EG&G
ROCKY FLATS

Final

Technical Memorandum No. 12

Human Health Risk Assessment Exposure Assessment

Rocky Flats Environmental Restoration Project

APRIL 1995

FINAL

TECHNICAL MEMORANDUM NO. 12

Human Health Risk Assessment
Exposure Assessment

Rocky Flats Environmental Technology Site
Woman Creek Priority Drainage

(Operable Unit Number 5)

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U.S. DEPARTMENT OF ENERGY
Golden, Colorado

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RFI/RI WORK PLAN TECHNICAL MEMORANDUM
APPROVAL SHEET

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
AOC	Area of Concern
Bq	Becquerel
BRA	Baseline Risk Assessment
C	Concentration of a radionuclide at exposure point
CDPHE	Colorado Department of Public Health and Environment
CEARP	Comprehensive Environmental Assessment and Response Program
COC	chemical of concern
CSM	conceptual site model
CT	central tendency
DC	dose coefficient
DOE	U.S. Department of Energy
EATM	Exposure Assessment Technical Memorandum
ED	exposure duration
EF	exposure frequency
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ERA	Ecological Risk Assessment
FFACO	Federal Facility Agreement and Consent Order
H&S	health and safety
HEAST	Health Effects Assessment Summary Table
HHRA	Human Health Risk Assessment
IAG	Interagency Agreement
IHSS	individual hazardous substance site
IR	Intake rate
LHSU	Lower Hydrostratigraphic Unit
OSHA	Occupational Safety and Health Act
OU5	Operable Unit Number 5
PA	Protected Area
PCOC	potential chemical of concern

RBC	risk based concentration
RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFLII	Rocky Flats Local Impacts Initiative
RME	reasonable maximum exposure
SID	South Interceptor Ditch
Sv	Sievert
UHSU	Upper Hydrostratigraphic Unit
VOC	volatile organic compound

EXECUTIVE SUMMARY

This Exposure Assessment Technical Memorandum (EATM) is presented in support of the Human Health Risk Assessment (HHRA) for Operable Unit Number 5 (OU5), which includes the Original Landfill and Filter Backwash Pond (IHSS 115/196), the Ash Pits (IHSS 133.1 to 133.4), the Incinerator (IHSS 133.5), the Concrete Wash Pad (133.6), Ponds C-1 and C-2 (IHSS 142.10 and 142.11), and the Surface Disturbances (IHSS 209, the Surface Disturbance west of IHSS 209, and the Surface Disturbances south of the Ash Pits) located at the Rocky Flats Environmental Technology Site (RFETS). Each of the areas may be the site of past waste disposal activities or where releases occurred.

This technical memorandum identifies potentially complete exposure pathways and human receptors at OU5 and presents quantitative values for exposure parameters and equations for estimating central tendency (CT) and reasonable maximum exposures (RMEs) to be used in the HHRA. This technical memorandum does not quantify chemical intake, which is dependent on the chemical concentration at exposure points.

The following subjects are covered in this technical memorandum:

- Identification of current onsite and offsite land uses and characterization of future land use scenarios as credible or improbable, depending on likelihood of occurrence.
- Identification of potential receptors based on current and future land use scenarios.
- Development of a conceptual site model (CSM), which is a schematic representation that summarizes information regarding chemical sources, chemical release mechanisms, environmental transport media, and human intake routes. The CSM also identifies pathways as potentially complete or incomplete and negligible.
- Identification of quantitative values for exposure parameters and equations to be used in estimating central tendency (CT) and reasonable maximum chemical intake for the potentially complete exposure pathways and receptors at OU5.

Current land use at OU5 includes onsite security surveillance and environmental restoration activities; current offsite land use includes open space, agricultural, residential, gravel mining, office space, and commercial/industrial. Future onsite land use scenarios that could reasonably be expected to occur at RFETS include onsite commercial/industrial, open space, and ecological reserve. Future offsite land use scenarios include open space, agricultural, commercial/industrial, office complex, gravel mining, and residential land use. Future OU5 onsite residential, commercial/industrial, gravel mining, and agricultural land uses are considered to be improbable (unlikely to occur) as is future offsite ecological reserve land use. The future onsite and offsite land use scenarios are consistent with recommendations from the Rocky Flats Future Site Use Working Group.

Potential receptors identified for evaluation in the HHRA include:

- Current onsite worker (security guard)
- Future onsite worker (office and construction)
- Future onsite ecological researcher
- Future onsite open space receptor.

Potential release mechanisms from contaminated soil in OU5, identified in the CSM, include storm water runoff, volatilization, wind suspension, infiltration and percolation to groundwater, direct oral and dermal contact with soil, root uptake from surface soil, and radioactive decay. Transport media include groundwater, surface water, and air. Based on evaluation of information on chemical sources, chemical release and environmental transport mechanisms, exposure points, and human intake routes, OU5 pathways are characterized as either potentially complete and significant, potentially complete and relatively insignificant, or negligible or incomplete. Negligible or incomplete pathways are discussed but are eliminated from further consideration in the quantitative HHRA.

Exposure pathways that result in potentially complete exposures to identified receptors are summarized in Table ES-1. The pathways identified in Table ES-1 will be quantitatively evaluated for each respective receptor and scenario.

Quantitative values for exposure factors to be used for estimating central tendency and reasonable maximum chemical intake are identified for each of the potentially complete exposure pathways and receptors. Exposure factors that have been agreed upon by the Environmental Protection Agency (EPA), the Colorado Department of Public Health and Environment (CDPHE), and the Department of Energy (DOE) are shown in tables in Attachment 1. Exposure factors are reasonable estimates of numerous variables including body weight, daily inhalation volume, daily ingestion rates, body surface area, soil or food matrix effects, and frequency and duration of exposure. Exposure point concentration (determined by chemical analytical results and fate and transport modeling) will be used with these exposure parameters and equations to obtain pathway-specific chemical intakes for use in the HHRA.

TABLE ES-1

RFETS OU5
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED IN THE OU5 HUMAN HEALTH RISK ASSESSMENT

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite worker (security guard)	Current	Inhalation of airborne particulates Ingestion of surface soil Dermal contact with surface soil External irradiation
Onsite office worker	Future	Inhalation of VOCs in indoor air Inhalation of airborne particulates Ingestion of surface soil Dermal contact with surface soil Dermal contact with seep sediments External irradiation
Onsite construction worker	Future	Inhalation of airborne particulates Ingestion of surface and subsurface soil Dermal contact with surface and subsurface soil Dermal contact with seep sediments External irradiation

TABLE ES-1
(Concluded)

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite ecological researcher	Future	Ingestion of surface water Ingestion of sediments Dermal contact with surface water Dermal contact with sediments Inhalation of airborne particulates Ingestion of soil Dermal contact with surface soil External irradiation
Onsite open space receptor	Future	Ingestion of surface water Ingestion of sediments Dermal contact with surface water Dermal contact with sediments Inhalation of airborne particulates Ingestion of soil Dermal contact with surface soil External irradiation

1.0 INTRODUCTION

This Exposure Assessment Technical Memorandum (EATM) is presented as part of the Human Health Risk Assessment (HHRA) for the Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) for the Woman Creek Priority Drainage, Operable Unit Number 5 (OU5), located at the Rocky Flats Environmental Technology Site (RFETS). The Baseline Risk Assessment (BRA) consists of the HHRA and the Ecological Risk Assessment (ERA). This EATM was developed to address the HHRA portion of the BRA for OU5. The HHRA evaluates human health risks for OU5 onsite and offsite receptors under current and future land-use conditions, assuming no remedial action takes place at OU5. This EATM describes present, future, potential, and reasonable use exposure scenarios to be evaluated for OU5 and identifies reasonable maximum intake parameters for estimating contaminant intake via these pathways. The RFI/RI is pursuant to the U.S. Department of Energy (DOE) Environmental Restoration (ER) Program, formerly known as the Comprehensive Environmental Assessment and Response Program (CEARP); a Compliance Agreement between DOE, the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Public Health and Environment (CDPHE), dated July 31, 1986; and the Federal Facility Agreement and Consent Order (FFACO), known as the Interagency Agreement (IAG 1991).

Objectives, scope, and organization of this technical memorandum are presented in the following subsections.

1.1 OBJECTIVES

The objectives of this EATM are to identify:

- Human receptor populations that may be exposed to contaminants released from the site
- Complete exposure pathways by which contaminants are transported from sources to human exposure points

- The route(s) of contaminant intake
- Intake parameters for each potentially contaminated medium, such as soil, water, and air.

This EATM does not quantify contaminant intake. The magnitude of exposure is dependent on the contaminant concentration at the exposure points, which will be estimated based on the analytical results of the Phase I Site Investigation and fate and transport modeling, as appropriate. The exposure assessment focuses on media (soil, water, and air) that potentially contain contaminants related to identified sources, identified exposure pathways, potential receptors, exposure points, and factors for potential human intake of impacted media.

1.2 SCOPE

The scope of this EATM identifies current and future human exposure scenarios for OU5, including identifying exposure pathways and intake routes. Potential scenarios are identified according to the EPA concept of reasonable maximum exposure (RME), defined as the highest exposure that is reasonably expected to occur at a site (EPA 1989a). The term "potential" means "a reasonable chance of occurrence within the context of the reasonable maximum exposure scenario" (EPA 1990). Using this approach, potential exposures are evaluated in Section 4.0 of this technical memorandum using a conceptual site model (CSM). In the CSM, exposure pathways are evaluated by their potential contribution to exposure and are classified as potentially complete and significant; potentially complete and relatively insignificant; or negligible or incomplete. In this EATM, significant pathways are those that involve relatively direct exposure or only moderately reduced concentrations due to contaminant fate and transport. Likewise, insignificant pathways are those that are expected to result in exposure concentrations one or more orders of magnitude lower than significant exposure pathways. In addition, negligible or incomplete pathways are those where fate and transport is expected to reduce contaminant concentrations by several orders of magnitude or more in comparison to significant exposure pathways. Significant and insignificant exposure scenarios will be evaluated quantitatively in the HHRA for OU5.

1.3 MEMORANDUM ORGANIZATION

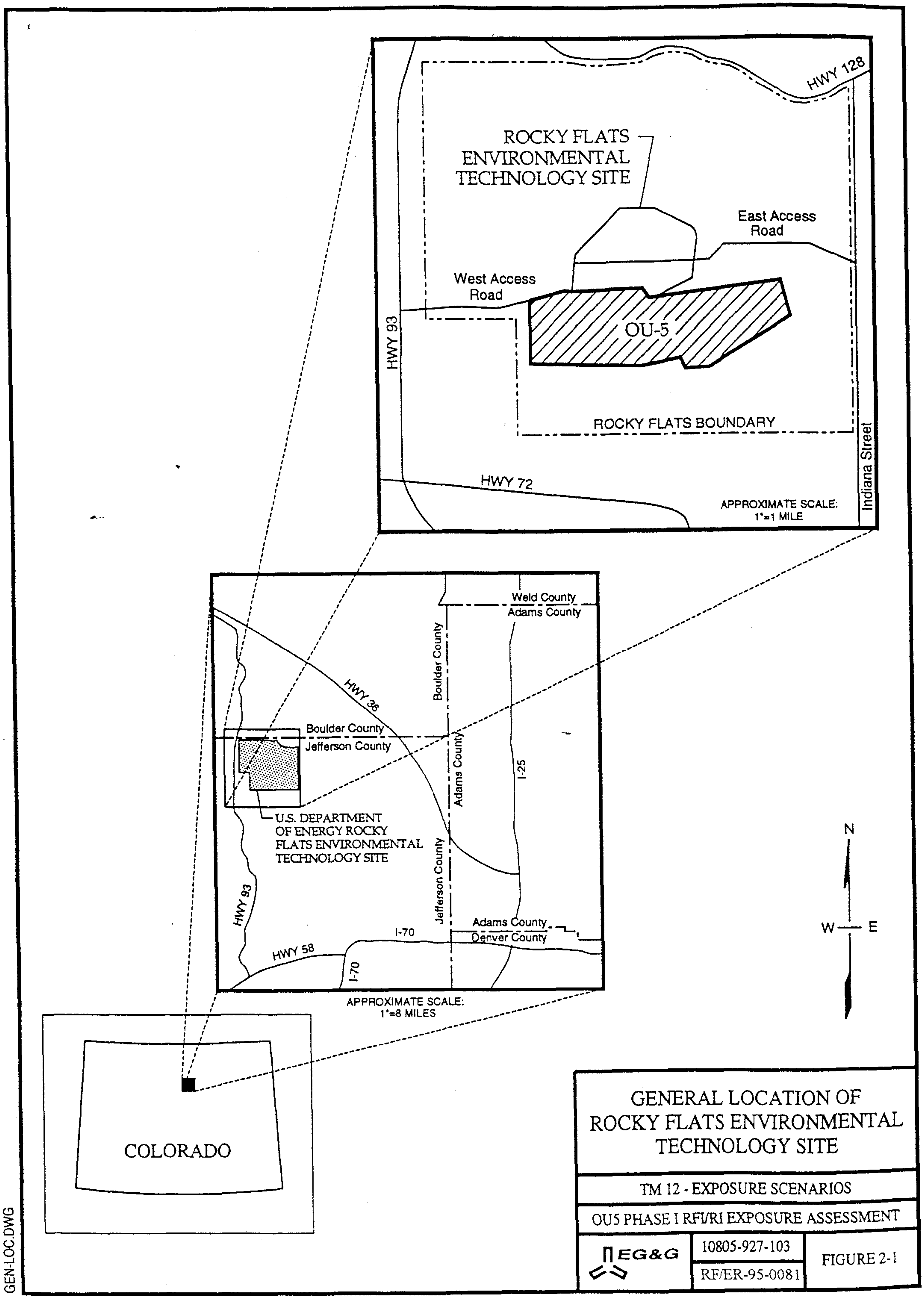
This EATM is organized as follows: Section 2.0, Site Description, cites the location of existing information on site characteristics relevant to assessing human exposures. Section 3.0, Potentially Exposed Receptor Populations, identifies the populations that may be exposed to contaminants originating from identified site-related sources. Land uses and exposure scenarios that are most likely to occur, given the site-specific conditions, are identified for quantitative assessment in the HHRA. Section 4.0, Exposure Pathways, discusses the potential release and transport of contaminants from the site, and identifies exposure pathways to be evaluated in the HHRA using a CSM. Section 5.0, Estimating Contaminant Intakes, describes the methodology used to approximate the intake of contaminants in various media and discusses contaminant intake factors for the calculation of contaminant intake by human receptors. Section 6.0 contains the references cited throughout this document. Attachment 1 contains tables with central tendency (CT) and RME intake factors that will be used for each receptor scenario being evaluated.

2.0 SITE DESCRIPTION

The RFETS is located on approximately 2,653 hectares (6,550 acres) of federally owned land in northern Jefferson County, Colorado, approximately 26 kilometers (16 miles) northwest of Denver (Figure 2-1). The RFETS consists of approximately 162 hectares (400 acres) of Protected Area (PA) or security area surrounded by a buffer zone of approximately 2,489 hectares (6,150 acres). Located primarily in the buffer zone on the southern side of the plant, the OU5 study area consists of approximately 292 hectares (720 acres) (Figure 2-2). Eleven individual hazardous substance sites (IHSSs) have been identified in OU5. They are the Original Landfill and Filter Backwash Pond (IHSSs 115 and 196), the Ash Pits (IHSSs 133.1-133.4), the Incinerator area (IHSS 133.5), the Concrete Wash Pad (IHSS 133.6), Ponds C-1 and C-2 (IHSSs 142.10 and 142.11), and the Surface Disturbances (IHSS 209, the Surface Disturbance west of IHSS 209, and the Surface Disturbance south of the Ash Pits).

Physical site characteristics such as meteorological, geological, and hydrological characteristics must be considered in the evaluation of fate and transport of contaminants to potential receptors. Detailed information on these site characteristics, as well as detailed information on local geography and IHSS histories, is presented in the *Phase I RFI/RI Work Plan Woman Creek Operable Unit No. 5* (EG&G 1992a).

Since this work plan was written, additional information on domestic wells east of the RFETS boundary and along Woman Creek has been identified and is included in this EATM. Although offsite wells located in the drainage of Woman Creek are of interest, it is unlikely that groundwater discharging from OU5 makes its way beyond the C-2 Pond. However, it does appear that surface water in Woman Creek is lost to groundwater east of the C-2 Pond and it is assumed the groundwater then flows offsite. Woman Creek is predominantly flowing east up to the west side of the C-2 Pond and continues to flow along the C-2 Pond diversion toward Indiana Avenue. East of RFETS, Woman Creek discharges into Mower reservoir and Standley Lake. In the area of Standley Lake, 14 wells are registered in the Woman Creek drainage (Figure 2-3). Table 2-1 lists information from completion reports for these wells that are on file at the Colorado State Engineer's Office. Screened depths given for these wells place the completion intervals within the basal Arapahoe to Upper Laramie Formations. The Upper Laramie Formation, in the vicinity of RFETS, is described as predominantly claystones with some thin discontinuous sandstone lenses and an occasional coal seam (DOE 1992). The thin, discontinuous character of these sandstones suggests that a hydraulic connection to the alluvium along Woman Creek is unlikely. Also, there are indications that the offsite wells may be hydraulically connected to Standley Lake, a large source of potential recharge (DOE 1992).



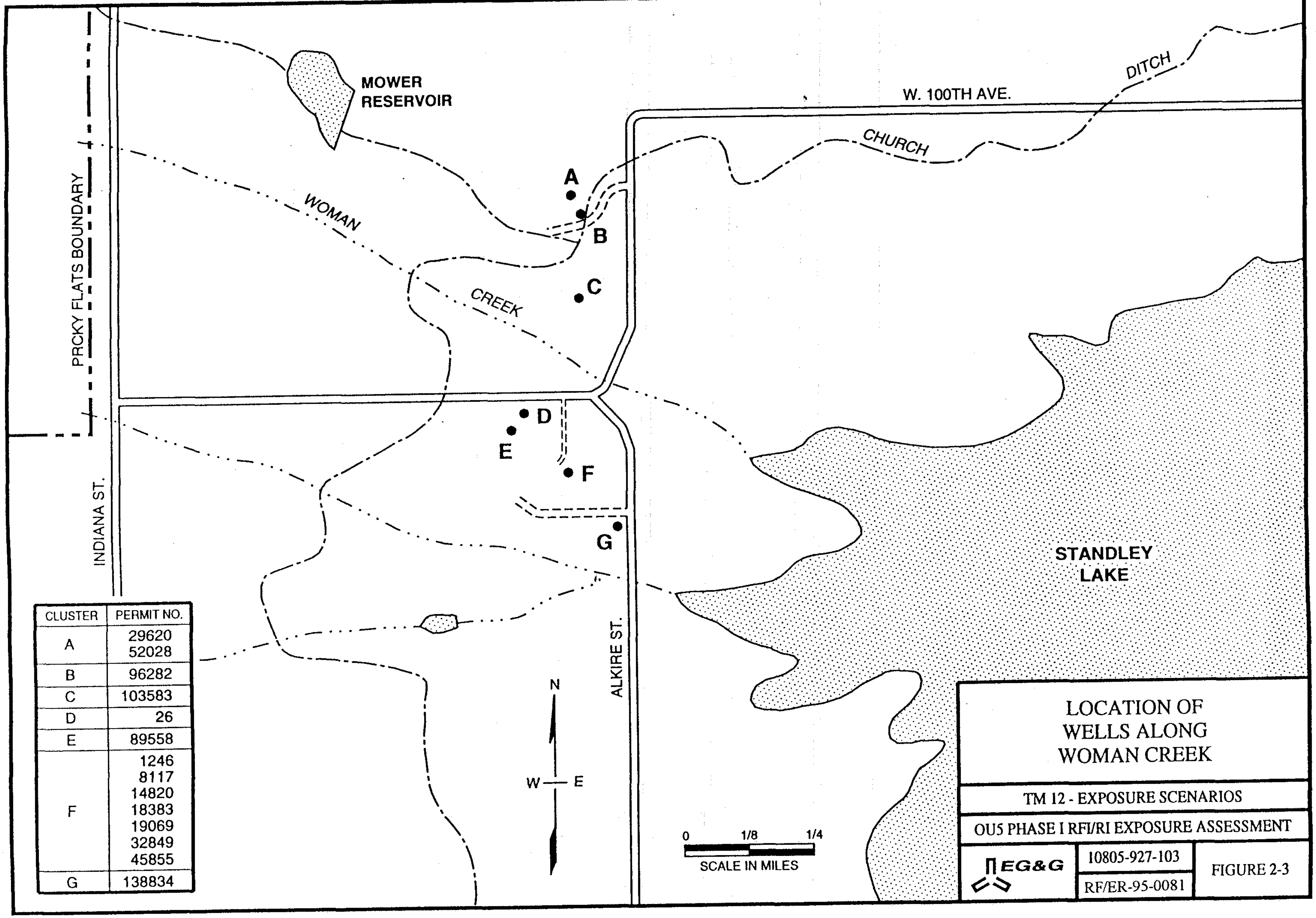
GENERAL LOCATION OF ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

TM 12 - EXPOSURE SCENARIOS

OU5 PHASE I RFI/RI EXPOSURE ASSESSMENT

EG&G | 10805-927-103 | RF/ER-95-0081 | FIGURE 2-1

WC-WELL.DWG



CLUSTER	PERMIT NO.
A	29620 52028
B	96282
C	103583
D	26
E	89558
F	1246 8117 14820 18383 19069 32849 45855
G	138834

LOCATION OF WELLS ALONG WOMAN CREEK

TM 12 - EXPOSURE SCENARIOS

OU5 PHASE I RFI/RI EXPOSURE ASSESSMENT

10805-927-103

RF/ER-95-0081

FIGURE 2-3

TABLE 2-1

WELLS NEAR WOMAN CREEK

Permit No.	Yield* (gpm)	Total Well Depth (ft)	Screened Interval (Feet Below Ground Surface)					
			Top	Bottom	Top	Bottom	Top	Bottom
26	15	125	45	85	105	125	--	--
1246	15	67	37	67	--	--	--	--
8117	12	70	20	70	--	--	--	--
14820	8	200	100	200	--	--	--	--
18383	12	75	50	75	--	--	--	--
19069	6	100	27	36	63	90	--	--
29620	15	112	85	112	--	--	--	--
32849	14	80	23	80	--	--	--	--
45855	15	110	30	110	--	--	--	--
52028	8	122	80	96	--	--	--	--
89558	15	150	30	50	70	90	130	150
96282	14	125	65	90	--	--	--	--
103583	15	125	90	125	--	--	--	--
138834	15	71	20	71	--	--	--	--

* Based on drillers' observations. Does not indicate sustainable well yields.
-- Not available
gpm = gallons per minute

Source: DOE 1992

3.0 POTENTIALLY EXPOSED RECEPTOR POPULATIONS

This section discusses the following topics relevant to potentially exposed receptor populations:

- Current and future land use
- Evaluation of potential human receptors
- Receptor locations and exposure areas

RFETS is located in a rural area of unincorporated Jefferson County, approximately 25 kilometers (km) (16 miles) northwest of Denver and approximately 16 km (10 miles) south of Boulder. The area to the west of RFETS is mountainous, sparsely populated, and primarily government-owned. The area east of RFETS is an arid plain, densely populated in some areas, and privately owned. Most of the development in the plains east of RFETS has occurred since the plant was built, and development is expected to continue in the future.

The most significant commercial and residential development within a 16 km (10-mile) radius of the center of RFETS is located to the southeast, in the cities of Westminster, Arvada, and Wheatridge. The cities of Boulder, to the northwest; Broomfield, Lafayette, and Louisville, to the northeast; and Golden, to the south, are also present within this 16 km (10-mile) radius.

3.1 CURRENT AND FUTURE LAND USE

Table 3-1 is a summary of land use corresponding to the Jefferson County Land Use Inventory. In general, current land use surrounding RFETS includes open space, agricultural, residential, office, gravel mining, and commercial/industrial. Table 3-2 summarizes the current patterns of land use at OU5 and near RFETS; the table also identifies categories for future land use scenarios as improbable (or scenarios that are unlikely to occur) or credible (scenarios that could reasonably occur or are expected to occur). Current and future land use, both offsite and onsite (OU5), is discussed in more detail in the following sections.

3.1.1 Current Offsite Land Use

Land surrounding RFETS is used for open space (recreational), agricultural, residential, gravel mining, office space, and commercial/industrial purposes. Predominant land uses in the area immediately southeast of RFETS include open space, single-family detached dwellings, and horse-boarding operations. The nearest residence is located across Indiana Street at the southeast corner of the RFETS property line. Another nearby residence in the predominant wind direction (southeast) is located about 0.8 miles east of Indiana Street, also near the southeast boundary of RFETS. Small cattle herds (approximately 10 to 60 cattle in each herd) have been observed grazing in fields east and southeast of the site. Industrial facilities to the south include the TOSCO laboratory, Great Western Inorganics Plant, and Frontier Forest Products (DOE 1990).

3.1.2 Future Offsite Land Use

The northeastern Jefferson County area near RFETS has been one of the most active of industrial development in the Denver metropolitan area. The "Northeast Community Profile" (Jefferson County 1989) contains a baseline profile of growth and land use in the area and projects compatible with future development scenarios. As a result of this study, Jefferson County expects that industrial land use will dominate the northeastern portion of the county. Industrial and commercial development of the area is attractive to businesses and developers because of the lower cost and lower taxes associated with locating on undeveloped land in an unincorporated portion of the county. With the increase in industrial development, household and population growth is expected to increase only moderately because of the reduced availability of land for residential development.

Future land use in the area is also the topic of "The North Plains Community Plan" (Jefferson County 1990). The plan is intended to serve as a guide to the county and cities to achieve compatible land use and development decisions, regardless of the jurisdiction in which they are proposed. The plan was developed by representatives of Jefferson County, five cities (Arvada, Broomfield, Golden, Superior, and Westminster), and participants from a variety of interest groups including homeowners, businesses, builders/developers, environmentalists, and special districts. The plan identifies RFETS and the Jefferson County Airport as potential constraints to future residential development in the area and recommends office and light industrial development. The plan further identifies the acquisition of land for open-space uses as a high priority for the area, recommending that large amounts of undeveloped land be provided for this purpose (Jefferson County 1990).

Under the plan, the predominant future land uses to the south and southeast of RFETS will consist of commercial, industrial, and office space. Directly to the east, the zoning and usage are expected to remain open-space and agricultural or vacant. The areas closest to RFETS are planned for gravel mining, industrial, commercial, or office space, with the areas farther from RFETS designated for residential development. Use of offsite areas as ecological reserves is considered improbable because of the disturbed nature of most parcels (cultivation or grazing) and the proximity to anticipated commercial/industrial or mixed commercial/residential uses.

To the north of RFETS, in Boulder County, the predominant land uses include open-space, park land, and industrial development. Two areas adjacent to RFETS have been annexed by the cities of Broomfield and Superior. These two cities have participated in the Jefferson County cooperative planning process and are planning business, industrial, and mixed land uses for the area (Jefferson County 1990; City of Broomfield 1990; Boulder County 1991).

This information indicates that land adjacent to RFETS is lightly populated, with the current use being primarily open space and agricultural. These uses, as well as gravel mining and commercial/industrial development, are likely to continue in the future. Residential development in the area northeast of the site may be impeded by the growth of business and industry that is expected to occur. However, land use in the area immediately east and southeast of the site is likely to continue to be open space, residential, agricultural, and commercial/industrial.

Future offsite residential and agricultural land uses are credible scenarios; however, these land uses will not be a subject of the OU5 HHRA. These scenarios will not be addressed in the individual OU5 HHRA in accordance with the agreement between DOE, EPA, and CDPHE.

3.1.3 Current Onsite Land Use

Current activities within OU5 consist of environmental investigations, monitoring, cleanup, and routine security surveillance. RFETS operations and maintenance activities are not conducted within OU5.

Elsewhere in the RFETS buffer zone, inside the western edge of the RFETS property, gravel mining operations have been conducted since the early 1900s. Western Aggregates, Inc. has operated a mine and processing plant there since 1990 (EG&G 1995a).

3.1.4 Future Onsite Land Use

RFETS is performing environmental restoration activities and planning for future decontamination and decommissioning, waste management, transition, and economic development.

The Rocky Flats Local Impacts Initiative (RFLII) is working with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the RFETS (RFLII 1992). Private industry could occupy existing buildings and use existing equipment after decontamination is complete. The RFLII is working to achieve this objective.

Large portions of the RFETS buffer zone surrounding the developed portions of the plant, including portions encompassed by OU5, could remain open space. When the U.S. Atomic Energy Commission (AEC) acquired the undeveloped land surrounding the production area, it established plans to preserve the land as open space (AEC 1972). Because open space is located adjacent to the RFETS property, it is possible that the buffer zone and OU5 area will be preserved as open space or as an ecological reserve.

Ecological surveys of the buffer zone, performed in compliance with the Threatened and Endangered Species Act, have identified the presence of several listed species at RFETS. Additional surveys are ongoing and may be performed in the future to identify and provide for the protection of any threatened and endangered species at the site, if necessary. Because the RFETS buffer zone, including OU5, has not been impacted by commercial development for many years, thus allowing progressive re-establishment of quality native habitats, the future use of this area as an ecological reserve is reasonable. This usage is consistent with DOE policy and plans (DOE 1992) and with the Jefferson County Planning Department's recommendations for the provision of large amounts of undeveloped land in the area (Jefferson County 1990). The Jefferson County Board of Commissioners has also adopted a resolution stating its support of maintaining, in perpetuity, the undeveloped buffer zone of open space around RFETS for environmental, safety, and health reasons (Jefferson County Board of Commissioners 1994).

Extensive development of the RFETS buffer zone is unlikely due to the potential for conversion of the buffer zone into an ecological reserve and the steep topography in parts of the drainages. The steep slopes associated with some of the drainages in the area, particularly the Walnut Creek drainage, are not conducive to extensive residential or commercial development. Due to the potential hazards associated with unstable slopes, landslides, and slope failures, Jefferson County emphasizes that development should only occur on slopes with grades of 30 percent or less (Jefferson County 1990). Approximately 25 percent of the land in the eastern portion of RFETS is at or approaching this grade.

Gravel mining was also evaluated as a future land use scenario, given the presence of current mining operations in the western portions of the RFETS buffer zone. However, at OU5, minable sand and gravel deposits that are greater than 20 feet in thickness exist along the northern edge of IHSS 115, 133.5, and 209, and the surface disturbance south of IHSS 133. However, the areal extent of the gravel deposits near these IHSSs is limited because they are on the edge of the Rocky Flats Alluvium pediment surface. Based on the limited volume of minable material available, these OU5 locations would not be amenable to mining (EG&G 1995b).

In summary, future onsite residential and agricultural development is inconsistent with land use plans for the area. Future land use would more likely involve industrial complexes at the developed portions of the RFETS and open space uses in the buffer zone. The portions of OU5 with suitable topography will also be evaluated further for construction of and subsequent use of an office complex. Thus, OU5 onsite use of office facilities and designation of the buffer zone as an ecological reserve and/or open space were considered to be credible future land use scenarios and are consistent with the recommendations of the Rocky Flats Future Site Use Working Group.

3.2 EVALUATION OF POTENTIAL HUMAN RECEPTORS

Current and future human population groups on and near the site are potential candidates for evaluation (i.e., receptors) based on their likelihood of exposure to site-related chemicals of concern (COCs). EPA guidance does not require an exhaustive assessment of every potential receptor and exposure scenario (EPA 1992a). Rather, the highest potential exposures that are reasonably expected to occur should be evaluated, along with an assessment of any associated uncertainty (EPA 1989a). However, all potential receptors will be identified and evaluated to ensure that important exposure pathways or receptors are not overlooked.

For the purpose of a qualitative evaluation of potential receptors, future land-use scenarios have been categorized as either improbable (unlikely to occur because of serious constraints) or credible (expected to occur given the right set of circumstances). Table 3-2 presents the probability classification for the seven major future land use categories (residential, office complex, commercial/industrial, open space, ecological reserve, agricultural, and gravel mining). Specific discussion of these potential land uses is provided in Section 3.1

Potential human receptors on and near the OU5 study area are current and future residents, current and future onsite workers, future onsite ecological researchers, and future open space receptors.

Current and future residents include OU5 onsite and offsite residential receptors. The current and future offsite residential receptor receives exposures of contaminants from the entire plant site and not just OU5. Because OU5 contributes only a portion of the exposures to this receptor, the current and future offsite resident will not be evaluated further in the OU5 HHRA. As discussed in section 3.1.4 future onsite residential development is inconsistent with land use plans, therefore a future onsite residential receptor will not be evaluated further in the OU5 HHRA.

Current and future OU5 onsite workers include current onsite security personnel, future office complex workers, and future construction workers. It is assumed that the current onsite security workers will continue to provide security services to the OU5 study area and that a majority of the security work will continue to be performed from patrol vehicles. Because some OU5 locations may be suitable for an office complex, a future office worker and a future construction worker to build the complex will be evaluated in the OU5 HHRA.

Because it is credible that the OU5 study area may be preserved as an ecological reserve or as open space, a future onsite ecological researcher and a future onsite open space receptor will be evaluated in the OU5 HHRA.

3.3 RECEPTOR LOCATIONS AND EXPOSURE AREAS

For HHRAs conducted at RFETS, onsite exposures will be evaluated in separate Areas of Concern (AOCs) identified in the operable unit. AOCs are defined as one or several contaminant source areas that are in close proximity and can be evaluated as a unit in the HHRA. Six contaminant source areas were identified in OU5 and they are: the IHSS 115/196 Source Area, the IHSS 133 Source Area, the Surface Disturbance south of IHSS 133 Source

Area, the South Interceptor Ditch (SID) and Pond C-2 Source Area, the Surface Disturbance west of IHSS 209 Source Area, and the Woman Creek and Pond C-1 Source Area (DOE 1994).

Of the six source areas identified in OU5, the IHSS 115/196 area and the IHSS 133 area are generally physically separated and are treated individually as AOCs (DOE 1994). The SID and Pond C-2 source area and the Woman Creek and Pond C-1 source area are interrelated and are treated together as one AOC (DOE 1994). The Surface Disturbance south of IHSS 133 source area did not exceed the CDPHE risk-based conservative screen criteria and, therefore, is not considered an AOC (DOE 1994). The Surface Disturbance west of IHSS 209 source area slightly exceeded the CDPHE conservative screen criteria due to one sample of Pu-239/240. The remaining samples are significantly less than the risk-based concentrations (RBC). Because the screening criteria were only slightly exceeded in a single sample for one potential chemical of concern (PCOC), this source area is not identified as an AOC (DOE 1994). Both the Surface Disturbance south of IHSS 133 source area and the Surface Disturbance west of IHSS 209 source area will be discussed in the OU5 HHRA uncertainty analysis (which will also address potential dermal exposure).

In summary, the OU5 AOCs are shown on Figure 3-1 and are identified as:

- AOC No. 1 is identical to the IHSS 115/196 Source Area
- AOC No. 2 is identical to the IHSS 133 Source Area
- AOC No. 3 contains the SID and Pond C-2 Source Area and the Woman Creek and Pond C-1 Source Area.

Grids are typically placed over the AOCs to define the areas in which a potential receptor can reasonably be expected to come in contact with COCs. Default grid sizes are 4 hectares (10 acres) for a residential receptor, 12 hectares (30 acres) for an industrial or office worker, and 20 hectares (50 acres) for an ecological researcher. However, due to the relatively small size of the three OU5 AOCs, only 10-acre grids will be placed over each AOC for all applicable receptors.

Risk calculations will be performed for the appropriate receptors using the grid in each AOC that presents the highest exposure, and also using AOC-wide concentrations for each COC.

Human populations on and near OU5 were evaluated to assess their likelihood of exposure to site-related COCs. The receptor populations selected for evaluation are those most likely to be exposed and potentially to have the greatest degree of exposure to site-related contaminants.

Receptor populations selected for quantitative evaluation in the HHRA at RFETS are current and future onsite workers, future onsite ecological researchers and future open space receptors. These receptors are summarized in Table 3-3. Using chemical sampling data and fate and transport modeling, as appropriate, the exposure point concentrations will be used to quantitatively evaluate contaminant intakes for receptors. Depending on the finding of the nature and extent investigation, exposures from localized contaminated areas may be evaluated. Table 3-4 identifies current and future receptors and potentially complete pathways as associated with specific AOCs.

3.3.1 Current and Future Onsite Workers

Currently, RFETS workers who spend the greatest amount of time in OU5 are plant security personnel. The security guards conduct routine patrols within OU5. The Health and Safety (H&S) of OU5 onsite workers is presently monitored under a comprehensive H&S program at RFETS. H&S activities at RFETS are directed by Support Operations and supported by several divisions including Radiological Operations, Occupational Safety, Health and Safety Area Engineering, Industrial Hygiene, Radiological Engineering, and Occupational Health (EG&G 1990). For ER work at RFETS, EG&G and DOE have adopted the Federal Occupational Safety and Health Administration's (OSHA's) standards for hazardous-waste site workers (EG&G

1990). EG&G has superseded some of the OSHA standards with more stringent policies established by EG&G, DOE, or other governmental agencies (EG&G 1990).

At RFETS, H&S plans are written for everyday activities and for specific projects. All subcontractors to EG&G must prepare their own site/project-specific H&S plans, and they must require and enforce standards that are at least as stringent as EG&G's requirements (EG&G 1990). Several programs exist at RFETS to support the H&S plans, including:

- Radiation protection
- Emergency response
- Occupational safety
- Vehicular and pedestrian safety
- Fire protection
- Contractor safety (EG&G 1992b).

The written programs contain the requirements and procedures to ensure a work environment that is free from exposure to chemical, physical, and biological hazards (EG&G 1992b). Additionally, responsibility for all aspects of compliance with the programs and plans is established, and an audit program is in place to evaluate whether compliance is in effect. RFETS personnel are trained in personal hygiene and safety, use of protective clothing, and emergency response procedures. The H&S of current workers at RFETS is thoroughly monitored with required baseline, annual, and exit physical examinations. The exposure of these workers to COCs is controlled and limited by monitoring to acceptable levels and is ensured by reporting requirements.

A future OU5 onsite worker, not protected by a similar H&S program will also be quantitatively evaluated in the HHRA. This worker is assumed to be unprotected and untrained in H&S matters. Based on the future development plans for OU5, the future onsite workers are assumed to be an office worker and a construction worker. The setting for the office worker is likely to have extensive paved areas and well-maintained landscaping. The future onsite construction worker is assumed to have direct contact with surface and subsurface soil during excavation activities associated with the construction of future commercial buildings onsite.

The future OU5 onsite construction worker and office worker are assumed to be exposed in AOC 1 and 2, but not in AOC 3 (refer to Table 3-4). It is assumed that no activities for these receptors will occur in the drainage.

3.3.2 Future Onsite Ecological Researcher and Open Space Receptor

The future use of the OU5 onsite area at RFETS will most likely involve open-space and ecological reserve scenarios. The receptors in an open-space scenario would include recreational users and a research biologist/ecologist conducting area studies. Field work for the ecological researcher may involve kneeling or lying on bare ground or vegetation, and contacting site soils, sediments, and surface water. The open space receptor would also spend time at the site and come in contact with the site's soils, sediments, and surface water. The future ecological researcher and open space receptor will be exposed to various media in all three AOCs, (refer to Table 3-4).

TABLE 3-1

RFETS OU5
CURRENT SURROUNDING LAND USE IN JEFFERSON COUNTY

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
22009	-	-	-
44001	Vacant	A-2	Vacant
44002	-	-	-
44003	Vacant	I-1	Industrial
44004	Vacant	A-2	Vacant
44005	-	-	-
44006	Vacant	I-3	Industrial
44007	Vacant	A-2	Vacant
45001	-	-	-
45002	Walnut Creek Unit 1	P-D	Single Family - Detached
45002	Walnut Creek Unit 1	P-D	Retail
45003	Vacant	A-2	Vacant
45004	Single Family - Detached	A-2	Single Family - Detached
45005	Single Family - Detached	A-2	Vacant
45006	Water	A-2	Water
45007	Single Family - Detached	A-2	Single Family - Detached
45007	SF-D	A-2	Farm/Ranching
46005	Vacant	A-2	Single Family - Detached

TABLE 3-1
(Continued)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
46006	Triple C Quarter Horses	A-2	Retail
46007	Horse Barn-Boarding & Breeding	A-2	Retail
46008	Single Family - Detached	A-1	Single Family - Detached
46009	Single Family - Detached	SR-2	Single Family - Detached
46011	Mountain View Tech Center	P-D	Industrial
46012	Jefcope	P-D	Industrial
46017	Water	A-2	Water
46019	Single Family - Detached	A-2	Single Family - Detached
47036	Vacant	SR-2	Single Family - Detached
47040	-	-	-
71001	Rocky Flats	A-2	Industrial
72001	Vacant	I-2	Industrial
72002	Vacant	A-2	Vacant
72003	Single Family - Detached	A-2	Single Family - Detached
72004	Vacant	I-2	Vacant
72004	Vacant	I-2	Industrial
72005	Tosco Flg 1	I-2	Industrial
72006	Rocky Flats Ind Park Flg 2	I-2	Industrial
72007	Rocky Flats Ind District Flg 1	I-2	Industrial

TABLE 3-1
(Continued)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
72008	Water Tank Ralston Val Stn 2	I-2	Utilities
72009	Vacant - Rocky Flats	A-2	Industrial
72010	Vacant	I-2	Industrial
72011	Northwest Industrial	I-2	Industrial
72012	Vacant	A-2	Vacant
72013	-	-	-
73001	Vacant	A-2	Vacant
73005	Wheat Ridge Gardens	A-2	Vacant
73019	Vacant	A-1	Vacant
73020	Single Family - Detached	SR-2	Single Family - Detached
73021	Vacant	RC	Office/Retail
73022	Westminster Gardens	A-2	Single Family - Detached
99001	Great Western Aggregate Quarry	I-1	Industrial
99005	Sawmill Operation	I-2	Industrial
99006	Great Western Aggregates	I-2	Industrial
99007	Vacant	I-2	Industrial
99008	Colorado Brick Comp Clay Mine	M-C	Mining
99009	Vacant	I-2	Industrial
100001	Rock Creek Ind Park Vacant	P-D	Industrial
100002	Vacant	I-1	Industrial

TABLE 3-1
(Concluded)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
100003	Rocky Flats - Vacant	I-1	Industrial
100004	Rocky Flats - Clay Extraction	M-C	Industrial
100005	Rocky Flats - Vacant	I-2	Industrial
100006	Electric Substation	M-C	Utilities
100006	Gravel Mine	M-C	Industrial
101001	Vacant	A-2	Vacant
101002	Vacant	M-C	Industrial
101003	Vacant	I-2	Industrial
101004	Mine and Water	I-2	Industrial
101005	Northwest Industrial	I-2	Industrial
101006	Vacant	M-C	Industrial
101007	Sanitary Landfill and Gravel	P-DA	Industrial
101008	Rocky Flats Lake	M-C	Water

1 Zoning Abbreviations are:

A-1	Agricultural 1
A-2	Agricultural 2
I-1	Industrial 1
I-2	Industrial 2
I-3	Industrial 3
P-D	Planned Development
SR-2	Suburban Residential 2
RC	Restricted Commercial
P-DA	Planned Development Amended.

Source: Jefferson County

TABLE 3-2

SUMMARY OF CURRENT AND FUTURE LAND USES[a,b]

Land Use Category	Current		Future	
	Offsite	Onsite (OU5)	Offsite	Onsite (OU5)
Residential	Yes	No	Credible	Improbable
Office Complex	Yes	No	Credible	Credible
Commercial/Industrial	Yes	No	Credible	Improbable[c]
Open Space	Yes	No	Credible	Credible[d]
Ecological Reserve	No	No	Improbable	Credible[d]
Agricultural	Yes	No	Credible	Improbable
Gravel Mining	Yes	No	Credible	Improbable[c]

[a] Credible is used to indicate scenarios that may reasonably occur.
[b] Improbable is used to indicate scenarios that are unlikely to occur.
[c] Expected in the currently developed area of the plant site but not in the OU5 area.
[d] Expected in the RFETS buffer zone including the OU5 area.

TABLE 3-3

RFETS OU5
POTENTIALLY EXPOSED RECEPTORS TO BE QUANTITATIVELY EVALUATED

Current Scenario	Future Scenario
• Onsite worker (security guard)	• Onsite worker (office and construction) • Onsite ecological researcher • Open space receptor

TABLE 3-4

RFETS OU5 RECEPTORS AND PATHWAYS

Potentially Exposed Receptor	**Potentially Complete Exposure Pathways by AOC**		
	IHSS 115/196 Source Area (AOC 1)	**IHSS 133 Source Area (AOC 2)**	**SID, C-2, Woman Creek, C-1 Source Area (AOC 3)**
Current			
Onsite worker (security guard)	Dermal contact with surface soil. Inhalation of airborne particulates. Ingestion of surface soil. External irradiation.	Dermal contact with surface soil. Inhalation of airborne particulates. Ingestion of surface soil. External irradiation.	No exposure.
Future			
Onsite construction worker	Dermal contact with surface and subsurface soil. Dermal contact with seep sediments Inhalation of airborne particulates. Ingestion of surface and subsurface soil. External irradiation.	Dermal contact with surface and subsurface soil. Dermal contact with seep sediments Inhalation of airborne particulates. Ingestion of surface and subsurface soil. External irradiation.	No exposure.
Onsite office worker	Dermal contact with surface soil. Dermal contact with seep sediments. Inhalation of VOCs in indoor air. Inhalation of airborne particulates. Ingestion of surface soil. External irradiation.	Dermal contact with surface soil. Dermal contact with seep sediments. Inhalation of VOCs in indoor air. Inhalation of airborne particulates. Ingestion of surface soil. External irradiation.	No exposure.

TABLE 3-4
(Concluded)

Potentially Exposed Receptor	Potentially Complete Exposure Pathways by AOC		
	IHSS 115/196 Source Area (AOC 1)	IHSS 133 Source Area (AOC 2)	SID, C-2, Woman Creek, C-1 Source Area (AOC 3)
Onsite ecological researcher	Dermal contact with surface soil. Dermal contact with seep sediments. Inhalation of airborne particulates. Ingestion of soil. Ingestion of seep sediments. External irradiation.	Dermal contact with surface soil. Dermal contact with seep sediments. Inhalation of airborne particulates. Ingestion of soil. Ingestion of seep sediments. External irradiation.	Dermal contact with surface water. Dermal contact with sediments. Ingestion of surface water. Ingestion of sediments.
Onsite open space receptor	Dermal contact with surface soil. Dermal contact with seep sediments. Inhalation of airborne particulates. Ingestion of soil. Ingestion of seep sediments. External irradiation.	Dermal contact with surface soil. Dermal contact with seep sediments. Inhalation of airborne particulates. Ingestion of soil. Ingestion of seep sediments. External irradiation.	Dermal contact with surface water. Dermal contact with sediments. Ingestion of surface water. Ingestion of sediments.

4.0 EXPOSURE PATHWAYS

This section discusses the potential release and transport of chemicals from OU5 and identifies exposure pathways by which the receptor populations identified in Section 3.0 may potentially be exposed to site chemicals.

An exposure pathway describes a specific environmental pathway by which an individual can be exposed to contaminants present at or originating from a site. An exposure pathway includes five necessary elements:

- A source of chemicals
- A mechanism of chemical release
- An environmental transport medium
- An exposure point
- A human intake route.

Each one of these five elements must be present for an exposure pathway to be complete. An incomplete pathway means that no human exposure can occur. Only potentially complete and relevant pathways will be addressed in the human health risk assessment for OU5. An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms, and identified receptors for that exposure pathway.

The following sections describe potential chemical release sources, potential receptors, respective exposure points, human uptake mechanisms, and the OU5 CSM.

4.1 CHEMICAL RELEASE SOURCES AND TRANSPORT MEDIA

The potential site sources at OU5 are the three AOCs as described in Section 3.3. Characterization of data from OU5 is provided in DOE 1994, Section 2. Environmental media that may transport contaminants of concern from OU5 to exposure points are described in the CSM described in Section 4.5.

4.2 POTENTIALLY EXPOSED RECEPTOR POPULATIONS

Potentially exposed receptor populations selected for quantitative assessment in the baseline HHRA were characterized in Section 3.0. The following list identifies the receptors selected for quantitative evaluation.

- Current onsite security worker will be assessed for impacts from AOCs 1 and 2.
- Future onsite construction worker will be assessed for impacts from AOCs 1 and 2.
- Future onsite office worker will be assessed for impacts from AOCs 1 and 2.
- Future onsite ecological researcher will be assessed for impacts from AOCs 1, 2, and 3.
- Future onsite open space receptor will be assessed for impacts from AOCs 1, 2, and 3.

4.3 EXPOSURE POINTS

An exposure point is a specific location where human receptors can come in contact with site-related chemicals. Exposure points are selected so that the RME will be quantitatively evaluated. Evaluation of receptor risks at these exposure points will bound the risks for receptors at other exposure points not selected for quantitative evaluation. The exposure points are presented in Table 4-1.

4.4 HUMAN UPTAKE MECHANISMS

A human uptake mechanism is the route by which a chemical is internally absorbed by the receptor. There are four basic human uptake mechanisms:

- Dermal absorption
- Inhalation
- Ingestion
- External irradiation if radionuclides are present.

Exposure pathways by which these mechanisms may occur include inhalation of volatile organic compounds (VOCs) and airborne particulates, soil ingestion, surface water and groundwater ingestion, and dermal contact with soil or surface water.

Dermal absorption of low-solubility metals from contact with soil is generally not considered a significant uptake route. Dermal contact with soil will only be assessed quantitatively if sampling results from the OU5 Phase I investigation and from the Addendum to the Field Sampling Plan, Technical Memorandum 15, demonstrate the presence of organic COCs in surface soil samples.

Because metals of low solubility in water tend to be bound to soil particles or sediments, dermal uptake of particulate-bound metals in surface water is judged to be a negligible exposure pathway. However, the soluble fraction of COCs, including metals, in surface water will be quantitatively evaluated. For radionuclides, EPA guidance states that "dermal uptake is generally not an important route of uptake for radionuclides, which have small dermal permeability constants" (EPA 1989a).

4.5 CONCEPTUAL SITE MODEL

Information concerning waste sources, waste constituent release and transport mechanisms, and locations of potentially exposed receptors is used in this section to develop a conceptual understanding of the site in terms of potential human exposure pathways. Figure 4-1 shows a CSM of potential human exposure pathways for OU5.

The CSM is a schematic representation of the contaminant sources, contaminant release mechanisms, environmental transport media, potential human intake routes, and potential human receptors. The purpose of the CSM is to:

- Provide a framework for problem definition
- Identify exposure pathways that may result in human health risks
- Aid in identifying data gaps
- Aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

Contaminant release mechanisms, environmental transport media, and potential human intake routes to the contaminated site soil were identified for each potentially exposed receptor and are discussed in Section 4.5.2.

In the CSM, potentially complete and significant exposure pathways are designated by an "S." Potentially complete and insignificant exposure pathways are designated by an "I." Both potentially complete and relatively significant exposure pathways and relatively insignificant exposure pathways will be quantitatively addressed in the risk assessment. Quantitatively addressing potentially complete and relatively insignificant exposure pathways will provide for risk estimates that do not underestimate actual risks. Negligible or incomplete exposure pathways are designated by an "N" and are not addressed in the risk assessment. In the following subsections and in the CSM, potentially complete dermal exposure pathways are designated as insignificant and will only be assessed quantitatively if results from the Phase I site investigation demonstrate the presence of organic and inorganic compounds that were determined to be COCs, as discussed in Section 4.4.

4.5.1 Site-Wide Negligible or Incomplete Exposure Pathways

The CSM indicates that the following four OU5 exposure pathways are negligible or incomplete for all receptors. These incomplete pathways will not be quantitatively addressed in the HHRA.

- Ingestion of fish caught from Woman Creek, and ingestion of livestock watered by this creek are negligible exposure pathways for all receptors. Woman Creek is an intermittent creek. High-flow periods for this creek generally occur from March to June. The amount of flow varies significantly from no-flow in dry years to approximately four times the predicted annual flow (Advanced Sciences, Inc. 1990). Potential affects of Woman Creek on offsite downstream areas, (such as Standley Lake and Mower Reservoir), will not be addressed in the OU5 HHRA.

Due to its intermittent nature, the creek does not support significant numbers of fish. The only fish observed have been minnows. However, it is possible for a few of the limited number of fish that reside in onsite ponds to migrate from these ponds along Woman Creek to Standley Reservoir during high-flow periods (Wright Water Engineers, Inc. 1991; Woodward-Clyde Consultants 1992). Because of the creek's intermittent nature, subsistence fishing is unlikely, and therefore, ingestion of fish is a negligible exposure pathway.

Current and future offsite residential receptors may have potentially complete pathways for beef ingestion. However, offsite residential receptors are potentially exposed to the cumulative effects of chemicals released from the entire plant site, not just OU5. Therefore, in accordance with the agreement between DOE, EPA, and CDPHE the offsite residential receptors will be addressed in the OU3 (offsite areas) HHRA.

The current and future onsite workers are unlikely to raise cattle or catch fish onsite because they are expected to work the entire time while onsite. Therefore, this pathway is considered negligible for these receptors. Ingestion of animals or fish in the future scenario by the ecological researcher is an incomplete pathway because it is unlikely that the researcher will ingest animal or fish specimens collected for research.

Inhalation of chemicals that have volatilized from site soils or groundwater to outdoor air are considered negligible pathways for all receptors. Volatile chemicals in surface soils, if once present, have already volatilized in the outdoors. Very few VOCs were detected in groundwater and those that were detected were at concentrations that were very low. Volatiles are not expected to be significant and are diluted to negligible concentrations in the outdoors.

4.5.2 Potentially Complete Exposure Pathways

Exposure pathways that result in potential exposure to identified receptors are discussed in the following sections and summarized in Table 4-2.

4.5.2.1 <u>Current Onsite Worker</u>

The CSM for the current onsite worker indicates that the following release mechanisms are the potential chemical release mechanisms from contaminated site soils to the environment:

- Storm water runoff
- Volatilization
- Wind suspension
- Infiltration and percolation
- Direct contact
- Radioactive decay.

Of these release mechanisms, only wind suspension, direct contact, and external irradiation result in associated potential exposure routes for the current onsite worker. If released via storm water runoff, COCs may be transported to surface water and/or sediments. Surface water is present onsite in Woman Creek and in surface water ponds, which are all located in the RFETS buffer zone. Incidental ingestion of, and dermal contact with surface water and suspended sediments are incomplete exposure pathways for current onsite workers (security guards). Security patrols consist of vehicular travel along roads that permit visual inspection of the area. The tops of the slopes afford the best vantage point, however, surface water is located at the bottom of slopes.

Semivolatile organic and inorganic COCs bound to soil, that are released via wind as particulate matter, represent potential inhalation, oral, or dermal exposure pathways. Current onsite workers may be directly exposed to airborne particulate matter via inhalation. Contact with directly contaminated soil or soil that has been contaminated through the deposition of airborne particulates will be evaluated. This pathway is accounted for by the direct contact release mechanism in Figure 4-1.

The pathway of exposure to surface water that is discharged from upper hydrostratigraphic unit (UHSU) groundwater is incomplete because the current onsite worker is expected to patrol along access roads and is not expected to come into contact with surface water at the Woman Creek drainage. Drinking water for onsite workers is supplied by a municipal water supply that does not tap water-bearing units at RFETS. This situation is expected to continue into the future.

Direct contact with soils represents potentially complete ingestion and dermal contact exposure pathways for current workers at the site. External irradiation from decay of radioactive materials in contaminated site surface soils is also a potentially complete exposure pathway due to the potential existence of contaminants in surficial soils. Exposure to radioactive materials via inhalation, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor. Currently, no offices or other permanent structures are located on OU5. Thus, the inhalation of VOCs indoors is an incomplete exposure pathway.

In summary, potentially complete human exposure pathways for the current onsite worker are:

- Inhalation of airborne particulates
- Ingestion of surface soil
- Dermal contact with surface soil
- External irradiation.

4.5.2.2 Future Onsite Worker

The CSM for the future onsite worker, office worker, and construction worker indicates that the following release mechanisms are the potential chemical release mechanisms from contaminated site soils to the environment:

- Storm water runoff
- Volatilization
- Wind suspension
- Infiltration and percolation
- Direct contact
- Radioactive decay.

Of these release mechanisms, all except storm water runoff result in associated potential exposure routes for the future onsite office worker. For the future onsite construction worker, wind suspension, direct contact, and radioactive decay result in associated potential exposures.

If released via storm water runoff, COCs may be transported to surface water and/or sediments. Surface water is present in OU5 onsite in Woman Creek and in surface water ponds. Incidental ingestion of and dermal contact with surface water and suspended sediments are incomplete exposure pathways for all types of future OU5 onsite workers because their work does not involve contact with surface water.

COCs that volatilize from groundwater and/or site soils and are released to indoor air represent a potentially complete inhalation pathway for the future onsite office worker. Although VOCs have not been detected in outdoor field measurements, it is possible for VOCs to accumulate indoors even though they may be dispersed and significantly diluted outdoors.

Semivolatile organic and inorganic COCs bound to soil, that are released via wind as particulate matter, represent potential inhalation, oral, or dermal exposure pathways. The future onsite workers may be directly exposed to airborne particulate matter via inhalation. Potential oral and dermal exposures will be evaluated via the direct contact release mechanism (Figure 4-1). Ingestion of contaminated vegetables is an incomplete pathway because gardening is not expected in an occupational setting.

The pathway of exposure to surface water that is discharged from UHSU groundwater is incomplete because the onsite workers are expected to remain in the work area and are not expected to come into contact with surface water at the Woman Creek drainage.

Direct contact with soils represents potentially complete ingestion, dermal contact, and inhalation exposure pathways for the future OU5 onsite construction worker. Seeps can be found on OU5 and therefore provide a potentially complete dermal exposure pathway for the future OU5 onsite construction and office worker. Direct contact with surface soil represents potentially complete ingestion, dermal, and inhalation exposure pathways for the future OU5 onsite office worker. External irradiation from decay of radioactive materials in contaminated OU5 surface soils is also a potentially complete exposure pathway. Exposure to radioactive materials via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for these receptors.

In summary, potentially complete human exposure pathways for the future OU5 onsite office worker and construction worker are:

- Inhalation of VOCs in indoor air (office worker only)
- Inhalation of airborne particulates
- Ingestion of soil
- Dermal contact with soil
- Dermal contact with seep sediments
- External irradiation.

4.5.2.3 <u>Future Onsite Ecological Researcher</u>

The CSM for the future onsite ecological researcher indicates that the following release mechanisms are the potential chemical release mechanisms from contaminated site soils to the environment:

- Storm water runoff
- Volatilization
- Wind suspension
- Infiltration and percolation
- Direct contact
- Radioactive decay.

Except for volatilization, all of these release mechanisms have associated exposure routes that are potentially complete for the future OU5 onsite ecological researcher.

If released via storm water runoff or transported via groundwater, COCs may be released to surface water and/or sediments. Incidental ingestion of surface water and sediments is a potentially complete exposure pathway for the ecological researcher who may be wading in Woman Creek. Suspended particulates in surface water resulting from the disturbance of sediment may be ingested and will be accounted for in the surface water ingestion exposure pathway. Dermal contact with surface water is a potentially complete exposure pathway. Dermal contact with sediments is also a potentially complete pathway for this receptor. Soluble chemicals in sediments may be released to surface water and dermally absorbed, and will be accounted for in the dermal contact with surface water exposure pathway.

COCs that volatilize from site soils or groundwater may be released to indoor air and outdoor air. Inhalation of VOCs in outdoor air is considered a negligible pathway for all receptors. Volatile chemicals in surface soils, if once present, will have already volatilized in the outdoors. Very few VOCs were detected in groundwater and those that were detected were at concentrations that were very low. Volatiles are not expected to be significant and are diluted to negligible concentrations in the outdoors. Inhalation of indoor air is also an incomplete exposure pathway because the researcher will spend his time outdoors in the buffer zone while onsite.

COCs that are bound to soils become particulate matter as they are mobilized via wind and represent potential inhalation, oral, and dermal exposure pathways. Future OU5 onsite ecological researchers may be directly exposed to airborne particulate matter via inhalation, the ingestion of contaminated soil, or dermal absorption of contaminants in soil. These pathways will be quantitatively evaluated as described previously for on-site workers. Direct contact with surface soils and sediment represents potentially complete oral and dermal absorption exposure pathways for future ecological researchers. Ingestion of contaminated plants is an incomplete pathway because it is unlikely that the ecological researcher will ingest plant specimens collected for research.

External irradiation from decay of radioactive materials in contaminated site surface soil is also a potentially complete exposure pathway. Exposure to radioactive chemicals via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor.

In summary, potentially complete human exposure pathways for the future OU5 onsite ecological researcher are:

- Ingestion of surface water
- Ingestion of sediments
- Dermal contact with surface water
- Dermal contact with sediments
- Inhalation of airborne particulates
- Ingestion of soil
- Dermal contact with soil
- External irradiation.

4.5.2.4 Future Onsite Open Space Receptor

The CSM for the future OU5 onsite open space receptor indicates that the following release mechanisms are the potential chemical release mechanisms from contaminated site soils to the environment:

- Storm water runoff
- Volatilization
- Wind suspension
- Infiltration and percolation
- Direct contact
- Radioactive decay.

Of these primary release mechanisms, all except volatilization provide potentially complete exposure routes to the future onsite open space receptor.

COCs that are discharged from groundwater to surface water or that are released from site soils to surface water via storm water runoff may be transported to surface water and/or sediments in Woman Creek. Incidental ingestion of surface water and sediments is a potentially complete exposure pathway for the future OU5 onsite open space receptor who may be wading in Woman Creek. Suspended particulates in surface water resulting from the disturbance of sediment may be ingested and will be accounted for in the surface water ingestion exposure pathway. Dermal contact with surface water in the future scenario is a potentially complete exposure pathway. Dermal contact with sediments is also a potentially complete pathway for this receptor. Soluble contaminants in sediments may be released to surface water and dermally absorbed, and will be accounted for in the dermal contact with surface water exposure pathway.

COCs that volatilize from site soils or groundwater may be released to indoor air and outdoor air. Inhalation of VOCs in outdoor air is considered a negligible pathway for all receptors. Volatile chemicals in surface soils, if once present, will have already volatilized in the outdoors. Very few VOCs were detected in groundwater and those that were detected were at concentrations that were very low. Volatiles are not expected to be significant and are diluted to negligible concentrations in the outdoors. Inhalation of indoor air is also an incomplete exposure pathway because the receptor will spend his time outdoors in the open space area.

Semivolatile organic and inorganic COCs that are released via wind as particulate matter represent potential inhalation, oral and dermal exposure pathways. Future onsite open space receptors may be directly exposed to airborne particulate matter via inhalation, the ingestion of contaminated soil, or dermal absorption of contaminants in soil. Direct contact with surface soils and sediment represents potentially complete oral and dermal absorption exposure pathways. Ingestion of contaminated plants is an incomplete pathway because it is unlikely an open space recreational receptor will ingest plants located in an open space.

External irradiation exposures to future OU5 onsite open space receptors resulting from decay of radioactive materials in contaminated site surface soil is also a potentially complete exposure pathway. Exposure to radioactive chemicals via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor.

In summary, potentially complete human exposure pathways for the future onsite open space receptor are:

- Ingestion of surface water
- Ingestion of sediments
- Dermal contact with surface water
- Dermal contact with sediments
- Inhalation of airborne particulates
- Ingestion of soil
- Dermal contact with soil
- External irradiation.

TABLE 4-1

EXPOSURE POINTS BY RECEPTOR AND LOCATION

Scenario	Receptor	Location
Current	Occupational	Onsite, within the OU5 study area.
Future	Occupational	Onsite, within the OU5 study area.
Future	Ecological Researcher	Onsite, within the OU5 study area.
Future	Open Space Receptor	Onsite, within the OU5 study area.

TABLE 4-2

RFETS OU5
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED IN THE OU5 HUMAN HEALTH RISK ASSESSMENT

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite worker (security guard)	Current	Inhalation of airborne particulates Ingestion of surface soil Dermal contact with surface soil External irradiation
Onsite office worker	Future	Inhalation of VOCs in indoor air Inhalation of airborne particulates Ingestion of surface soil Dermal contact with surface soil Dermal contact with seep sediments External irradiation
Onsite construction worker	Future	Inhalation of airborne particulates Ingestion of surface and subsurface soil Dermal contact with surface and subsurface soil Dermal contact with seep sediments External irradiation

TABLE 4-2
(Concluded)

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite ecological researcher	Future	Ingestion of surface water Ingestion of sediments Dermal contact with surface water Dermal contact with sediments Inhalation of airborne particulates Ingestion of soil Dermal contact with surface soil External irradiation
Onsite open space receptor	Future	Ingestion of surface water Ingestion of sediments Dermal contact with surface water Dermal contact with sediments Inhalation of airborne particulates Ingestion of soil Dermal contact with surface soil External irradiation

5.0 ESTIMATING CONTAMINANT INTAKES

This section presents general methodology for estimating contaminant intakes for each of the receptors and exposure pathways identified in the previous sections. Intakes of site-specific contaminants are not discussed in this memorandum because such intakes are dependent on pending site characterization COC data and fate and transport modeling, as appropriate. The fate and transport models to be used in the OU5 BRA are presented in Technical Memorandum 13, Model Descriptions.

Using the exposure point concentrations of COCs in soils, surface water, and air, it is possible to estimate the potential human intake of those chemicals via each exposure pathway. Intakes are expressed in terms of milligram (mg) chemical ingested, inhaled or dermally absorbed per kilogram of body weight per day (mg/kg-day). Intakes are calculated following guidance in *Risk Assessment Guidance for Superfund* (EPA 1989a), the *Exposure Factors Handbook* (EPA 1989b), other EPA guidance documents as appropriate, and professional judgment regarding likely site-specific exposure conditions. Intakes are estimated using reasonable estimates of body weight, inhalation volume, ingestion rates, soil or food matrix effects, and frequency and duration of exposure.

Intakes are estimated for RME and CT conditions as recommended by EPA (EPA 1992c). The RME is estimated by selecting values for exposure variables so that the combination of all variables results in the value for the maximum exposure that can reasonably be expected to occur at the site. CT values are used to characterize a typical case and are estimated by selecting mean exposure variables.

The general equation for calculating intake in terms of mg/kg-day is:

$$\text{Intake} = \frac{\text{chemical concentration} \times \text{contact rate} \times \text{exposure frequency} \times \text{exposure duration}}{\text{body weight} \times \text{averaging time}}$$

with corresponding units of:

$$\text{mg/kg-day} = \frac{\text{mg/volume} \times \text{volume/day} \times \text{day/year} \times \text{year}}{\text{kg} \times \text{day}}$$

The variable "averaging time" is expressed in days to calculate daily intake. For noncarcinogens, intakes are calculated by averaging over the period of exposure to yield an average daily intake. For carcinogens, intakes are calculated by averaging the total cumulative dose over a lifetime, yielding "lifetime average daily intake." Different averaging times are used for carcinogens and noncarcinogens because it is thought that their effects occur by different mechanisms. The approach for carcinogens is based on the current scientific opinion that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime. Therefore, regardless of exposure duration, the intake of a carcinogen is averaged over a 70-year lifetime (EPA 1989a). Intake of noncarcinogens is averaged over the period of exposure because the average concentration of a noncarcinogen is compared with the threshold dose for an effect that would be expected to occur during the period of exposure.

Omitting contaminant concentrations from the intake equation yields an "intake factor" that is constant for each exposure pathway and receptor. The intake factor can be multiplied by the concentration of each contaminant to obtain the pathway-specific intake of that contaminant. Intake factors are calculated separately for each potentially exposed receptor and exposure pathway identified in Section 4.5. Contact rates, such as dermal contact, caloric intake, and inhalation (but not soil ingestion) are approximately proportional to body weight. It is acknowledged that body weight is not exactly proportional to surface area and that age-specific body weight/inhalation rates differ by factors of two or less. However, these differences are assumed to be negligible when compared to the other uncertainties associated with risk assessment.

5.1 INTAKE FACTOR ASSUMPTIONS

Several exposure assumptions, such as exposure duration, body weight, and averaging times, have general application in all intake estimations, regardless of pathway. These general assumptions, as well as pathway-specific assumptions, are detailed in Attachment 1. The term "occupational exposures" includes exposures to the current and future onsite worker and to the future ecological researcher. The following sections outline the assumptions used for exposure to radionuclides.

5.1.1 Internal Exposure to Radionuclides

Internal exposure to radionuclides identified as COCs will be evaluated in two ways. First, the dose equivalent based on intake of radionuclides via ingestion or inhalation will be calculated and compared to radiation protection standards. The second method for evaluation of internal radionuclide exposure will be conducted by calculating the intake of radionuclides and multiplying that intake by EPA-derived carcinogenic slope factors for each radionuclide of concern (EPA 1989a). The result of this calculation will be the unitless carcinogenic risk associated with ingestion or inhalation of a given radionuclide of concern.

Calculation of intake for radionuclides is conducted in a similar manner as for nonradioactive COCs. Intake of radionuclides by either ingestion or inhalation is a function of radionuclide activity, contact rate (or the amount of contaminated medium contacted per unit time or event), and exposure frequency and duration. The only difference between calculating intake for radionuclides and nonradioactive substances is that the averaging time and body weight are excluded as divisors from the intake equation for radionuclides. The intake of radionuclides through inhalation or ingestion can be estimated using the following general equation:

$$\text{Intake} = C \times IR \times EF \times ED$$

Where:

Intake	=	Internal radionuclide intake via inhalation or (picocuries or pCi);
C	=	Concentration of a radionuclide at the exposure point (pCi/m^3, pCi/l, or pCi/kg)
IR	=	Intake rate [(breathing rate (m^3/day), drinking rate (l/day), or ingestion rate (kg/day)] and
EF, ED	=	Exposure frequency and duration [(i.e., how often and how long exposure occurs) (days/year x years)].

The resulting calculation is an estimate of the radionuclide intake, expressed in units of activity (e.g., pCi) (EPA 1989a). This value is then multiplied by either a dose coefficient or a carcinogenic slope factor to estimate equivalent dose or carcinogenic risk, respectively. The dose coefficient (DC - expressed in units of Sieverts ((Sv) per pCi)) is used to estimate the equivalent dose (Sv), which can then be compared to a radiation protection standard. The cancer slope factor for radionuclides of concern are multiplied by the estimated radionuclide intake (either inhaled or ingested) to estimate risk (EPA 1989a).

5.1.2 External Irradiation

Carcinogenic risks from exposure to external irradiation from radionuclide contaminated materials are determined using external source slope factors found in Health Effects Assessment Summary Tables (HEAST) (EPA, 1992b). Slope factors for each radionuclide of concern correlate best estimate risks of radiation induced carcinomas with the activity concentration and time of exposure having units of risk/year per Becquerel/gram (gm) pCi/gm soil (source material). Average *radionuclide activity concentrations* (Bq/gm or pCi/gm) will be determined by direct measurement or model estimation as appropriate. The risk is estimated by multiplying the slope factor for each radionuclide of concern by radionuclide activity concentrations and the correct cumulative time of exposure. One method of determining the correct cumulative time of exposure is to employ an exposure factor which adjusts a 24 hour/day 365 day/year potential exposure to more reasonable exposure times on a case by case basis. The exposure factor is analogous to an intake factor and is calculated by:

$$\text{Exposure factor} = \frac{\text{Exposure time} \times \text{exposure frequency} \times \text{exposure duration}}{\text{baseline exposure time} \times \text{baseline exposure frequency}}$$

Dividing of RME exposure times and exposure frequencies by the baseline values of 24 hours per day and 365 days per year accommodates exposure scenarios that are not continuous.

The total dose of radiation experienced by a receptor on OU5 is composed of both an external (groundshine) and internal (ingestion and inhalation) dose component. According to the *Risk Assessment Guidance for Superfund* (EPA 1989a), the dose equivalents for external and internal exposures are considered to be additive. Consequently, radionuclide dose equivalents will be summed for all pathways of exposure for each receptor evaluated in the BRA.

5.2 INTAKE FACTOR CALCULATIONS

The assumptions in Section 5.1 and values will be used to calculate intake factors for each exposure pathway and receptor. Parameters to be used for calculations of intake factors are shown in Attachment 1. Exposure point concentrations will be used with these parameters to obtain pathway-specific intakes.

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ATTACHMENT 1

EXPOSURE FACTORS FOR HUMAN HEALTH RISK ASSESSMENT

TABLE 1. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

		POTENTIALLY EXPOSED RECEPTORS						
FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		**Current Off-Site Resident**	**Current On-Site Industrial Worker**	**Future On-Site Office Worker**	**Future On-Site Construction Worker**	**Future On-Site Ecological Worker**	**Future On-Site Resident**	**Future Off-Site Resident**
SOIL/DUST INGESTION								
Ingestion Rate-Child (mg/day)	RME☞ CT☞	**200**[1,3] 100[2,4]	NA NA	NA NA	NA NA	NA NA	**200**[3] 100[4]	**200**[3] 100[4]
Ingestion Rate-Adult (mg/day)		**100**[1,3] 50[2,4]	**50**[5] 10[6]	**50**[5] 5[7]	**480**[8] 95[9]	**106**[10] 33[10]	**100**[3] 50[4]	**100**[3] 50[4]
Fraction Ingested from Contaminated Source-Child		1.0[11] 0.82[11]	NA NA	NA NA	NA NA	NA NA	1.0[11] 0.82[11]	1.0[11] 0.82[11]
Fraction Ingested from Contaminated Source-Adult		1.0[11] 0.64[11]	1.0[12] 0.9[12]	1.0[12] 0.9[12]	1.0[12] 0.9[12]	1.0[12] 0.9[12]	1.0[11] 0.64[11]	1.0[11] 0.64[11]
Matrix Effect in GI Tract (Absorption Factor)		CS[13] CS[13]	CS CS	CS CS	CS CS	CS CS	CS CS	CS CS
Exposure Frequency (days/yr)		**350**[5] 234[14]	**250**[5] 219[14]	**250**[5] 219[14]	30[15] 30[15]	65[15] 65[15]	**350**[5] 234[14]	**350**[5] 234[14]
Exposure Duration-Child/Adult (years)		**6/24**[5] 2/7[16]	**25**[5] 4[17]	**25**[5] 4[17]	1[15] 1[15]	2.5[15] 2.5[15]	**6/24**[5] 2/7[16]	**6/24**[5] 2/7[16]

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	POTENTIALLY EXPOSED RECEPTORS						
	Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
Body Weight-Child/Adult (kg)[5]	**15/70** 15/70	**70** 70	**70** 70	**70** 70	**70** 70	**15/70** 15/70	**15/70** 15/70
Averaging Time-Child/Adult: Noncarcinogenic (days) [18]	2190/8760 730/2555	9125 1460	9125 1460	365 365	915 915	2190/876 0 730/2555	2190/8760 730/2555
Averaging Time: Carcinogen (days)[19]	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(CS) Chemical-specific exposure parameter determined from quantitative analysis and toxicology literature.

(1) Top entry is based on high-end (HE) exposure used to characterize the RME risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set at central tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on CT used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure" when used in combination with selected high-end values). Average risks are derived using professional judgement to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) EPA RAGS, HHEM, Standard Default Exposure Factors (1991). A defensible alternative HE value for the child is 110 mg/day, the approximate 95th %ile using Zr tracer study of Calabrese and others, 1989 (Md =16 mg/day, 95% CI = 8-24 mg/day, n = 128, American Industrial Health Council, 1994). An alternative HE assumption for the adult is 55 mg/day (0.5 x child rate).

(4) Preliminary CT default values (EPA, 1993). A defensible alternative CT value of the child is 16 mg/day based on Calabrese and Stanek (1992); also estimated by AIHC (1994) using the dataset of Calabrese and others (1989). An alternative CT assumption for the adult is 8 mg/day based on EPA (1991) assumption of 0.5 x child rate (16 mg/day) and on Calabrese and others (1990) estimated at 0.1-10 mg/day by American Industrial Health Council (1994).

(5) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a.

(6) Average of CT soil ingestion rates of 15 mg/day (outdoor industrial worker) and 5 mg/day (indoor industrial worker) based on inferences drawn from Finley and Paustenbach, 1994.

(7) One-half of industrial workers based on inferences drawn from Finley and Paustenbach, 1994; soil ingestion rates for workers indoors (e.g., office workers) are one-half the average of workers both indoors and outdoors (e.g., industrial workers).

(8) Hawley, 1985, and EPA Exposure Factors Handbook, 1989a. A more defensible HE default is 205 mg/day based on adjusting Hawley's soil adherence value from 3.5 mg/cm^2 to the correct upper bound of 1.5 mg/cm^2 (EPA, 1992a) (480 x 1.5/3.5).

(9) Estimated using HE ingestion rate ratio of construction worker to industrial worker (480/50 = 9.6; CT = 9.6 x 10 mg/day), but a more defensible CT default is 40 (see Note 8).

(10) Based on RME and CT exposure assessment work at Rocky Mountain Arsenal. (Integrated Endangerment Assessment/Risk Characterization) Rocky Mountain Arsenal, August 1993.

(11) The RME is set to 1.0. The CT is based on average time spent at home (0.64 adult; 0.82 child) (American Industrial Health Council, 1994); EPA RAGS, HHEM Pt. A (1989b), recognizes the need for a soil "fraction ingested" (FI) from a contaminated source to reflect "population activity patterns."

(12) As in Note 11 based on average weekly time spent at work (0.9) using a base of 40 hours per week.

(13) In the absence of a CS value, consult methods to estimate maximum oral bioavailability (absorption in the gastrointestinal tract) such as reported by EPA (1994) for lead in soil and by Finley and Paustenbach (1994) for TCDD in soil. Assuming chemical toxicity values are based on absorption from drinking water, absorption adjustments are indicated because toxic chemicals only partially desorb from soil particles (EPA RAGS, HHEM Pt. A, 1989b - Appendix A).

(14) Preliminary CT default value (EPA, 1993).

(15) Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(16) Preliminary CT default values, adding to 9 years total exposure duration (EPA, 1993). A current alternative value for total CT exposure duration is EPA's Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(17) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(18) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(19) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 2. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		POTENTIALLY EXPOSED RECEPTORS						
		Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
SOIL/DUST INHALATION								
Inhalation Rate (m^3/hr)	RME☞ CT☞	**0.83**[1,3] 0.63[2,4]	**0.83**[3] 0.83[3]	**0.83**[3] 0.63[5]	**1.4**[6] 1.25[6]	**1.4**[6] 0.83[3]	**0.83**[3] 0.63[4]	**0.83**[3] 0.63[4]
Respirable Fraction (PM_{10})[7]		0.36 0.36	0.36 0.36	0.36 0.36	0.36 0.36	0.36 0.36	0.36 0.36	0.36 0.36
Respiratory Deposition Factor (unitless)[8]		0.85 0.85	0.85 0.85	0.85 0.85	0.85 0.85	0.85 0.85	0.85 0.85	0.85 0.85
Exposure Time (hr/day)		**24**[3] 15[9]	**8**[3] 7.2[10]	**8**[3] 7.2[10]	**8**[3] 7.2[10]	**8**[3] 7.2[10]	**24**[3] 15[9]	**24**[3] 15[9]
Exposure Frequency (days/yr)		**350**[3] 234[11]	**250**[3] 219[11]	**250**[3] 219[11]	30[6] 30[6]	65[6] 65[6]	**350**[3] 234[11]	**350**[3] 234[11]
Exposure Duration (years)		**30**[3] 9[12]	**25**[3] 4[13]	**25**[3] 4[13]	1[6] 1[6]	2.5[6] 2.5[6]	**30**[3] 9[12]	**30**[3] 9[12]
Body Weight (kg)[3]		**70** 70	**70** 70	**70** 70	**70** 70	**70** 70	**70** 70	**70** 70

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	POTENTIALLY EXPOSED RECEPTORS						
	Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
Averaging Time: Noncarcinogen (days)[14]	10950 3285	9125 1460	9125 1460	365 365	915 915	10950 3285	10950 3285
Averaging Time-Carcinogen (days)[15]	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the RME risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set at central tendency (CT) values in order to characterize the HE risks to a very small proportion of an exposed population.

(2) Bottom entry is based on CT used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure" when used in combination with selected high-end values). Average risks are derived using professional judgment to set all exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) E{A RAGS, HHEM, Standard Default Exposure Factors 1991a.

(4) CT residential inhalation rate (adult) based on EPA RAGS, HHEM Part B, 1991b. Note that the CT rate for the child-81% of adult rate based on 6-year-old and adult males at moderate activity (EPA Exposure Factors Handbook, 1989a) cannot result in a greater inhalation intake for the child, assuming EPA standard default values for exposure duration and body weight (adult=0.63 m3/hr x 24 yr/70 kg = 0.22 m^3/hr-kg/yr; child = 0.63 m3/hr x 0.81 x 6 yr/15 kg = 0.20 m^3/hr-kg/yr.

(5) CT worker inhalation rate of 0.63 m^3/hr (adult indoors) based on EPA Exposure Factors Handbook (1989a).

(6) Outdoor inhalation rate from EPA Exposure Factors Handbook (1989a) and the CT from Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(7) Five-year (1988-1992) mean annual ratio of PM_{10} soil or dust particles to total suspended particulates (TSP) as reported in 1992 RFP Site Environmental Report; EPA Exposure Factors Handbook (1989a) recognizes the need for a "respirable fraction of particulates" (RF) to indicate the total respirable fraction assumed deposited in the lung (100% of PM_{10}).

(8) Based on Exposure Assessment work done at Rocky Mountain Arsenal (Integrated Endangerment Assessment/Risk Characterization, August 1993).

(9) Based on average time spent at home (0.64 adult) (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(10) Based on average time spent at work (36 hr/wk) (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(11) Preliminary CT default value (EPA, 1993).

(12) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(13) American Industrial Health Council, 1994, Gephart, Tell and Triemer, 1994.

(14) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(15) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 3. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

		POTENTIALLY EXPOSED RECEPTORS						
FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		**Current Off-Site Resident**	**Current On-Site Industrial Worker**	**Future On-Site Office Worker**	**Future On-Site Construction Worker**	**Future On-Site Ecological Worker**	**Future On-Site Resident**	**Future Off-Site Resident**
SOIL/DUST DERMAL CONTACT								
Exposed Skin Surface (cm^2)	RME☛ CT☛	**5300**[1,3] 2000[2,4]	3400[5] 3400[5]	2100[5] 2100[5]	4700[5] 4700[5]	4700[5] 4700[5]	**5300**[3] 2000[4]	**5300**[3] 2000[4]
Fraction Contacted from Contaminated Source		1.0[6] 0.64[6]	1.0[6] 0.9[7]	1.0[6] 0.9[7]	1.0[6] 0.9[7]	1.0[6] 0.9[7]	1.0[6] 0.64[6]	1.0[6] 0.64[6]
Soil Adherence (mg/cm^2)		**1.0**[3] 0.2[3]	**1.0**[3] 0.2[3]	**1.0**[3] 0.2[3]	**1.0**[3] 0.2[3]	**1.0**[3] 0.2[3]	**1.0**[3] 0.2[3]	**1.0**[3] 0.2[3]
Skin Absorption Factor		CS[8] CS[8]	CS CS	CS CS	CS CS	CS CS	CS CS	CS CS
Exposure Frequency (days/yr)		**350**[9] 234[10]	**250**[9] 219[10]	**250**[9] 211[10]	30[11] 30[11]	65[11] 65[11]	**350**[9] 234[10]	**350**[9] 234[10]
Exposure Duration (years)		**30**[10] 9[12]	**25**[9] 4[13]	**25**[9] 4[13]	1[11] 1[11]	2.5[11] 2.5[11]	**30**[9] 9[12]	**30**[9] 9[12]
Body Weight (kg)[9]		**70** 70	**70** 70	**70** 70	**70** 70	**70** 70	**70** 70	**70** 70

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	POTENTIALLY EXPOSED RECEPTORS						
	Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
Averaging Time: Noncarcinogen (days)[14]	10950 3285	9125 1460	9125 1460	365 365	915 915	10950 3285	10950 3285
Averaging Time-Carcinogen (days)[15]	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550	25550 25550

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1992a; EPA 1991a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(CS) Chemical-specific exposure parameter determined from quantitative analysis and toxicology literature.

(1) Top entry is based on High-End (HE) exposure used to characterize the RME risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set *one* or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set at central tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on CT used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure" when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) EPA Dermal Exposure Assessment: Principles and Applications, 1992a.

(4) CT adult skin surface exposed is 11% of *mean* surface area (18150 cm^2) (EPA Dermal Exposure Assessment: Principles and Applications, 1992a). Note that the CT skin surface of the child-41% of adult surface area based on 6-year-old and adult males (EPA Exposure Factors Handbook, 1989a) cannot result in a greater dermal intake for the child, assuming EPA standard default values for exposure duration and body weight and twice the fraction exposed (adult = 18150 cm^2 x 0.11 x 24 yr/70kg = <u>685 cm^2/kg-yr;</u> child = 18150 cm^2 x 0.41 x 0.22 x 0.22 x 6 yr/15 kg = <u>655 cm^2</u>/kg-yr).

(5) Industrial worker HE value is an average between exposed skin surfaces of 4,700 cm^2 (outdoor construction or ecological worker) and 2,100 cm^2 (indoor office worker) based on EPA Exposure Factors Handbook, 1989a; indoor worker exposure assumes median surface area of adult head and hands (1,200 cm^2 + 900 cm^2), whereas outdoor worker assumes median surface area of adult head, hands, and arms (1,200 cm^2 + 900 cm^2 + 2,600 cm^2).

(6) RME based on EPA guidance. The CT is based on average time spent at home (0.64 adult; 0.82 child) (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(7) As in Note 6, based on average weekly time spent at work (0.9) using a base of 40 hours per week.

(8) In the absence of a CS value, consult EPA Region IV Interim Guidance dated 11 February 1992 (default values: 0.01 organics; 0.001 inorganics) (EPA, 1992c). However, alternative values of 0.06 (organic compounds) and 0.01 (metals) are based on maximum dermal bioavailability as reported in "Dermal Absorption Factors for Multiple Chemicals" (15 December 1992; EPA, 1992d).

(9) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a (for consistency with soil/dust ingestion and inhalation).

(10) Preliminary CT default value (EPA, 1993).

(11) Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(12) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(13) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(14) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(15) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 4. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

		POTENTIALLY EXPOSED RECEPTORS						
FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		**Current Off-Site Resident**	**Current On-Site Industrial Worker**	**Future On-Site Office Worker**	**Future On-Site Construction Worker**	**Future On-Site Ecological Worker**	**Future On-Site Resident**	**Future Off-Site Resident**
SURFACE WATER/SUSPENDED SEDIMENT INGESTION*								
Ingestion Rate (L/hr)	RME☞ CT☞	NA NA	NA NA	NA NA	NA NA	0.05[1, 3] 0.01[2, 4]	**0.05**[5] 0.01[4]	**0.05**[5] 0.01[4]
Exposure Rate (hr/day)		NA NA	NA NA	NA NA	NA NA	1[6] 1[6]	**2.6**[7] 1.0[8]	**2.6**[7] 1.0[8]
Exposure Frequency (days/yr)		NA NA	NA NA	NA NA	NA NA	12[3] 7[3]	**7**[9] 5[10]	**7**[9] 5[10]
Exposure Duration (years)		NA NA	NA NA	NA NA	NA NA	2.5[3] 2.5[3]	**30**[11] 9[12]	**30**[11] 9[12]
Body Weight (kg)		NA NA	NA NA	NA NA	NA NA	70[3] 70[3]	**70**[11] 70[11]	**70**[11] 70[11]
Averaging Time: Noncarcinogen (days)[13]		NA NA	NA NA	NA NA	NA NA	915 915	10950 3285	10950 3285
Averaging Time: Carcinogen (days)[14]		NA NA	NA NA	NA NA	NA NA	25550 25550	25550 25550	25550 25550

* Direct ingestion of exposed *in situ* shoreline sediments will utilize *OU-specific* exposure factors.

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991b; EPA 1989b) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the RME risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set at central tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on CT used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable worst case", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) The RME is based on EPA guidance. The CT is from the Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(4) On the premise that actual swimming rather that wading is unlikely, the CT ingestion rate while wading is assumed to be one-fifth as much as while swimming.

(5) Default value for ingestion of surface water and suspended sediment while *swimming* (EPA RAGS, HHEM Pt. A, 1989b); *wading* ingestion rate is indeterminate from available sources.

(6) An exposure "event" for the ecological worker (see Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995) is assumed to last 1 hour per day.

(7) Default value for swimming exposure time (EPA RAGS, HHEM Pt. A, 1989b); *wading* exposure time is indeterminate from available sources.

(8) On the premise that actual swimming rather than wading is unlikely, the CT *exposure time* while wading is assumed to be 1 hour.

(9) Default value for *swimming* exposure frequency (EPA RAGS, HHEM Pt. A, 1989b); *wading* exposure frequency is indeterminate from available sources.

(10) On the premise that actual swimming rather than wading is unlikely, the CT exposure frequency while wading is assumed to be 5 events per year.

(11) Appendix B.1, EPA RAGS, HHEM Pt. B, 1991b.

(12) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(13) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(14) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 5. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		POTENTIALLY EXPOSED RECEPTORS: Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
SURFACE WATER DERMAL CONTACT*								
Exposed Skin Surface (cm^2)	RME☞	NA	NA	NA	NA	9275[1, 3]	**18150**[4]	**18150**[4]
	CT☞	NA	NA	NA	NA	9275[2, 3]	9275[5]	9725[5]
Dermal Permeability (cm/hr)	RME	NA	NA	NA	NA	CS[6]	CS[6]	CS[6]
	CT	NA	NA	NA	NA	CS[6]	CS[6]	CS[6]
Exposure Time (hr/day)	RME	NA	NA	NA	NA	1[7]	**2.6**[8]	**2.6**[8]
	CT	NA	NA	NA	NA	1[7]	1.0[9]	1.0[9]
Exposure Frequency (days/yr)	RME	NA	NA	NA	NA	12[10]	**7**[11]	**7**[11]
	CT	NA	NA	NA	NA	7[10]	5[12]	5[12]
Exposure Duration (years)	RME	NA	NA	NA	NA	2.5[10]	**30**[13]	**30**[13]
	CT	NA	NA	NA	NA	2.5[10]	9[14]	9[14]
Body Weight (kg)	RME	NA	NA	NA	NA	70[10]	**70**[13]	**70**[13]
	CT	NA	NA	NA	NA	70[10]	70[13]	70[13]

* Direct dermal contact with exposed *in situ* shoreline sediment will utilize *OU-specific* exposure factors.

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	POTENTIALLY EXPOSED RECEPTORS: Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
Averaging Time: Noncarcinogen (days)[16]	NA NA	NA NA	NA NA	NA NA	915 915	10950 3285	10950 3285
Averaging Time: Carcinogen (days)[16]	NA NA	NA NA	NA NA	NA NA	25550 25550	25550 25550	25550 25550

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1989a; EPA 1989b) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(CS) Chemical-specific exposure parameter determined from quantitative analysis and toxicology literature.

(1) Top entry is based on High-End (HE) exposure used to characterize the Reasonable Maximum Exposure (RME) risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) On the premise that actual swimming by the ecologist, rather than wading, is highly unlikely, the exposed adult skin surface while wading and reaching underwater is assumed to include the legs (5950 cm^2), feet (1250 cm^2), forearms (1175 cm^2), and hands (900 cm^2) (EPA Exposure Factors Handbook, 1989a).

(4) Typical value for total adult skin surface area exposed while swimming (EPA Exposure Factors Handbook, 1989a).

(5) On the premise that actual swimming by the resident, rather than wading is unlikely, the exposed adult skin surface while wading is assumed to include the legs (5950 cm^2), feet (1250 cm^2), forearms (1175 cm^2), and hands (900 cm^2) (EPA Exposure Factors Handbook, 1989a).

(6) In the absence of a CS value, consult methods to estimate maximum dermal bioavailability. Possible maxima are: HE value of 1.0 cm/hr determined experimentally for ethylbenzene and toluene among *organic* compounds; HE value of 0.001 cm/hr determined experimentally for cadmium chloride and mercuric chloride among *inorganic* compounds (EPA Dermal Exposure Assessment: Principles and Applications, 1992a).

(7) An exposure "event" for the ecological worker (see Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1994) is assumed to last 1 hour per day.

(8) Default value for *swimming* exposure time (EPA RAGS, HHEM Pt. A, 1989b); *wading* exposure time is indeterminate from available sources.

(9) On the premise that actual swimming, rather than wading, is unlikely, the CT exposure time while wading is assumed to be 1 hour.

(10) RME is from EPA guidance. The CT is from the Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995 (for consistency with surface water ingestion).

(11) Default value for *swimming* exposure frequency (EPA RAGS, HHEM Pt. A, 1989b); *wading* exposure frequency is indeterminate from available sources.

(12) On the premise that actual swimming rather than wading is unlikely, the CT exposure frequency is assumed to be 5 events per year.

(13) EPA RAGS, HHEM Pt. A, 1989b.

(14) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(15) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(16) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 6. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

		POTENTIALLY EXPOSED RECEPTORS						
FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		**Current Off-Site Resident**	**Current On-Site Industrial Worker**	**Future On-Site Office Worker**	**Future On-Site Construction Worker**	**Future On-Site Ecological Worker**	**Future On-Site Resident**	**Future Off-Site Resident**
HOMEGROWN PRODUCE INGESTION								
Ingestion Rate (g/day)	RME☞ CT☞	**200/140**[1, 3] 200/140[2, 3]	NA NA	NA NA	NA NA	NA NA	**200/140**[1,3] 200/140[1,3]	**200/140**[1,3] 200/140[1,3]
Fraction Ingested from Contaminated Source		**0.4/0.3**[4] 0.25/0.2[4]	NA NA	NA NA	NA NA	NA NA	**0.4/0.3**[4] 0.25/0.2[4]	**0.4/0.3**[4] 0.25/0.2[4]
Washoff Factor		1.0[5] 0.5[5]	NA NA	NA NA	NA NA	NA NA	1.0[5] 0.5[5]	1.0[5] 0.5[5]
Exposure Frequency (days/yr)		**350**[6] 150[7]	NA NA	NA NA	NA NA	NA NA	**350**[6] 150[7]	**350**[6] 150[7]
Exposure Duration (years)		**30**[8] 9[9]	NA NA	NA NA	NA NA	NA NA	**30**[8] 9[9]	**30**[8] 9[9]
Body Weight (kg)		**70**[8] 70[8]	NA NA	NA NA	NA NA	NA NA	**70**[8] 70[8]	**70**[8] 70[8]

	POTENTIALLY EXPOSED RECEPTORS						
FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	**Current Off-Site Resident**	**Current On-Site Industrial Worker**	**Future On-Site Office Worker**	**Future On-Site Construction Worker**	**Future On-Site Ecological Worker**	**Future On-Site Resident**	**Future Off-Site Resident**
Averaging Time: Noncarcinogen (days)[10]	10950 3285	NA NA	NA NA	NA NA	NA NA	10950 3285	10950 3285
Averaging Time-Carcinogen (days)[11]	25550 25550	NA NA	NA NA	NA NA	NA NA	25550 25550	25550 25550

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a; EPA 1989a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the Reasonable Maximum Exposure (RME) risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) Average adult vegetable intake/average adult fruit intake (EPA Exposure Factors Handbook, 1989a).

(4) The HE and CT fraction ingested (FI) is based on the fraction of fruits or vegetables consumed daily that is *home-grown* (EPA Exposure Factors Handbook, 1989a).

(5) RME is the EPA default value. For the CT, it is assumed that

residents consuming their own home-grown fruits or vegetables also wash off *at least* one-half of all contaminated soil or dust particles adhering to root and leaf vegetables and to fruits.

(6) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a. A conservative exposure frequency would be 215 days (first harvest May 1; last harvest December 1) (Jefferson County Horticulturalist Robert Cox, 21 October 1994). The default exposure frequency of 350 days per year would assume an additional 135 days consuming only *preserved* home-grown produce.

(7) Based on typical site-specific fraction of the year home-grown produce is harvested on Colorado's Eastern Plains (first harvest May 15; last harvest October 15) (Jefferson County Horticulturalist Robert Cox, 21 October 1994).

(8) EPA RAGS, HHEM, Standard Default Exposure factors, 1991a.

(9) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(10) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(11) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 7. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		POTENTIALLY EXPOSED RECEPTORS: Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
GROUND WATER INGESTION								
Ingestion Rate (L/day)	RME☞	NA	NA	1.0	NA	NA	**2.0**[1, 3]	NA
	CT☞	NA	NA	1.0	NA	NA	1.4[2, 3]	NA
Fraction Ingested from Contaminated Source		NA	NA	1.0	NA	NA	**1.0**[4]	NA
		NA	NA	0.3	NA	NA	0.3[4]	NA
Exposure Frequency (days/yr)		NA	NA	250	NA	NA	**350**[5]	NA
		NA	NA	219	NA	NA	234	NA
Exposure Duration (years)		NA	NA	25	NA	NA	**30**[5]	NA
		NA	NA	4	NA	NA	9[7]	NA
Body Weight (kg)		NA	NA	70	NA	NA	**70**[5]	NA
		NA	NA	70	NA	NA	70[5]	NA
Averaging Time: Noncarcinogen (days)[8]		NA	NA	9125	NA	NA	10950	NA
		NA	NA	1460	NA	NA	3285	NA
Averaging Time: Carcinogen (days)[9]		NA	NA	25550	NA	NA	25550	NA
		NA	NA	25550	NA	NA	25550	NA

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a; EPA 1989a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the Reasonable Maximum Exposure (RME) risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) HE and CT adult total water-based beverage intakes, including tap water (EPA Exposure Factors Handbook, 1989a).

(4) The CT fraction ingested (FI) is based on 64% of adult time spent at home (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994) and on 46% tap water ingestion out of adult total water-based beverage intake (EPA Exposure Factors Handbook, 1989a) (0.64 x 0.46 = 0.3).

(5) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a.

(6) Preliminary CT default value (EPA, 1993).

(7) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(8) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(9) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 8. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		POTENTIALLY EXPOSED RECEPTORS: Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
GROUND WATER/SUBSOIL VOC INHALATION*								
Inhalation Rate (m^3/hr)	RME☞	NA	NA	**0.83**[1, 3]	1.4[6]	NA	**0.63**[3]	NA
	CT☞	NA	NA	0.63[2, 4]	1.25[6]	NA	0.63[3]	NA
Exposure Time (hr/day)		NA	NA	**8**[3]	**8**[3]	NA	**24**[3]	NA
		NA	NA	7.2[7]	7.2[7]	NA	15[8]	NA
Exposure Frequency (days/yr)		NA	NA	**250**[3]	30[6]	NA	**350**[3]	NA
		NA	NA	219[9]	30[6]	NA	234[9]	NA
								NA
								NA
Exposure Duration (years)		NA	NA	**25**[3]	1[6]	NA	**30**[3]	NA
		NA	NA	4[10]	1[6]	NA	9[11]	NA
Body Weight (kg)[3]		NA	NA	**70**	**70**	NA	**70**	NA
		NA	NA	70	70	NA	70	NA

* Includes *indoor* VOC vapor from household use of a groundwater supply and VOC vapor infiltration from subsoil into homes and offices; also *outdoor* VOC vapor from subsoil excavation at construction sites.

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE	POTENTIALLY EXPOSED RECEPTORS						
	Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
Averaging Time: Noncarcinogen (days)[12]	NA NA	NA NA	9125 1460	365 365	NA NA	10950 3285	10950 NA
Averaging Time: Carcinogen (days)[13]	NA NA	NA NA	25550 25550	25550 25550	NA NA	25550 25550	NA NA

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a; EPA 1989a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the Reasonable Maximum Exposure (RME) risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991a.

(4) CT worker inhalation rate of 0.63 m^3/hr (adult indoors) based on EPA Exposure Factors Handbook, 1989a.

(5) RME is based on EPA guidance. The CT is from the Final Rocky Flats Programmatic Risk-Based preliminary Remediation Goals, 1995.

(6) CT residential inhalation rate (adult indoors) based on EPA RAGS, HHEM Standard Default Exposure Factors, 1991a. Note that the CT rate for the child - 81% of adult rate based on 6-year-old and adult males at moderate activity (EPA Exposure Factors Handbook, 1989a) - cannot result in a greater inhalation intake for the child, assuming EPA standard default values for exposure duration and body weight (adult = 0.63 m^3/hr x 24 yr/70 kg = 0.22 m^3/hr-kg/yr; child = 0.63 m^3/hr x 0.81 x 6 yr/15 kg = 0.20 m^3/hr-kg/yr.

(7) Based on average time spent at work (36 hr/wk) (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(8) Based on average time spent at home (0.64 adult; 0.82 child) (American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994).

(9) Preliminary CT default value (EPA, 1993).

(10) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(11) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

(12) Exposure duration (years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

(13) Lifetime exposure (70 years) x 365 days (EPA RAGS, HHEM Pt. A, 1989b).

TABLE 9. Rocky Flats Site-Specific Exposure Factors for Quantitative Human Health Risk Assessment

FACTORS FOR POTENTIALLY COMPLETE ROUTES OF EXPOSURE		POTENTIALLY EXPOSED RECEPTORS						
		Current Off-Site Resident	Current On-Site Industrial Worker	Future On-Site Office Worker	Future On-Site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
EXTERNAL IRRADIATION								
Gamma Exposure Time Factor (T_e)	RME☞	NA	**0.3**[1, 3]	**0.3**[3]	**0.3**[3]	**0.3**[3]	**1.0**[4]	NA
	CT☞	NA	0.3[2, 3]	0.3[3]	0.3[3]	0.3[3]	0.75[5]	NA
Gamma Shielding Factor ($1-S_e$)		NA	**0.8**[6]	**0.8**[6]	**1.0**[8]	**1.0**[8]	**0.8**[6]	NA
		NA	0.5[7]	0.5[7]	0.8[9]	0.8[9]	0.5[7]	NA
Exposure Frequency (days/yr)		NA	**250**[4]	**250**[4]	30[11]	65[11]	**350**[4]	NA
		NA	219[10]	219[10]	30[11]	65[11]	234[10]	NA
Exposure Duration (years)		NA	**25**[4]	**25**[4]	1[11]	2.5[11]	**30**[4]	NA
		NA	4[12]	4[12]	1[11]	2.5[11]	9[13]	NA

NOTES:

(BOLD) Standard Default Exposure Factor (EPA, 1991a; EPA 1989a) used to calculate conservative risks based on Reasonable Maximum Exposure (RME) by combining high-end (>90th %ile) and central tendency (X or Md) exposure factors to represent exposure "that is both protective and reasonable, not the worst possible case."

(NA) Not applicable because the exposure pathway is incomplete.

(1) Top entry is based on High-End (HE) exposure used to characterize the Reasonable Maximum Exposure (RME) risks in a baseline or remediation risk assessment. RME risks are derived using professional judgment to set one or more sensitive exposure parameters at HE (90-98th %ile) values in combination with others set a Central Tendency (CT) values in order to characterize the high-end risks to a very small proportion of an exposed population.

(2) Bottom entry is based on Central Tendency (CT) used to characterize the typical case in a baseline or remediation risk assessment (or a "reasonable maximum exposure", when used in combination with selected high-end values). Average risks are derived using professional judgment to set *all* exposure parameters at 50th %ile (median) or mean values in order to characterize the mid-range risk to the largest proportion of an exposed population.

(3) Assuming the HE fraction of time exposed (8 out of 24 hours or 0.33) according to EPA RAGS, HHEM Pt. B-Revised (Dinan, 1992).

(4) EPA RAGS, HHEM, Standard Default Exposure Factors, 1991b.

(5) Assuming the CT fraction of time spent at home (average of adult - 0.64 and child - 0.82) (American Industrial Health Council 1994; Gephart, Tell and Triemer, 1994).

(6) Standard default screening value specified in EPA RAGS, HHEM Pt. B, 1991b (1 - 0.2 = 0.8), assuming substantial time shielded by structures.

(7) Estimated typical value for residents and indoor workers shielded by buildings (DOE documents for RFP, such as "Mining Exposure Scenario for Baseline Risk Assessments at the Rocky Flats Environmental Technology Site" (9 August 1994).

(8) Standard default screening value specified in EPA RAGS, HHEM Pt. B, 1991b, assuming limited time shielded by structures.

(9) Assumed typical value for outdoor workers with only limited shielding indoors.

(10) Preliminary CT default value (EPA, 1993).

(11) Final Rocky Flats Programmatic Risk-Based Preliminary Remediation Goals, 1995.

(12) American Industrial Health Council, 1994; Gephart, Tell and Triemer, 1994.

(13) Preliminary CT default value (EPA, 1993). A current alternative value is EPA's CT Residential Occupancy Period (ROP) of 8.1 years for total population (EPA, 1992b; American Industrial Health Council, 1994).

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TABLE 10A—OPEN-SPACE EXPOSURE PARAMETERS INCIDENTAL INGESTION

	DUST, SURFACE SOIL, OR SEDIMENT	
	Typical Exposure (CT)	High-End Exposure (RME)
Ingestion Rate—Child (mg/visit)	15 (1)	100 (1)
Ingestion Rate—Adult (mg/visit)	8 (1)	50 (1)
Matrix Effect in GI Tract (Absorption Factor)	CS	CS
Exposure Frequency (visits/yr)	10 (2)	25 (2)
Exposure Duration—Child (yr)	2	6
Exposure Duration—Adult (yr)	7	24
Body Weight—Child (kg)	15	15
Body Weight—Adult (kg)	70	70
Averaging Time—Child, Non-carcinogen (days)	730	2,190
Averaging Time—Adult, Non-carcinogen (days)	2,555	8,760
Averaging Time—Carcinogen (days)	25,550	25,550

(1) Assumes standard default *residential* rates as specified for open-space recreational users at DOE's Fernald Site and Hanford Site (RME=200 mg/day for children and 100 mg/day for adults) and at Denver's Lowry Landfill Superfund Site (CT=100mg/day for children and 50 mg/day for adults). Assumes that Exposure Time is 1.5 hours per day (CT); 5.0 hours per day (RME) (see Note 2, Table 4B) and that total soil ingestion occurs over 10 daylight hours (1.5/10 = 0.15; 5.0/10 = 0.5). Using the default daily ingestion rates, soil ingestion per visit for children is calculated as RME=0.5x200=100 mg/visit; CT=0.15x100=51 mg/visit. For adults the ingestion rates are RME=50 and CT=8. Actual open-space recreational intakes would vary, depending on the activity, possibly with dirt biking at one extreme and photographing wildlife at the other.

(2) Exposure Frequency based upon Boulder County's Park and Open Space Visitor Interviews of 1985 (est. 7 days/yr, CT; 25 days/yr, RME), DOE's Hanford Site recreational user (7 days/yr, CT), and Department of thel'nerior's (DOI) National Survey of Fishing, Hunting, and Nonconsumptive Wildlife Recreation of 1985 for Colorado (9.4 days/yr for nonconsumptive use, CT; 15.4 days/yr for fishing and hunting, CT).

TABLE 10B—OPEN-SPACE EXPOSURE PARAMETERS PARTICULATE INHALATION

	DUST, SURFACE SOIL, OR DRY SEDIMENT	
	Typical Exposure (CT)	High-End Exposure (RME)
Inhalation Rate (m^3/hr)	0.83 (1)	1.4 (1)
Respirable Fraction (PM_{10})	0.36	0.46
Respiratory Deposition Factor	0.85	0.85
Exposure Time (hr/visit)	1.5 (2)	5.0 (2)
Exposure Frequency (visits/yr)	10 (3)	25 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time—Noncarcinogen (days)	3,285	10,950
Averaging Time—Carcinogen (days)	25,550	25,550

(1) Inhalation Rate based upon DOE's Fernald Site and Hanford Site recreational users (0.83 m^3/hr, CT) and on EPA's *Exposure Factors Handbook* (1.4 m^3/hr, RME), which assumes 7% heavy activity, 37% moderate activity, 28% light activity, and 28% resting for an adult.

(2) Exposure Time based upon Boulder County's Park and Open Space Visitor Interviews of 1992 (est. 1.6 hr/day, CT; 5.0 hr/day, RME), DOD's Rocky Mountain Arsenal Site recreational user (1.6 hr/day, CT; 5.0 hr/day, RME), and City of Boulder's Open Space Visitation Study of 1993 (1.0 hr/day, CT; 2.0 hr/day, RME).

(3) Exposure frequency based on Boulder County's Park and Open Space Visitor Interviews of 1985 (estimated 7 days/year, CT; 25 days/year, RME), DOE's Hanford Site recreational user (7days/year, CT), and DOI's National Survey of Fishing, Hunting, and Nonconsumptive Wildlife Recreation of 1985 for Colorado (9.4 days/year for nonconsumptive use, CT; 15.4 days/year for fishing and hunting, CT).

TABLE 10C—OPEN-SPACE EXPOSURE PARAMETERS DERMAL CONTACT

	DUST, SURFACE SOIL, OR SEDIMENT	
	Typical Exposure (CT)	High-End Exposure (RME)
Exposed Skin Surface (cm²)	[illegible]00 (1)	5,300 (1)
Fraction Contacted from Contaminated Source	0.15 (2)	0.5 (2)
Soil Adherence to Skin (mg/cm²)	0.2	1.0
Skin Absorption Factor	CS	CS
Exposure Frequency (days/yr)	10 (3)	25 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time—Noncarcinogen (days)	3,285	10,950
Averaging Time—Carcinogenogen (days)	25,550	25,550

(1) Exposed Skin Surface based upon EPA's *Dermal Exposure Assessment: Principles and Applications*, which specifies typical and high-end default values for the adult outdoors (2,000 cm² and 5,300 cm²). The CT exposed skin surface is limited to head and hands, while the RME value assumes head, hands, forearms, and lower legs are exposed. DOE's Fernald Site recreational user adopts a comparable RME value (5,000 cm²). It is conservatively assumed that a persons heade will contact sediments.

(2) See Table 4A and 4B, Note 2.

(3) See Table 4B, Note 3.

TABLE 10D—OPEN-SPACE EXPOSURE PARAMETERS INGESTION WHILE WADING

	SHALLOW SURFACE WATER	
	Typical Exposure (CT)	High-End Exposure (RME)
Ingestion Rate (mL/hr)	25 (1)	50 (1)
Exposure Time (hr/visit)	0.5 (2)	1.0 (2)
Exposure Frequency (visits/yr)	5 (3)	15 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time—Noncarcinogen (days)	3,285	10,950
Averaging Time—Carcinogen (days)	25,550	25,550

(1) Ingestion Rate based upon open-space recreational user wading at Denver's Lowry Landfill Superfund Site (50 mL/day, RME; 25 mL/day, CT). For comparison, a single value of 35 mL/day is specified for DOE's Fernald Site (wading in shallow Paddy's Run).

(2) Exposure Time based upon DOE's Fernald Site recreational user (0.5 hr/day, CT) and on the Clear Creek/Central City Superfund Site recreational user (1.0 hr/day, RME, assuming that wading time would be the same as swimming time).

(3) Assumes that CT Exposure Frequency for *wading* is one-half the EF of 10 days/yr for all visitors (0.5 x 10 = 5 days/yr) and RME is 60% of the EF of 25 (0.6 x 25 = 15 days/yr). See Table 4A, Note 3. On the average, users are very unlikely to wade on a year-round basis during each visit to the site.

TABLE 10E—OPEN-SPACE EXPOSURE PARAMETERS DERMAL CONTACT WHILE WADING

	SHALLOW SURFACE WATER	
	Typical Exposure (CT)	High-End Exposure (RME)
Exposed Skin Surface (cm^2)	4,550 (1)	9,275 (1)
Dermal Permeability (cm/hr)	CS	CS
Exposure Time (hr/visit)	0.5 (2)	1.0 (2)
Exposure Frequency (visits/yr)	5 (3)	15 (3)
Exposure Duration (yr)	9	30
Body Weight (kg)	70	70
Averaging Time—Noncarcinogen (days)	3,285	10,950
Averaging Time—Carcinogen (days)	25,550	25,550

(1) Typical exposed adult skin surface while wading and reaching underwater (4,550 cm^2) assumes the lower legs, feet, and hands are exposed; high-end exposed surface (9,275 cm^2) assumes the thighs, lower legs, feet, forearms, and hands are exposed (EPA's *Exposure Factors Handbook*).

(2) See Table 4D, Note 2.

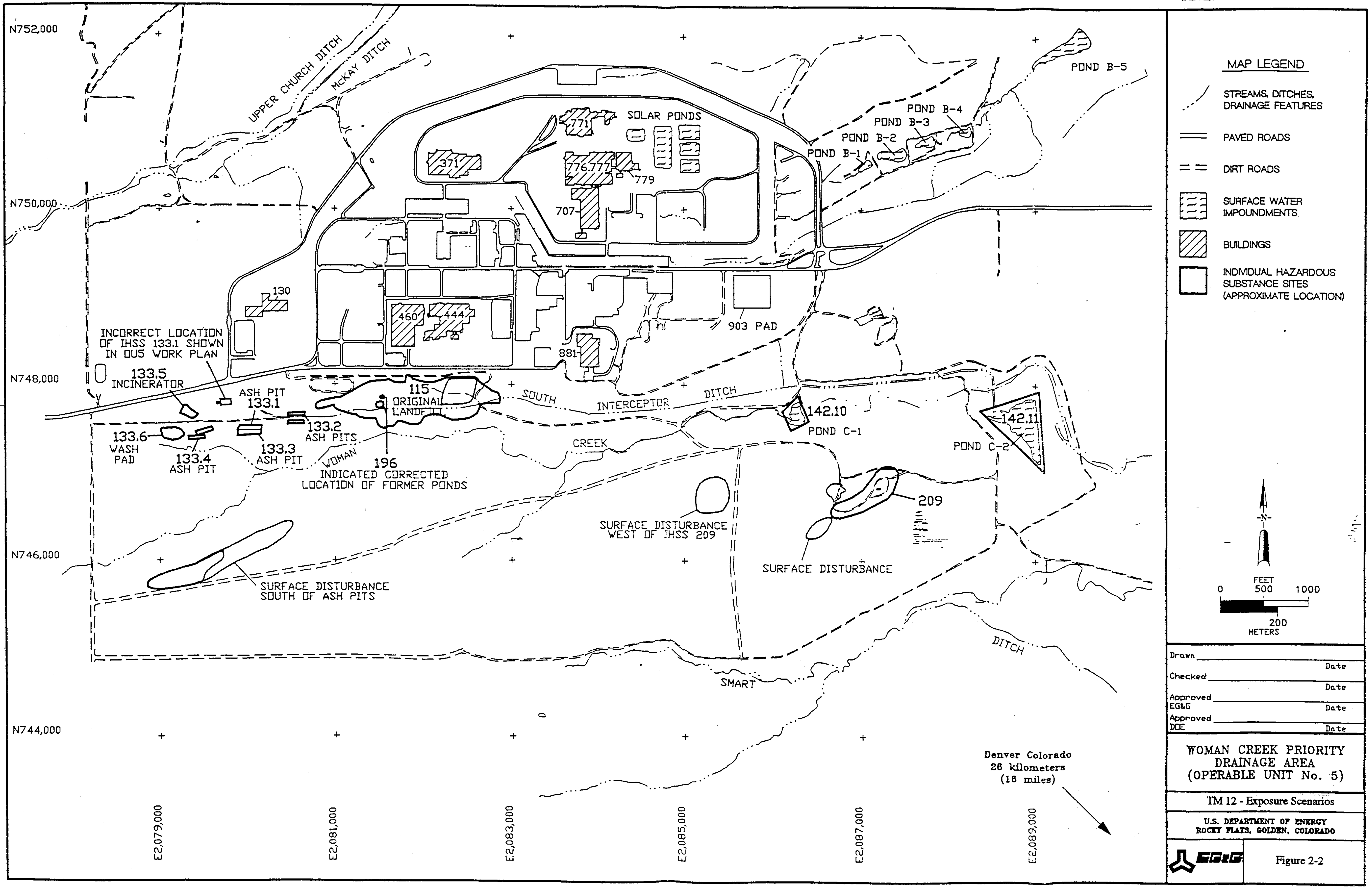
(3) See Table 4D, Note 3.

TABLE 10F—OPEN-SPACE EXPOSURE PARAMETERS

	EXTERNAL IRRADIATION	
	Typical Exposure (CT)	High-End Exposure (RME)
Gamma Exposure Time Factor (T_e)	0.1 (1)	0.2 (1)
Gamma Shielding Factor ($1-S_e$)	0.8	1.0
Exposure Frequency (days/yr)	10 (2)	225 (2)
Exposure Duration (yr)	9	30

(1) Assumes the high-end fraction of time exposed (1.5 out of 24 hours, CT; 5.0 out of 24 hours, RME) (1.5/24 = 0.1; 5.0/24 = 0.2) (see Table 4B, Note 2).

(2) See Table 4A, Note 3.



Drawn ______ Date
Checked ______ Date
Approved EG&G ______ Date
Approved DOE ______ Date

WOMAN CREEK PRIORITY DRAINAGE AREA (OPERABLE UNIT No. 5)

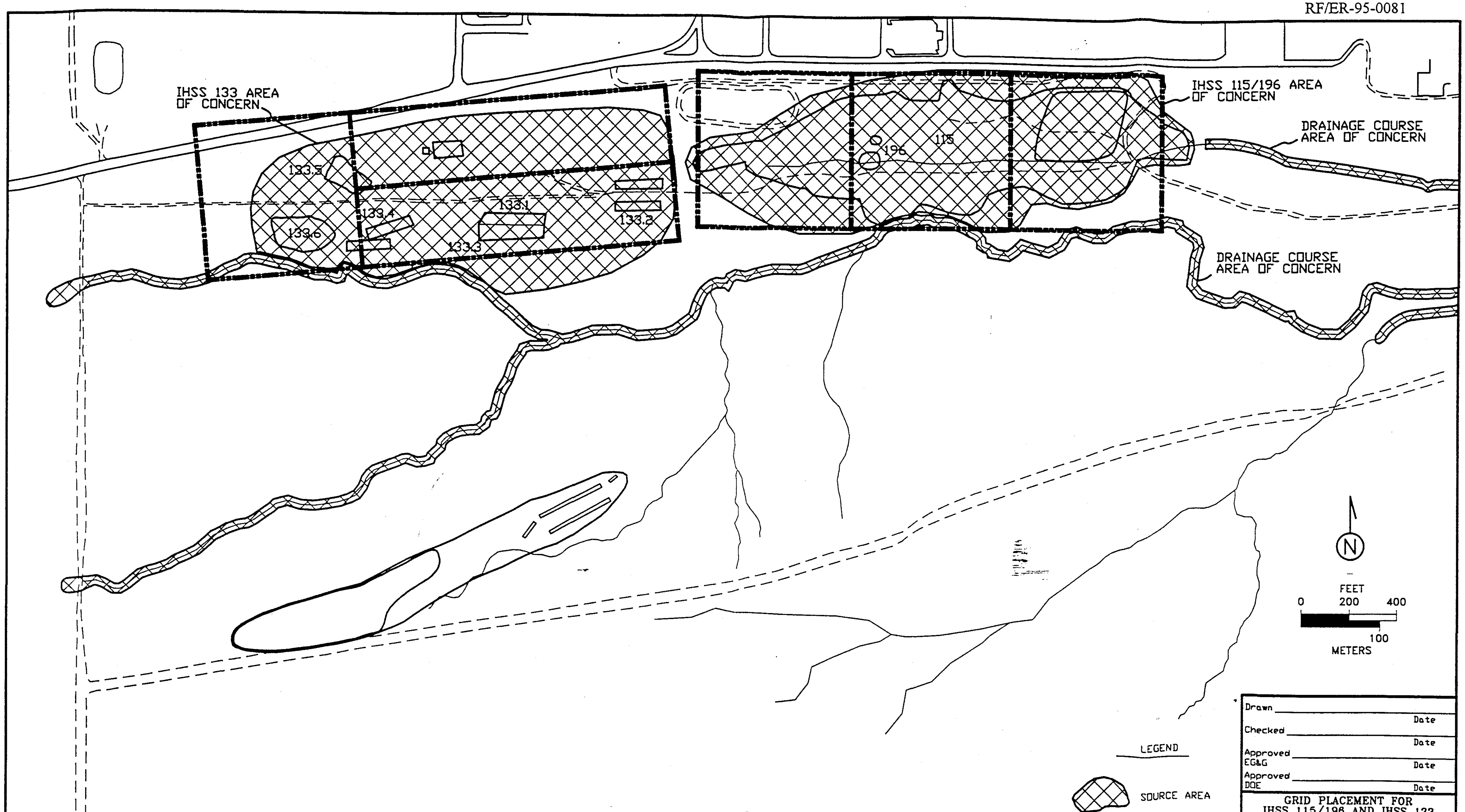
TM 12 - Exposure Scenarios

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS, GOLDEN, COLORADO

EG&G

Figure 2-2

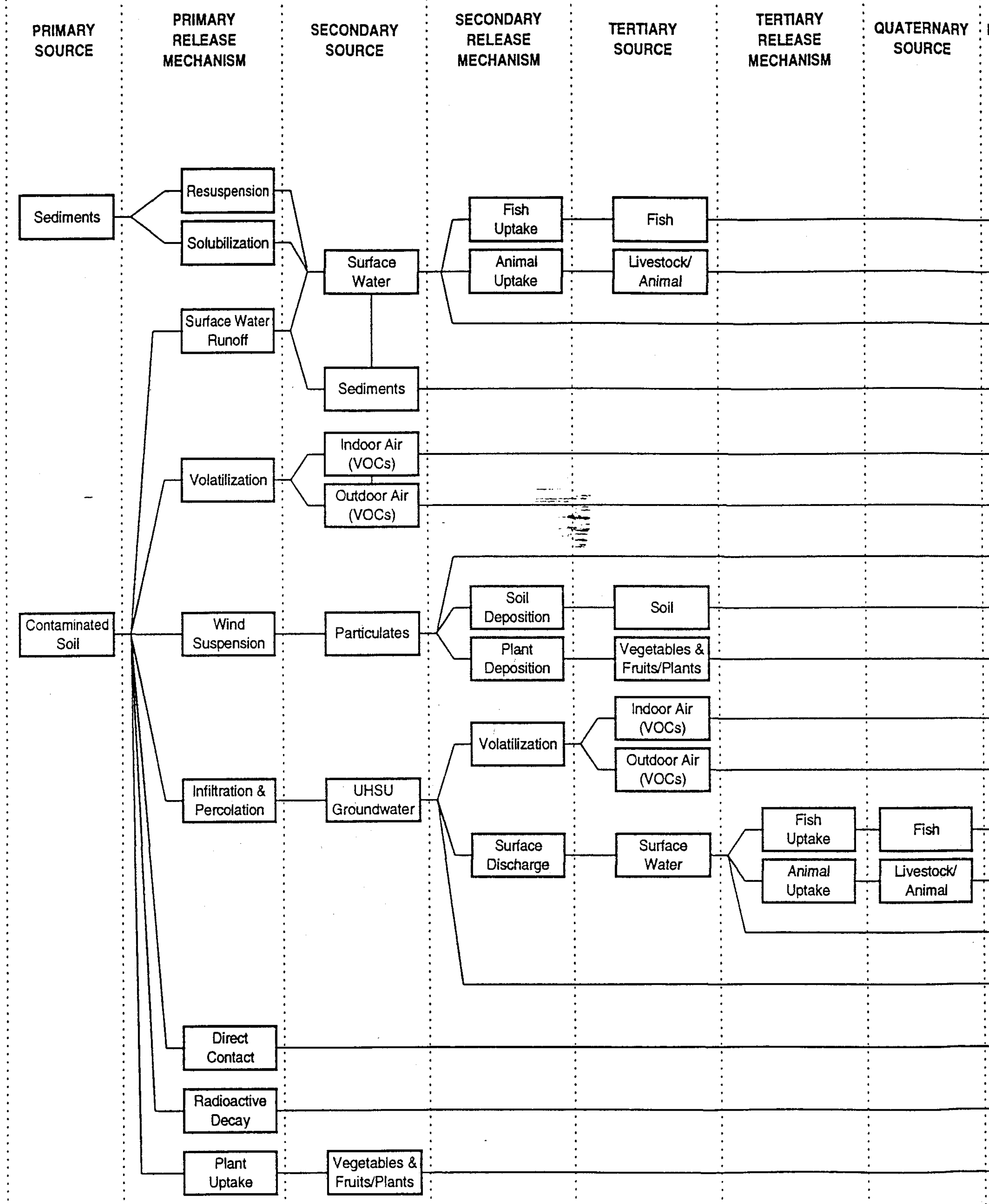
A1-1.DWG



Note: West end of SID will be covered in IHSS 115 area of concern. Drainage course area of concern consists of Woman Creek, SID, ponds C-1, and C-2. The grid includes the drainage continuing east to C-2.

Drawn ____ Date	
Checked ____ Date	
Approved EG&G ____ Date	
Approved DOE ____ Date	
GRID PLACEMENT FOR IHSS 115/196 AND IHSS 133 AREAS OF CONCERN	
EXPOSURE ASSESSMENT TM	
OU5 PHASE I RFI/RI IMPLEMENTATION	
EG&G	Figure 3-1

FIGX.DWG



EXPOSURE ROUTE	Current Onsite Worker	Future Onsite Office Worker	Future Onsite Construction Worker	Future Onsite Ecological Researcher	Future Onsite Recreational Receptor
Oral	N	N	N	N	N
Oral	N	N	N	N	N
Oral	N	N	N	S	S
Dermal	N	N	N	I	I
Oral	N	N	N	S	S
Dermal	N	I	I	I	I
Inhalation	N	S	N	N	N
Inhalation	N	←N	N	N	N
Inhalation	I	I	I	I	I
Oral	N	N	I	N	N
Dermal	N	N	I	N	N
Oral	N	N	N	N	N
Inhalation	N	S	N	N	N
Inhalation	N	N	N	N	N
Oral	N	N	N	N	N
Oral	N	N	N	N	N
Oral	N	N	N	S	S
Dermal	N	N	N	I	I
Oral	N	N	N	N	N
Oral	S	I	S	S	S
Dermal	I	I	I	I	I
External Radiation	I	I	I	I	I
Oral	N	N	N	N	N

S - Significant Potential Exposure Pathway
I - Insignificant Potential Exposure Pathway
N - Negligible or Incomplete Exposure Pathway
UHSU - Upper Hydrostratigraphic Unit

NOTES:
1. Potentially complete dermal pathways will be quantitatively assessed only if investigation demonstrates presence of organic contaminants of concern.
2. Significant and insignificant potential exposure pathways will be quantitatively evaluated.

CONCEPTUAL SITE MODEL
FOR ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
OU5

TM 12 - EXPOSURE SCENARIOS

OU5 PHASE I RFI/RI EXPOSURE ASSESSMENT

EG&G | 10805-927-103 | FIGURE 4-1

SITEMODL.DWG