3 miles.

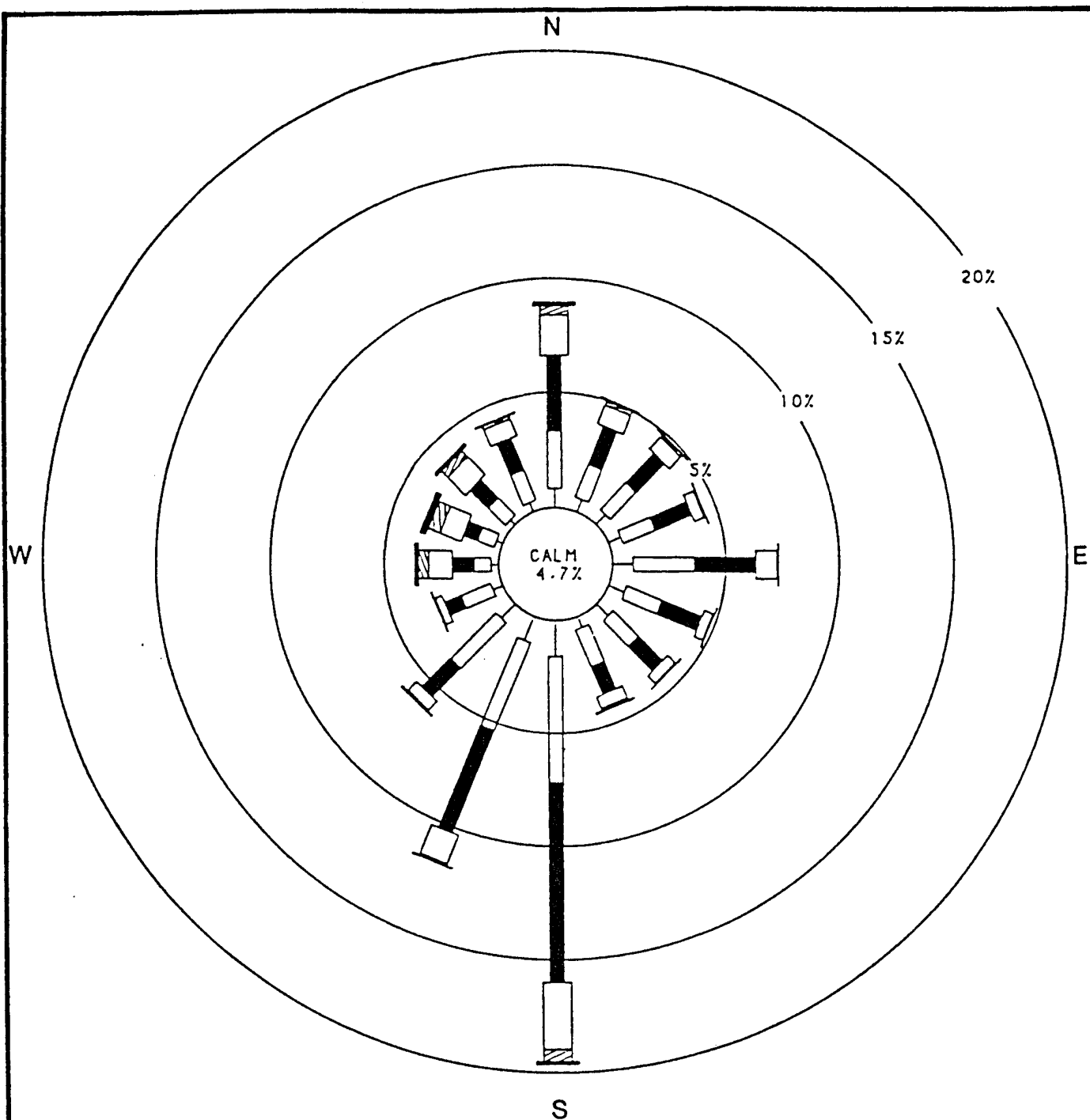
5.1.2 Applicable Contaminant Migration Pathways

Possible contaminant migration pathways were evaluated to determine mechanisms that would permit exposures to humans off-post. The migration pathways were limited to those associated with the transport of contaminants from soils located in areas of proposed disturbance since other environmental media are not applicable (see Section 4.1). These migration pathways are volatilization of contaminants from soil and the transport of contaminants sorbed to airborne soil particulates.

5.1.3 Applicable Off-Post Human Exposure Pathways

Applicable off-post human exposure pathways were determined through the consideration of contaminant properties, impacts of IRA activities, and applicable contaminant migration pathways. Exposure pathways applicable to the sanitary sewer were limited to inhalation of both volatilized contaminants and wind entrained contaminated soil particulates from the soil excavation activities in southeastern Section 35.

Exposures of off-post human populations to contaminants transported by air depend on wind direction, wind speed, and size of the entrained particulates. Wind direction and speed data for Stapleton International Airport, southwest of RMA, are depicted in the wind rose diagram presented in Figure 5.1-2. As indicated in the figure, south winds are most frequent, although winds are observed in all other directions. Wind speeds are generally highest from the north, south, and west, and are generally below 24 miles per hour. Due to the high variability in wind direction and speed, all identified populations surrounding RMA may potentially be exposed to contaminants via air transport from the Sanitary Sewer IRA activities.



Source: ESE, 1988a

Prepared for:

U.S. Army Program Manager
Rocky Mountain Arsenal Contamination Cleanup

FIGURE 5.1-2

Annual Wind Rose for RMA Vicinity
(Stapleton International Airport 1975-1979)

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

The nearest location of a possible off-post human receptor of wind transported contaminants was assumed to be approximately 2 miles directly south of the trench excavation, in an area zoned for residential and light industrial land uses. Figure 5.1-3 illustrates the spatial relationship between the trench excavation and the nearest possible off-post human receptor.

5.1.4 Computation of Ground Level Air Contaminant Concentrations

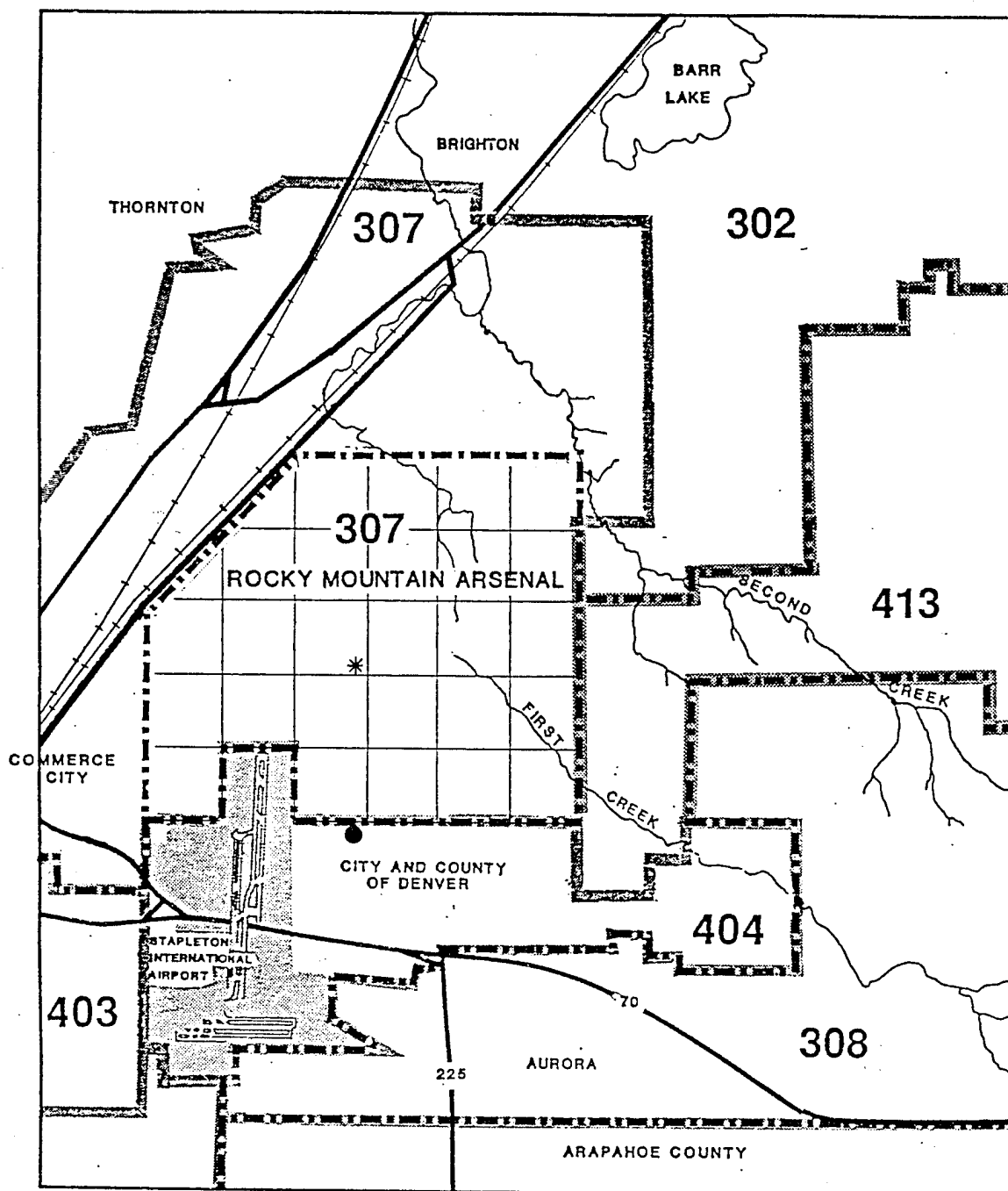
Contaminant concentrations at the nearest RMA boundary were calculated based on volatile and fugitive dust emissions, and subsequent atmospheric dispersion.

5.1.4.1 Description of Excavation

Construction of the proposed force main from the Firehouse to the Administration Area requires excavation of a 5 ft deep, 2 ft wide trench across a 10 ft swath of potentially contaminated soil in southeastern Section 35. As discussed in Section 4, aldrin, methylene chloride, and trichloroethylene are COCs potentially present in these soils at maximum concentrations of 2, 1, and 0.6 $\mu\text{g/g}$, respectively. Excavation of the entire trench is expected to take two weeks using a backhoe, and excavation of the trench in the area of potentially contaminated soil is estimated to take 1 hour (excavation and backfill time). The volume of material excavated from the trench is estimated to be over 1,000 yd^3 and the soil pile is estimated to have an exposed surface area of up to 450 ft^2 . The equations used in the following sections require input parameters to be in Systems Internationale (SI) units, therefore, the excavation dimensions have been converted. The total volume of excavated material is estimated to be 100 cubic meters (m^3), and the mass of excavated soil is estimated to be 4,760 kg.

5.1.4.2 Emission Rate Calculations

Standardized dispersion calculations were performed to estimate a maximum one hour ground level ambient concentration of contaminants at the nearest point of exposure. The worst-case exposure, in the form of an estimated ground level air contaminant concentration for each COC, was then used to estimate potential intake rates.



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REGIONAL STATISTICAL AREAS (308)

- * APPROXIMATE LOCATION OF CONTAMINANT SOURCE
- APPROXIMATE LOCATION OF NEAREST OFFPOST RESIDENCE

Prepared for:
U.S. Army Program Manager
Rocky Mountain Arsenal Contamination Cleanup

Figure 5.1-3
Location of Contaminant Source
and Nearest Off-post Residence

Emissions of contaminants from the proposed activity are expected to occur as volatile releases and fugitive dust. The fugitive dust emissions will occur as the result of excavation activities and wind erosion. The rates for each type of emission and each compound were calculated separately for use in evaluating the ambient contaminant concentrations.

Volatile Emission Rate

The emission rates due to volatile releases were estimated using a landfill equation for volatile releases (USEPA, 1988a). This equation, based on Fick's Law of steady state diffusion, assumes that diffusion into the atmosphere occurs at a plane surface where concentrations remain constant. Diffusion through a clean soil cover is a controlling factor. For this application a minimal soil cover thickness of 1 cm was assumed as a conservative estimate. The landfill equation is expressed as:

$$E_i = D_i C_{si} A (P_t^{4/3}) \frac{M_i}{d_{tc}} \quad (1)$$

where:

- E_i = emission rate of contaminant (g/s)
- D_i = diffusion coefficient of contaminant in air (cm²/s)
- C_{si} = saturation vapor concentration of component i (g/cm³)
- A = exposed area (cm²)
- P_t = total soil porosity (dimensionless)
- M_i = mole fraction of toxic component in waste (g-mole/g-mole)
- d_{tc} = effective depth of clean soil cover (cm).

The saturation vapor concentration, C_{si} , can be determined by:

$$C_{si} = \frac{PMW_i}{RT} \quad (2)$$

where:

- P = vapor pressure of the contaminant (mmHg)
- MW_i = molecular weight of the contaminant (g/mole)
- R = molar gas constant (mmHg cm³/mole K)
- T = absolute temperature (K).

Table 5.1-1 summarizes the parameter values used to estimate contaminant emissions as well as the resulting emission rates. In accordance with EPA guidance (USEPA,1988a), the maximum summertime ambient temperature at RMA (37°C) and the default soil porosity for dry uncompacted soils (0.55) were used as inputs.

Fugitive Dust Emission Rate

The emission rates of contaminants sorbed to particulate matter must be estimated for wind erosion and excavation activities. The emission rates due to wind erosion were estimated using the storage pile emission factor equation for soils handling (USEPA,1989c). For short-term estimates (24 hours), this equation may be expressed as

$$E_p = 1.8U \quad (3)$$

where:

$$\begin{aligned} E_p &= \text{total particulate loading rate per unit } \left(\frac{\text{kg}}{\text{hectare-hour}} \right) \\ U &= \text{wind speed (m/s)} \\ 1.8 &= \text{empirical constant } \frac{\text{s} - \text{kg}}{\text{m-hectare-hour}} \end{aligned}$$

The emission rate for each COC is the product of the total particulate loading rate, the total area of exposed potentially contaminated soil, and the concentration of the COC being considered. This relation is expressed by equation 4,

$$E_i = E_p AC \quad (4)$$

where:

$$\begin{aligned} E_i &= \text{emission rate for component i (g/s)} \\ E_p &= \text{total particulate loading rate per unit area } \left(\frac{\text{kg}}{\text{hectare-hour}} \right) \\ A &= \text{area of exposed soil (m}^2\text{)} \\ C &= \text{concentration of component i in soil (}\mu\text{g/g).} \end{aligned}$$

and appropriate conversion factors must be applied for consistency in the units.

Table 5.1-1 Parameter Values and Results of Volatile Emission Rate Calculations*

<u>Parameter</u>	<u>Units</u>	<u>Aldrin</u>	<u>Methylene</u>	<u>Trichloroethylene</u>
D_i	cm ² /sec	8.4×10^{-3}	0.14	0.11
C_{ii}	g/cm ³	1.1×10^{-10}	1.6×10^{-3}	3.9×10^{-4}
P	mmHg	6×10^{-6}	362	57.9
MW	g/mole	365	85	131
R	mmHg-cm ³ /mole-°K	62361	62361	62361
T	°K	310	310	310
A	cm ²	2.32×10^5	2.32×10^5	2.32×10^2
P_i	dimensionless	0.55	0.55	0.55
M_i	mole/mole	2×10^{-6}	1×10^{-6}	0.6×10^{-6}
d_{sc}	cm	1	1	1
<u>Results</u>				
E_i	g/s	2.0×10^{-13}	2.3×10^{-5}	2.7×10^{-6}

*Parameters listed in this table are from equations 1 and 2.

The fugitive dust emission rates due to agitation of soils during excavation activities were estimated using the dumping emission factor equation for soils handling (USEPA, 1989c).

$$E_d = K (0.0016) \left(\frac{U}{2.2} \right)^{1.3} \left(\frac{M}{2} \right)^{-1.4} \quad (5)$$

where:

- E_d = total suspended particulate loading factor (kg/Mg)
- K = particle size multiplier (dimensionless)
- U = wind speed (m/s)
- M = soil moisture content (percent).

The emission rate for each COC is then the product of the total suspended particulate loading factor, the excavation rate, and the concentration of that COC in the soil. This relation is expressed as equation 6,

$$E_i = E_d \cdot r \cdot C \quad (6)$$

where:

- E_i = emission rate for component i (g/s)
- E_d = total suspended particulate loading factor (kg/Mg)
- A = area of exposed soil (kg/hour)
- C = concentration of component i in soil ($\mu\text{g/g}$).

and appropriate conversion factors must be applied for consistency in the units.

Excavation through the 10 ft section of potentially contaminated soil was assumed to take 1 hour. The mass of soil excavated (4,760 kg) was calculated assuming a bulk soil density for RMA of 1.7 g/cm^3 and a total volume of 2.8 m^3 . The particle size multiplier was set equal to 1, and the summer average soil moisture content for surface soils at RMA was taken to be 2 percent.

The parameter values and results for equations 3 through 6 are listed in Table 5.1-2. The total fugitive dust emission rate presented in the table is the sum of the emission rates from wind erosion and excavation activities.

5.1.4.3 Atmospheric Dispersion

Atmospheric dispersion of contaminants from the sewer excavation was estimated using the Gaussian dispersion model EPA-SCREEN (USEPA, 1988b). EPA-SCREEN is a single source, short-term dispersion model that was used for calculating maximum one-hour ground level concentrations at specified distances from the source. EPA-SCREEN may be used for point-source (stack) emissions, flare releases, and area emissions and accounts for specific meteorological conditions and local terrain variations. The model explicitly calculates the effects of multiple reflections of the plume off the ground when calculating concentrations under limited mixing conditions. Dispersion coefficients as a function of downwind distance and stability parameter are also calculated. The model assumes that all particulate matter behaves as a gas and that deposition is negligible (Hanna, 1971).

The input parameters for the model are shown in Table 5.1-3. Typical worst-case meteorological conditions (windspeed of 2.5 m/s and stable conditions (F)) were used in the dispersion calculation (Turner, 1970). The model was run in the "area" mode for an area of 25 m², the total area of the trench and storage pile (see Section 5.1.4.1). The receptor was assumed to be located at the nearest site boundary, approximately 3.5 km south of the proposed activity, and at a height of 1.5 m (breathing zone) (Figure 5.1-3).

The ambient concentrations of the contaminants were calculated separately for the gas phase and the particulate phase. The sum of the emission rates for fugitive dust due to wind erosion and excavation were used in the concentration calculations and are listed in Table 5.1-4. The dispersion model output (Appendix A) contains ambient concentrations for an emission rate of 1 g/s. The one hour average ambient concentration at 3,500 m for a 1 g/s emission rate is 41.25 µg/m³.

Table 5.1-2 Parameter Values and Results of Fugitive Dust Emission Calculations*

<u>Parameter</u>	<u>Units</u>	<u>Aldrin</u>	<u>Methylene Chloride</u>	<u>Trichloroethylene</u>
<u>Wind Erosion</u> (equations 3 and 4)				
A	M ²	25	25	25
U	m/s	11	11	11
E _i	g/s	2.8x10 ⁻⁸	1.4x10 ⁻⁸	8.4x10 ⁻⁹
<u>Excavation Activity</u> (equations 5 and 6)				
K	-	1	1	1
U	m/s	11	11	11
M	%	2	2	2
E _i	g/s	3.4x10 ⁻⁸	1.7x10 ⁻⁸	1.0x10 ⁻⁸
<u>Total Fugitive Dust</u>				
E _i	g/s	6.2x10 ⁻⁸	3.1x10 ⁻⁸	1.8x10 ⁻⁸

*Parameters listed in this table are from equations 3 through 6.

Table 5.1-3 Parameter Values and Results of Dispersion Modeling

<u>Parameter</u>	<u>Units</u>	<u>Value</u>
Emission Rate	g/s	1.0
Source Height	m	0.5
Area	m ²	2.5
Receptor Height	m	1.5
Distance to Receptor	m	3,500
Rural/Urban Option		Rural
Wind Speed	m/s	2.5
Stability Class	F (Stable)	
<u>Results</u>		
Maximum 1 Hour Concentration	µg/m ³	41.25

Table 5.1-4 Parameter Values and Results of Ambient Air Concentration Calculations at the Point of Exposure

<u>Parameter</u>	<u>Units</u>	<u>Aldrin</u>	<u>Methylene Chloride</u>	<u>Trichloroethylene</u>
x/q^{17}	µg/m ³ per g/s	41.25	41.25	41.25
<u>Volatile Emissions</u>				
C (maximum 1 hour concentration)	µg/m ³	8.3×10^{-12}	9.5×10^{-4}	1.1×10^{-4}
<u>Fugitive Dust Emissions</u>				
C (maximum 1 hour concentration)	µg/m ³	2.6×10^{-6}	1.3×10^{-6}	7.4×10^{-7}

¹⁷ x/q is calculated using the dispersion screen (USEPA, 1988a) and represents a unit emission rate concentration (µg/m³ per g/s).

5.1.5 Computation of Contaminant Intake Rates

For children and adults, contaminant intake rates were estimated for each COC based on volatile and fugitive dust emissions using the following model presented in EPA guidance (USEPA, 1989a):

$$\text{Intake Rate (mg/kg-day)} = \frac{\text{CA} \times \text{IR} \times \text{ET} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \quad (7)$$

where:

CA	=	contaminant concentration in air (mg/m ³)
IR	=	breathing rate (m ³ /hr)
ET	=	exposure time (hrs/day)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yrs)
BW	=	body weight of an exposed individual (kg)
AT	=	averaging time (days).

Contaminant intake rates were computed differently for evaluation of noncarcinogenic and carcinogenic contaminants. For noncarcinogenic exposures, short-term parameter values were used in equation 7 to reflect the actual duration of exposure (i.e., one unique eight hour period). For carcinogenic contaminant intake rates, EPA guidance (USEPA, 1989a) states that exposures to high concentrations of carcinogens over short periods of exposure are equivalent to exposures to lower concentrations of carcinogens averaged over longer periods (i.e., lifetime). Therefore, resulting intake rates for exposures to carcinogens reflect lifetime (70 years) averaged exposures.

The following additional assumptions were made in computing the intake rates: (1) all particulate matter is respirable and retained in the pulmonary tract; and (2) all contaminants are completely (100 percent) absorbed. The values assumed for the model input parameters in equation 7 are presented in Table 5.1-5. Computed contaminant intake rates are presented in Table 5.1-6. Fugitive dust and volatiles emissions intakes were added to give a total intake for each COC.

Table 5.1-5 Parameter Values Used in Contaminant Intake Rate Calculations*

<u>Parameter</u>	<u>Units</u>	<u>Child</u>	<u>Adults</u>	<u>Comment/Description</u>
CA	mg/m ³	---	---	Contaminant concentration in air (see Table 5.1-1)
IR	m ³ /hr	2.1x10 ⁻¹	8.3x10 ⁻¹	Average breathing rate for children and adults
ET	hr/day	8	8	1 working day actual exposure
EF	day/yr	1	1	1 day of excavation
ED	yrs	2.74x10 ⁻³	2.74x10 ⁻³	1 day expressed in years
BW	kg	10	70	Average body weight for children and adults
AT ^u	day(s)	1 (25,550)	1 (25,550)	Period over which exposure is averaged

* Parameters listed in this table are from equation 7.

^u Number in parentheses represents the value used in computing average lifetime intake rates for carcinogens.

Table 5.1-6 Estimated Contaminant Intake Rates

<u>Contaminant of Concern</u>	<u>Short-Term Intake Rates (mg/kg-day)</u>			<u>Chronic Daily Intake Rates (mg/kg-day)</u>		
	<u>Volatile Intake Rate</u>	<u>Fugitive Dust Intake Rate</u>	<u>Total Intake Rate</u>	<u>Volatile Intake Rate</u>	<u>Fugitive Dust Intake Rate</u>	<u>Total Intake Rate</u>
Aldrin						
Child	3.8×10^{-18}	1.2×10^{-12}	1.2×10^{-12}	1.5×10^{-22}	4.7×10^{-17}	4.7×10^{-17}
Adult	2.2×10^{-18}	6.8×10^{-13}	6.8×10^{-13}	8.6×10^{-23}	2.6×10^{-17}	2.6×10^{-17}
Methylene Chloride						
Child	4.4×10^{-10}	6.0×10^{-13}	4.4×10^{-10}	1.7×10^{-14}	2.3×10^{-17}	1.7×10^{-14}
Adult	2.5×10^{-10}	3.4×10^{-13}	2.5×10^{-10}	9.8×10^{-15}	1.3×10^{-17}	9.8×10^{-15}
Trichloroethylene						
Child	5.1×10^{-11}	3.4×10^{-13}	5.1×10^{-11}	2.0×10^{-15}	1.3×10^{-17}	2.0×10^{-15}
Adult	2.9×10^{-11}	1.9×10^{-13}	2.9×10^{-11}	1.1×10^{-15}	7.4×10^{-18}	1.1×10^{-15}

5.2 TOXICITY ASSESSMENT

The toxicity assessment step of a risk assessment is comprised of two elements. The first, hazard identification, is intended to characterize the nature and extent of the health hazards associated with chemical exposures. The second, the dose-response assessment, determines the relationship between the magnitude of exposure to a chemical and the occurrence of adverse health effects. Generally, hazard identification is addressed through the development of a toxicological summary for each COC that discusses various health effects associated with exposures to the chemicals at different concentrations over varying time periods. The dose-response assessment involves a detailed analysis of the relationships between the severity or frequency of adverse effects and the levels of exposure at which these effects occur for each COC. A review of the toxicologic literature is performed to identify chemical-specific allowable intakes (AI) via oral and inhalation routes of exposure. The assessment for the Sanitary Sewer IRA uses the dose-response estimates of the EPA.

5.2.1 Hazard Identification

Toxicity profiles have been developed for each COC and are included in Appendix B. These profiles were compiled from current toxicological literature, and include the following information:

- Chemical and physical properties
- Summary of toxic effects to humans, lab animals, and wildlife
- Regulations and standards
- Dose-response assessment

The information used in compiling the toxicity profiles was obtained from the following sources:

- Exposure Assessment for Rocky Mountain Arsenal (EA for RMA), Volume I, Toxicity Assessment (Ebasco, 1989)
- Computerized literature searches of the following on-line databases:
 - Medline (on-line biomedical bibliographic records)
 - HSDB (Hazardous Substances Data Base)
 - IRIS (EPA's Integrated Risk Information System)

The EA for RMA contained toxicity profiles that were originally developed from information obtained from the EPA Office Waste Programs Enforcement (OWPE) and the U.S. Army Biomedical Research and Development Laboratory (USABRDL). This information was supplemented by computerized literature searches of the Dialog and Chemical Information Systems databases. These toxicity profiles were used as a basis for inclusion in this Risk Assessment, and were updated using the sources listed above.

5.2.2 Dose-Response Assessment

To develop a quantitative dose-response assessment, an extrapolation from high doses, reported in studies of human epidemiology and laboratory animals, to the relatively low doses generally associated with environmental exposures is usually required. The goal of the dose-response assessment is to estimate an allowable intake rate for different routes of exposure based on a rigorous review of the toxicological literature. Intake rates have been developed by EPA and are typically presented as Reference Doses (RfDs) for noncarcinogens and Cancer Potency Factors (CPFs) for carcinogens. In compiling the dose-response estimates for COCs, a hierarchy of reference sources was established and includes, in decreasing order of priority:

- EPA Integrated Risk Information System (IRIS), a computerized chemical data base (IRIS, 1989);
- EPA Health Effects Assessment Summary Tables (USEPA, 1989d).

Reference intake rates are computed differently by EPA for noncarcinogenic and carcinogenic chemicals as discussed below.

5.2.2.1 Noncarcinogens

The general methodology used to derive reference intake rates (i.e., RfDs) for noncarcinogenic effects is based on the identification of no-observed-adverse-effect-levels (NOAELs) or lowest-observed-adverse-effect-levels (LOAELs) with the incorporation of uncertainty (i.e., margin of safety factors). One or more of these factors are included in the derivation of the RfD based on considerations of the following: (1) the duration of the experimental exposure; (2) effects elicited (if any); (3) extrapolation of the data to other

species (i.e., to humans); and (4) sensitive subgroups (i.e., intraspecies variability). The general formula to compute an RfD is as follows:

$$\text{RfD (mg/kg-day)} = \frac{\text{NOAEL or LOAEL}}{\text{Uncertainty Factor}}$$

RfDs are generally developed for both short-term (i.e., subchronic) and long-term (i.e., chronic) exposures. The basis for each of the RfDs used in the current analysis is detailed in each of the chemical-specific toxicity profiles presented in Appendix B. Specific RfDs are listed in Table 5.2-1.

5.2.2.2 Carcinogens

For carcinogenic chemicals, the general methodology used to derive a reference intake rate (i.e., the risk-specific dose, RSD) is based on EPA cancer potency factors and a predetermined cancer risk level for the general population. The cancer potency estimates computed by EPA are 95th percentile upper confidence limits determined from a linearized multi-stage model. This mathematical model assumes a linear, nonthreshold dose-response relationship at very low doses extrapolated from the high doses employed in laboratory studies. The general formula to compute an RSD is as follows:

$$\text{RSD (mg/kg-day)} = \frac{\text{RL}_A}{\text{CPF}}$$

where RL_A is the acceptable cancer risk level (EPA typically considers 10^{-4} to 10^{-7}) and CPF is the cancer potency factor. In the present risk assessment, RSDs were computed using an acceptable cancer risk level (RL_A) of one in a million, or 10^{-6} . The inhalation RSD for aldrin presented in Table 5.2-1 would therefore be calculated from the RL_A of 10^{-6} and the cancer potency factor as follows:

$$\begin{aligned} \text{RSD} &= \frac{10^{-6}}{17 \text{ (mg/kg-day)}^{-1}} \\ &= 5.9 \times 10^{-8} \text{ mg/kg-day} \end{aligned}$$

Table 5.2-1 Dose-Response Estimates for Contaminants of Concern

<u>Contaminant</u>	<u>RfD</u>		<u>RSD^{1/} (mg/kg-day)</u>	<u>Cancer Potency Factor (mg/kg-day)⁻¹</u>	<u>Weight of Evidence Classification</u>
	<u>Child (mg/kg-day)</u>	<u>Adult (mg/kg-day)</u>			
Aldrin	NA	NA	5.9×10^{-8}	17	B2
Methylene Chloride	1.5 ^{2/}	8.6×10^{-1} ^{3/}	7.1×10^{-5}	1.4×10^{-2}	C
Trichloro- ethylene	NA	NA	7.7×10^{-5}	1.3×10^{-2}	B2

^{1/} RSD is Risk-Specific Dose calculated at a risk level of 10^{-6} (applicable to all age groups)

^{2/} HEAST lists Ambient Air Subchronic Concentration = 3 mg/m^3
 Child RfD = $3 \text{ mg/m}^3 \times 5 \text{ m}^3/\text{day}$ (average child inhalation rate) $\times$ $1/10 \text{ kg}$ (average weight of child) = 1.5 mg/kg-day

^{3/} HEAST lists Ambient Air Subchronic concentration = 3 mg/m^3
 Adult RfD = $3 \text{ mg/m}^3 \times 20 \text{ m}^3/\text{day}$ (average adult inhalation rate) $\times$ $1/70 \text{ kg}$ (average weight of adult) = $8.6 \times 10^{-1} \text{ mg/kg-day}$

NA Data not available in IRIS database or HEAST (USEPA, 1989d)

The CPFs and corresponding RSDs are listed in Table 5.2-1, together with the EPA Weight of Evidence Category. These weight of evidence categories identify the extent to which the available data indicate that an agent is a human carcinogen. The basis for the CPFs and RSDs used in the current analysis is detailed in each of the chemical-specific toxicity profiles presented in Appendix B.

5.3 RISK CHARACTERIZATION

In this section, the estimated contaminant intake rates computed in Section 5.1.5 are compared with the dose-response estimates (i.e., allowable intake rates) developed in Section 5.2-2 to permit characterization of risks to potentially exposed individuals. Risks to public health are computed and discussed separately for noncarcinogenic and carcinogenic contaminants.

5.3.1 Noncarcinogenic Health Risks

Noncarcinogenic health risks resulting from simultaneous exposures to multiple contaminants are characterized through the evaluation of a hazard index, expressed mathematically as

$$\text{Hazard Index} = E_1/RfD_1 + E_2/RfD_2 + \dots + E_i/RfD_i \quad (8)$$

where E_i is the estimated intake rate for a given contaminant, and RfD_i is the corresponding reference dose. Each ratio (i.e., hazard quotient) within the above summation represents the risk of noncancer health effects to an individual(s) posed by exposure to a single contaminant. The hazard index represents the potential noncancer risk posed by simultaneous exposure to multiple contaminants. This approach assumes that simultaneous exposure to multiple contaminants at subthreshold levels (a threshold being a dose at which an adverse effect may be observed) could result in an adverse health effect. When the hazard index exceeds a value of one, there may be a potential health risk.

Subchronic RfD s were not available for aldrin and trichloroethylene, therefore, the potential for noncancer health effects could not be evaluated for these contaminants. The hazard

index for noncarcinogenic effects was based on data for methylene chloride and was estimated to be 2.9×10^{-10} for children and adults. The magnitude of the computed hazard index, which is significantly less than one for both children and adults under the assumed exposure conditions, indicates that noncancer health effects to off-post populations are not likely to occur as a result of the activities of this IRA.

Estimated particulate intake rates were also compared to short-term acceptable exposure levels, such as time weighted average (TWA) and short-term exposure limit (STEL), presented by the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the American Conference of Governmental Industrial Hygienists (ACGIH). No exceedances of these standards were noted. It should be pointed out, however, that these standards have been developed to evaluate worker populations rather than general populations such as those under consideration for this risk assessment.

5.3.2 Carcinogenic Health Risks

Carcinogenic health risks resulting from human exposures to contaminants are characterized by the sum of cancer risks posed by each contaminant. Mathematically this sum is expressed as:

$$\text{Risk}_T = \sum \text{Risk}_i$$

where Risk_T is the total cancer risk (expressed as a unitless probability), and Risk_i is the estimated cancer risk for a given contaminant (unitless). Risk_i is determined using the linear low-dose cancer risk model (USEPA, 1989a):

$$\text{Risk} = \text{CDI} \times \text{CPF} \quad (9)$$

where CDI is the estimated chronic daily intake in mg/kg-day (averaged over 70 years), and CPF is the cancer potency factor (mg/kg-day^{-1}). Because CPF values are calculated using 95 percent confidence limits, the carcinogenic risks calculated using the linear low-dose risk model are upperbound estimates of cancer risks.

Estimated upperbound cancer risks for children and adults are presented for each COC in Table 5.3-1. The total cancer risk posed by simultaneous exposure to all carcinogenic COCs was estimated to be 1.1×10^{-15} for children and 5.9×10^{-16} for adults. Computed cancer risks are well below the EPA acceptable risk level of 10^{-6} (one chance in one million of contracting cancer). Therefore, exposure of off-post humans to IRA implementation activities is highly unlikely to result in any measurable increased cancer risk.

Table 5.3-1 Estimated Upperbound Individual Cancer Risk for Contaminants of Concern

Contaminant of Concern	Chronic Daily Intake (mg/kg-day)	Cancer Potency Factor (mg/kg-day) ⁻¹	Risk Estimate
Aldrin			
Child	4.7×10^{-17}	17	8.0×10^{-16}
Adult	2.6×10^{-17}	17	4.4×10^{-16}
Methylene Chloride			
Child	1.7×10^{-14}	1.4×10^{-2}	2.4×10^{-16}
Adult	9.8×10^{-15}	1.4×10^{-2}	1.4×10^{-16}
Trichloroethylene			
Child	2.0×10^{-15}	1.3×10^{-2}	2.6×10^{-17}
Adult	1.1×10^{-15}	1.3×10^{-2}	1.4×10^{-17}

5.4 UNCERTAINTY CONSIDERATIONS

The following section discusses the information and key assumptions used in the human health risk assessment and how the uncertainties associated with their use affect the computed risk estimates. Although a rigorous quantitative evaluation of these uncertainties is beyond the scope of this assessment, it is important to consider, at least qualitatively, the effect of various assumptions used throughout this analysis. These assumptions are likely to have an effect on the final intake and risk values computed. Uncertainty considerations are discussed in relation to each of the key steps in the risk assessment, toxicity assessment, exposure assessment, and risk characterization.

5.4.1 Toxicity Assessment

Toxicity data for chemicals found at waste sites are usually limited. Therefore, uncertainties are associated with the dose-response estimates employed in the analysis. The major sources of uncertainty that could over- or underestimate contaminant risks in the current analysis include:

- The potential overestimation of toxicity due to the use of dose-response data from effects observed at high doses to predict the adverse health effects that may occur following exposure to the low concentrations typically encountered from human contact with the chemical in the environment.
- The use of dose-response data from animal studies to predict effects in humans (could over- or underestimate toxicity).
- The potential underestimation of toxicity from the use of dose-response data from homogenous populations (animal, human) to predict the effects in the general population, which includes individuals of varying sensitivity.

5.4.2 Exposure Assessment

Contaminant intakes computed in the exposure assessment also have a considerable amount of uncertainty inherent in their estimation. The major sources of uncertainty that could over- or underestimate the calculated intake rates include:

- The use of environmental data from the RI, while generally representative, may or may not sufficiently characterize soil contamination at specific discrete locations across the entire sanitary sewer line.
- The overestimation of risks from the use of maximum measured contaminant concentrations.
- The potential overestimation of risks from the use of contaminant emission and transport models to estimate concentrations of ambient air contaminants assumed to be related to the site.
- The use of standard assumptions, including body weights, exposure frequencies and durations, and media contact rates in computing intake rates.
- The potential underestimation of risk as a consequence of removing chemicals from the risk evaluations based on a lack of reference dose.
- The potential overestimation of intake rates through the use of simplifying assumptions, such as the assumption of 100 percent pulmonary retention and absorption in calculating intake rates.
- The potential underestimation of risk through the lifetime averaging of short-term intakes for carcinogenic contaminants.

5.4.3 Risk Characterization

Risks estimated from contaminant intake rates may be under- or overestimated based on the uncertainties inherent in the methodology used in their computation. The major sources of uncertainty in the calculated cancer and noncancer risk estimates include:

- The assumption of dose additivity for noncarcinogenic compounds that are not expected to induce the same type of effects, or that do not act by the same toxicological mechanism (could over- or underestimate risks).
- The assumed independence of toxicological action by all chemicals (noncarcinogens and carcinogens) evaluated (i.e., that there are no antagonistic, synergistic, or other types of interactions; this could over- or underestimate risks).
- The assumed additivity of cancer risks for carcinogenic compounds that may overestimate risks (e.g., 95th percentile cancer potency factors are not strictly additive).
- The assumption that risks for carcinogens can be summed equally without consideration of the weight-of-evidence categories (i.e., equal weight is given to known human carcinogens and suspected human carcinogens; this could over- or underestimate risks).

6.0 ECOLOGICAL RISK ASSESSMENT

The purpose of the Ecological Risk Assessment is to evaluate the probability of adverse biological and ecological effects related to potential site contamination during IRA activities. In Section 4.3 of this report, aldrin, methylene chloride, and trichloroethylene were identified as COCs for evaluation in the ecological risk assessment.

This section presents a qualitative evaluation of the potential short-term effects and likely fate of the biota COCs resulting from implementation of the Sanitary Sewer IRA, and consists of the following elements:

- Species and habitat distribution
- Exposure assessment
- Toxicity assessment
- Risk characterization for biota

6.1 SPECIES AND HABITAT DISTRIBUTION

This section provides a brief overview of RMA ecological resources (i.e., vegetation and wildlife) that are endemic to the IRA implementation area and potentially subject to impacts from implementation of the IRA. Included in this section is a discussion of transitory species that may frequent the IRA implementation area.

6.1.1 Vegetation Resources

A variety of terrestrial and aquatic ecosystem components have been observed on RMA. Habitat alterations on RMA have led to an increase in diversity and abundance of several plant species. In some areas, a decrease in diversity has resulted from the persistence of early successional weedy species.

In 1989, Morrison-Knudsen Engineers, Inc. (MKE) mapped RMA vegetation into five general community types: weedy forbs, cheatgrass/weedy forbs, cheatgrass/perennial grass, native perennial grassland, and crested wheatgrass (ESE, 1989).

In the area of proposed IRA activities, the vegetation is variable. Near the interceptor line between Manholes 98 and 46, several areas are vegetated, interspersed with small marshes or wet, open ground. Most areas of the interceptor line are dominated by aggressive annual grasses or weedy forbs, and have been severely disturbed by vehicular traffic, waste effluent drainage, or other nearby disposal activities. A few areas near Manholes 78, 79, 82, 83, 87, and 88 are sparsely vegetated, having been decimated by prairie dog activity, and subsequently invaded by weedy forbs. The area planned for trenching in Section 35 is primarily a mixture of perennial grasses, cheatgrass, and weedy forbs.

Both the North Plants and South Plants areas affected by the IRA are typically devoid of vegetation, except for annual forbs and grasses. This is due, in part, to surface disturbances including pavement, gravel emplacement, compaction, and other industrial types of activities.

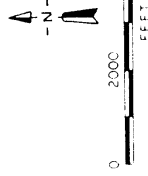
The area defined by the Sanitary Sewer IRA does not directly impact any unique habitats, vulnerable vegetative communities, or unusual landscape features, although three are present nearby: ancient alluvial terraces containing heavily cemented gravels along the northern edge of Section 36 and southern edge of Section 25; a relatively undisturbed 28 acre parcel of gravelly soils atop Rattlesnake Hill; and remnant areas of natural vegetation dominated by ring-muhly, winterfat, and sideoats gram, also on Rattlesnake Hill. Each of these areas currently supports sensitive biota populations and are identified in Figure 6.1-1.

6.1.2 Wildlife Resources

The prairie, steppe, and savannah communities characteristic of the Great Plains region and existing on RMA support a variety of terrestrial fauna. The diversity of wildlife in this region is enhanced by the wide variety of habitats present. Abundant food, cover, and other habitat components improve reproductive success and support large populations. An inventory of RMA wildlife species and details on their distribution are found in the Biota RI (ESE, 1989), and the MKE report on wildlife resources of RMA (MKE, 1989).

Legend

- Sanitary Sewer Main
- Lift Station
- Area Boundary
- Manhole with Number
- Section Number
- Approximate Location of Potentially Contaminated Soil
- Approximate Location of New Sanitary Sewer Line Construction
- Grasslands
- Gravels--Ancient Alluvial Terrace Remnants
- 1986 Active Kestrel Nest
- 1986 Swainson's Hawk Nest
- 1986 Red-Tailed Hawk Nest
- 1987 Great Horned Owl Nest



Prepared for :

U.S. Army Program Manager
Rocky Mountain Arsenal Contamination
Cleanup

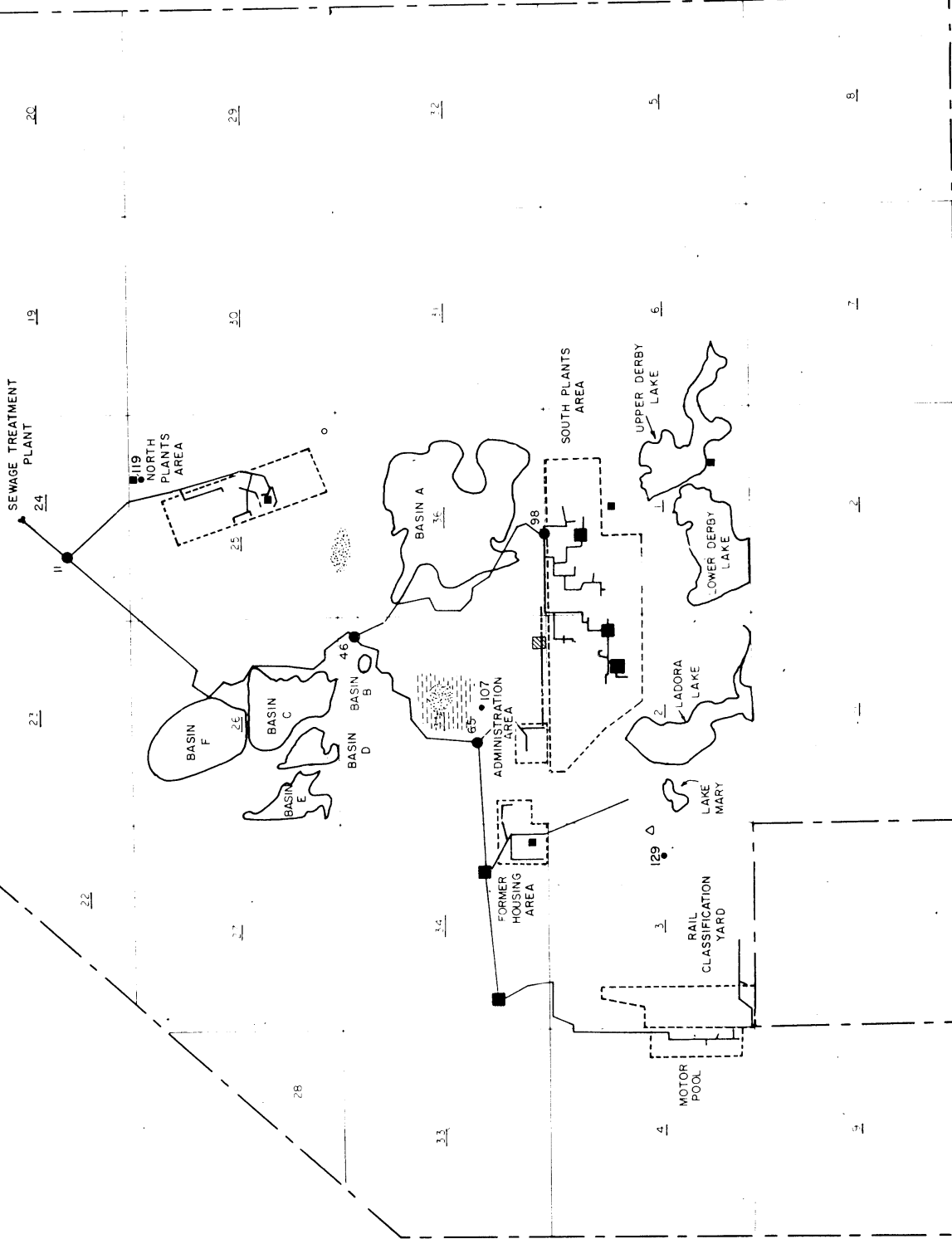
FIGURE 6.1-1

Biota Areas of Special Interest
Near Sanitary Sewer IRA Area

Rocky Mountain Arsenal

Prepared by Ebasco Services Incorporated

6-3



Seventeen species of raptors were observed on RMA between 1985 and 1989. These raptors vary in abundance seasonally (ESE, 1989). Eagles, rough-legged hawks, ferruginous hawks, red-tailed hawks, and several species of owls are commonly observed wintering on RMA. Near the IRA implementation area, two great-horned owl nests were observed in 1987, one in North Plants, and one southeast of South Plants. In addition, one kestrel nesting box was observed several hundred yards north of the IRA implementation area in Section 35. These features are also noted in Figure 6.1-1.

In the winters of 1986-1987 and 1987-1988, several bald eagle (a Federally endangered species) subadults were observed feeding both in and near North Plants and in Section 36 (Basin A), within a few hundred yards of the interceptor line. No observations were made in the South Plants area (ESE, 1989). Details of the bald eagle study on RMA are found in the 1986-1988 Bald Eagle Studies report (ESE, 1988).

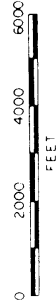
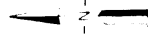
Other top carnivores expected to be present in the IRA implementation area include badgers, coyotes, red foxes, and long-tailed weasels. The major prey species for the top carnivores on RMA is the black-tailed prairie dog. Active prairie dog colonies are shown in Figure 6.1-2 and occur along the Sanitary Sewer IRA in Section 36 (near Manholes 82, 83, 87, and 88) and in Section 35 (near Manholes 46, 75, 78, and 79). A few isolated colonies occur in Section 35 north of December 7th Avenue, between the Firehouse and Administration Building where trenching activities will occur. Pheasants and mourning doves are common upland game birds that are often seen in riparian, tall grass, and weedy vegetation types within or near the IRA implementation area.

Several species of rodents and small mammals are present in the vicinity of the IRA implementation areas. These small- and medium-sized mammals are for the most part primary consumers (herbivores) in the food chain, and are preyed upon by top carnivores.

Deer are commonly observed throughout South Plants and along the Sanitary Sewer Interceptor line near Manhole 98 and slightly north. Deer are primary consumers (herbivores) in the food chain, and weakened or young deer may provide a food source for local carnivores.

Legend

- Sanitary Sewer Main
- Lift Station
- Manhole with Number
- Section Number
- Area Boundary
- Approximate Location of New Sanitary Sewer Line Construction
- Approximate Location of Potentially Contaminated Soils
- Existing Prairie Dog Towns



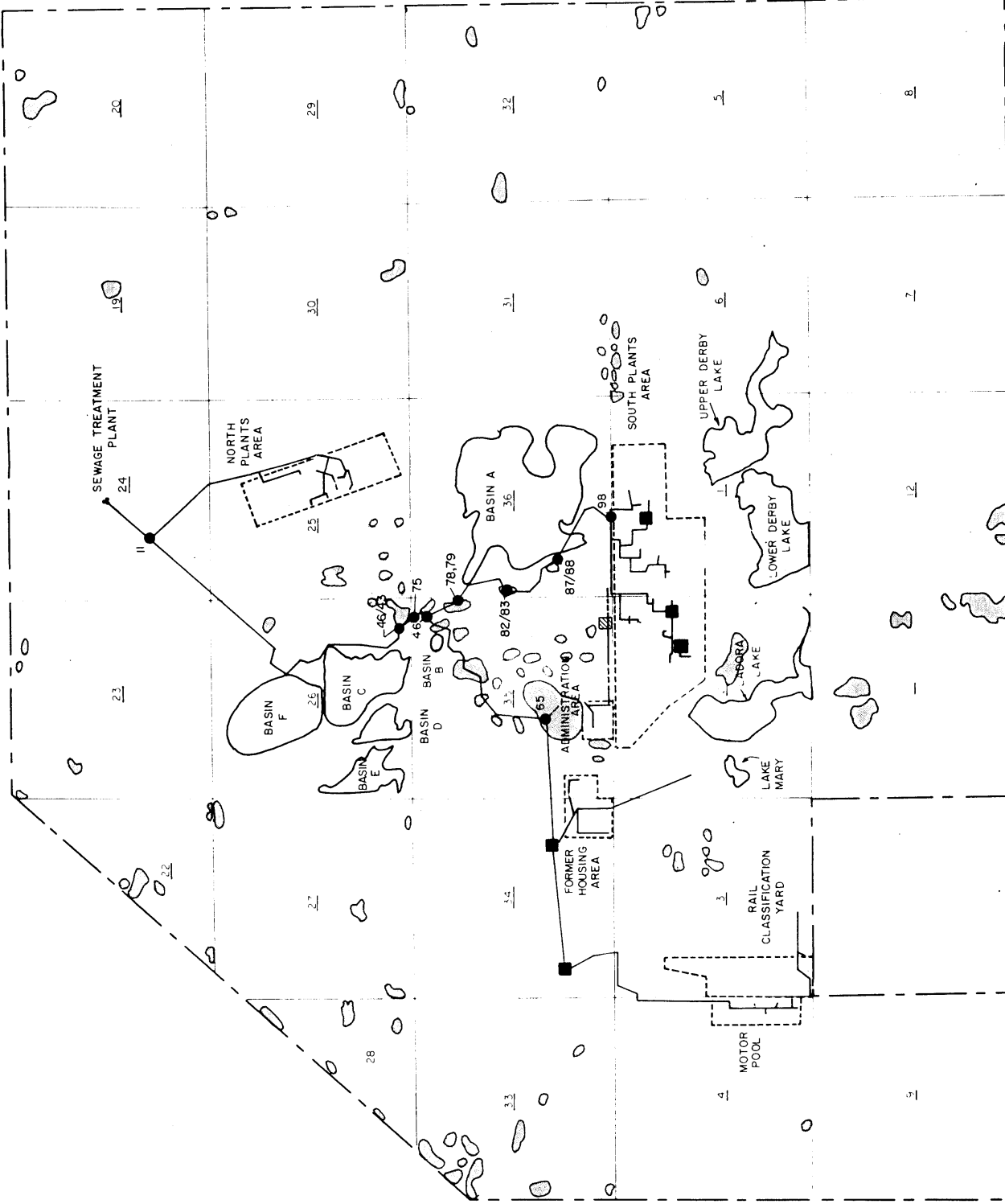
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Rocky Mountain Arsenal Contamination
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FIGURE 6.1-2

September 1989 Prairie Dog
Colonies and Sanitary Sewer Features
Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated



6.2 EXPOSURE ASSESSMENT

The ecological exposure assessment for the Sanitary Sewer IRA qualitatively evaluates the biological resources that may be exposed to COCs during IRA activities. This includes a summary of the species potentially located in the IRA implementation area, a discussion of significant mechanisms of contaminant transport to points of exposure for biota, and a qualitative evaluation of the magnitude of biota exposure during IRA activities.

6.2.1 Potentially Exposed Biota Populations

This section summarizes the biota species most likely to be impacted by the Sanitary Sewer IRA. For this IRA, the terrestrial food web was identified as the biotic community having the greatest potential for impact by the IRA, since no aquatic communities exist in the IRA implementation area. The plant, animal, and invertebrate species that represented key components of one or more RMA terrestrial food chains were summarized in the Biota RI (ESE, 1989). Key species identified in the Biota RI were selected based on the following criteria, as defined by ESE (1989):

- Species listed as Federally threatened and endangered (T&E), or considered as a candidate species for listing by the USFWS
- Species considered important components of RMA ecosystems (e.g., abundant prey for important species such as T&E species)
- Species that represent each of the basic trophic levels (e.g., herbivore, omnivore, carnivore, detritivore)
- Species that are economically important (e.g., game and pest species)
- Species that represent a higher trophic level in food chains/webs in RMA ecosystems.

The terrestrial species that may potentially be affected by the Sanitary Sewer IRA have been selected from the Biota RI (ESE, 1989). These species are endemic to, or have potential access to, the IRA area and may be affected by the level of disturbance from the IRA. Specific data regarding previous biota exposure to contaminants in the immediate vicinity of the Sanitary Sewer IRA are not available. Therefore, the species selected for analyses during the Biota RI and the Comprehensive Monitoring Program (CMP) (Table 6.2-1) were considered for evaluation in the risk assessment due to their ecological

importance on RMA. The species that are components of RMA terrestrial food webs can be broken down into terrestrial-sedentary and terrestrial-mobile species, as noted in Table 6.2-1. All species listed in Table 6.2-1 are potential components of terrestrial food webs in the vicinity of IRA activities. These particular food webs were considered relevant to these IRA implementation activities because: (1) several kestrel nesting areas are within a reasonable distance of the IRA area; and (2) excavated materials may serve as an "instant" and potentially contaminated food source otherwise unavailable to higher food web species (e.g., earthworms and insect larvae).

Variations in food consumption during the year and at different life stages, as well as the timing of the IRA, may result in the introduction of species other than those mentioned above into the exposure pathway scenario.

6.2.2 Applicable Contaminant Transport Mechanisms

Contaminant transport is evaluated to determine mechanisms that would permit exposures to on-post biota. The transport mechanisms are limited to those associated with the transport of contaminants from soils located in areas of proposed disturbance, since other environmental media are not applicable (see Section 4.1). These transport mechanisms are volatilization of contaminants from soil, transport of contaminants sorbed to airborne soil particulates, and transport of contaminants that have adhered to personnel and equipment.

Transport from contaminant sources to biologic receptors is governed by several interrelated factors, including: the chemical and physical properties of the contaminant source and surrounding media; the chemical and physical processes that affect the migration potential of contaminants; and several biological factors including species, trophic level, age, food web, pattern of movement, reproductive frequency, and physiological behavior.

The chemical and physical properties of the biota COCs are summarized in the chemical toxicity profiles, presented in Appendix B.

Table 6.2-1 RMA Terrestrial Species that may Potentially be Exposed to Contaminants.

Targeted RI and CMP-Biota Terrestrial Species	Taxonomic Group	Trophic Level	Game Species	Prey Item for Endangered Species	Widespread Distribution on RMA	Home Range Limited to RMA	Other Historical Contaminant Data ¹
Mobile Species							
Mule Deer/Adult	mammal	herbivore	X		X		X
Mule Deer/Juvenile	mammal	herbivore	X		X		X
Desert Cottontail	mammal	herbivore	X	X	X	X	X
Black-tailed Prairie Dog/Adult	mammal	herbivore		X		X	X
American Kestrel/ Egg	bird	-				X	X
American Kestrel/ Juvenile	bird	carnivore				X	X
Ring-necked Pheasant/Juvenile	bird	insectivore	X		X	X	X
Ring-necked Pheasant/Adult	bird	granivore	X		X		X
Sedentary Species							
Deer Mouse/Adult	mammal	omnivore			X	X	X
Thirteen Lined Ground Squirrel	mammal	omnivore			X	X	X
Grasshopper	invertebrate	herbivore/ detritivore			X	X	X
Earthworm	invertebrate	detritivore				X	X

¹ Includes studies by the army, U.S. Fish and Wildlife Service, and other contractors dating back to 1952.

Table 6.2-1 RMA Terrestrial Species that may Potentially be Exposed to Contaminants.

Targeted RI and CMP-Biota Terrestrial Species	Taxonomic Group	Trophic Level	Game Species	Prey Item for Endangered Species	Widespread Distribution on RMA	Home Range Limited to RMA	Other Historical Contaminant Data ¹
Plants	plant	primary producer			X	X	X
• Cheatgrass	-	-					X
• Kochia	-	-					
• Sunflower	-	-					
• Prickly lettuce	-	-					
• Morning glory	-	-					

¹ Includes studies by the army, U.S. Fish and Wildlife Service, and other contractors dating back to 1952.

NOTE: Other Supplemental terrestrial species collected by U.S. Fish and Wildlife included the following: mourning dove, bald eagle, golden eagle, ferruginous hawk, red-tailed hawk, great horned owl, northern harrier, coyote, and badger. These species were collected fortuitously i.e. samples of chance (ESE, 1989).

6.2.3 Evaluation of Exposure to Biota

A qualitative evaluation of potential exposures to biological receptors is presented in this section. A general discussion of the potential routes of exposure to ecological receptors during this IRA is presented below.

Exposure routes that may pose a threat to biota in the IRA area are ingestion, inhalation, and dermal contact from contaminated soils that are excavated. These potential exposures would be expected to occur in the immediate area of the IRA activities. However, given the small scale of the planned invasive activities, the low concentrations of COCs measured in the soils, and the short exposure duration of the IRA, short-term impacts (i.e., acute effects) are not expected to be significant.

6.3 TOXICITY ASSESSMENT

In accordance with the Risk Assessment Guidance for Superfund (RAG) (EPA, 1989a) and the EPA Region I Guidance for Public Health and Ecological Risk Assessments (USEPA, 1989b), toxicity assessments were prepared for the COCs (aldrin, methylene chloride, and trichloroethylene) identified in this assessment.

The toxicity assessment is typically comprised of two elements. The first, hazard identification, is intended to characterize the nature and extent of biota health hazards associated with chemical exposures. The second, dose-response assessment, determines the relationship between the magnitude of exposure to a chemical and the occurrence of adverse health effects.

General dose-response information has been presented where available as part of the hazard identification. However, dose-response estimates for allowable exposures have not been developed for biota as was done for humans. The information comprising the hazard identification for each COC is discussed in the "Toxicity to Wildlife" section of each toxicity profile in Appendix B.

6.4 RISK CHARACTERIZATION

This section summarizes the results of the exposure and toxicity assessments to characterize the risks to biotic receptors from implementation of the IRA.

6.4.1 Qualitative Estimate of Risk

As indicated in the exposure assessment, the absence of allowable exposure criteria for biota and the absence of standardized data regarding biota intake rates resulted in a qualitative discussion of potential exposures to ecological receptors.

As indicated previously, exposures to biota from implementation of the IRA are anticipated to be negligible given the low concentrations of COCs detected in soils, the small scale of the planned invasive soil activities, and the short-term duration of the IRA (eight hours in areas with potential contamination). Therefore, it is concluded that the risk of acute health effects to biota receptors is correspondingly low.

6.4.2 Uncertainty Considerations

The characterization of risk to ecologic receptors includes several areas of uncertainty. Primarily, quantitative dose-response estimates and potential carcinogenicity data were not available to define contaminant exposures for terrestrial wildlife. This lack of standardized data for use in computing contaminant intake rates and a lack of quantitative risk assessment methodology for biotic receptors led to a qualitative rather than quantitative risk assessment. Based on these inherent uncertainties, the potential risks to ecological receptors may be over- or underestimated.

6.4.3 Summary of Risks

In summary, although it is not possible to quantify the risks to ecological receptors as a result of IRA activities, it is expected that exposures of COCs to biota will be low. Some of the IRA activities could result in increased contaminant transport, destruction of vegetation, and disruption of sensitive biota populations.

7.0 SOCIAL IMPACTS

Social impacts will be defined for this discussion as the interference of an individual's enjoyment of his environment. This may be thought of as an interference with "comfortable living" rather than loss, damage, or injury.

7.1 NOISE IMPACTS

Noise is generally described as "unwanted sound", and hence it follows that people may wish to be protected from its undesirable effects. The Colorado Noise Abatement Statute requires local authorities to take action to restrict noise amounting to public nuisance. Local ordinances restrict noise levels (sound pressure levels or SPLs) in residential areas to 55 dBA¹ during the day and 50 dBA at night.

The noise generated from this interim action will be from the heavy equipment used for excavation, grouting, and driving sheet pile. Heavy equipment (excavators, bulldozers, front-end loaders, etc.) generally have a sound power level (SPL) of 120 dB (Beaulieu, 1981).

Sound Propagation Calculation:

$$SPL = SWL - (20)\log(r) - 11 \text{ dB}$$

where:

SPL = Sound Pressure Level

SWL = Sound Power Level

r = Distance from the noise source (ft)

Setting SPL = 55 dB and solving for r gives r = 500 ft

$$SPL = 120 \text{ dB} - (20)\log(500) - 11 \text{ dB}$$

$$SPL = 55 \text{ dB}$$

¹ dB or decibel is a term used to express sound levels associated with noise measurements. It is a unitless value that is a ratio of a measured sound pressure to a reference sound pressure. This reference value is a sound pressure of 20 micropascals or 0 dB - the starting point on the scale of noise levels. This starting point is considered the level of the weakest sound that can be heard by a person with good hearing in a quiet location. The "A" designation is part of a weighing network, used in measuring sound pressure levels, that discriminates against low frequencies.

At 500 ft from the source the sound pressure level will be 55 dB, which is the maximum noise level allowed by the State of Colorado in residential areas during the day. The nearest population of concern is 2 miles or 10,560 ft from this interim action, and therefore will not be affected.

7.2 ODOR IMPACTS

Activities associated with implementation of this IRA are not expected to produce unacceptable odorous emissions. Similar excavations have been undertaken for routine installation and maintenance of utilities at RMA in the past and have not produced unacceptable odors. The low concentrations of organic compounds that may exist in the excavation area, and the limited area of exposed soil will not result in odors greater than those generated by similar activities in uncontaminated soils.

7.3 VISUAL IMPACTS

Awareness of air pollution often depends heavily upon visual perception. Many of the COCs cannot be seen, unless attached to dust. The dust generation from implementation of this IRA is expected to be minimal due to the duration and size of the project and, therefore, is not expected to create any visual impacts to human populations off-post.

7.4 VEHICULAR IMPACTS

Vehicular traffic due to IRA activities will not impact local traffic routes because the small work force will not generate enough commuting trips over the work period to be noticeable and all activity will be in a restricted area on the Rocky Mountain Arsenal. It is not anticipated that vehicular traffic generated as a result of implementation of this IRA will affect the level of service that nearby local roads provide.

8.0 CONCLUSIONS AND RECOMMENDATIONS

This risk assessment has addressed potential health risks to off-post human populations and to on-post ecological receptors resulting from implementation of the sanitary sewer IRA. The human health and ecologic risk assessments were treated separately for the purposes of this report.

The human health risk assessment was quantitative in nature and included an evaluation of carcinogenic and noncarcinogenic health risks. In addition, noise, odor, visual, and vehicular impacts to off-post human populations were evaluated. It was concluded that implementation of this IRA will not result in adverse effects to off-post human populations.

The risk assessment for on-post ecological receptors was qualitative in nature due to a lack of standardized toxicological data. It was concluded that on-post sedentary biotic receptors such as small mammals, invertebrates, and plants may be impacted by implementation of this IRA. The following actions are recommended to minimize these impacts.

- Avoid activities in three nearby areas containing unique habitats and vulnerable vegetative communities. These areas are: the ancient alluvial terraces along the northern edge of Section 36 and southern edge of Section 25; a 28 acre parcel of gravelly soils atop Rattlesnake Hill; and remnant areas of natural vegetation dominated by ring-muhly, winterfat, and sideoats gram, also on Rattlesnake Hill.
- Minimize windblown particulate from the trench excavation where the trench crosses through potentially contaminated soil.
- Include appropriate equipment and personnel decontamination procedures so that potentially contaminated soils will not be transported to other areas of RMA.
- Minimize ground surface modifications such as excavations, placement of potentially contaminated soil, compaction due to vehicular traffic, and standing crop damage.

In addition to the specific recommendations listed above, it is also recommended that activities be coordinated with the U.S. Fish and Wildlife service to minimize potential wildlife exposures.

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APPENDIX A
SCREEN MODEL RESULTS

RF66/RPT0064.RF6 1/25/90 1:30 pm sma

01-08-90 16:39:11
 *** SCREEN-1.1 MODEL RUN ***
 *** VERSION DATED 88300 ***

UNIT DISPERSION CALCULATIONS

SIMPLE TERRAIN INPUTS:

SOURCE TYPE = AREA
 EMISSION RATE (G/S) = 1.000
 SOURCE HEIGHT (M) = .50
 LENGTH OF SIDE (M) = 5.00
 RECEPTOR HEIGHT (M) = 1.50
 IOPT (1=URB,2=RUR) = 2

<INPUT PARAMETERS>

BUOY. FLUX = .00 M**4/S**3; MOM. FLUX = .00 M**4/S**2.

*** STABILITY CLASS 6 ONLY ***
 *** 10-METER WIND SPEED OF 2.5 M/S ONLY ***

<METEOROLGY>

 *** SCREEN AUTOMATED DISTANCES ***

<MAXIMUM AMBIENT
 CONCENTRATIONS>

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
2000.	91.16	6	2.5	2.5	5000.0	.5	64.4	21.6	NO
2100.	84.98	6	2.5	2.5	5000.0	.5	67.3	22.2	NO
2200.	79.48	6	2.5	2.5	5000.0	.5	70.2	22.8	NO
2300.	74.56	6	2.5	2.5	5000.0	.5	73.0	23.3	NO
2400.	70.13	6	2.5	2.5	5000.0	.5	75.8	23.9	NO
2500.	66.13	6	2.5	2.5	5000.0	.5	78.7	24.4	NO
2600.	62.50	6	2.5	2.5	5000.0	.5	81.5	25.0	NO
2700.	59.20	6	2.5	2.5	5000.0	.5	84.3	25.5	NO
2800.	56.18	6	2.5	2.5	5000.0	.5	87.1	26.0	NO
2900.	53.41	6	2.5	2.5	5000.0	.5	89.9	26.5	NO
3000.	50.87	6	2.5	2.5	5000.0	.5	92.6	27.0	NO
3500.	41.25	6	2.5	2.5	5000.0	.5	106.3	29.0	NO
4000.	34.41	6	2.5	2.5	5000.0	.5	119.9	30.8	NO

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 2000. M:									
2000.	91.16	6	2.5	2.5	5000.0	.5	64.4	21.6	NO

DWASH=NO MEANS NO BUILDING DOWNWASH USED

APPENDIX B
TOXICITY PROFILES

APPENDIX B

TOXICITY PROFILES

Toxicity Profiles were developed for each contaminant of concern evaluated for the Sanitary Sewers Interim Response Action. These profiles were developed to provide a brief overview of the toxicological properties and environmental behavior of the contaminants of concern to human and biota receptors at RMA. These profiles were not meant to be complete sources of toxicological or environmental information. These profiles were compiled from current toxicological literature, and include the following information:

- Chemical and physical properties
- Summary of toxic effects to humans, lab animals, and wildlife
- Regulations and standards
- Dose-response assessment

The information used in compiling the toxicity profiles was obtained from the following sources:

- Exposure Assessment for Rocky Mountain Arsenal, Volume I-II (Toxicity Assessment)
- Computerized literature searches of the following on-line databases:
 - Medline (on-line biomedical bibliographic records)
 - HSDB (Hazardous Substances Data Base)
 - IRIS (USEPA's Integrated Risk Information System - access date October 28, 1989)

The EA for RMA contained toxicity profiles that were originally developed from information obtained from the USEPA Office Waste Programs Enforcement (OWPE) and the U.S. Army Biomedical Research and Development Laboratory (USABRDL). This information was supplemented by computerized literature searches of the Dialog and Chemical Information Systems databases. These toxicity profiles were included in this risk assessment and updated using the sources listed above.

ALDRIN/DIELDRIN¹

SUMMARY

In the environment aldrin degrades to its persistent epoxide derivative dieldrin. Both pesticides have been shown to produce teratogenic and reproductive effects in animal studies. Aldrin and dieldrin have been shown to cause liver toxicity and central nervous system abnormalities in humans following chronic exposure. Both have been shown to be acutely toxic, with oral LD₅₀ values ranging from 39-60 mg/kg in rats. Both pesticides are very toxic to aquatic organisms and have been associated with large-scale kills of terrestrial wildlife in treated areas.

CAS Number: Aldrin: 309-00-2
Dieldrin: 60-57-1

Chemical Formula: Aldrin: C₁₂H₈Cl
Dieldrin: C₁₂H₈Cl₂O

IUPAC Name: Aldrin: 1,2,3,4,10,10-hexachloro-1,4,4a,5,8, 8a-hexahydro-1,4:
5,8-exo-dimethanonaphthalene
Dieldrin: 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,
8a-octahydro-endo,exo-1,4:5,8-di methanonaphthalene

CHEMICAL AND PHYSICAL PROPERTIES

Molecular Weights: Aldrin: 365
Dieldrin: 381

¹ Compiled from: U.S. Environmental Protection Agency, Office of Waste Program Enforcement. September 1985. Chemical, physical and biological properties of compounds present at hazardous waste sites. A Final Report Prepared by Clement Associates, Inc., Arlington, Virginia

Also: United States Army Medical Bioengineering Research and Development Laboratory (USAMBRDL), 1985. Physical/Chemical and Toxicological Summaries for 62 Rocky Mountain Arsenal Contaminants. USAMBRDL. Fort Detrick, Frederick, MD.

Melting Point: Aldrin: 104°C
Dieldrin: 176°C

Solubility in Water: Aldrin: 200 µg/liter at 25°C
Dieldrin: 200 µg/liter at 25°C

Solubility in Organics: Soluble in most organic solvents

Log Octanol/Water Partition Coefficient (K_{ow}):

Aldrin: 3.01 (Hansch, 1979)
5.66 (Geyer et al., 1984)
7.40 (Briggs, 1981)
5.66 (Kenaga, 1980, Table III)
5.30 (USEPA, 1986)

Dieldrin: 4.32 (Davies and Dobbs, 1984)
6.2 (Briggs, 1981)
3.69 (Rao and Davidson, 1983)
5.48 (Kenaga, 1980, Table III)
3.5 (USEPA, 1986)

Soil/Water Partition Coefficient (K_{oc}):

Aldrin: 76,000 (Versar, 1984)
28,200 (Briggs, 1981, Table III)
96,000 (USEPA, 1986)

Dieldrin: 3,300; 12,880 (Kadeg et al., 1986, literature values)
7,413 (Briggs, 1981, Table III, experimental)
35,600 (Kenaga, 1980, Table III, experimental)
1,700 (USEPA, 1986)

Bioconcentration Factor:

Aldrin: 1,555 (Davies and Dobbs, 1984, Eqn C, $\log k_{ow} = 5.66$)
13,640 (Davies and Dobbs, 1984, Eqn C, $\log k_{ow} = 7.4$)
1,500 (Lyman et al., 1982)
3,140 (Kenaga, 1980, Table 3, experimental)
10,800 (Kenaga, 1980, Table 3, experimental)
3,690 (Davies and Dobbs, 1984, Eqn B, $\log k_{ow} = 5.66$)
40,345 (Davies and Dobbs, 1984, Eqn C, $\log k_{ow} = 7.4$)
11,792 (Lyman et al., 1982, Eqn 5-2, $\log k_{ow} = 5.66$)

247,742 (Lyman et al., 1982, Eqn 5-2, $\log k_{ow} = 7.4$)
 1,810 (Davies and Dobbs, 1984, Eqn C, $\log k_{ow} = 6.12$)
 6,940 (Davies and Dobbs, 1984, Eqn B, $\log k_{ow} = 6.12$)
 26,400 (Lyman et al., 1982, Eqn 5-2, $\log k_{ow} = 6.12$)
 4,571 (Hawker et al., 1986)

Dieldrin: 5,800; 4,420 (Kenga, 1980, Table 3, experimental)
 1,489 (Davies and Dobbs, 1984, Eqn B, $\log k_{ow} = 5.0$)
 12,590 (Davies and Dobbs, 1984, Table 2, experimental)
 292 (Davies and Dobbs, 1984, Eqn C, $\log k_{ow} = 4.32$)
 1,130 (Lyman et al., 1982, Eqn 5-2, $\log k_{ow} = 4.32$)
 30,339 (Lyman et al., 1982, Eqn 5-2, $\log k_{ow} = 6.2$)
 1,350.7 (Davies and Dobbs, 1984, Eqn a, $S = 0.25$)
 480 (Davies and Dobbs, 1984, Eqn C, $\log k_{ow} = 5.0$)
 3,700 (Lyman et al., 1982, Eqn 5-2, $\log k_{ow} = 5.0$)

Vapor Pressure: Aldrin: 2.31×10^{-5} mm Hg at 20°C
 6×10^{-6} mm Hg (USEPA, 1986)

Dieldrin: 2.8×10^{-6} mm Hg at 20°C

Henry's Law Constant:

Aldrin: 2.4×10^{-5} atm-m³/mole (calculated)
 1.6×10^{-5} atm-m³/mole (USEPA, 1986)

Dieldrin: 1.4×10^{-5} atm-m³/mole (calculated)
 4.58×10^{-7} atm-m³/mole (USEPA, 1986)

TRANSPORT AND FATE

Aldrin evaporates rapidly from aquatic environments and soil. Photolysis occurs in aqueous solution or on plant surfaces, with conversion primarily to dieldrin, although a small fraction (generally less than 5 percent) is slowly converted to photodieldrin (Rosenblatt et al., 1975). Hydrolysis of dieldrin is also quite slow with a half-life in excess of 4 years (USEPA, 1979).

A range of experimental and estimated soil-water partition coefficients (K_{oc}) is reported above and indicates that substantial sorption of aldrin and dieldrin to soils/sediments and dissolved organic material will occur. Pavlou (1980) estimates that sorption of nonpolar hydrophobic pesticides is very high; therefore, little environmental mobility would be expected for these compounds.

In soil, aldrin is converted to its epoxide dieldrin, by oxidation. The conversion may be enhanced by microorganisms (Rosenblatt et al., 1975). The conversion appears to have a half-life on the order of 1 year. This degradation also occurs in vivo. The persistence of dieldrin in soil is variable but may range upwards of 7 years (Rosenblatt et al., 1975). Over 90 percent of applied dieldrin was still present in the top three inches of a loam soil after a period of 17 months (Rosenblatt et al., 1975). Microbial degradation does occur slowly with the main products being close derivatives (i.e., dihydroxydihydroaldrin, Rosenblatt et al., 1975).

Uptake of dieldrin in plants is variable. For example, potatoes grown in dieldrin treated soil had concentrations almost twice as high as soil levels (Telekar et al., 1983), while peeled beets had levels only one third the concentration in soil (Kohli et al., 1973). Concentrations in pasture crops appear to be less than the concentrations of the soil in which they were grown (Chawla et al., 1981).

A range of experimental and estimated bioconcentration factors (BCFs) for aldrin and dieldrin is also reported above. Bioconcentration factors for aldrin range from 1,500 to 247,000 indicating a high potential for biomagnification of residues up food chains. ASTM (1985) indicates that chemicals with bioconcentration factors less than approximately 100 have low potential for causing harm to wildlife and human health via biomagnification of residues up food chains. Dieldrin is nonpolar and lipophilic, attracted to fats, plant waxes, and organic matter in sediments or soils (ESE, 1989), and it is expected that aldrin behaves similarly. Dieldrin does not leach readily, and neither mixing of soil nor adding organic matter appear to influence loss of residues through volatilization (ESE, 1989). It is expected that aldrin exhibits similar environmental behavior.

HEALTH EFFECTS

Both aldrin and dieldrin are probable carcinogens that have been shown to cause increases in a variety of tumors in rats at low but not at high doses. They also produce a higher incidence of liver tumors in mice. The reason for this reversed dose-response relationship is unclear. Neither appears to be mutagenic when tested in a number of systems. On the

basis of the criteria proposed by the Carcinogen Assessment Group of the USEPA for evaluating the overall weight of evidence for carcinogenicity to humans, both aldrin and dieldrin are classified as Group B2 carcinogens (probable human carcinogens) (USEPA, 1989).

Aldrin and dieldrin have been shown to cause teratogenic and reproductive toxicity in animal test species. Reproductive effects include decreased fertility, increased fetal death, and effects on gestation. Teratogenic effects include cleft palate, webbed foot, and skeletal anomalies. Human chronic effects attributed to aldrin and dieldrin include liver toxicity and central nervous system abnormalities. Both chemicals are acutely toxic. The oral LD₅₀ for aldrin in rats is 39-60 mg/kg (Merck, 1983). The oral LD₅₀ for dieldrin in rats is 46 mg/kg (Merck, 1983). The dermal LD₅₀ for both aldrin and dieldrin is approximately 100 mg/kg.

TOXICITY TO AQUATIC AND TERRESTRIAL WILDLIFE

Aquatic Organisms

Aldrin and dieldrin are both acutely toxic to freshwater species at low concentrations. Tests in fish showed that the two chemicals have similar toxicities, with LC₅₀ values ranging from 1 to 53 µg/liter for different species. Final acute values (i.e., the concentration of material protecting 95 percent of the organisms; USEPA, 1980) for freshwater species were determined to be 2.5 µg/liter of dieldrin and 3.0 µg/liter for aldrin. Saltwater species were also quite sensitive to aldrin and dieldrin. The range of LC₅₀ values was similar to that for freshwater species: 2 to 100 µg/liter for aldrin and 1 to 34 µg/liter for dieldrin. The saltwater Final Acute Values were 1.3 µg/liter for aldrin and 0.71 µg/liter for dieldrin.

Chronic studies have been conducted on the effects of dieldrin on freshwater and saltwater species. For freshwater organisms, chronic values as low as 0.2 µg/liter were obtained. The Final Acute Chronic Ratio was determined to be 8.5, and the calculated Freshwater Final Chronic Value was 0.29 µg/liter. Only one chronic study was done on saltwater species. Therefore, the saltwater Final Chronic Value of 0.084 µg/liter was determined by

dividing the Final Acute Value by the Acute-Chronic Ratio. No chronic studies were identified for aldrin, but because its acute toxicity is comparable to that of dieldrin and because it is readily converted to dieldrin in animals and in the environment, it likely exhibits similar chronic toxicity.

Plants

Limited information was available in the literature reviewed regarding the phytotoxicity of aldrin. This information indicated that the uptake of organochlorine pesticides in plants following chronic exposure is variable, and that uptake is more likely in sandy soils than in soils with a high organic content.

Invertebrates

Earthworms were shown to concentrate aldrin-dieldrin residues up to 15 times the level found in field soil in long-term simulated ecosystem studies, and various insect species showed residue concentration factors of 11.9 to 58.4 times the soil level (ESE, 1989).

Birds

Aldrin has been associated with large scale bird kills in treated areas. Acute oral LD₅₀ values for aldrin in bobwhite quail and pheasants were 6.59 and 16.8 mg/kg of body weight, respectively (Hudson et al., 1984).

Mammals

Both aldrin and dieldrin are acutely toxic with oral LD₅₀ values ranging from 43 to 64 mg/kg in rats (ESE, 1989). Both pesticides have been associated with large scale mammal kills in treated areas and oral LD₅₀ values for dieldrin in mule deer were 75 to 150 mg/kg body weight (Hudson et al., 1984). Both pesticides are associated with increased tumor induction in mice.

This pesticide has been shown to be carcinogenic in rats and mice, and is a teratogenic and reproductive toxicant. Aldrin causes liver toxicity and central nervous system disorders

following chronic exposure, and has been shown to be acutely toxic to a variety of avian species.

REGULATIONS AND RECOMMENDED STANDARDS

Ambient Water Quality Criteria (USEPA, 1986):

Aquatic Life (Freshwater)

Acute Toxicity: Aldrin: 3.0 µg/liter
Dieldrin: 2.5 µg/liter

Chronic Toxicity: Aldrin: No available data
Dieldrin: 0.0019 µg/liter

Aquatic Life (Saltwater)

Acute Toxicity: Aldrin: 1.3 µg/liter
Dieldrin: 0.71 µg/liter

Chronic Toxicity: Aldrin: No available data
Dieldrin: 0.0019 µg/liter

Human Health

Due to the carcinogenicity of both aldrin and dieldrin the ambient water criterion is set at zero. However, estimates of the carcinogenic risks due to ingestion of both contaminated water and contaminated fish and shellfish are:

<u>Risk</u>	<u>Aldrin Concentration</u>	<u>Dieldrin Concentration</u>
10 ⁻⁵	0.74 ng/liter	0.71 ng/liter
10 ⁻⁶	0.074 ng/liter	0.071 ng/liter
10 ⁻⁷	0.0074 ng/liter	0.0071 ng/liter

OSHA PEL 29 CFR 1910.1000 (air)*:

TWA^u = 0.25 mg/m³ (skin designation)

NIOSH REL (air)*:

TWA = 0.15 mg/m³

ACGIH Threshold Limit Value*:

TWA = 0.25 mg/m³ (skin designation)

*Applies to both aldrin and dieldrin

¹Time Weighted Average

DOSE-RESPONSE ASSESSMENT

The human dose-response parameter estimates for carcinogens and noncarcinogens are computed differently by EPA; therefore, these estimates are presented separately below.

Carcinogenic Effects

The Cancer Assessment Group (CAG) of the USEPA has derived an oral cancer potency estimate for aldrin of 1.7×10^1 mg/kg/day (USEPA, 1989). This estimate is based on the geometric mean of three potency slope factors determined for lower tumors in mice (Davis, 1965; Epstein, 1975; and NCI, 1978). The CAG has also derived an inhalation cancer potency estimate of 1.7×10^1 mg/kg/day calculated from the oral data presented above (USEPA, 1989). The oral slope factor for dieldrin, a metabolite of aldrin, was determined to be essentially identical to that of aldrin (USEPA, 1989).

Aldrin Oral Cancer Potency Estimate:

1.7×10^1 (mg/kg/day)⁻¹
(USEPA, 1989)

Aldrin Inhalation Cancer Potency Estimate:

1.7×10^1 (mg/kg/day)⁻¹
(USEPA, 1989)

The inhalation cancer potency estimate was calculated from the oral cancer potency estimate (IRIS, 1989).

Derivation of RSD

A risk-specific dose (RSD) can be calculated for carcinogenic effects based on a predetermined cancer risk level and the cancer potency factor(s). A cancer risk level of

10^{-6} (one chance in one million of contracting cancer) has been assumed. Since the cancer potency factor for dieldrin has been reported to be the same as for aldrin (USEPA, 1989), the derivation of the RSD for aldrin/dieldrin is as follows:

Oral

$$\text{RSD} = \frac{\text{Risk Level}}{\text{Cancer Potency Factor}}$$

$$\text{RSD} = \frac{1 \times 10^{-6}}{17 \text{ (mg/kg/day)}^{-1}}$$

$$\text{RSD} = 5.9 \times 10^{-8} \text{ mg/kg/day}$$

Inhalation

$$\text{RSD} = \frac{\text{Risk Level}}{\text{Cancer Potency Factor}}$$

$$\text{RSD} = \frac{1 \times 10^{-6}}{17 \text{ (mg/kg/day)}^{-1}}$$

$$\text{RSD} = 5.9 \times 10^{-8} \text{ mg/kg/day}$$

Noncarcinogenic Effects

The USEPA has computed chronic oral reference doses (RfD) of 3.0×10^{-5} (mg/kg/day) for aldrin/dieldrin (USEPA, 1989) based on 2-year chronic feeding study with rats, which identified a LOAEL (lowest-observed-adverse-effects-level) of 0.025 mg/kg/day (Fitzhugh et al., 1964). Higher doses produced liver lesions characteristic of chlorinated insecticide poisoning. An uncertainty factor of 1,000 was incorporated to account for uncertainties in extrapolating animal data to humans (10), to account uncertainties in the range of human sensitivities (10), and an additional uncertainty because the RfD is based on a LOAEL rather than a NOAEL (no-observed-adverse-effects-level [10]). An inhalation RfD is not currently available.

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METHYLENE CHLORIDE²

SUMMARY

Methylene chloride (dichloromethane) has been shown to increase the incidence of lung and liver tumors and sarcomas in exposed rats and mice. Methylene chloride yielded positive results in mutagenicity tests utilizing bacterial test systems. In humans, methylene chloride irritates the eyes, mucous membranes, and skin. Exposure to high levels adversely affects the central and peripheral nervous systems and the heart. In experimental animals, methylene chloride is reported to cause kidney and liver damage, convulsions, and paresis (incomplete paralysis).

CAS Number: 75-09-2

Chemical Formula: CH_2Cl_2

IUPAC Name: Dichloromethane

Important Synonyms and Trade Names: Methylene dichloride, methane dichloride

CHEMICAL AND PHYSICAL PROPERTIES

Molecular Weight: 84.93

Boiling Point: 40°C (USEPA, 1979)

Melting Point: -95.1°C

Specific Gravity: 1.3266 at 20°C

Solubility in Water: 13,200-20,000 mg/liter at 25°C (USEPA, 1979); 19,000 mg/liter (Valvani et al., 1980)

Solubility in Organics: Miscible with alcohol and ether

Log Octanol/Water Partition Coefficient: 1.25 (USEPA, 1979)
1.30 (USEPA, 1986a)

² Compiled from: U.S. Environmental Protection Agency, Office of Waste Program Enforcement. September 1985. Chemical, physical and biological properties of compounds present at hazardous waste sites. A Final Report Prepared by Clement Associates, Inc., Arlington, Virginia.

Also: United States Army Medical Bioengineering Research and Development Laboratory (USAMBRDL). 1985. Physical, Chemical, and Toxicological Data Summaries of 62 Compounds Present at Rocky Mountain Arsenal. USAMBRDL. Fort Detrick, Frederick, MD.

Soil/Water Partition Coefficient (K_{ow}):

27.5 (Sabljić, 1984, experimental)
114; 121 (Lyman et al., 1982, Eqn 4-8, $\log K_{ow} = 1.25; 1.30$)
27; 30 (Lyman and Loreti, 1987, $\log K_{ow} = 1.25; 1.30$)
8.8 (USEPA, 1986a)

Bioconcentration Factor:

2.9 - 2.3 (Davis and Dobbs, 1984, Eqn A, $S = 13,200 - 20,000$)
5.25 (Lyman et al., 1982, Eqn 5-2, $\log K_{ow} = 1.25$)
8.60 (Davis and Dobbs, 1984, Eqn C, $\log K_{ow} = 1.25$)
5.81 (Davis and Dobbs, 1984, Eqn B, $\log K_{ow} = 1.25$)
16.4 (Lyman et al., 1982, Eqn 5-2, $\log K_{ow} = 1.9$)
21 (Davis and Dobbs, 1984, Eqn B, $\log K_{ow} = 1.9$)
14.2 (Davis and Dobbs, 1984, Eqn C, $\log K_{ow} = 1.9$)

Vapor Pressure: 362 mm Hg at 20°C (USEPA, 1986a)
436 mm Hg at 25°C (Berkowitz et al., 1978)

Vapor Density: 2.93

Henry's Law Constant:

2.6×10^{-3} atm-m³/mole (calculated)
 2.03×10^{-3} atm-m³/mole (USEPA, 1986a)
 8.53×10^{-2} Dimensionless

TRANSPORT AND FATE

Volatilization to the atmosphere appears to be the major mechanism for removal of methylene chloride from aquatic systems as its primary environmental transport process (USEPA, 1979). The reported vapor pressure for methylene chloride indicates that near surface concentrations would rapidly volatilize to the atmosphere. Concentrations at deeper levels may not be volatilized, but would tend to strongly adhere to soil particles.

Photooxidation in the troposphere appears to be the dominant chemical fate of methylene chloride following its release to the air. Once in the troposphere, the compound is attacked by hydroxyl radicals, resulting in the formation of carbon dioxide, and to a lesser extent, carbon monoxide and phosgene. Phosgene is readily hydrolyzed to HCl and CO₂. About one percent of tropospheric methylene chloride would be expected to reach the stratosphere where it would probably undergo photodissociation resulting from interaction with high energy ultraviolet radiation. Aerial transport of methylene chloride is partly

responsible for its relatively wide environmental distribution. Atmospheric methylene chloride may be returned to the earth in precipitation.

Photolysis, oxidation, and hydrolysis do not appear to be significant environmental fate processes for methylene chloride. A range of experimental and estimated soil-water partition coefficients (K_{oc}) is reported above and indicates that some sorption of methylene chloride to soils/sediments and dissolved organic material will occur. Pavlou (1980) estimates that sorption of volatile organic compounds will range from low to moderate. The combined high water solubility and low organic partitioning of methylene chloride suggest that this compound will exhibit a high degree of environmental mobility. Although methylene chloride is potentially biodegradable, especially by acclimatized microorganisms, biodegradation occurs at a very slow rate.

A range of bioconcentration factors (BCFs) for methylene chloride is also reported above. ASTM (1985) indicates that chemicals with bioconcentration factors (BCF) less than approximately 100 have low potential for causing harm to wildlife and human health via biomagnification of residues up food chains. The magnitude of the concentration factors suggest that appreciable bioconcentration or biomagnification of methylene chloride residues is not likely to occur.

HEALTH EFFECTS

The carcinogenicity of methylene chloride is currently under review by the National Toxicology Program (NTP, 1984; USEPA, 1985). Preliminary results indicate that it produced an increased incidence of lung and liver tumors in mice and mammary tumors in female and male rats. In a chronic inhalation study, male rats exhibited an increased incidence of sarcomas in the ventral neck region (Burek et al., 1984); however the authors suggest that the relevance and toxicological significance of this finding is uncertain in light of available toxicity data. Methylene chloride has been classified according to USEPA's Guidelines for Carcinogenic Risk Assessment, in USEPA's Group B2 (probable human carcinogen), based upon positive results in animal studies and inadequate evidence in humans (USEPA, 1985).

Methylene chloride is reported to be mutagenic in bacterial test systems (IRIS, 1989). It has also produced positive results in the Fischer rat embryo cell transformation test (IRIS, 1989). However, it has been suggested that the observed cell-transforming capability may have been due to impurities in the test material. There is no conclusive evidence that methylene chloride exposure produces teratogenic effects.

In humans, direct contact with methylene chloride produces eye, respiratory tract, and skin irritation (USEPA, 1985). Mild poisonings due to inhalation exposure produce somnolence, lassitude, numbness and tingling of the limbs, anorexia, and lightheadedness, followed by rapid and complete recovery. More severe poisonings generally involve correspondingly greater disturbances of the central and peripheral nervous systems. Methylene chloride also has acute toxic effects on the heart, including the induction of arrhythmia. Fatalities reportedly due to methylene chloride exposure have been attributed to cardiac injury and heart failure. Methylene chloride is metabolized to carbon monoxide in vivo, and levels of carboxyhemoglobin in the blood are elevated following acute exposures. In experimental animals, methylene chloride is reported to cause kidney and liver damage, convulsions, and distal paresis. An oral LD₅₀ value of 2,136 mg/kg, and an inhalation LC₅₀ value of 88,000 mg/m³/30 minutes are reported for the rat.

TOXICITY TO AQUATIC AND TERRESTRIAL WILDLIFE

Aquatic Organisms

Very little information concerning the toxicity of methylene chloride to and wildlife exists (USEPA, 1980). Acute values for the freshwater species Daphnia magna, the fathead minnow, and bluegill are 224,000, 193,000, and 224,000 µg/liter, respectively. Acute values for the saltwater mysid shrimp and sheepshead minnow, are 256,000 and 331,000 µg/liter, respectively. No data concerning chronic toxicity are available. The 96 hour EC₅₀ values for both freshwater and saltwater algae are greater than the highest test concentration, 662,000 µg/liter.

Plants

No information was found in the literature reviewed regarding the toxicity of methylene chloride to plants.

Invertebrates

No information was found in the literature reviewed regarding the toxicity of methylene chloride to invertebrates.

Birds

No information was found in the literature reviewed regarding the toxicity of methylene chloride to birds.

Mammals

No information was found in the literature reviewed regarding the toxicity of methylene chloride to mammals.

REGULATIONS AND RECOMMENDED STANDARDS

Ambient Water Quality Criteria (USEPA, 1986b)

Available data are not adequate for establishing criteria, however, USEPA does report the lowest values known to be toxic in aquatic organisms:

Aquatic Life (Freshwater)

Acute Toxicity: 11,000 µg/liter

Chronic Toxicity: No data are available

Aquatic Life (Saltwater)

Acute Toxicity: 12,000 µg/liter

Chronic Toxicity: 6,400 µg/liter

Human Health

Due to the carcinogenicity of methylene chloride the ambient water criterion is set at zero. However, estimates of the carcinogenic risks associated with lifetime

exposure form ingestion of contaminated water and contaminated aquatic organisms are:

<u>Risk</u>	<u>Concentration</u>
10^{-5}	1.9 $\mu\text{g/liter}$
10^{-6}	0.19 $\mu\text{g/liter}$
10^{-7}	0.019 $\mu\text{g/liter}$

OSHA PEL 29 CFR 1910.1000:

TWA^{1/} = 100 ppm

Ceiling Level = 200 ppm

Peak Concentration = 300 ppm (5 minutes in any 3 hours)

NIOSH REL:

TWA = 75 ppm

ACGIH Threshold Limit Value:

TWA = 175 mg/m^3 (suspected human carcinogen)

^{1/} Time Weighted Average

^{2/} Short-Term Effect Level

DOSE-RESPONSE ASSESSMENT

The human dose-response parameter estimates for carcinogens and noncarcinogens are computed differently by USEPA; therefore, these estimates are presented separately below.

Carcinogenic Effects

The Cancer Assessment Group (CAG) of the USEPA has derived an oral cancer potency estimate for methylene chloride of $7.5 \times 10^{-3} (\text{mg/kg/day})^{-1}$ (USEPA, 1989). This estimate is based on the arithmetic mean of the potency slope factors determined for hepatocellular adenomas and carcinomas in mice derived from the lifetime inhalation exposure studies conducted by the National Toxicology Program (NTP, 1986) and the National Coffee Association (NCA, 1983). The CAG has also derived an inhalation cancer potency estimate of $1.4 \times 10^{-2} (\text{mg/kg/day})^{-1}$ based on the combined incidence of adenomas and carcinomas of the liver or lung from the NTP study (NTP, 1986).

Oral Cancer Potency Estimate: $7.5 \times 10^{-3} \text{ (mg/kg/day)}^{-1}$ (USEPA, 1989)

Inhalation Cancer Potency Estimate: $1.4 \times 10^{-2} \text{ (mg/kg/day)}^{-1}$ (USEPA, 1989)

Derivation of RSD

A risk-specific dose (RSD) can be calculated for carcinogenic effects based on a predetermined cancer risk level and the cancer potency factor(s). A cancer risk level of 10^{-6} (one chance in one million of contracting cancer) has been assumed.

The derivation of the RSD for methylene chloride is as follows:

Oral

$$\text{RSD} = \frac{\text{Risk Level}}{\text{Cancer Potency Factor}}$$

$$\text{RSD} = \frac{1 \times 10^{-6}}{7.5 \times 10^{-3} \text{ (mg/kg/day)}^{-1}}$$

$$\text{RSD} = 1.3 \times 10^{-4} \text{ mg/kg/day}$$

Inhalation

$$\text{RSD} = \frac{\text{Risk Level}}{\text{Cancer Potency Factor}}$$

$$\text{RSD} = \frac{1 \times 10^{-6}}{1.4 \times 10^{-2} \text{ (mg/kg/day)}^{-1}}$$

$$\text{RSD} = 7.1 \times 10^{-5} \text{ mg/kg/day}$$

Noncarcinogenic Effects

The USEPA has computed a chronic oral reference dose (RfD) of $6 \times 10^{-2} \text{ mg/kg/day}$ for methylene chloride (USEPA, 1989) based on a 2-year drinking water study with rats, which identified a NOAEL (no-observed-adverse-effect-level) of 6 mg/kg/day (NCA, 1982).

Higher doses produced histological alterations of the liver. An uncertainty factor of 100 was incorporated to account for uncertainties in extrapolating animal data to humans (10) and to account for sensitive human subgroups (10) (USEPA, 1989). An inhalation RfD is not currently available.

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TRICHLOROETHYLENE³

SUMMARY

Trichloroethylene (TCE) has been shown to induce hepatocellular carcinomas in mice following oral administration, and was mutagenic when tested using several microbial assay systems. Chronic inhalation exposure to high concentrations caused liver, kidney, and neurological damage and dermatological irritation in animals.

CAS Number: 79-01-6

Chemical Formula: C_2HCl_3

IUPAC Name: Trichloroethylene

Important Synonyms and Trade Names: Trichloroethylene, TCE, and ethylene trichloride

CHEMICAL AND PHYSICAL PROPERTIES

Molecular Weight: 131.5

Boiling Point: 87°C

Melting Point: -73°C

Specific Gravity: 1.4642 at 20°C

Solubility in Water: 1,100 mg/liter (Rogers et al., 1980) Table IV0
825 mg/liter (Valvani et al., 1980)

Solubility in Organics: Soluble in alcohol, ether, acetone, and chloroform

Log Octanol/Water Partition Coefficient (K_{ow}):

2.29 (Hansch and Leo, 1979)
2.29 (Rogers et al., 1980)
2.42 (Veith et al., 1983)
2.53 (Tewari et al., 1982)
3.24 (Geyer et al., 1984)
3.3 (Valvani et al., 1980)
3.3 (Davies and Dobbs, 1984)

³ Compiled From: U.S. Environmental Protection Agency, Office of Waste Program Enforcement. September 1985. Chemical, physical, and biological properties of compounds present at hazardous waste sites. A Final Report Prepared by Clement Associates, Inc., Arlington, Virginia.

Also: United States Army Medical Bioengineering Research and Development Laboratory (USAMBRDL). 1985. Physical, Chemical, and Toxicological Data Summaries of 62 Compounds Present at Rocky Mountain Arsenal. USAMBRDL. Fort Detrick, Frederick, MD.

2.38 (USEPA, 1986a)

Soil/Water Partition Coefficient (K_{oc}):

188 (Rogers et al., 1980, Table V, experimental)
420; 1,487 (Lyman et al., 1982, Eqn 4-8, $\log K_{ow} = 2.29$; 3.30)
175; 1,073 (Lyman and Loreti, 1987, $\log K_{ow} = 2.29$; 3.30)

Bioconcentration Factor:

95 (Davies and Dobbs, 1984, Eqn B, $\log K_{ow} = 3$)
17 (Kenage, 1980, Table 3, experimental)
17 (Davies and Dobbs, Table 2, experimental)
31.8 (Lyman et al., 1982, Eqn 5-2, $\log K_{ow} = 2.28$)
32.4 (Lyman et al., 1982, Eqn 5-2, $\log K_{ow} = 2.29$)
40.7 (Lyman et al., 1982, Eqn 5-2, $\log K_{ow} = 2.42$)
189.7 (Lyman et al., 1982, Eqn 5-2, $\log K_{ow} = 3.3$)
14 (Davies and Dobbs, 1984, Eqn A, $S = 825$)
27.5 (Davies and Dobbs, 1984, Eqn C, $\log K_{ow} = 2.57$)
52.8 (Davies and Dobbs, 1984, Eqn B, $\log K_{ow} = 2.57$)
52.9 (Lyman et al., 1982, Eqn 5-2, $\log K_{ow} = 2.57$)

Vapor Pressure: 60 mm Hg at 20°C
57.9 mm Hg at 25°C (USEPA, 1986a)

Vapor Density: 4.53

Henry's Law Constant:

1.3×10^{-2} atm-m/mole (calculated)
 9.1×10^{-3} /mole (USEPA, 1985a)
 3.82×10^{-1} Dimensionless

TRANSPORT AND FATE

Trichloroethylene (TCE) rapidly volatilizes into the atmosphere from surface waters and soil surfaces where it reacts with hydroxyl radicals to produce hydrochloric acid, carbon monoxide, carbon dioxide, and carboxylic acid. The atmospheric lifetime of TCE estimated on the basis of reactions with hydroxyl radicals is 54 hours (USEPA, 1985a). The reported vapor pressure of trichloroethylene indicates that near surface concentrations would have previously volatilized to the atmosphere.

A range of experimental and estimated soil-water partition coefficients (K_{oc}) is reported above and indicates that some sorption of trichloroethylene to soils/sediments and dissolved organic material will occur. Pavlou (1980) estimates that sorption of volatile organic

compounds will range from low to moderate. The combined water solubility and organic partitioning of trichloroethylene suggests that this compound will exhibit some degree of environmental mobility. There is evidence that microorganisms can metabolize TCE; however, it is unclear whether trichloroethylene bound to organic materials can be transformed directly or whether it must be desorbed in order to be degraded.

A range of experimental and estimated bioconcentration factors (BCFs) for trichloroethylene is also reported above. ASTM (1985) indicates that chemicals with bioconcentration factors less than approximately 100 have low potential for causing harm to wildlife and human health via biomagnification of residues up food chains. The magnitude of the concentration factors suggests that appreciable bioconcentration or biomagnification of trichloroethylene residues is not likely to occur.

HEALTH EFFECTS

Trichloroethylene was mutagenic in tests using several microbial assay systems. It was carcinogenic in mice producing hepatocellular carcinomas following oral administration (NCI, 1976; NTP, 1982). Trichloroethylene has been classified according to USEPA's Guidelines for Carcinogenic Risk Assessment in USEPA's Group B2 (probable human carcinogen), based on the finding of liver tumors in orally exposed mice and inadequate evidence in humans (USEPA, 1985a).

Embryo toxicity occurred in rats exposed via inhalation to TCE at 1,800 ppm for 2 weeks prior to mating and during days 1-20 of gestation (USEPA, 1985a). Inhalation for 3 weeks prior to mating and during gestation days 1-18 (rat) and during gestation days 1-21 (rabbit) also resulted in embryo toxicity. TCE has been shown to cause renal toxicity, hepatotoxicity, neurotoxicity, and dermatological reactions in animals following chronic exposure to levels greater than 2,000 mg/m³ for 6 months (USEPA, 1985a). The acute oral LD₅₀ value of trichloroethylene in the rat is 4,920 and 2,402 mg/kg in the mouse.

In humans, chronic exposure is characterized by dizziness, nausea, headache, ataxia, decreased appetite, and sleep disturbances (USEPA, 1985a). Effects of short-term exposure

include mild eye irritation, nausea, vertigo, headache and confusion. Unconsciousness and death may occur following exposure to excessive concentrations (USEPA, 1985a). The Biological Exposure Index (BEI) of trichloroethylene in and exhaled air prior to shift and end of work week is 0.5 ppm.

TOXICITY TO AQUATIC AND TERRESTRIAL WILDLIFE

Aquatic Organisms

Only limited data were available on the toxicity of trichloroethylene to aquatic organisms. The acute toxicity to freshwater species was similar in the three species tested, with LC50 values ranging from 20 to 40 mg/liter (USEPA, 1980). No LC₅₀ values were available for saltwater species (USEPA, 1980). However, 2 mg/liter caused erratic swimming and loss of equilibrium in the grass shrimp. No chronic toxicity tests were reported.

Plants

No information was found in the literature reviewed regarding the toxicity of trichloroethylene to plants.

Invertebrates

No information was found in the literature reviewed regarding the toxicity of trichloroethylene to invertebrates.

Birds

No information was found in the literature reviewed regarding the toxicity of trichloroethylene to birds.

Mammals

No information was found in the literature reviewed regarding the toxicity of trichloroethylene to mammals.

REGULATIONS AND RECOMMENDED STANDARDS

Ambient Water Quality Criteria (USEPA, 1986b):

The available data are not adequate for establishing criteria. However, USEPA does report the lowest values known to be toxic in aquatic organisms.

Aquatic Life (Freshwater)

Acute Toxicity: 45 mg/liter

Chronic Toxicity: 21.9 mg/liter

Aquatic Life (Saltwater)

Acute Toxicity: 2 mg/liter

Chronic Toxicity: No available data

Human Health

Due to the carcinogenicity of trichloroethylene the ambient water criterion is set at zero. Estimates of the carcinogenic risks associated with lifetime exposure from ingestion of contaminated water and contaminated aquatic organisms are:

<u>Risk</u>	<u>Concentration</u>
10^{-5}	27 mg/liter
10^{-6}	2.7 mg/liter
10^{-7}	0.27 mg/liter

National Primary Drinking Water Standard 52 FR 35690 (MCL):

0.005 mg/liter

OSHA PEL 29 CFR 1910.1000 (air):

TWA¹⁷ = 100 ppm

Ceiling Level = 200 ppm/15 min

NIOSH REL (air):

TWA = 250 ppm

ACGIH Threshold Unit Values

TWA = 270 $\mu\text{g}/\text{m}^3$

STEL = 1,080 mg/m^3

Peak concentrations = 300 ppm (5 minutes in any 2 hours)

1/ Time Weighted Average

DOSE-RESPONSE ASSESSMENT

The human dose-response parameter estimates for carcinogens and noncarcinogens are computed differently by USEPA; therefore, these estimates are presented separately below.

Carcinogenic Effects

The carcinogen assessment summary for this substance has been withdrawn from the IRIS data pending further review. A new carcinogen summary is in preparation by the CRAVE work group (USEPA, 1989). Therefore, neither oral nor inhalation cancer potency estimates, nor risk-specific doses can be presented in this toxicity profile. A previously estimated cancer potency estimate (CPF) value of 1.3×10^{-2} was used to quantify carcinogenic risks in this risk assessment.

Noncarcinogenic Effects

Currently, the USEPA has not derived a reference dose (RfD) for trichloroethylene; however, the IRIS database indicates that an oral RfD is pending (USEPA, 1989).

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