

# **NOTICE**

**All drawings located at the end of the document.**

**TECHNICAL MEMORANDUM NO. 5**

**HUMAN HEALTH RISK ASSESSMENT  
903 PAD, MOUND, AND EAST  
TRENCHES AREAS  
OPERABLE UNIT NO 2  
EXPOSURE SCENARIOS**

**DRAFT FINAL**

**ROCKY FLATS PLANT**

**U S DEPARTMENT OF ENERGY  
Rocky Flats Plant  
Golden, Colorado**

**ENVIRONMENTAL MANAGEMENT DEPARTMENT**

REVIEWED FOR CLASSIFICATION/UCNI

By *[Signature]*

Date 8/28/92 (NATP)

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**ADMIN RECORD**

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## EXECUTIVE SUMMARY

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This Exposure Assessment Technical Memorandum (EATM) is presented as part of the Baseline Risk Assessment (BRA) for the 903 Pad Mound and East Trenches areas otherwise known as Operable Unit Number 2 (OU 2) located at the Rocky Flats Plant (RFP). The BRA consists of the Human Health Risk Assessment (HHRA) and the Environmental Evaluation (EE). The objective of this technical memorandum is to identify current and future receptor populations that will be quantitatively evaluated in the HHRA portion of the BRA for OU 2. The HHRA will evaluate human health risks for on site and off site receptors under current land use conditions and under future land use conditions, assuming no remedial action takes place at OU 2. This memorandum describes present, future potential and reasonable use exposure scenarios to be evaluated for OU 2 and identifies reasonable maximum intake parameters for estimating chemical intake via these pathways. This memorandum is being submitted prior to initiating the HHRA for OU 2 as part of the Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI). 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 Health (CDH) dated July 31, 1986 and the Federal Facility Agreement and Consent Order (FFACO) known as the Interagency Agreement IAG.

The Rocky Flats Plant (RFP) 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. Surrounding cities include Boulder, Superior, Broomfield, Westminster, and Arvada, which are located less than 16 kilometers (10 miles) to the northwest, north, northeast, and southeast, respectively. Within RFP is an approximately 162 hectare (400 acres) Protected Area (PA) or security area surrounded by a buffer zone of approximately 2,489 hectares (6,150 acres).

The objectives of this EATM are to identify (1) human receptor populations that may be exposed to chemicals released from OU 2, (2) complete exposure pathways by which chemicals are transported from sources to human exposure points, (3) the route(s) of

chemical intake and (4) intake parameters for each potentially contaminated medium (e.g. soil, water, air). This EATM does not quantify chemical intake. The magnitude of exposure is dependent on the chemical concentration at the exposure points, which will be estimated based on the analytical results of the Phase II Site Investigation and fate and transport modeling, as appropriate.

The receptor populations selected for evaluation are those most likely to be exposed and potentially have the greatest degree of exposure to site-related chemicals (reasonable maximum exposures [RME]). Receptor populations selected for evaluation in the human health risk assessment at RFP include current and future off-site residents, future on-site workers, and future on-site ecological researchers. Exposure points were selected to reflect the most reasonable locations where chemical exposures are expected to occur for each of these receptors. These areas are consistent with current and future land use at the site and depict locations where each of the respective human receptors is expected to spend the majority of the time. Using collected data and fate and transport modeling at these locations, as appropriate, the exposure point concentrations will be used to quantitatively evaluate chemical intakes for receptors at the selected locations. The following exposure points were selected for evaluation in the HHRA:

#### **Current Scenario**

- **Residential receptor.** Nearest residence to RFP (located at the southeast corner of the RFP property boundary) and nearest residence to RFP which is in the predominant wind direction.

#### **Future Scenario**

- **Occupational receptor.** On site, within the OU 2 industrial complex.
- **Ecological researcher.** On site within RFP buffer zone east of OU 2, bounded by Woman and South Walnut Creeks.
- **Residential receptors.** Hypothetical off-site residences at the following locations:
  - (1) Point at which South Walnut Creek intersects the eastern Rocky Flats Plant property boundary.

- (2) Point at which Woman Creek intersects the eastern Rocky Flats Plant property boundary

Information concerning waste sources waste constituent release and transport mechanisms and locations of potentially exposed receptors was used to develop a conceptual site model (CSM) of potential human exposure pathways for OU 2. The CSM is a schematic representation of the chemical source areas chemical 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, to identify exposure pathways that will be quantitatively evaluated in the HHRA, to aid in identifying data gaps and to aid in identifying effective cleanup measures if necessary that are targeted at significant contaminant sources and exposure pathways. Complete human exposure pathways to be evaluated as part of the HHRA for OU 2 are

**Current Off Site Resident**

- Soil ingestion (deposition of particulates on residential soil)
- Dermal contact with soil, following deposition of airborne particulates
- External irradiation
- Ingestion of vegetables (surface deposition of particulates)
- Inhalation of airborne particulates

**Future On Site Worker**

- Soil ingestion
- Dermal contact with soil
- External irradiation
- Inhalation of Volatile Organic Chemicals (VOCs) in indoor air
- Inhalation of airborne particulates

### **Future On Site Ecological Researcher**

- Soil ingestion
- Dermal contact with soil
- Surface water ingestion
- Dermal contact with surface water
- Inhalation of airborne particulates
- External irradiation

### **Future Off Site Resident**

- Soil ingestion (deposition of particulates on residential soil)
- Dermal contact with soil
- Surface water ingestion
- Dermal contact with surface water
- Ingestion of homegrown vegetables (surface deposition of particulates)
- Inhalation of particulates
- External irradiation

Using the exposure point concentrations of chemicals 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 mg chemical per kilogram body weight per day (mg/kg day). Intakes will be calculated following guidance in Risk Assessment Guidance for Superfund (EPA 1989a), Exposure Factors Handbook (EPA 1989b) other EPA guidance documents, and professional judgment regarding likely site specific exposure conditions, as appropriate.

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 will be estimated for reasonable maximum exposure (RME) conditions. The RME is estimated by selecting values for exposure variables so that the combination of all variables results in the maximum exposure that can reasonably be expected to occur at the site. The intake parameters to be used in the HHRA for each of the exposure scenarios indicated above are presented in Section 5.0 of this Technical Memorandum.

This Exposure Assessment Technical Memorandum (EATM) is presented as part of the Baseline Risk Assessment (BRA) for the 903 Pad Mound, and East Trenches areas otherwise known as Operable Unit Number 2 (OU 2) located at the Rocky Flats Plant (RFP). The BRA consists of the Human Health Risk Assessment (HHRA) and the Environmental Evaluation (EE). This technical memorandum has been developed to address the HHRA portion of the BRA for OU 2. The HHRA will evaluate human health risks for on site and off site receptors under current land use conditions and under future land use conditions assuming no remedial action takes place at OU 2. This memorandum describes present, future potential and reasonable use exposure scenarios to be evaluated for OU 2 and identifies reasonable maximum intake parameters for estimating chemical intake via these pathways. This memorandum is being submitted prior to initiating the HHRA for OU 2 as part of the Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI). 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 Health (CDH) dated July 31, 1986 and the Federal Facility Agreement and Consent Order (FFACO) known as the Interagency Agreement (IAG 1191).

## 1.1 OBJECTIVES

The objectives of this EATM are to identify (1) human receptor populations that may be exposed to chemicals released from the site, (2) complete exposure pathways by which chemicals are transported from sources to human exposure points, (3) the route(s) of chemical intake, and (4) intake parameters for each potentially contaminated medium (e.g., soil, water, air). This EATM does not quantify chemical intake. The magnitude of exposure is dependent on the chemical concentration at the exposure points, which will be estimated based on the analytical results of the Phase II Site Investigation and fate and transport modeling as appropriate. The exposure assessment focuses on media (soil, water, and air) that potentially contain chemicals 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 technical memorandum is limited to the identification of current and future human exposure scenarios for OU 2 including identifying exposure pathways and intake routes. Potential scenarios are identified according to the Environmental Protection Agency (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 is used to mean 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 using a conceptual site model (CSM). In the CSM the likelihood of an exposure scenario occurring is classified as significant, insignificant, or negligible (i.e., incomplete). In this document negligible or incomplete scenarios are those that are unlikely to occur, significant scenarios are those that could conceivably occur, and insignificant scenarios are those that could also occur but are expected to result in relatively lower levels of exposure (i.e., by one or more orders of magnitude) with respect to significant exposure pathways. Thus in order of increasing credence the terms range from negligible or incomplete (unlikely to occur) through insignificant (conceivable though not as important) to significant (conceivable and important when considering exposure). Both significant and insignificant exposure scenarios will be evaluated quantitatively in the HHRA for OU 2.

This EATM is organized as follows. Section 2.0 Site Description, describes site characteristics that potentially impact human exposures. These characteristics include site history, meteorology, geology, and surface and groundwater hydrology. Section 3.0 Potentially Exposed Receptor Populations identifies the populations that may be exposed to chemicals 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 chemicals from the site and identifies exposure pathways to be evaluated in the HHRA using a conceptual site model. Section 5.0 Estimating Chemical Intakes describes the methodology used to approximate the

wastes and disposal of solid radioactive materials at another DOE facility. However, historically, the operating procedures included both on-site storage and disposal of hazardous and radioactive wastes. Preliminary assessments under the ER Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

The RFP is currently performing environmental restoration activities and planning for decontamination and decommissioning. In a recent speech given at RFP, the Secretary of the Energy, James Watkins, outlined DOE's plans for the future use of RFP. Watkins characterized RFP as an attractive site for manufacturers and other businesses (Denver Post, June 13, 1992). He indicated that approximately half of the complex could be occupied by private industry within two years (Boulder Camera, June 13, 1992).

A group of local businesses and government representatives, referred to as the Rocky Flats Local Impacts Initiative (RFLII), has been formed to identify and mitigate negative economic impacts associated with the transition currently occurring at the RFP. One of the RFLII's goals is to work with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the RFP (RFLII, 1992). To this end, the RFLII recently drafted criteria to be applied in targeting businesses for future occupation of the RFP.

## **2.1 HISTORY OF OU 2**

This Phase II RFI/RI Exposure Assessment Technical Memorandum addresses OU 2, which contains the 903 Pad Mound and East Trenches areas located on the east side of the RFP security area. Several individual hazardous substances sites (IHSSs) are included in each area. Figure 2.2 shows the locations of these areas, the IHSSs within each area, and the OU 2 boundary. The following sections provide a brief history of OU 2 and describe preliminary site characterization information.

The following section is based on the RFP CEARP Phase I Installation Assessment and the RCRA Part B Operating Permit Application as reported in EG&G (1991a). These descriptions are based on historical records, aerial photography review, and interviews with RFP personnel.

## 2 1 1 903 Pad Area

The five IHSS s located within the 903 Pad Area include the following

- 903 Drum Storage Site (IHSS Ref No 112)
- 903 Lip Site (IHSS Ref No 155)
- Trench T 2 Site (IHSS Ref No 109)
- Reactive Metal Destruction Site (IHSS Ref No 140)
- Gas Detoxification Site (IHSS Ref No 183)

The 903 Drum Storage Site (IHSS Ref No 112) was used from October 1958 to January 1967 for storage of radioactively contaminated oil drums. Contents of the drums included plutonium, uranium, carbon tetrachloride hydraulic oils vacuum pump oil trichloroethylene perchloroethylene silicone oils acetone still bottoms and ethanalamine

Drum leakage into the soil was noted at the site in 1964, and corrective action consisted of transferring the contents of leaking drums to new drums and fencing the area to restrict access. The shipment of drums to the 903 Drum Storage Site ended in January 1967 when drum removal efforts began. Removal of all drums and wastes was completed in June 1968.

In November 1968 site grading began in preparation for applying an asphalt cap over the area. This work included moving contaminated soil from around the fenced area to inside the fenced area. Two courses of clean fill material (15 cm of loose gravel and 8 cm of fill dirt) were placed over the site during the late summer of 1969. An asphalt cap (approximately 8 cm thick) was applied in October 1969. In February 1970 additional road base course material was applied to soils directly east and south of the asphalt pad due to soil contamination.

The Trench T 2 Site (IHSS Ref No 109) located approximately 61 meters (200 feet) south of the 903 Pad area, was used prior to 1968 for the disposal of sanitary sewage sludge and flattened drums contaminated with uranium and plutonium.

During drum removal and cleanup activities associated with the 903 Drum Storage Site winds redistributed plutonium beyond the pad to the south and east. The highest chemical concentrations were noted at the 903 Lip Site (IHSS Ref No 155) immediately adjacent to the pad to the south and southeast. Soil cleanup efforts were undertaken in 1976, 1978, and 1984 to remove plutonium containing soils from three different areas within the 903 Lip Site. After the first two cleanup efforts, the excavated area was covered with clean top soil and revegetated with native grasses. After the 1984 cleanup was performed, the excavated area was backfilled with clean topsoil.

The Reactive Metal Destruction Site (IHSS Ref No 140) was used during the 1950s and 1960s primarily for the destruction of lithium metal (DOE 1986). The residues primarily lithium carbonate were buried. Smaller quantities of sodium, calcium, magnesium, solvents, and unknown liquids were also destroyed at this location.

The Gas Detoxification Site (IHSS Ref No 183) was used to detoxify various gases from lecture bottles between June 1982 and August 1983. The lecture bottles used in research and development work, held approximately one liter of compressed gases such as nitrogen oxides, chlorine, hydrogen sulfide, sulfur tetrafluoride, methane, hydrogen fluoride, and ammonia. Gas detoxification was accomplished by using various commercial neutralization processes.

## 2.1.2 Mound Area

The Mound Area includes the following IHSS's:

- Mound Site (IHSS Ref No 113)
- Trench T 1 Site (IHSS Ref No 108)
- Oil Burn Pit No 2 Site (IHSS Ref No 153)
- Pallet Burn Site (IHSS Ref No 154)

The Mound Site (IHSS Ref No 113) was used between April 1954 and September 1958 for disposal of drums containing primarily depleted uranium and beryllium contaminated lathe coolant. It is likely that some of the coolant also contained enriched uranium and plutonium. Some drums contained perchloroethylene. Cleanup of the

Mound Site was accomplished in May 1970 and the materials removed were packaged and shipped to an off site DOE facility for disposal

The Trench T 1 Site (IHSS Ref No 108) was used from 1954 until 1962 It contains approximately 125 drums filled with approximately 25 000 kg (55 125 pounds) of depleted uranium chips and plutonium chips coated with small amount of lathe coolant This trench is now covered with about 0 6 meters (2 feet) of soil and the corners are marked

The Oil Burn Pit No 2 Site (IHSS Ref No 153) is two parallel trenches that were used in 1957 and from 1961 to 1965 to burn drums of oil containing uranium The drums used for the oil burning operation were generally reused however, some empty drums were discarded by flattening and burning them in the trenches The residues from the burning operations and the flattened drums were covered with backfill In 1978 the area was excavated to a depth of approximately 1 5 meters (five feet) and the contaminated soil was removed and shipped off site to an authorized DOE disposal site

The Pallet Burn Site (IHSS Ref No 154) southwest of Oil Burn Pit No 2 was reportedly used to destroy wooden pallets in 1965 The types of hazardous substances or radionuclides that may have been spilled on these pallets is unknown The site was reportedly remediated and reclaimed in the 1970s

### **2 1 3 East Trenches Area**

The East Trenches Area consists of nine burial trenches (IHSS Ref Nos 110 and 111 1 111 8) and two spray irrigation sites (IHSS Ref Nos 216.2 and 216 3) The burial trenches were used from 1954 to 1968 for disposal of uranium and plutonium contaminated sanitary sewage sludge and flattened empty drums contaminated with uranium The wastes in these trenches have not been disturbed since their burial

The East Spray Irrigation Sites were used for spray irrigation of sewage treatment plant effluent Effluent containing low concentrations of chromium was inadvertently sprayed in the area in February and March 1989

## **2 2 PHYSICAL SETTING**

The natural environment of RFP and its vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. RFP is directly east of the north-south trending Front Range and is located approximately 26 kilometers (16 miles) east of the Continental Divide on a broad eastward sloping plain of coalescing alluvial fans developed along the Front Range at an elevation of approximately 1 850 meters (6 000 feet) above mean sea level. The fans extend approximately 8 kilometers (5 miles) in an eastward direction from their origin at Coal Creek Canyon and terminate on the east at a break in the slope to low rolling hills. The operational area at RFP is located near the eastern edge of the fans on a terrace between stream cut valleys (North Walnut Creek and Woman Creek).

Three intermittent streams drain RFP with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek. Rock Creek drains the northwestern corner of RFP and flows northeast through the buffer zone to its off-site confluence with Coal Creek. An east-west trending interfluvial separates the Walnut and Woman Creek drainages. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the RFP security area. These three forks of Walnut Creek join in the buffer zone and flow toward Great Western Reservoir which is approximately one mile east of the confluence. This flow is routed around Great Western Reservoir by the Broomfield Diversion Canal operated by the City of Broomfield. Woman Creek drains the southern RFP buffer zone and flows eastward to Mower Reservoir and Standley Lake.

## **2 3 METEOROLOGY**

RFP has a semi-arid climate and receives an average of approximately 38 centimeters (15 inches) of precipitation annually. Approximately 50 percent of the precipitation is received from snowfall during the winter and spring. Summer thunderstorms account for approximately 30 percent of this moisture and the remainder is received as light rain and snowfall in the fall. Annually snowfall averages 216 centimeters (85 inches). Annual free water evaporation is approximately 114 centimeters (45 inches) (DOE 1992) which is greater than the amount of annual precipitation.

The general annual wind direction, as shown in Figure 2 3 indicates that winds flow from the northwest approximately 46 percent of the year Wind flows from the west southwest approximately 7 2 percent of the year The highest wind velocity is from the northwest and is greater than approximately 56 kilometers per hour (34 5 mph) Atmospheric dispersion from RFP could affect areas to the east and southeast of the plant

## 2 4 GEOLOGY

The surficial deposits at OU 2 consist of pediment alluvium, colluvium, valley fill alluvium and artificial fill that unconformably overlay bedrock Surficial deposits at RFP are Quaternary and Pleistocene in age The near surface bedrock formations of the Arapahoe and Laramie as well as the Rocky Flats Alluvium, are shown on Figure 2 4 and will be discussed below The regional dip of the bedrock is approximately two degrees to the east in the vicinity of OU 2

The Rocky Flats Alluvium is a pediment gravel deposited in a laterally coalescing alluvial fan environment It was deposited across a gently sloping erosional surface cut into the underlying soft bedrock The deposit consists of poorly to moderately sorted poorly stratified clays silts sands gravels and cobbles The colors of the Rocky Flats Alluvium include light to dusky brown, dark yellowish orange grayish orange and dark gray The Rocky Flats Alluvium ranges in thickness from 0 to 15 meters (0 to 50 feet) beneath OU 2 Subsequent dissection and headward erosion by creeks to the south and north of OU 2 have cut through the alluvium into the underlying bedrock This dissection has left the base of the alluvium exposed along the valley walls approximately 12 to 37 meters (40 to 120 feet) above the present valley floor Remnants of younger terrace deposits of the Verdus and Slocum Alluviums occur at lower elevations in some locations along the valley slopes of OU 2

Colluvial materials in OU 2 were derived from slope wash and creep of the Rocky Flats Alluvium, and the Arapahoe and Laramie Formations The colluvium consists of clays, sands and gravels and ranges in thickness from 1 to 6 meters (3 to 20 feet) Colluvium derived from the Rocky Flats Alluvium characteristically covers the alluvial/bedrock

contact along the hillsides. Artificial fill and disturbed ground occur in localized areas of the 903 Pad Mounds and Northeast Trenches. Recent valley fill alluvium occurs in the active stream channels of Walnut and Woman Creeks. This material is derived from reworked older alluvial and bedrock deposits.

The Cretaceous age Arapahoe Formation unconformably underlies the surficial material at OU 2. The Arapahoe Formation, which is approximately 46 meters (150 feet) thick (EG&G 1991a) in the vicinity of RFP, is the product of a fluvial depositional environment and is composed of channel point bar and overbank fluvial deposits of claystones, siltstones, sandstones, and occasional lignitic coal seams and ironstones. The Arapahoe occasionally outcrops along Walnut and Woman Creeks stream valleys.

The sandstones of the Arapahoe are primarily very fine to coarse grained quartz sands, moderate to well sorted and subangular to well rounded. Some clay rip up clasts and iron nodules are present in the sandstones of the Arapahoe Formation. The colors of the sandstone are light gray to olive gray. The weathered sandstones are mainly dusty yellow to dark yellowish orange as a result of iron oxide staining. The colors of the claystones are light to medium gray and dark yellowish orange when weathered. Individual sandstone lenses which comprise the fluvial facies of the Arapahoe are local in extent and may or may not be in hydraulic communication with one another. Multiple overlapping sandstone sequences exist within the Arapahoe Formation (EG&G 1992a).

The No. 1 Sandstone channel unconformably underlies the Rocky Flats Alluvium and colluvium and is generally located in the northwest side of the 903 Pad Mounds and Northeast Trenches areas of OU 2. The No. 1 Sandstone is a heterogeneous sandstone body consisting of sandstone with interbedded siltstone and claystone layers. Medium to coarse grained sand and an occasional conglomeratic sandstone have been identified at the base of the No. 1 Sandstone in OU 2. The unit ranges from 0 to 12 meters (0 to 40 feet) in thickness.

The Laramie Formation is Cretaceous in age and gradationally underlies the Arapahoe Formation at OU 2. The Laramie Formation, which is approximately 244 meters (800 feet) thick (EG&G 1991a) in the vicinity of RFP, is divided into two units. The lower

unit which is approximately 76 meters (250 feet) thick, is composed of several sandstone layers and many coal seams. The upper unit which is approximately 168 meters (550 feet) thick is composed of deltaic claystones, siltstones, some fluvial sandstones, and an occasional coal layer. The sandstones in the lower unit are light to medium gray, fine to coarse grained, poorly sorted, and subangular. The upper unit claystones and siltstones are light olive gray to olive black in color with some carbonaceous material.

## **2.5 HYDROLOGY**

### **2.5.1 Upper Hydrostratigraphic Unit (UHSU)**

The upper hydrostratigraphic unit (UHSU) at OU 2 consists of the Rocky Flats Alluvium, colluvium, valley fill, and the Arapahoe No. 1 Sandstone. In addition, limited areas of subcropping claystone may be saturated, particularly where the claystone is fractured and weathered (EG&G 1991b). Groundwater in the UHSU exists under unconfined conditions. Groundwater flow across the area is generally west to east, but local variations occur. Groundwater in the Rocky Flats Alluvium will locally follow the scoured lows on the top of the underlying claystone bedrock, while flow in the No. 1 Sandstone is controlled by the geometry of the sandstone body (EG&G 1991b). Groundwater in the colluvium mantling the valley slopes bordering OU 2 has a localized flow toward Walnut and Woman Creeks.

Recharge to the UHSU beneath OU 2 is primarily due to precipitation, snowmelt, and water loss from ditches, streams, and ponds. Groundwater levels in the aquifer respond dynamically to seasonal changes and stream and ditch flow. Groundwater levels reach their highest in the spring and early summer and decline the remainder of the year, with periodic changes due to precipitation or irrigation events.

Groundwater discharge in the UHSU occurs at seeps and springs at the contact between the Rocky Flats Alluvium or the No. 1 Sandstone and the claystone bedrock. This water is consumed by evapotranspiration or flows downslope through the colluvial deposits where it primarily discharges to Walnut Creek (northeast of OU 2). Minor discharge to the south interceptor ditch (SID) (southeast of OU 2) and Woman Creek (south of OU 2) also occurs, or groundwater is consumed by evapotranspiration (EG&G 1991b).

Phase I data indicate that chemicals in groundwater are localized in the UHSU below OU 2. Additional characterization of the vertical and horizontal extent of the contamination plume below OU 2 is currently being investigated under Phase II activities. Phase II activities will also provide additional information that will enable a better definition of groundwater movement and better define groundwater/surface water interactions in the OU 2 area (EG&G 1991a).

### **2.5.2 Confined Groundwater Flow Systems**

Groundwater under confined conditions beneath OU 2 occurs in the Laramie Formation. Flow within individual sandstones is generally from west to east (Robson et al 1981) but the geometry of the groundwater flow path is not fully understood due to a present lack of information on the continuity of the sandstones and their hydraulic connection (EG&G 1991b). Recharge to this system occurs at outcrop areas exposed to surface water flow and infiltration at outcrops along the Front Range located approximately 2.4 kilometers (1.5 miles) west of the western edge of OU 2. The confined groundwater system is hydraulically disconnected from the UHSU at OU 2 by an impermeable claystone that varies from 15 to 30 meters (50 to 100 feet) in thickness (Robson et al 1981).

### **2.5.3 Surface Water**

Surface water at RFP is currently managed and monitored in accordance with the RFP's surface water management plan (EG&G 1991e). The surface water management program at the RFP, which includes a National Pollutant Discharge Elimination System (NPDES) permit, is designed to protect public health and the environment from chemicals that may occur in surface water. This program has been approved by the EPA to provide for treatment of surface water, if necessary, prior to release from the RFP.

Two intermittent streams, Walnut Creek and Woman Creek, are located in the vicinity of OU 2 and generally flow from west to east. Walnut Creek, north of OU 2, flows through a series of detention ponds (A and B series) and is currently diverted around Great Western Reservoir via the Broomfield Diversion Ditch. Woman Creek, south of

OU 2 discharges into Mower Reservoir and Standley Lake. These streams are ephemeral because of the seasonal response to freezing spring runoff and storm events.

Intermittent groundwater seeps or springs occur near IHSS 140 in the 903 Pad Area, IHSS 154 in the Mound Area, and northeast of the East Trenches Area, along the south side of the Walnut Creek drainage. These areas are currently being remediated as Interim Measures at the RFP (EG&G 1991c). Collected surface water will be treated using cross flow membrane filtration (for particulate radionuclide removal) followed by liquid phase granulated activated carbon (GAC) filtration (for organics removal). These Interim Measures will eliminate the potential contribution of site related chemicals from these seeps to surface water in the Walnut and Woman Creek drainages.

Figure 2.2 illustrates the current surface water bodies in the Woman and Walnut Creek drainages. Detention Ponds C 1 and C 2 are located on Woman Creek. Pond C 2 receives flow only from the South Interceptor Ditch (SID) which lies on the northern flank of the Woman Creek drainage between OU 2 and Woman Creek. The SID collects runoff from the southern RFP security area including portions of OU 2. The Pond C 2 flow is not discharged to Woman Creek but is pumped to the Broomfield Diversion Ditch approximately semi annually in accordance with the current surface water management program per EPA approval.

Detention Ponds B 1 through B 5 are located on South Walnut Creek and receive surface and groundwater flows from the northern portion of OU 2. Surface water in the Walnut Creek drainage is monitored in accordance with RFP's surface water management plan (EG&G 1991e) and National Pollutant Discharge Elimination System (NPDES) permit prior to treatment (if required) and discharge from B 3 and B 5.

#### **2.5.4 Domestic Wells Along the South Walnut and Woman Creek Drainages**

The groundwater in the UHSU beneath OU 2 is discharged by seeps and springs along the contact between the Rocky Flats Alluvium/Arapahoe No. 1 Sandstone and the underlying bedrock claystones. This water eventually enters the valley fill along the adjoining creeks and migrates downgradient. Off site wells located in the drainages of

Walnut and Woman Creeks are therefore of particular interest since groundwater in OU 2 discharges into these drainages

Walnut Creek which is the primary drainage for OU 2 flows eastward and is currently diverted around Great Western Reservoir. Land surrounding the creek drainage outside the RFP boundary and reservoir is used as open space and does not contain residential or commercial developments. No water wells are registered at the Colorado State Engineer's (CSE) office for this area.

Woman Creek drains the southern portion of OU 2 and discharges into Mower reservoir and Standley Lake. Fourteen wells west of Standley Lake are registered in this drainage (Figure 2.5). Table 2.1 lists information from completion reports for these wells that are on file at the CSE 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 RFP 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 suggest that a hydraulic connection to the alluvium along Woman Creek is unlikely. Also there are indications that the off site wells may be hydraulically connected to Standley Lake a large source of potential recharge (DOE 1992).

## 2.6 ECOLOGY

The following section presents a brief summary of biological resources at the RFP and is not intended to characterize ecological processes. A more detailed evaluation of ecological processes and potential environmental impacts at the RFP will be presented in the Environmental Evaluation portion of the BRA. The scope of this Technical Memorandum is limited to the evaluation of exposure pathways for the HHRA.

OU 2 contains diverse and unique vegetation. Species of flora representative of tall grass prairie, short grass plains, lower mountain, and foothill ravine regions can be found within the boundaries of RFP. Grasses predominantly cover the steep sides of the hillsides along Walnut Creek and Woman Creek drainages. The Walnut Creek and

Woman Creek drainages also host grasses cattails rushes and cottonwood trees Since the acquisition of RFP vegetative recovery has occurred as evidenced by the presence of disturbance sensitive grass species such as big bluestem and side oats grama No vegetative stresses attributable to hazardous waste contamination have been identified (EG&G 1991b)

The animal life inhabiting RFP and the buffer zone consists of species associated with western prairie regions The most common large mammal is the mule deer of which there are approximately 125 permanent residents A number of small carnivores such as coyote red fox striped skunk, and long tailed weasel are present at RFP The bird population at RFP includes the western meadowlark, mourning doves, vesper sparrows, great horned owl, and ferruginous and American rough legged hawks Many varieties of ducks killdeer and redwing blackbirds have been observed near the ponds on Woman and Walnut Creeks Minnows have been observed in both creeks and it is possible that other fish may use the creeks but most likely this would occur only during high flow periods Bull snakes and rattlesnakes can be seen on the hillsides of OU 2, while the western painted turtle and western plains garter snake inhabit the greens near the ponds

Ecological surveys at the RFP performed in compliance with the Threatened and Endangered Species Act indicate the presence of habitat that is potentially suitable to four plant species and several wildlife species of concern The plant species include the forktip threeawn, Colorado butterfly plant toothcup and Diluvium lady s tresses (EG&G 1991d) The wildlife species include the bald eagle, peregrine falcon, whooping crane, and the black footed ferret (DOE 1991 USFWS 1990) Because of the unique and undisturbed nature of the buffer zone it is possible that it will receive future designation as an ecological reserve or as a National Environmental Research Park This is consistent with DOE policy and plans (DOE 1992) and with Jefferson County (Jefferson County 1990) planning as detailed in Section 3 0

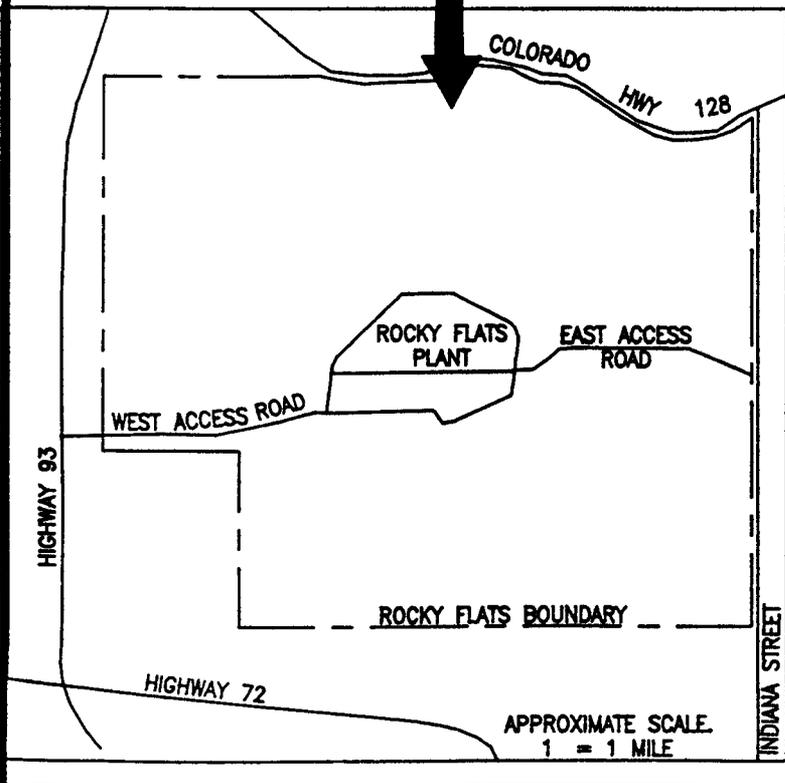
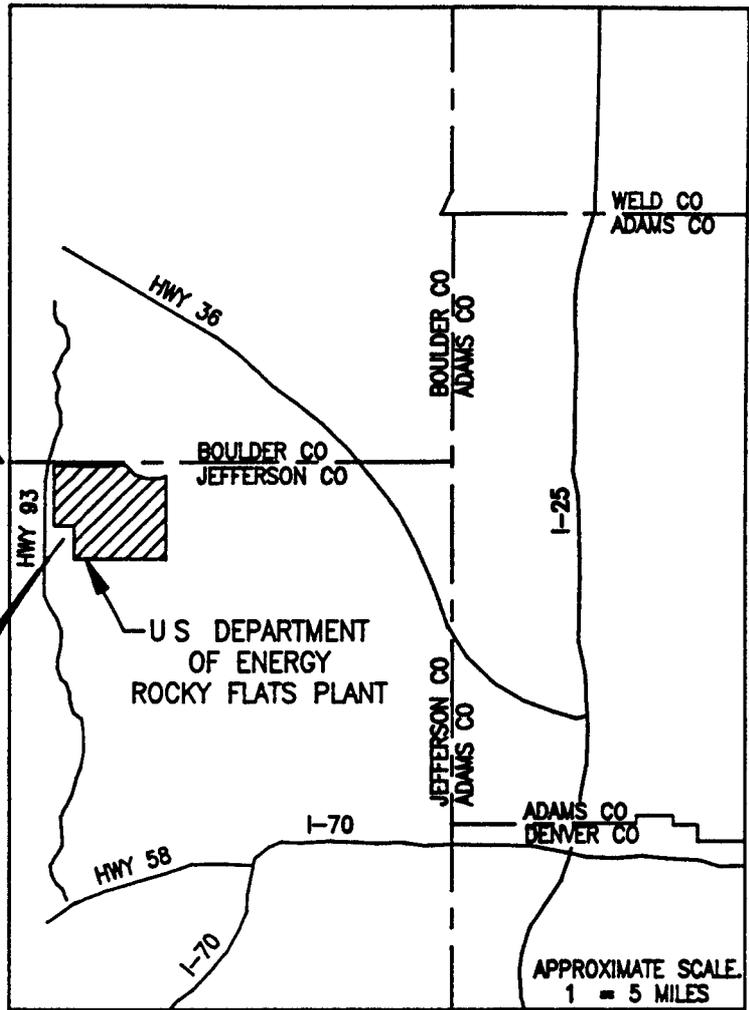
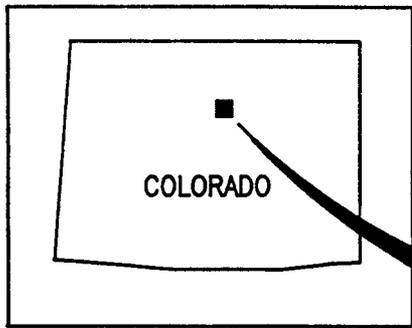
**TABLE 2 1**  
**WELLS NEAR WOMAN CREEK\***

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				

\* Source Colorado State Engineer s Office

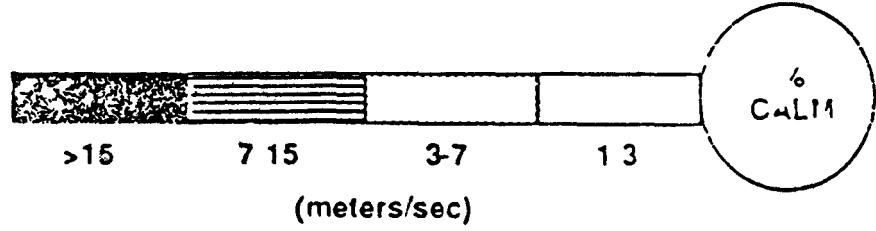
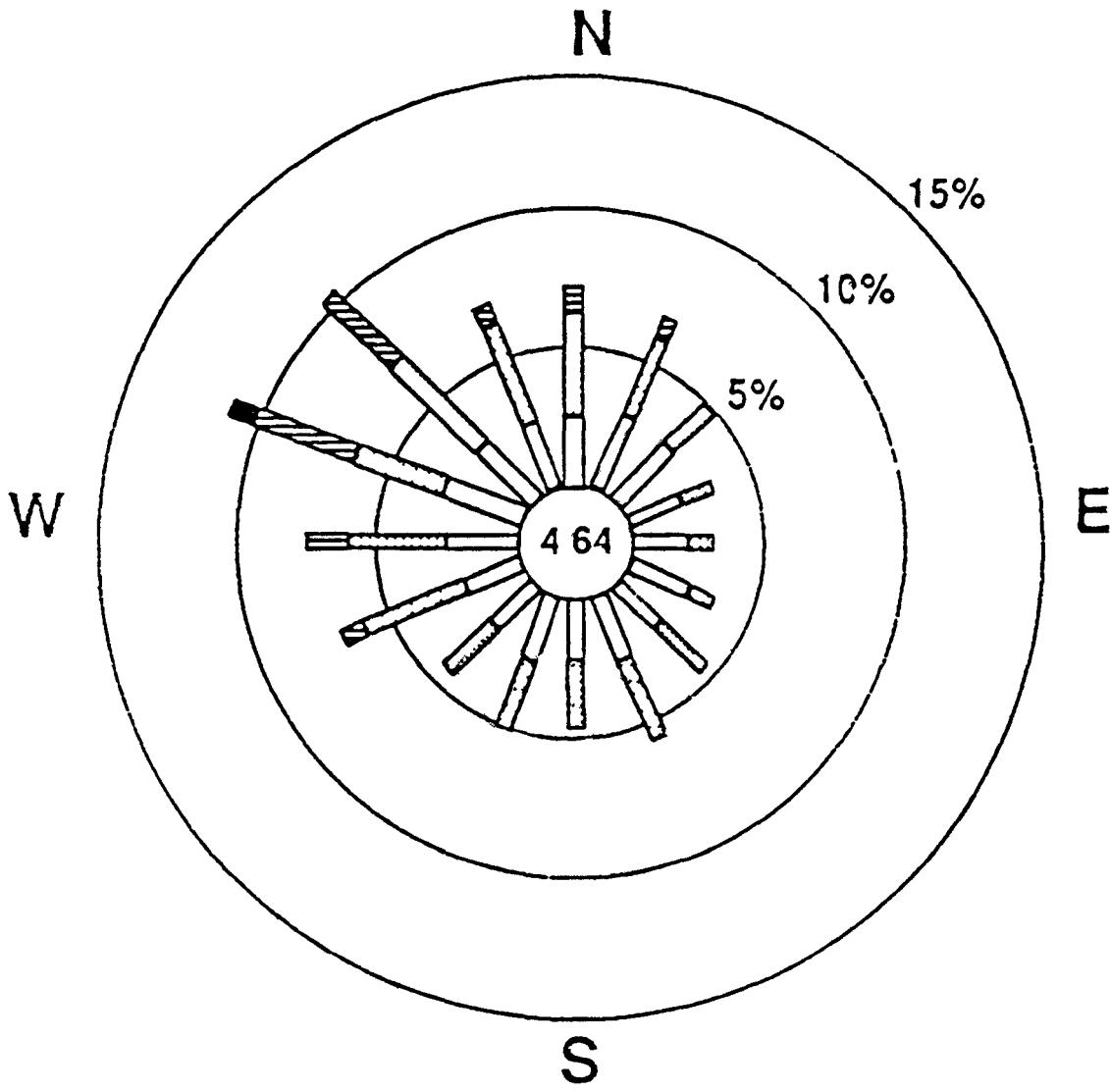
\*\* Based on drillers observations Does not indicate sustainable well yields

Source DOE 1992



U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant Golden, Colorado  
OPERABLE UNIT 2  
PHASE II RFI/RI  
EXPOSURE ASSESSMENT  
TECHNICAL MEMORANDUM  
GENERAL LOCATION OF  
ROCKY FLATS PLANT

FIGURE 2-1



U S DEPARTMENT OF ENERGY  
 Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2  
 PHASE II RFI/RI EXPOSURE  
 TECHNICAL MEMORANDUM

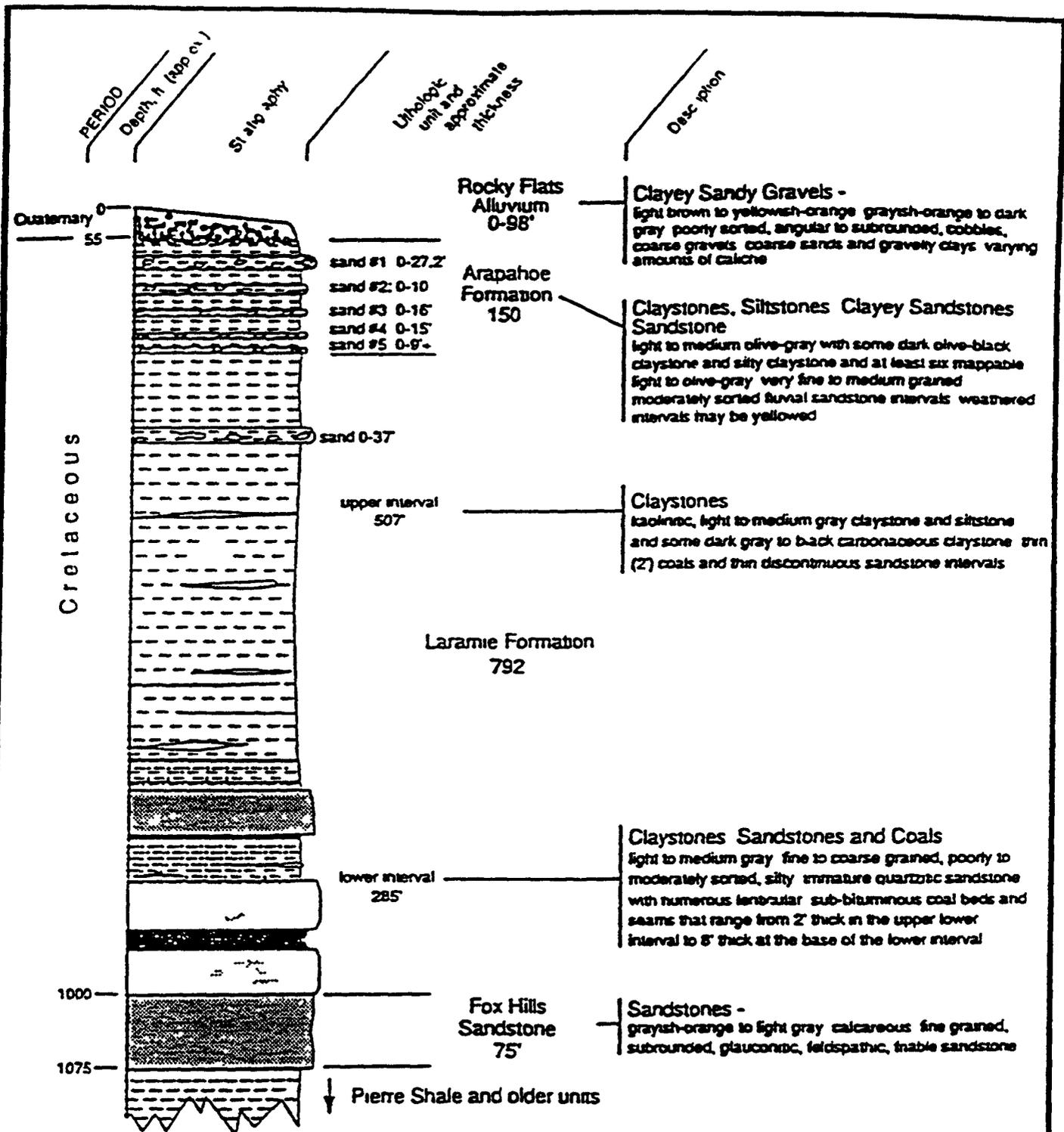
WIND ROSE FOR THE  
 ROCKY FLATS PLANT  
 1990 ANNUAL

SOURCE EG&G 1990

FIG NO 2-3

JUNE 1992

23047023



**LEGEND**

- |  |  |   |
|--|--|---|
|  Alluvium                           |  Fine-grained sandstone |  Siltstone and claystone |
|  Fine-grained and coarser sandstone |  Silty sandstone        |  Coal                    |

U.S. DEPARTMENT OF ENERGY  
Rocky Flats Plant Golden, Colorado  
OPERABLE UNIT 2  
PHASE II RFI/RI EXPOSURE  
TECHNICAL MEMORANDUM

NEAR SURFACE  
STRATIGRAPHIC SECTION

Modified from LeRoy & Werner 1971 and Werner 1973

FIGURE 2-4 6/92

**POTENTIALLY EXPOSED RECEPTOR POPULATIONS**

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The potentially exposed populations were characterized primarily using the 1989 Population, Economic, and Land Use Data for Rocky Flats Plant (DOE 1990), developed by the Denver Regional Council of Governments (DRCOG). This DRCOG study encompassed an 81 kilometer (50 mile) radius area from the center of Rocky Flats Plant and included all or part of 14 counties and 72 incorporated cities with a 1989 combined population of 2,206,550.

**3.1 DEMOGRAPHICS**

The Rocky Flats Plant is located in a rural area of unincorporated Jefferson County approximately 16 miles northwest of Denver and approximately 10 miles south of Boulder. RFP is situated on a 6,550 acre parcel of federally owned land. The plant facility is located in the approximate center of the parcel and is surrounded by a buffer zone of approximately 6,150 acres. The area to the west of RFP is mountainous, sparsely populated and primarily government owned. The area east of RFP is generally a high arid plain, densely populated and privately owned. The majority of the population included in the DRCOG study is located within 30 miles of RFP to the east and southeast in the Denver metropolitan area. The majority of the development of the plains to the east of RFP has occurred since the plant was built and according to projections by DRCOG future development is expected to continue (DOE 1992).

Within a 6.4 mile radius of the center of RFP there is little residential or commercial development. Between 4 and 10 miles development increases with approximately 316,000 residents within a 10-mile radius. The most significant development exists to the southeast in the cities of Westminster, Arvada, and Wheat Ridge. The cities of Boulder to the northwest, Broomfield, Lafayette and Louisville, to the northeast, and Golden, to the south also contain significant developments within this 10-mile radius (DOE 1992). The DRCOG study projected populations through the year 2010.

Figure 3 1 (DOE 1990) illustrates the 1989 residential population found within an 8 kilometer (five mile) radius of RFP. The 2010 projected residential population is illustrated in Figure 3 2 (DOE 1990). Sectors 1 and 2 represent land within the RFP boundary and therefore, are relevant to on site scenarios. Sectors 3, 4, and 5 represent property outside of the RFP boundary and are relevant to off site scenarios. Radial Segments D through I represent the predominant downwind and downstream directions from the OU 2 area and, thus, the areas relevant to exposure scenarios. The 1989 and projected 2010 population data shown in Figures 3 1 and 3 2 are summarized in Table 3 1. The information presented in Table 3 1 indicates that zero population growth is projected in the next 20 years for areas immediately adjacent to the RFP boundary (Sector 3).

The nearest school is Witt Elementary School which is approximately 2.7 miles east of the RFP buffer zone (EG&G 1991a). All other sensitive subpopulation facilities (e.g. hospitals and nursing homes) are located beyond the five mile radius from the center of RFP. There are 93 schools, eight nursing homes, and four hospitals within a 10 mile radius of RFP (DOE 1992).

The nearest drinking water supply is Great Western Reservoir located approximately 2.3 miles to the east of the center of RFP. The City of Broomfield operates a water treatment facility immediately downstream from Great Western Reservoir. This facility supplies drinking water to approximately 28,000 persons. Standley Lake Park, a recreational area and a drinking water supply for the cities of Thornton, Northglenn, Westminster, and Federal Heights, is located 3.5 miles to the southeast of RFP. From the reservoir, water is piped to each city's water treatment facilities. Boating, picnicking, and limited overnight camping is permitted at Standley Lake Park.

## **3.2 OFF SITE LAND USE**

### **3.2.1 Current**

Current land use in the area surrounding RFP is shown in the Jefferson County Land Use Inventory Map (Figure 3 3) and the Boulder County Road Map (Figure 3-4). Table 3 2 is a summary of land use corresponding to the Jefferson County Land Use Map. In

general current land use surrounding RFP includes open space (recreational) agricultural residential and commercial/industrial The northeastern Jefferson County and RFP area is currently one of the most concentrated areas of industrial development in the Denver metropolitan area (Jefferson County 1989)

Current land use in the area relevant to the OU 2 exposure scenarios (immediately southeast of RFP and OU 2) includes all of the uses mentioned above, with the predominant uses appearing to be open space single family detached dwellings and horse boarding operations Two small cattle herds (approximately 10 to 20 cattle in each herd) were observed one to the southeast where 96th Avenue turns into Alkire and crosses Woman Creek and one to the east of RFP between Alkire and Simms Streets and north of 100th Avenue Industrial facilities within the relevant area, to the south, include the TOSCO laboratory Great Western Inorganics Plant, and Frontier Forest Products (EG&G 1991a)

### 3.2.2 Future

Future land use generally follows existing land use patterns Jefferson County in its Northeast Community Profile (Jefferson County 1989) a socio economic study of its northeastern area, developed a baseline profile of growth and land use in the area Using the baseline profile and historic trends future scenarios were developed As a result of this study Jefferson County expects that industrial land uses will continue to dominate the northeastern portion of the county Along with the increase in industrial development, the county expects income and employment growth to increase dramatically while household and population growth is expected to increase only moderately In other words with industrial growth, employment opportunities are expected to increase yet, as the land is developed for industry the availability of land for residential development decreases and as a result, household and population growth will be limited

Industrial and commercial development of the area is attractive to businesses and developers for several reasons (1) the availability of undeveloped and, therefore, lower cost lands (2) the lower taxes associated with locating in an unincorporated portion of

the county, and (3) the future alignment of W 470 a segment of proposed highway providing access to the area

The completion of W-470 encircling the entire Denver metropolitan area, is expected to have significant impacts on growth in the area. The highway, in its proposed alignment will skirt the southern and eastern boundaries of RFP. Commercial growth particularly light industrial and office development, is expected to occur along the highway (Jefferson County 1989)

Residential development is not as attractive as industrial development of the area for several reasons including the proposed alignment of W-470 the proximity to Jefferson County Airport and the current industrial nature of the area. The decreased desirability of living near a major highway or an airport for traffic and noise reasons, is a deterrent to residential development. The proximity of RFP and the general industrial nature of the area also decreases the desirability of housing in the area.

Future land use in the area is 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. Representatives of Jefferson County and 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 cooperatively developed this plan. The plan identifies the Rocky Flats Plant and the Jefferson County Airport as constraints to future residential development in the area, and recommends office and light industrial development. The plan further identifies the acquisition of lands 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).

The North Plains Community Development Plan Study Area Summary Map (Figure 3.5) and the Jefferson Center Comprehensive Development Plan (Figure 3.6) show that the predominant future land uses to the south and southeast of RFP will consist of commercial, industrial and office space. Directly to the east, the zoning and usage are expected to remain open space and agricultural/vacant. As illustrated in these maps, the

areas closest to RFP are planned for industrial commercial or office space with the areas further from RFP designated for residential development This planning is consistent with the projected residential growth rate of zero in the next 20 years for areas immediately adjacent to the RFP (DOE 1990)

To the north of RFP, in Boulder County the predominant land uses include open space, park land and industrial development as shown in Figure 3-4 Two areas adjacent to RFP 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)

The above information indicates that current land use in the immediate vicinity of the RFP is primarily commercial/industrial and that such land use will continue into the future It is therefore likely that the potential for residential development in this area will be impeded by the growth of business and industry that is expected to occur

### **3.3 ON SITE LAND USE**

#### **3.3.1 Current**

Rocky Flats Plant production and maintenance activities do not occur in the OU 2 area The 903 Pad portion of OU 2 is capped A large portion of OU 2 is located within the buffer zone, outside of the security fence and protected area (PA) Current activities in OU 2 consist of environmental investigations and routine security surveillance RFP is currently planning for decontamination and decommissioning (D&D) which is expected to begin in the near future

#### **3.3.2 Future**

Future plans for RFP activities are discussed in the Nuclear Weapons Complex Reconfiguration Study The two preferred reconfiguration options in the study include relocation of RFP functions (DOE 1992) Future land use alternatives are discussed in the RFP Site Wide Environmental Impact Statement (EIS) There are four

alternatives that are addressed in that document including the no action alternative. These alternatives which may be subject to change are summarized below (DOE 1992)

- The no action alternative involves completing nuclear production upgrades, maintenance of production standby and compliance with the IAG environmental restoration (ER) commitments
- Alternative 1 involves nuclear production at reduced levels, compliance with IAG ER commitments and placement of surplus facilities into safe storage. Due to the recent decision to implement decontamination and decommissioning (D&D) at RFP, this alternative is no longer considered viable.
- Alternative 2 allows nuclear production at up to 1989 levels, increased non nuclear production, placement of surplus facilities into safe storage and completion of ER by 2020. Due to the recent decision to implement D&D at RFP, this alternative is no longer considered viable.
- Alternative 3 involves transition to no production of nuclear or non nuclear components, completion of ER by 2020, D&D of selected facilities, and placement of other facilities into safe storage.

Occupation by private industry is planned for the future use of the on site production areas at RFP according to a June 12, 1992, speech by Secretary of Energy James Watkins. Watkins characterized RFP as an attractive site for manufacturers and other businesses (Denver Post, June 13, 1992). Private industry could relocate to existing buildings and use existing equipment at RFP after necessary decontamination is complete (Boulder Camera June 13, 1992). One organization working to achieve this objective is the Rocky Flats Local Impacts Initiative (RFLII). This group is comprised of representatives from local businesses and government agencies and has been formed to develop a strategy to transform future changes at the RFP into economic, socioeconomic, educational, land use, environmental and infrastructural advantages. One of this group's goals is to work with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the RFP (RFLII 1992).

When the AEC acquired the undeveloped land surrounding the production area it established plans to preserve the land as open space (AEC 1972) With the present open space located nearby, it is plausible that the buffer zone and OU 2 area will be preserved as open space The buffer zone is being considered as a potential ecological preserve or National Environmental Research Park

There are at least three reasons why Rocky Flats would make an exceptional environmental research area First, the site presents an excellent sample of a shortgrass prairie/montane ecotone Second it also provides an almost unique opportunity to conduct environmental research in an area which abuts a major metropolitan area Third the site has an abundance of wetlands and would be an excellent outdoor laboratory for a variety of wetland related ecological research (Knight 1992)

Ecological surveys of the buffer zone performed in compliance with the Threatened and Endangered Species Act, may indicate the presence of several listed species at the RFP Additional threatened and endangered species 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 (EG&G 1992b) Because the buffer zone 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) In addition, this type of site use is consistent with the Jefferson County Planning Department's recommendations for the provision of large amounts of undeveloped land in the area (Jefferson County 1990)

Extensive development of the area is unlikely due to the historical use of RFP the potential for conversion of the buffer zone into an ecological preserve the limited availability of water 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) Much of the area, approximately 25 percent in the eastern RFP property are at or approaching this grade

The limited availability of water is also a factor affecting development of the RFP area, as with all of the Denver metropolitan area. The Denver Water Board controls most of the metropolitan water supply and currently provides much of the suburban area's water. The Denver Water Board, however, is under no obligation to supply water to the suburbs, making the future supply questionable (Jefferson County 1989). Due to the quantity of industrial development expected in the area surrounding RFP, it is expected that competition for water will exist. In addition, existing facilities within the RFP are already served by municipal water supplies from the City of Golden, increasing the likelihood that existing structures will be targeted for use by industry and businesses.

In summary, residential development of the area is highly unlikely due to the industrial nature of the RFP site, the general industrial nature of the area, and the proximity of the proposed W-470 corridor and Jefferson County Airport. Future residential land use is inconsistent with current Jefferson County and DOE land use plans for the area. Future land use generally follows existing land use patterns and would likely involve industrial/office or open space uses.

#### **3.4 RECEPTORS SELECTED FOR QUANTITATIVE RISK ASSESSMENT**

Human populations on and near the site were evaluated to assess their likelihood of exposure to site-related chemicals of concern. EPA guidance does not require an exhaustive assessment of every potential receptor and exposure scenario (EPA 1992). Rather, the highest potential exposures that are reasonably expected to occur (reasonable maximum exposures) should be evaluated along with an assessment of any associated uncertainty (EPA 1989a). 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 chemicals.

Receptor populations selected for evaluation in the human health risk assessment at RFP are summarized in Table 3.3 and include current and future off-site residents, future on-site workers, and future on-site ecological researchers. Each of these receptors is described in further detail below. The receptor locations are shown in Figure 3.7. The areas and/or exposure points presented in Figure 3.7 were selected to reflect the most reasonable locations where chemical exposures are expected to occur for each of

the receptors. These areas are reasonably consistent with current and future land use at the site and depict locations where each of the respective human receptors are expected to spend the majority of their time. The exposure area for the industrial worker includes all IHSS s for OU 2. The exposure area for the ecological researcher is bounded by Woman and South Walnut Creeks and the entire buffer zone included in OU 2. The areas presented in Figure 3.7 were selected to provide an accurate evaluation of potential chemical intakes in each of the receptors identified. Using collected data and fate and transport modeling at these locations, as appropriate, the exposure point concentrations will be used to quantitatively evaluate chemical intakes for receptors at the selected locations.

#### **3.4.1 Current and Future Off Site Residents**

The human health risk assessment will evaluate current off site residents at existing locations since the public is restricted from access to RFP, and access to OU 2 is generally limited to on site workers. Present levels of security at the RFP include secure fencing, frequent armed security patrols, and modern electronic security and surveillance systems. Fencing is posted to warn potential intruders that they are trespassing on federal property and, if caught, will be arrested. Plant security personnel report that there have been no incidents of trespassing in the buffer zone in the past seven years. Thus, even if trespassing were to occur at the RFP, it is highly unlikely that such events would occur repeatedly for the same individual.

This scenario will evaluate the reasonable maximum risk to the present population both now and in the future. Based on the future industrial/commercial land use plans for the area, hypothetical future residents will be evaluated off site in the vicinity of existing residential areas due to the existence of current residences. These future residents will be quantitatively evaluated at the site boundary where Woman and Walnut Creeks leave the RFP site. These locations will correspond to the most reasonable locations for maximum exposures due to their proximity to the site, the direction of prevailing winds, and the proximity of surface water bodies originating on site. Since residents are likely to spend the greatest amount of time at or near their home, the residential scenario will represent the maximum frequency and duration of exposure that is reasonably expected to occur.

### 3.4.2 Future On Site Worker

The human health risk assessment will evaluate future on site workers. Based on the future industrial development plans in the area, the worker will be assumed to be an industrial or office worker. The location of this receptor is shown in Figure 3.7. This location is in the direct vicinity of existing facilities at the RFP and their corresponding utilities and services. Future use of the RFP as a business or industrial center will undoubtedly focus on use of the existing infrastructure. It is expected that desirable locations for future development of commercial facilities will be in close proximity to existing structures and utilities. The location designated for on site worker represents a reasonable exposure area for that receptor. Since the health and safety of on site workers is presently monitored under a comprehensive health and safety program at RFP, potential exposures to current on site workers will not be evaluated in the risk assessment. The health and safety programs and policies are discussed in more detail below.

Health and safety (H&S) activities at RFP are directed by the Associate General Manager for 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). An organizational chart is provided in Figure 3.8. For environmental restoration work at RFP, EG&G (Rocky Flats Plant) and DOE have adopted the Federal Occupational Safety and Health Administration's (OSHA) 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 RFP, H&S programs are written for everyday activities as well as 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 RFP to support the H&S plans and programs, including radiation protection, emergency response, occupational safety, vehicular and pedestrian safety, fire protection, and contractor safety (EG&G 1992c). The written programs contain the requirements and procedures to be followed to ensure

a work environment that is free from exposure to chemical, physical and biological hazards (EG&G 1992c) 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 RFP personnel are trained in personal hygiene and safety use of protective clothing and emergency response procedures The health and safety of current workers at RFP is thoroughly monitored with required baseline annual and exit physical examinations The exposure of these workers to chemicals of concern is controlled and limited by monitoring to acceptable levels and is ensured by reporting requirements In light of these thorough health and safety programs the current on site worker will not be quantitatively evaluated in the human health risk assessment

A future on site worker not protected by a similar health and safety program (i e no action) will be quantitatively evaluated This worker is assumed to be unprotected and untrained in health and safety matters Based on the future industrial development plans for the area the future on site worker is assumed to be an industrial or office worker at an appropriate facility This setting is likely to have extensive paved areas and well maintained landscaping This evaluation will be performed since all future land uses point to this setting as the most probable future land use of the industrial area of RFP

### **3 4 3 Future On Site Ecological Researcher**

Since the future use of the on site non production areas at RFP will most likely involve an open space/ecological reserve scenario this scenario will be evaluated for the area outside of the OU 2 IHSSs The receptors in an open space scenario would include day hikers and a research biologist/ecologist conducting area studies Of these two potential receptors the research biologist is likely to spend more time at the site and come in close contact with the soils plants and surface water as specimens are studied Field work may involve kneeling or lying on bare ground or vegetation, and contacting site soils sediments and surface water The day hiker would most likely spend less time at the site and come in less contact with the site s soils and surface water Therefore the most reasonable receptor in this setting is the hypothetical future ecological researcher The area applicable to this receptor is shown in Figure 3 7 and includes the areas between Woman and Walnut Creeks This receptor will be quantitatively evaluated in the risk assessment

**TABLE 3 1**

**CURRENT AND PROJECTED POPULATIONS  
IN THE OU 2 EXPOSURE ASSESSMENT AREA**

Year 1989/2010						
Sector	D	E	F	G	H	I
1	0/0	0/0	0/0	0/0	0/0	0/0
2	0/0	0/0	0/0	0/0	0/0	0/0
3	0/0	0/0	0/0	17/17	0/0	7/7
4	0/14	283/644	46/142	50/50	215/1007	3/3
5	25/25	3671/5009	477/601	578/1879	2355/10186	469/2124

Source        DOE 1990    1989 Population, Economic and Land Use Data for Rocky  
                 Flats Plant

**TABLE 3 2**  
**ROCKY FLATS PLANT**  
**OU 2**  
**CURRENT SURROUNDING LAND USE IN JEFFERSON COUNTY**

Parcel #	Current Use/ Project Name	Zoning <sup>1</sup>	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
46006	Triple C Quarter Horses	A 2	Retail

**TABLE 3 2  
(Continued)**

Parcel #	Current Use/ Project Name	Zoning <sup>1</sup>	Land Use Type
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
72008	Water Tank Ralston Val Stn 2	I 2	Utilities

**TABLE 3 2**  
**(Continued)**

Parcel #	Current Use/ Project Name	Zoning <sup>1</sup>	Land Use Type
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
100003	Rocky Flats Vacant	I 1	Industrial

**TABLE 3 2  
(Continued)**

Parcel #	Current Use/ Project Name	Zoning <sup>1</sup>	Land Use Type
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

<sup>1</sup> Zoning Abbreviations are as follows

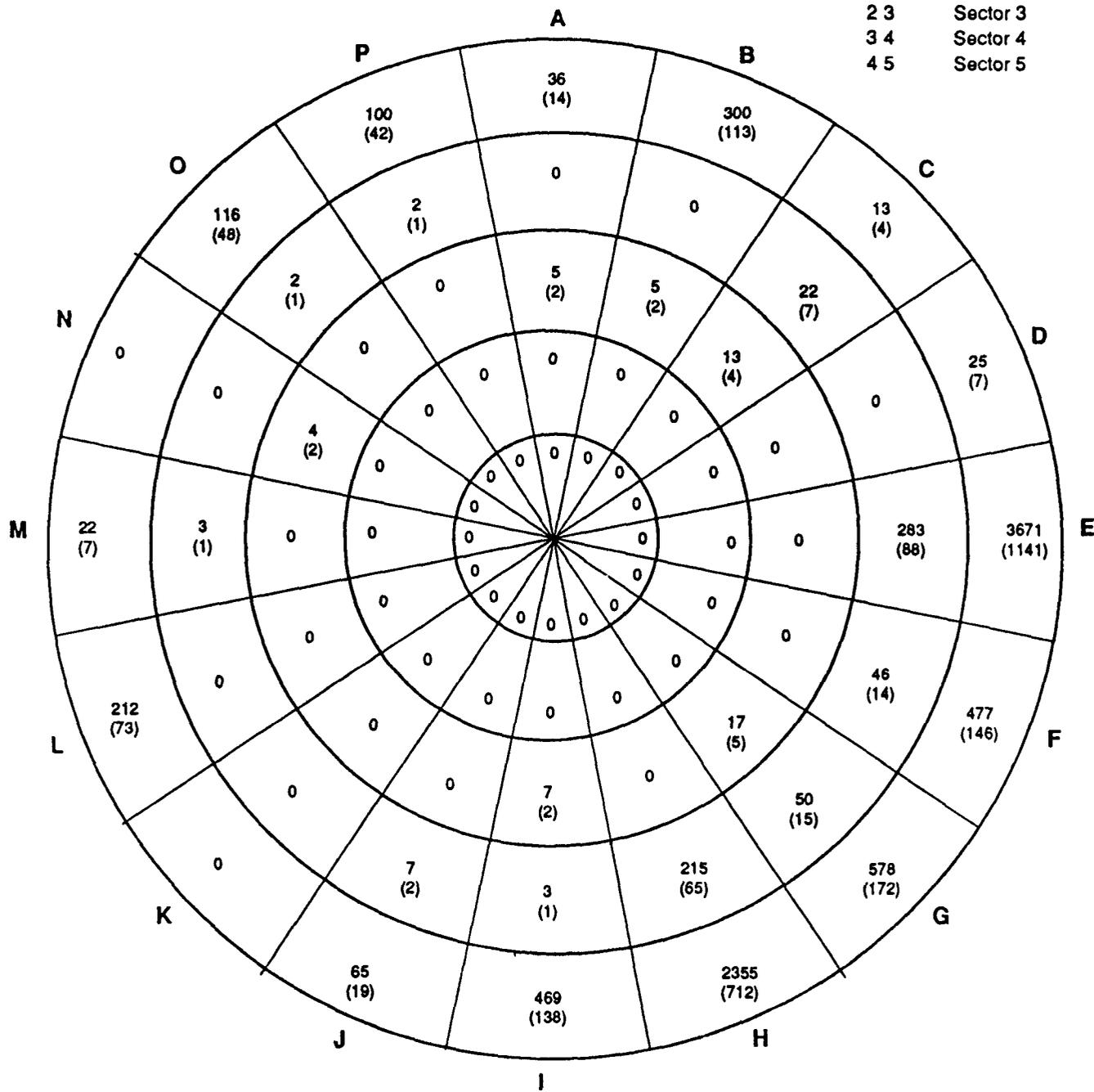
A 1	Agricultural 1
A 2	Agricultural 2
I 1	Industrial 1
I 2	Industrial 2
I 3	Industrial 3
P D	Planned Development
SR 2	Suburban Residential 2
RC	Restricted Commercial
P DA	Planned Development Amended
Source	Jefferson County

**TABLE 3 3**  
**ROCKY FLATS PLANT**  
**OU 2**  
**POTENTIALLY EXPOSED RECEPTORS TO BE QUANTITATIVELY EVALUATED**

<b>Current Scenario</b>	<b>Future Scenario</b>
Off site resident	On site worker On site ecological researcher Hypothetical off site resident

- (1) A future off site hypothetical resident will be quantitatively evaluated at the following locations
  - (a) Point at which Walnut Creek intersects the eastern Rocky Flats Plant property boundary
  - (b) Point at which Woman Creek intersects the eastern Rocky Flats Plant property boundary

Miles	Sector Name
0 1	Sector 1
1 2	Sector 2
2 3	Sector 3
3 4	Sector 4
4 5	Sector 5



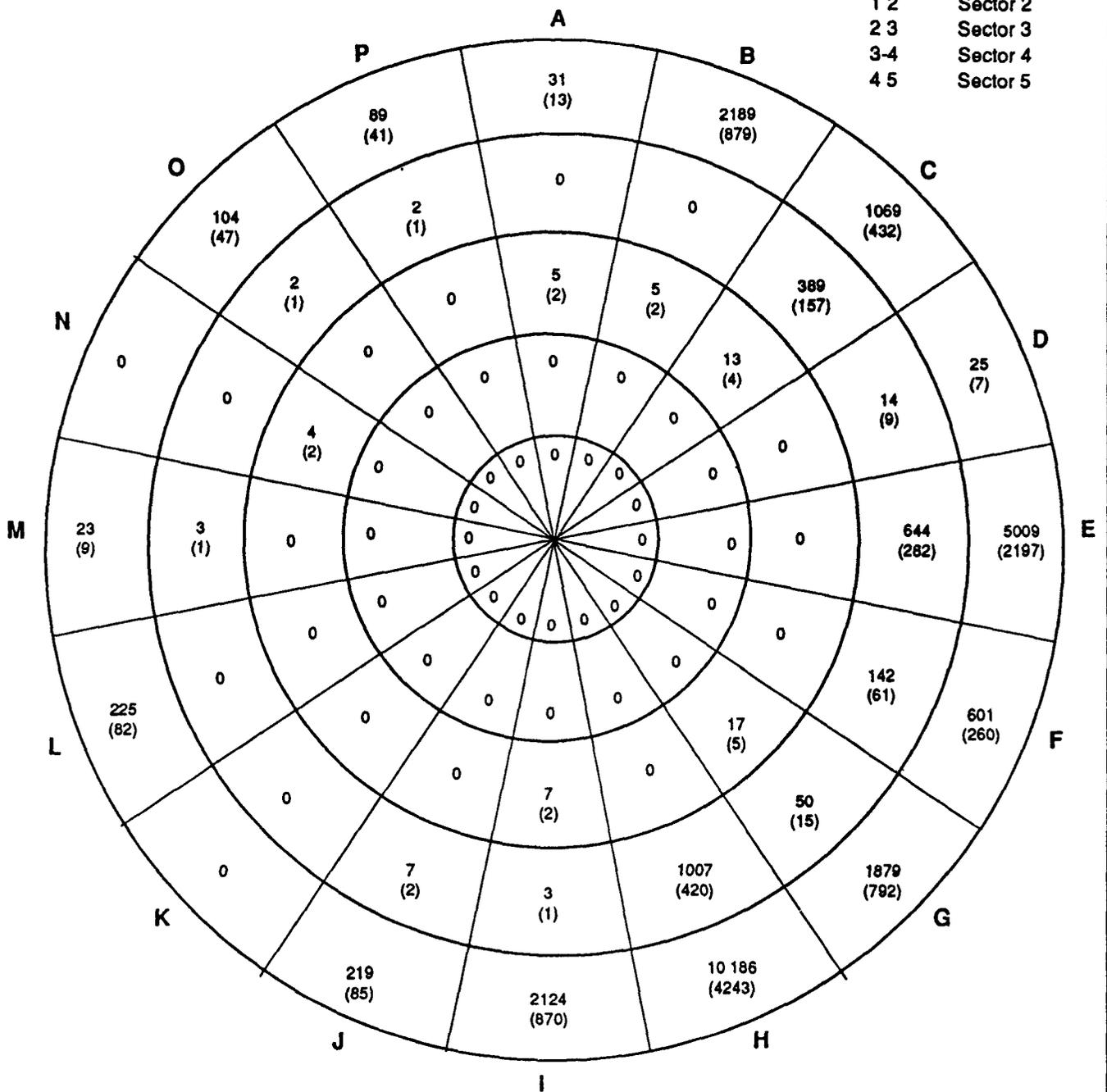
**U S DEPARTMENT OF ENERGY**  
**Rocky Flats Plant Golden Colorado**  
  
**OPERABLE UNIT 2**  
**PHASE II RFI/RI EXPOSURE**  
**TECHNICAL MEMORANDUM**  
  
**1989 POPULATION AND**  
**(HOUSEHOLDS) SECTORS 1-5**

23047031

SOURCE DOE 1990

FIG NO 3-1 JUNE 1992

Miles	Sector Name
0 1	Sector 1
1 2	Sector 2
2 3	Sector 3
3-4	Sector 4
4 5	Sector 5



U S DEPARTMENT OF ENERGY  
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2  
PHASE II RFI/RI EXPOSURE  
TECHNICAL MEMORANDUM

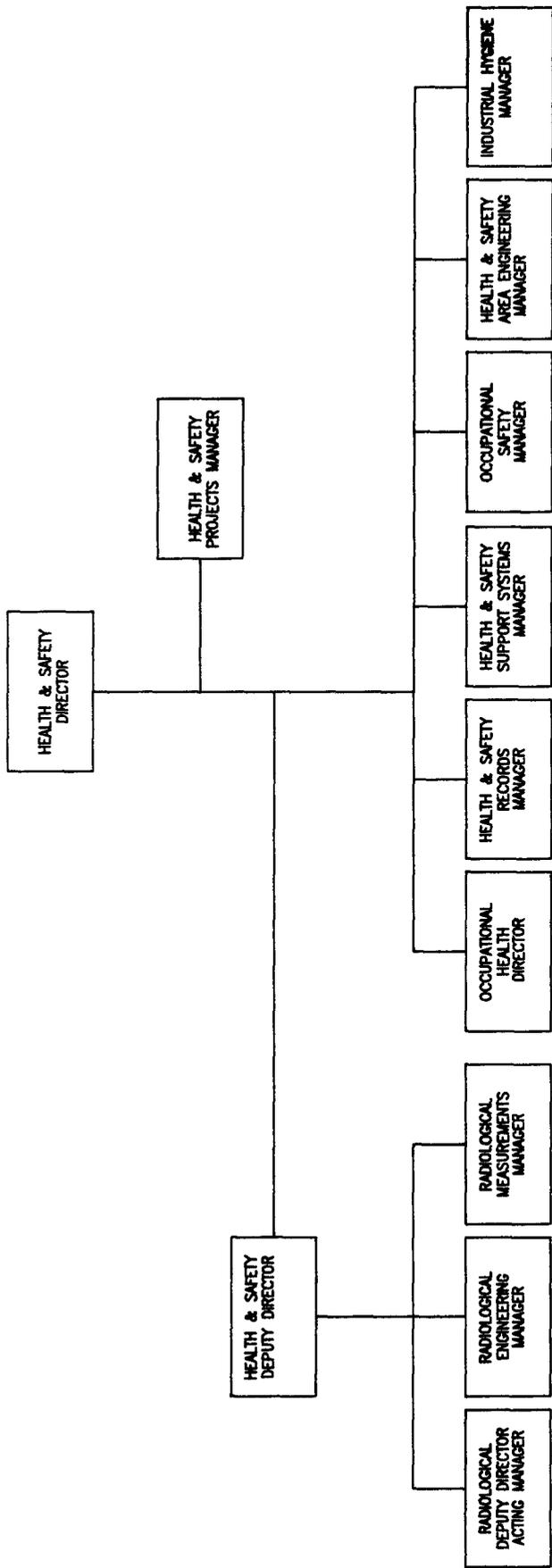
2010 POPULATION AND  
(HOUSEHOLDS) SECTORS 1-5

SOURCE DOE 1990

FIG NO 3-2

JUNE 1992

23047032



U S DEPARTMENT OF ENERGY  
 Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2  
 PHASE II RFI/RI EXPOSURE  
 TECHNICAL MEMORANDUM

EG&G ROCKY FLATS  
 HEALTH & SAFETY ORGANIZATION

**EXPOSURE PATHWAYS**

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This section discusses the potential release and transport of chemicals from OU 2 and identifies exposure pathways by which the receptor populations identified in Section 3.0 may be potentially exposed to site chemicals

An exposure pathway describes a specific environmental pathway by which an individual can be exposed to chemical constituents 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 OU 2. 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.

**4.1 CHEMICAL RELEASE SOURCES AND TRANSPORT MEDIA**

The identified site sources at OU 2 are the 903 Pad Mound and East Trenches areas. The BRA will evaluate contaminated soil at these OU 2 sites as the primary source of chemical release. A description of activities conducted at OU 2 was provided in Section 2.1. Environmental media that may transport chemicals of concern from OU 2 to exposure points are described below in the conceptual site model.

## **4.2 POTENTIALLY EXPOSED RECEPTOR POPULATIONS**

Potentially exposed receptor populations selected for quantitative assessment in the baseline human health risk assessment were characterized in Section 3.0. The following receptors were selected:

- Current off site resident
- Future on site worker
- Future on site ecological researcher
- Future off site resident

The current off site resident is evaluated under current land use conditions which assume that the RFP surface water management plan is in effect. This program includes surface water treatment as necessary prior to discharge off site. The future land use scenario assumes no action takes place at OU 2 (i.e., no surface water management plan is in place and no surface water treatment occurs) and estimates exposures for future receptor populations under this condition. Because the Interim Measures currently planned for seeps along the Walnut and Woman Creek drainages will be permanent and will therefore eliminate the potential contribution of chemicals to surface water from these locations, these seeps will be excluded from future modeling of exposure point concentrations for surface water.

## **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 reasonable maximum exposures 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 following exposure points were selected for reasonable maximum estimates of risk. These locations are shown in Figure 3.7.

### Current Scenario

- Residential receptor Nearest residence to RFP (located at the southeast corner of the RFP property boundary) and nearest residence to RFP which is in the predominant wind direction

### Future Scenario

- Occupational receptor On site within the OU 2 industrial complex
- Ecological researcher On site within RFP buffer zone east of OU 2 bounded by Woman and South Walnut Creeks
- Residential receptors Hypothetical off site residences at the following locations
  - (1) Point at which South Walnut Creek intersects the eastern Rocky Flats Plant property boundary
  - (2) Point at which Woman Creek intersects the eastern Rocky Flats Plant property boundary

## 4 4 HUMAN UPTAKE MECHANISMS

A human uptake mechanism is the mechanism by which a chemical is internally absorbed by the receptor. There are four basic human uptake mechanisms: dermal absorption, inhalation, ingestion, and if radionuclides are present, external exposures. Exposure pathways by which these mechanisms may occur include inhalation of VOCs and airborne particulates, soil ingestion, surface and groundwater ingestion, and dermal contact with soil or surface water. These uptake mechanisms are described further in Section 5.0.

Dermal absorption of metals from contact with soil is not considered a significant uptake route by EPA. In the Preliminary Risk Assessment for Leadville, Colorado, EPA Region VIII states:

Metals bind strongly to soil, greatly reducing their bioavailability. Through complex processes, most metals form strong, stable bonds with other soil

constituents that reduce the available concentration of a dissolved metal. In addition, due to polarity and solubility, metals are not absorbed well across the skin. Therefore, relative to other exposure routes, dermal absorption is expected to be inconsequential (EPA 1989a).

Likewise, because metals are not highly soluble in water and 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 chemicals of concern, 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). Dermal contact with soil will only be assessed quantitatively if sampling results from the OU 2 Phase II investigation demonstrate the presence of organic chemicals of concern in surface soil samples at concentrations exceeding background levels.

#### **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 conceptual site model (CSM) of potential human exposure pathways for OU 2.

The CSM is a schematic representation of the chemical source areas, chemical 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, to identify exposure pathways that may result in human health risks, to aid in identifying data gaps, and to aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

Chemical 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 below in Section 4.5.2.

In the CSM potentially complete and significant exposure pathways are designated by an S. Potentially complete and relatively 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 discussion and in the CSM potentially complete dermal exposure pathways are designated as insignificant and will only be assessed quantitatively if results from the Phase II site investigation demonstrate the presence of organic chemicals or soluble metals of concern, as previously discussed in Section 4.4.

#### 4.5.1 Site Wide Incomplete Exposure Pathways

The CSM indicates that the following OU 2 exposure pathways are negligible or incomplete for all receptors. These incomplete pathways will not be quantitatively addressed in the risk assessment.

- Ingestion of fish caught from Woman or Walnut Creeks and ingestion of livestock watered by these creeks are incomplete exposure pathways for all receptors. Walnut and Woman Creeks are both intermittent creeks. High flow periods for these creeks 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).

Due to their intermittent nature, the creeks do not support significant numbers of fish. The only fish observed have been minnows. However, it is possible for fish that reside in on-site ponds to migrate from these ponds along Woman Creek to Standley Reservoir or along South Walnut Creek during high flow periods (WWE 1991, WCC 1992). However, because of the creeks' intermittent nature, subsistence fishing is unlikely.

Therefore ingestion of fish is a negligible exposure pathway for both current and future residential receptors

Because plant growth over the creeks does not allow ready access to the creek and because the intermittent creek flow does not support consistent livestock watering ingestion of livestock is a negligible pathway for both current and future residential receptors

The future on site worker is unlikely to raise cattle or catch fish on site since he/she is expected to work the entire time while on site Therefore this pathway is considered negligible for this receptor 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 is a negligible pathway for all receptors because volatile chemicals in surface soils have already volatilized and volatile chemicals released from groundwater are expected to be significantly retarded through the vadose zone and diluted in the ambient air

#### **4.5.2 Potentially Complete Exposure Pathways**

Exposure pathways that result in potential exposure to identified receptors are discussed below

##### **4.5.2.1 Current Off Site Resident**

The CSM for the current off site resident indicates that storm water runoff volatilization, wind suspension, and infiltration and percolation are the primary chemical release mechanisms from contaminated site soils to the environment Of these release mechanisms only the exposure routes associated with wind suspension are potentially complete for the current off site resident as detailed in the discussion below Direct contact with site soils and on site external irradiation from radioactive decay of site soils

are also primary release mechanisms but are eliminated as exposure pathways to this receptor because site access is restricted. Therefore, current off site residents could not directly come into contact with or come close to contaminated soils on site.

Groundwater in the UHSU at OU 2 may either discharge to surface water in the Walnut Creek basin or is lost via evaporation from seeps and springs. (Annual free water evaporation in this region is greater than the amount of annual precipitation.) Chemicals potentially discharged from groundwater to surface water or potentially released from site soils to surface water via storm water runoff may be transported to surface water and/or sediments in Walnut or Woman Creek. Groundwater and surface water runoff from OU 2 that reaches the Walnut Creek drainage is captured on site by the B series ponds and treated in accordance with RFP's surface water management plan (see Section 2.5.3). A smaller proportion of UHSU groundwater and surface water runoff from OU 2 flows south to the Woman Creek basin or is captured by the south interceptor ditch (SID). The SID surface water flows to the C 2 Pond. Surface water in the C 2 Pond and in Woman Creek is sampled in accordance with the RFP's surface water management plan, which has received EPA approval. Under this monitoring program, surface water is monitored and discharged at concentrations that meet applicable federal and state surface water requirements. Therefore, incidental ingestion of and dermal contact with surface water and/or sediments in the creeks are considered negligible exposure pathways for the current off site resident.

Groundwater in the UHSU is hydraulically disconnected from the lower confined aquifer by an impermeable claystone ranging from 15 to 30 meters (50 to 100 feet) in thickness (see Section 2.0). Thus, potential exposure pathways (including inhalation of indoor VOCs that may volatilize from groundwater) associated with domestic wells located west of Standley Lake and along the Woman Creek drainage are considered incomplete. There are no domestic wells located west of Great Western Reservoir in the Walnut Creek drainage.

Chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral dermal, and external irradiation exposure pathways. Current off site residents may be directly exposed to airborne particulate matter via inhalation. For the purpose of the HHRA, it will be assumed that indoor air particulate

concentrations are equal to outdoor air particulate concentrations. Therefore for all potentially exposed receptor populations potential risks from inhalation of indoor particulates will be accounted for by the quantitative evaluation of potential risks from inhalation of outdoor particulates. Homegrown garden vegetables contaminated by deposition of airborne particulates from the site represent a potentially complete ingestion pathway. Likewise soil that is contaminated represents potentially complete oral (significant), dermal (relatively insignificant), and external irradiation (relatively insignificant) exposure pathways for this receptor.

External irradiation exposures to off site residents resulting from deposition of radionuclides via airborne particulate are expected to be relatively insignificant since relatively low concentrations of radionuclides in off site residential soils due to fugitive dust deposition are expected and the primary radionuclides of concern at the RFP, plutonium and americium, do not have highly penetrating radiation associated with them. Nonetheless this pathway will be quantitatively evaluated.

As shown in the CSM, plant uptake of contaminants deposited as windblown particulates on soil may potentially occur. However this uptake is considered negligible for the following reasons:

- As mentioned in Section 4.4 metals bind tightly to soil thus greatly reducing their bioavailability to plants (EPA 1991a)
- Chemical concentrations from particulates deposited on residential soil will be significantly diluted by tilling.

For these reasons, chemical concentrations in garden vegetables, due to surface deposition of chemicals onto plants are expected to be greater than chemicals taken up by vegetables from the soil. It is expected that direct contact exposures to surface soil (dermal absorption and ingestion) will greatly exceed chemical intakes associated with plant uptake and subsequent ingestion. These pathways are therefore considered negligible. Therefore current residential intake of vegetables will only be evaluated for surface deposition of particulates on plants.

In summary potentially complete human exposure pathways for the current off site resident are

- Soil ingestion (deposition of particulates on residential soil)
- Dermal contact with soil following airborne deposition of particulates
- Ingestion of vegetables (surface deposition of particulates)
- Inhalation of airborne particulates
- External irradiation, following airborne particulate deposition of radionuclides on residential soil

#### **4.5.2.2 Future On Site Worker**

The CSM for the future on site worker indicates that storm water runoff volatilization, wind suspension, infiltration and percolation, direct contact and radioactive decay are the primary chemical release mechanisms from contaminated site soils to the environment. Of these primary release mechanisms, all except storm water runoff result in an associated potential exposure route to the future on site worker.

If released via storm water runoff site chemicals may be transported to surface water and/or sediments. Surface water is present on site in Woman and Walnut Creeks and in surface water treatment ponds which are all located in the RFP buffer zone (see Section 2.5). Incidental ingestion of and dermal contact with surface water and sediments are negligible exposure pathways for future on site workers because these receptors work in the industrial complex and would have no reason to come into contact with surface water.

Chemicals that volatilize from site soils and are released to indoor air represent a potentially complete inhalation pathway for the future on site 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 chemicals bound to soil, that are released via wind as particulate matter represent potential inhalation, oral, or dermal exposure pathways. Future on site workers may be directly exposed to airborne particulate matter via inhalation. Direct contact with soil that has been contaminated through the

deposition of airborne particulates represents potentially complete oral (significant) and dermal (relatively insignificant) exposure pathways. Similarly, ingestion of contaminated vegetables is an incomplete pathway because gardening is not expected in an occupational setting.

Volatilization of VOCs from alluvial groundwater to indoor air represents a potentially complete and significant inhalation exposure pathway for future on site workers because although VOCs may have already volatilized and dispersed outdoors, they have the potential to accumulate indoors.

Exposure to surface water that is discharged from alluvial groundwater is negligible because the on site worker is expected to remain in the industrial complex and is not expected to come into contact with surface water at the Woman or Walnut Creek drainages.

Direct contact with soils represents potentially complete ingestion (significant) and dermal contact (insignificant) exposure pathways for future workers at the site. External irradiation from decay of radioactive materials in contaminated site surface soils is also a potentially complete (significant) 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 this receptor.

In summary, potentially complete human exposure pathways for the future on site worker are:

- Soil ingestion
- Dermal contact with soil
- External irradiation
- Inhalation of VOCs in indoor air
- Inhalation of airborne particulates

#### **4 5 2 3 Future On Site Ecological Researcher**

The CSM for the future on site ecological researcher indicates that storm water runoff volatilization, wind suspension, infiltration and percolation, direct contact and radioactive decay are the primary chemical release mechanisms from contaminated site soils to the environment. Except for volatilization, all of these primary release mechanisms have associated exposure routes that are potentially complete for the future ecological researcher.

If released via storm water runoff or transported via groundwater, site chemicals may be released to surface water and/or sediments. Incidental ingestion of surface water and sediments is a potentially complete and significant exposure pathway for the ecological researcher who may be wading in Walnut or Woman Creek. 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 the surface water and sediments is a relatively insignificant but potentially complete exposure 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.

Chemicals 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 exposure pathway because volatile chemicals in surface soils have already volatilized and volatile chemicals in groundwater are expected to be significantly retarded through the vadose zone and diluted in the ambient air. Inhalation of indoor air is a negligible exposure pathway because the researcher will spend his time outdoors in the buffer zone while on site.

Chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral and dermal exposure pathways. Future on site ecological researchers may be directly exposed to airborne particulate matter via inhalation, the ingestion of chemical containing soil, or dermal absorption of chemicals in soil. 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 soils 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 chemicals released from contaminated site soils for the future ecological researcher are:

- Soil ingestion
- Dermal contact with soil
- Surface water ingestion
- Dermal contact with surface water
- Inhalation of airborne particulates
- External irradiation

#### **4.5.2.4 Future Off Site Resident**

The CSM for the future off site resident indicates that storm water runoff, volatilization, wind suspension, and infiltration and percolation are the primary chemical release mechanisms from contaminated site soils to the environment. Of these primary release mechanisms, all except volatilization provide potential exposure routes to the future off site resident.

Chemicals 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 Walnut or Woman Creek. Incidental ingestion of surface water and/or sediments is a potentially complete (significant) exposure pathway for the future off site resident because it is assumed that in the future scenario, storm water runoff from the site is not monitored, intercepted, or treated. Particulates in surface water resulting from disturbance to this medium may be ingested and will be accounted for in the surface water ingestion exposure pathway. Dermal contact with surface water and sediments in the future scenario is a relatively insignificant but potentially complete exposure 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

Groundwater in the UHSU either discharges to surface water in Walnut and Woman Creeks or is lost to evapotranspiration. The UHSU is hydraulically disconnected from the lower confined aquifer by an impermeable claystone ranging from 15 to 30 meters (50 to 100 feet) in thickness (see Section 2.0). Thus potential exposure pathways (including inhalation of indoor VOCs that may volatilize from groundwater) associated with domestic wells located west of Standley Lake and along the Woman Creek drainage are considered incomplete. There are no domestic wells located west of the Great Western Reservoir in the Walnut Creek drainage.

Semivolatile organic and inorganic chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral, dermal, and external irradiation exposure pathways. Future off-site residents may be directly exposed to airborne particulate matter via inhalation. Homegrown vegetables contaminated by deposition of airborne particulates from the site represent a potentially complete ingestion pathway. Contact with soil that is similarly contaminated represents potentially complete oral (insignificant), dermal (insignificant), and external irradiation exposure pathways for this receptor.

As shown in the CSM, plant uptake of contaminants deposited as windblown particulates on soil may potentially occur. However, this uptake is considered negligible for the following reasons:

- As mentioned in Section 4.4, metals bind tightly to soil, thus greatly reducing their bioavailability to plants (EPA 1991a).
- Chemical concentrations from particulates deposited on residential soil will be significantly diluted by tilling.

For these reasons, chemical concentrations in garden vegetables due to surface deposition of chemicals onto plants are expected to be greater than chemicals taken up by vegetables from the soil. It is expected that direct contact exposures to surface soil

(dermal absorption and ingestion) will greatly exceed chemical intakes associated with plant uptake and subsequent ingestion and will, therefore be negligible Therefore future residential intake of vegetables will only be evaluated based on surface deposition of particulates on plants

External irradiation exposures to future off site residents resulting from deposition of radionuclides via airborne particulate are expected to be relatively insignificant since relatively low concentrations of radionuclides in off site residential soils due to fugitive dust deposition are expected and the primary radionuclides of concern at the RFP plutonium and americium do not have highly penetrating radiation associated with them

In summary potentially complete human exposure pathways for chemicals released from contaminated site soils for the future off site resident are

- Soil ingestion (deposition of particulates on residential soil)
- Dermal contact with soil
- Surface water ingestion
- Dermal contact with surface water
- Ingestion of homegrown vegetables (surface deposition of particulates)
- Inhalation of particulates
- External irradiation (following airborne particulate deposition of radionuclides on residential soil)

A summary of potentially complete exposure pathways that will be quantitatively evaluated in the baseline human health risk assessment is provided in Table 4 1

**TABLE 4 1**  
**ROCKY FLATS PLANT**  
**OU 2**  
**POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED**

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Off site resident	Current	Soil ingestion Dermal contact with surface soil Ingestion of vegetables (surface deposition of particulates) Inhalation of outdoor particulates External irradiation (airborne particulate deposition of radionuclides on residential soil)
	Future	Soil ingestion Inhalation of indoor VOCs Inhalation of outdoor particulates Dermal contact with soil External irradiation
On site ecological researcher	Future	Soil ingestion Inhalation of outdoor particulates Surface water ingestion Dermal contact with surface soil Dermal contact with surface water External irradiation
	Future	Soil ingestion Ingestion of vegetables (surface deposition of particulates) Inhalation of outdoor particulates Surface water ingestion Dermal contact with surface soil Dermal contact with surface water External irradiation (deposition of airborne particulate radionuclides on residential soil)

## ESTIMATING CHEMICAL INTAKES

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This section presents reasonable maximum intake parameters for each of the receptors and exposure pathways identified in previous sections. Chemical intakes are not present in this memorandum since they are dependent on pending site characterization chemical data and fate and transport modeling as appropriate. The fate and transport models to be used in the OU 2 BRA will be presented as a separate Technical Memorandum.

Using the exposure point concentrations of chemicals 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 chemical (mg)/body weight (kg)/day. Intakes are calculated following guidance in Risk Assessment Guidance for Superfund (EPA 1989a) and 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 reasonable maximum exposure (RME) conditions. The RME is estimated by selecting values for exposure variables so that the combination of all variables results in the maximum exposure that can reasonably be expected to occur at the site.

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

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

$$\text{mg/kg/day} = \frac{\text{mg/vol} * \text{vol/day} * \text{day/year} * \text{year}}{\text{kg} * \text{day}}$$

The variable averaging time is expressed in days to calculate daily intake. For noncarcinogenic chemicals 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 for whatever 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 since the average concentration of a noncarcinogen is compared with the threshold dose for an effect.

Omitting chemical concentrations from the intake equation yields an intake factor that is constant for each exposure pathway and receptor. The intake factor can then be multiplied by the concentration of each chemical to obtain the pathway specific intake of that chemical. Intake factors are calculated separately for each potentially exposed receptor and exposure pathway that was identified in Section 4.5. Because contact rates (except soil ingestion) are approximately proportional to body weight, child residential intakes are not estimated for any exposure pathway except soil ingestion. The assumptions used in deriving intake factors are discussed below.

## **5.1 INTAKE FACTOR ASSUMPTIONS**

Several exposure parameters 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 the section below. The term occupational exposures includes exposures to both the future on site worker and the future ecological researcher.

### **5.1.1 General Exposure Assumptions**

- For all exposure scenarios except dermal contact with surface water the RME exposure frequency has been estimated to be 7 days/week for 50

weeks (350 days) for the current and future off site resident (EPA 1991b) 5 days/week for 50 weeks (250 days) for the on site worker (EPA 1991b) and 2 days/week for 50 weeks (100 days) for the ecological researcher These exposure frequencies assume that exposures occur routinely at these sites when in fact exposures are not routine and may not occur at all due to precipitation, snow cover and frozen surface water

- Residential RME exposure duration is assumed to be 30 years (EPA 1991b)
- Occupational RME exposure durations are assumed to be 25 years This reasonable maximum duration is the 95th percentile duration of work at the same location (EPA 1991b)
- Averaging time is the product of the exposure duration and the number of days in a year (365) Occupational and residential RME averaging time is 9 125 days (25 years) and 10 950 days (30 years) respectively
- Averaging time for carcinogenic effects is 70 years (25 550 days) in the reasonable maximum case
- The average adult body weight is assumed to be 70 kg (EPA 1989b)

### **5 1.2 Inhalation Assumptions**

Uptake of chemicals through inhalation is a function of the volume of air inhaled per day the exposure frequency and duration, and pulmonary deposition (for particulate inhalation) Intake factors for exposure via indoor particulate inhalation were estimated for all receptors An intake factor for exposure via VOC inhalation was estimated for the future on site worker The following assumptions will be used to estimate exposure to chemicals of concern through this route

- The RME respiratory volume of air for all receptors is assumed to be 20 m<sup>3</sup>/day (0.83 m<sup>3</sup>/hr) This rate assumes that all time is spent at activities equivalent to walking (EPA 1991b)
- On site occupational receptors are assumed to breathe on site air 8 hours/day in the RME case
- Current and future residential receptors are assumed to inhale particulates 24 hours/day in the RME case This exposure frequency assumes that residential receptors are at home all day Indoor air particulate concentrations are assumed to be equal to outdoor air particulate concentrations
- Twenty five percent of inhaled particles are deposited in the lung it is assumed that all chemicals in that fraction are absorbed (MRI 1985)

### 5.1.3 Soil Ingestion Assumptions

Uptake of chemicals via incidental ingestion of soil and dust is a function of the ingestion rate the fraction of ingested soil or dust that is contaminated the frequency and duration of exposure and the bioavailability of the chemical adhered to the particulates ingested

The calculation of an RME 30 year residential exposure to soil will be divided into two parts First a six year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion Second a 24-year exposure duration is assessed for older children and adults using a lower soil ingestion rate By time averaging the child residential soil ingestion risk with the risk calculated for the adult, a child residential risk from soil ingestion is taken into account

Intake factors for exposure via soil ingestion were calculated for an adult resident a child resident a future on site ecological researcher and a future on site worker The following assumptions will be used in estimating intake through this route

- Occupational receptors are assumed to ingest 50 mg/day of soil in the RME case (EPA 1991b)
- The calculation of a 30 year residential exposure to soil is time averaged by assessing a six year exposure duration followed by a 24 year exposure duration. The six year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg) (EPA 1991b). The 24 year exposure duration is assessed for older children and adults and accounts for the period of lower soil ingestion (100 mg/day) and an adult body weight (70 kg) (EPA 1991b)
- The fraction ingested (FI) from the contaminated source is assumed to be 0.125 for the future on site worker and 0.5 for the future on site ecological researcher and the current and future residential receptor. The FI for the future on site worker is based on 1 hour of exposure to contaminated soil per 8 hour workday. This assumes that the on site worker spends his/her entire lunch hour outside, which is a conservative assumption since it does not account for inclement weather or periods when the ground is expected to be frozen or covered with snow. The future on site ecological researcher is assumed to spend half of his time at OU 2 while at RFP. Residential receptors are assumed to be exposed to contaminated soils for 50 percent of the time that they are present at their homes.
- The matrix effect of soil on bioavailability of ingested contaminants is assumed to be 0.15 in the RME case for all receptors. The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same chemical dose administered in solution. Therefore the soil matrix has the effect of reducing chemical intake (Poiger and Schlatter 1980)

#### **5 1 4 Homegrown Produce Ingestion Assumptions**

Uptake of chemicals via ingestion of homegrown vegetables is a function of the ingestion rate the fraction of contaminated homegrown produce ingested, the frequency and duration of exposure and bioavailability of the chemical adhered to the produce ingested. It is assumed that contamination of homegrown produce may occur by surface deposition of particulates. An intake factor for exposure via vegetable ingestion was calculated for current and future residential receptors. The future on site worker and ecological researcher are not expected to ingest contaminated produce (see Section 4 5). The following assumptions will be used in estimating intake through this route:

- Current and future residential receptors are assumed to ingest 80 000 mg/day of vegetables in the RME case. This figure is based on the typical consumption value of vegetables (200 000 mg/day), assuming the reasonable worst case proportion that is homegrown as 40 percent (EPA 1991b).

Homegrown vegetables are assumed to be potentially contaminated by surface deposition of airborne particulates from OU 2 soils as described in Section 4 5 2 Potentially Complete Exposure Pathways. Modeled wet and dry deposition rates will be applied to reasonable maximum estimates of vegetable surface areas, weights, and human consumption rates to estimate chemical intake from this potential exposure pathway.

- The matrix effect of produce on bioavailability of ingested contaminants is assumed to be 1 0 in the RME case.

Reductions in chemical concentrations due to washing, cooking, or peeling of produce are not accounted for.

#### **5 1 5 Surface Water Ingestion Assumptions**

Uptake of chemicals via surface water ingestion is a function of the daily intake rate, fraction ingested from the contaminated source, and exposure frequency and duration.

Intake factors for surface water ingestion were calculated for the future ecological researcher and the future hypothetical residential receptor. The following assumptions will be used in estimating intake through this route:

- Both the future ecological researcher and hypothetical off site resident are assumed to ingest 0.05 liters/day (50 ml/day) (EPA 1989b)
- The FI from the contaminated source is assumed to be 1.0 for both the future ecological researcher and the future hypothetical off site resident. For the future ecological researcher, it will be assumed that 50 percent of the surface water exposure will be from Walnut Creek and 30 percent will be from Woman Creek.
- The RME exposure frequency is assumed to be 7 events/year for the future ecological researcher and the future hypothetical off site resident (EPA 1989a)

#### 5.1.6 Dermal Contact with Soil

Uptake of chemicals of concern through dermal contact with surface soil is a function of body surface area, absorbed fraction, an adherence factor that describes how much soil adheres to skin, the fraction of soil contacted that is from a contaminated source, and exposure frequency and duration. Dermal uptake of metals is negligible and is not addressed in human health risk assessments (EPA 1991a). Dermal contact with surface soil will only be evaluated if sampling demonstrates the presence of organics. The following assumptions will be used to estimate exposure to chemicals of concern through dermal contact with soil route for all receptors:

- The RME exposed body surface area for all receptors is assumed to be 2,190 cm<sup>2</sup>/day. The reasonable maximum surface area is assumed to be 15 percent of total body surface (equivalent to face, forearms, and hands) (EPA 1989b)

- The absorbed fraction is the estimated fraction of organic compounds (if available) adhered to soil particles that partitions to and is absorbed through skin. This fraction is chemical specific. Percent absorbed depends upon soil loading, organic carbon content of soil, contaminant concentration, duration of exposure, animal species used in the experiment, and whether the experiment is conducted in vitro or in vivo. The absorbed fraction will be determined on a chemical specific basis using data available in the scientific literature.
- The soil adherence factor used is 0.5 mg/cm<sup>2</sup> in the RME case (Sedman 1989).
- The fraction contacted (FC) from the contaminated medium is assumed to be 0.125, 0.5, and 0.5 in the RME case for the future on site worker, the future on site ecological researcher, and the current and future residential receptor, respectively. The FC for the future on site worker is based on 1 hour of exposure to contaminated soil per 8 hour workday. The future on site ecological researcher is assumed to spend half of the time at OU 2 while conducting field research at RFP. Residential receptors are assumed to be exposed to contaminated soil for 50 percent of the time that they are at their residence. This fraction assumes that 16 hours per day are spent at home and 8 hours per day are spent away from home at work or school. Of the 16 hours spent at home, it is assumed that 8 hours are spent indoors and the remaining 8 hours are spent outdoors in activities that may potentially involve dermal contact with contaminated soil.

#### **5.1.7 Dermal Contact with Surface Water**

Uptake of chemicals through dermal contact with surface water is a function of body surface area, a chemical specific permeability constant, and exposure time, frequency, and duration. Dermal uptake of metals (including radionuclides) is negligible and will only be addressed for this media for the soluble fraction of metals. Therefore, dermal contact with surface water will only be evaluated if sampling demonstrates the presence

of organics or soluble metals. Dermal absorption of chemicals in sediment that is disturbed during surface water contact events will be accounted for as part of this exposure pathway by incorporating a suspended sediment factor into the surface water model used to calculate exposure point concentrations in water. The following assumptions were used to estimate exposure to chemicals of concern through dermal contact with the surface water route from a wading scenario for the future residential receptor and ecological researcher:

- The RME exposed body surface area for future residential receptors and the ecological researcher is assumed to be 4 850 cm<sup>2</sup>/day. The reasonable maximum surface area is assumed to be 25 percent of total body surface (equivalent to hands, feet and lower legs) (EPA 1989b)
- The water permeability constant of 8.0E-04 cm/hour is used. However, the chemical specific permeability constants for aqueous solutions will be used if available when the contaminants of concern are identified.
- The RME exposure time is assumed to be 2.6 hours per day for both the future residential receptor and ecological researcher (EPA 1989a)
- The exposure frequency is assumed to be 7 events per year for both the future ecological researcher and the future residential receptor.

#### **5.1.8 Internal Exposure to Radionuclides**

Calculation of intake rates for radionuclides from the environment into the body can be made in the same manner as other nonradioactive chemicals. Intake of radionuclides by either ingestion or inhalation is a function of radionuclide concentration, contact rate (or the amount of contaminated medium contacted per unit time or event) and exposure frequency and duration. The exception between calculating intake for radionuclides and other nonradioactive substances is that averaging time and body weight are excluded as divisors from the intake equation. The resulting calculation is an estimate of the radionuclide intake expressed in units of activity (e.g. Bq) (EPA 1989a). For radionuclides, a reference body weight is already incorporated with a dose conversion

factor (DCF) which is used to represent the dose equivalent per unit intake and the dose is an expression of energy deposited per gram of body tissue

Slope factors for radionuclides of concern will be multiplied by the estimated exposure activity (that is either inhaled or ingested) to estimate risk (EPA 1989a)

### **5 1 9 External Irradiation**

To estimate exposure from external irradiation, radionuclide concentrations on the ground surface ( $\text{Bq}/\text{m}^2$ ) whether directly measured or predicted by modeling will be multiplied by the external dose conversion factor (DCF) for specific radionuclides ( $\text{Sv}/\text{hr}$  per  $\text{Bq}/\text{m}^2$ ) and the duration of exposure (hours) (EPA 1989a) This will result in an estimate of the effective dose equivalent which can be compared to radiation protection standards and criteria The external slope factors do not include contributions from decay (daughter) products or products of in growth Risks for the ground surface pathway will be computed as the product of the slope factor the soil concentration ( $\text{Bq}/\text{m}^2$ ) and the duration of the exposure for each radionuclide (EPA 1989a)

## **5.2 INTAKE FACTOR CALCULATIONS**

The above assumptions 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 Tables 5 1 through 5 19 Exposure point concentrations will be used with these parameters to obtain pathway specific intakes

**TABLE 5 1**

**SOIL INGESTION  
CURRENT OFF SITE RESIDENT (ADULT AND CHILD)<sup>(1)</sup>**

Intake Factor = $\frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$			
Parameter	RME		
	<u>Adult</u>	<u>Child</u>	
IR = Ingestion rate (mg/day) <sup>(2)</sup>	100	200	
FI = Fraction ingested from contaminated source <sup>(3)</sup>	0.5	0.5	
ME = Matrix effect <sup>(4)</sup>	0.15	0.15	
EF = Exposure frequency (days/year) <sup>(2)</sup>	350	350	
ED = Exposure duration (years) <sup>(2)</sup>	24	6	
CF = Conversion factor (kg/mg)	$10^{-6}$	$10^{-6}$	
BW = Body weight (kg)	70	15	
AT = Averaging time (days)			
Noncarcinogenic	8,760	2,190	
Carcinogenic	25,550	25,550	

<sup>(1)</sup> The calculation of a 30 year residential exposure to soil is divided into two parts. First a six year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second a 24 year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time averaged (EPA 1991b).

<sup>(2)</sup> EPA 1991b

<sup>(3)</sup> The RME (FI) assumes that residents are in contact with contaminated soils 50 percent of their time at home.

<sup>(4)</sup> The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore the soil matrix has the effect of reducing the intake of the compound (Poiger and Schlatter 1980).

TABLE 5 2

INGESTION OF HOMEGROWN VEGETABLES  
(SURFACE DEPOSITION OF PARTICULATES)  
CURRENT OFF SITE RESIDENT

Intake Factor = $\frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$		
Parameter		RME
IR	Ingestion rate vegetables (mg/day) <sup>(1)</sup>	8E + 04
FI	Fraction ingested from contaminated source	1 0
ME	Matrix effect	1 0
EF	Exposure frequency (days/year) <sup>(2)</sup>	350
ED	Exposure duration (years)	30
CF	Conversion factor (kg/mg)	10 <sup>-6</sup>
BW	Body weight (kg)	70
AT	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25 550

(1) This ingestion rate is based on the typical consumption value of vegetables (200 000 mg/day) with the reasonable worst case proportion that is homegrown assumed to be 40 percent (EPA 1991b)

(2) EPA 1991b

**TABLE 5 3**

**INHALATION OF PARTICULATES  
CURRENT OFF SITE RESIDENT**

---

Intake Factor =  $\frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$

---

Parameter	RME
IR = Inhalation rate (m <sup>3</sup> /hr) <sup>(1)</sup>	0 83
ET = Exposure time (hours/day) <sup>(2)</sup>	24
EF = Exposure frequency (days/year) <sup>(3)</sup>	350
ED = Exposure duration (years) <sup>(3)</sup>	30
DF = Deposition factor <sup>(4)</sup>	0 25
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	10,950
Carcinogenic	25 550

---

(1) This is equivalent to 20 m<sup>3</sup>/day (EPA 1991b)

(2) This RME exposure time assumes that 24 hours per day is spent at home  
EPA 1991b

(3) EPA 1991b

(4) Twenty five percent of inhaled particles are deposited and remain in the lung  
it is assumed that all chemicals in that fraction are absorbed (MRI 1985)

**TABLE 5-4**

**DERMAL CONTACT WITH SURFACE SOIL  
CURRENT OFF SITE RESIDENT**

---

Intake Factor =  $\frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$

---

Parameter	RME
SA = Surface area (cm <sup>2</sup> ) <sup>(1)</sup>	2,910
AB = Absorption factor <sup>(2)</sup>	chemical specific
AF = Adherence factor (mg/cm <sup>2</sup> ) <sup>(3)</sup>	0.5
FC = Fraction contacted from contaminated source <sup>(4)</sup>	0.5
EF = Exposure frequency (days/year) <sup>(5)</sup>	350
ED = Exposure duration (years) <sup>(5)</sup>	30
CF = Conversion factor (kg/mg)	10 <sup>-6</sup>
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	10 950
Carcinogenic	25 550

---

- (1) The RME surface area is equivalent to face forearms and hands or 15 percent of total body surface (EPA 1989b)
- (2) Absorption of metals from a soil matrix is negligible (EPA 1991a) The absorption factor for semivolatiles volatiles and other organics is likely to be lower and will be determined on a chemical specific basis
- (3) Sedman 1989
- (4) The FC assumes that residents are in contact with chemical containing media 50 percent of their time at home
- (5) EPA 1991b

**TABLE 5 5**  
**SOIL INGESTION**  
**FUTURE ON SITE WORKER**

Intake Factor = $\frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$	
Parameter	RME
IR = Ingestion rate (mg/day) <sup>(1)</sup>	50
FI = Fraction ingested from contaminated source <sup>(2)</sup>	0.125
ME = Matrix effect <sup>(3)</sup>	0.15
EF = Exposure frequency (days/year) <sup>(1)</sup>	250
ED = Exposure duration (years) <sup>(1)</sup>	25
CF = Conversion factor (kg/mg)	10 <sup>-6</sup>
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	9,125
Carcinogenic	25,550

<sup>(1)</sup> EPA 1991b

<sup>(2)</sup> Based on 1 hour of exposure to soil per 8 hour workday

<sup>(3)</sup> The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore the soil matrix has the effect of reducing the intake of a compound (Poiger and Schlatter 1980)

**TABLE 5 6**

**INHALATION OF PARTICULATES  
FUTURE ON SITE WORKER**

Intake Factor = $\frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$		
Parameter		RME
IR =	Inhalation rate (m <sup>3</sup> /hr) <sup>(1)</sup>	0 83
ET =	Exposure time (hours/day) <sup>(2)</sup>	8
EF =	Exposure frequency (days/year) <sup>(3)</sup>	250
ED =	Exposure duration (years) <sup>(3)</sup>	25
DF =	Deposition factor <sup>(4)</sup>	0 25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9 125
	Carcinogenic	25 550

<sup>(1)</sup> This is equivalent to 20 m<sup>3</sup>/day (EPA 1991b)

<sup>(2)</sup> The ET is based on an 8 hour workday

<sup>(3)</sup> EPA 1991b

<sup>(4)</sup> Twenty five percent of inhaled particles are deposited and remain in the lung it is assumed that all of the chemicals in that fraction are absorbed (MRI 1985)

**TABLE 5 7**

**INHALATION OF VOCs  
FUTURE ON SITE WORKER**

Intake Factor = $\frac{IR \times ET \times EF \times FC \times ED}{BW \times AT}$	
Parameter	RME
IR = Inhalation rate (m <sup>3</sup> /hr) <sup>(1)</sup>	0.83
ET = Exposure time (hours/day) <sup>(2)</sup>	8
EF = Exposure frequency (days/year) <sup>(3)</sup>	250
ED = Exposure duration (years) <sup>(3)</sup>	25
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	9,125
Carcinogenic	25,550

- (1) This is equivalent to 20 m<sup>3</sup>/day (EPA 1991b)
- (2) The ET is based on an 8 hour workday
- (3) EPA 1991b

**TABLE 5 8**

**DERMAL CONTACT WITH SURFACE SOIL  
FUTURE ON SITE WORKER**

$$\text{Intake Factor} = \frac{\text{SA} \times \text{AB} \times \text{AF} \times \text{FI} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}$$

Parameter	RME
SA = Surface area (cm <sup>2</sup> ) <sup>(1)</sup>	2,910
AB = Absorption factor <sup>(2)</sup>	chemical specific
AF = Adherence factor (mg/cm <sup>2</sup> ) <sup>(3)</sup>	0.5
FC = Fraction contacted from contaminated source <sup>(4)</sup>	0.125
EF = Exposure frequency (days/year) <sup>(5)</sup>	250
ED = Exposure duration (years) <sup>(5)</sup>	25
CF = Conversion factor (kg/mg)	10 <sup>-6</sup>
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	9,125
Carcinogenic	25,550

- (1) The RME surface area is equivalent to face, forearms, and hands or 15 percent of total body surface (EPA 1989b)
- (2) Absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower and will be determined on a chemical specific basis.
- (3) Sedman 1989
- (4) Based on 1 hour of exposure to soil per 8 hour workday
- (5) EPA 1991b

**TABLE 5 9**

**SOIL INGESTION  
FUTURE ON SITE ECOLOGICAL RESEARCHER**

Intake Factor = $\frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$	
Parameter	RME
IR = Ingestion rate (mg/day) <sup>(1)</sup>	50
FI = Fraction ingested from contaminated source <sup>(2)</sup>	0 5
ME = Matrix effect <sup>(3)</sup>	0 15
EF = Exposure frequency (days/year) <sup>(4)</sup>	100
ED = Exposure duration (years) <sup>(5)</sup>	25
CF = Conversion factor (kg/mg)	10 <sup>-6</sup>
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	9 125
Carcinogenic	25 550

- (1) EPA 1991b
- (2) The FI assumes that while at RFP the ecological researcher spends half of his time at OU 2
- (3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same dose administered in solution. Therefore, the soil matrix has the effect of reducing the intake of a compound (Poiger and Schlatter 1980)
- (4) Equivalent to 2 days/week for 50 weeks
- (5) EPA 1991b

TABLE 5 10

INHALATION OF PARTICULATES  
FUTURE ON SITE ECOLOGICAL RESEARCHER

Intake Factor = $\frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$		
Parameter		RME
IR =	Inhalation rate (m <sup>3</sup> /hr) <sup>(1)</sup>	0.83
ET =	Exposure time (hours/day) <sup>(2)</sup>	8
EF =	Exposure frequency (days/year) <sup>(3)</sup>	100
ED =	Exposure duration (years) <sup>(4)</sup>	25
DF =	Deposition factor <sup>(5)</sup>	0.25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) This is equivalent to 20 m<sup>3</sup>/day (EPA 1991b)

(2) The ET assumes an 8 hour workday

(3) Equivalent to 2 days/week for 50 weeks

(4) EPA 1991b

(5) Twenty five percent of inhaled particles are deposited and remain in the lung it is assumed that all chemicals in that fraction are absorbed (MRI 1985)

**TABLE 5 11**  
**SURFACE WATER INGESTION**  
**FUTURE ON SITE ECOLOGICAL RESEARCHER**

Intake Factor = $\frac{IR \times EF \times ED \times FI}{BW \times AT}$		
	Parameter	RME
IR	Intake rate (1/event) <sup>(1)</sup>	0 05
EF	Exposure frequency (events/year) <sup>(2)</sup>	7
ED	Exposure duration (years) <sup>(3)</sup>	25
FI	Fraction ingested from contaminated source	1 0
BW	Body weight (kg)	70
AT	Averaging time (days)	
	Noncarcinogenic	9 125
	Carcinogenic	25 550

- (1) Equivalent to 50 ml of incidental surface water ingestion per day for on site surface water research (EPA 1989b)
- (2) EPA 1989a
- (3) This figure is highly conservative for this receptor

TABLE 5 12

DERMAL CONTACT WITH SURFACE SOIL  
FUTURE ON SITE ECOLOGICAL RESEARCHER

$$\text{Intake Factor} = \frac{\text{SA} \times \text{AB} \times \text{AF} \times \text{FC} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}$$

Parameter	RME
SA = Surface area (cm <sup>2</sup> ) <sup>(1)</sup>	2 910
AB = Absorption factor <sup>(2)</sup>	chemical specific
AF = Adherence factor (mg/cm <sup>2</sup> ) <sup>(3)</sup>	0 5
FC = Fraction contacted from contaminated source <sup>(4)</sup>	0 5
EF = Exposure frequency (days/year) <sup>(5)</sup>	100
ED = Exposure duration (years) <sup>(6)</sup>	25
CF = Conversion factor (kg/mg)	10 <sup>-6</sup>
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	9 125
Carcinogenic	25 550

- (1) The RME surface area is equivalent to face forearms, and hands or 15 percent of total body surface (EPA 1989b)
- (2) Absorption of metals from a soil matrix is negligible (EPA 1991a) The absorption factor for semivolatiles volatiles and other organics is likely to be lower and will be determined on a chemical specific basis when data become available
- (3) Sedman 1989
- (4) The FC assumes that while at RFP, the ecological researcher spends half of his time at OU 2
- (5) Equivalent to 2 days/week for 50 weeks
- (6) EPA 1991b

**TABLE 5 13**

**DERMAL CONTACT WITH SURFACE WATER  
FUTURE ON SITE ECOLOGICAL RESEARCHER**

Intake Factor = $\frac{SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$		
Parameter		RME
SA =	Surface area (cm <sup>2</sup> ) <sup>(1)</sup>	4 850
PC =	Permeability constant (cm/hr) <sup>(2)</sup>	8 0E 04
ET =	Exposure time (hours/event) <sup>(3)</sup>	2 6
EF =	Exposure frequency (events/year) <sup>(3)</sup>	7
ED =	Exposure duration (year) <sup>(4)</sup>	25
CF =	Conversion factor (l/cm <sup>3</sup> )	10 <sup>3</sup>
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25 550

- (1) The RME surface area is equivalent to hands feet, and lower legs or 25 percent of total body surface (EPA 1989b)
- (2) The permeability constant of water is used but chemical specific permeability constants will be used, if available for aqueous solutions
- (3) EPA 1989a
- (4) EPA 1991b

TABLE 5 14

SOIL INGESTION  
 HYPOTHETICAL FUTURE OFF SITE RESIDENT (ADULT AND CHILD)<sup>(1)</sup>

$$\text{Intake Factor} = \frac{\text{IR} \times \text{FI} \times \text{ME} \times \text{EF} \times \text{ED} \times \text{CF}}{\text{BW} \times \text{AT}}$$

Parameter	RME	
	Adult	Child
IR = Ingestion rate (mg/day) <sup>(2)</sup>	100	200
FI = Fraction ingested from contaminated source <sup>(3)</sup>	0.5	0.5
ME = Matrix effect <sup>(4)</sup>	0.15	0.15
EF = Exposure frequency (days/year)	350	350
ED = Exposure duration (years) <sup>(2)</sup>	24	6
CF = Conversion factor (kg/mg)	10 <sup>-6</sup>	10 <sup>-6</sup>
BW = Body weight (kg)	70	15
AT = Averaging time (days)		
Noncarcinogenic	8 760	2 190
Carcinogenic	25 550	25 550

(1) The calculation of a 30 year residential exposure to soil is divided into two parts. First a six year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second a 24 year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time averaged (EPA 1991b)

(2) EPA 1991b

(3) The RME FI assumes that residents are in contact with chemical containing media 50 percent of their time at home

(4) The matrix effect describes the reduced availability due to absorption of chemicals to soil compared to the same dose administered in solution. Therefore the soil matrix has the effect of reducing the intake of a compound (Poiger and Schlatter 1980)

**TABLE 5 15**

**INGESTION OF HOMEGROWN VEGETABLES  
(SURFACE DEPOSITION OF PARTICULATES)  
HYPOTHETICAL FUTURE OFF SITE RESIDENT**

Intake Factor = $\frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$		
Parameter		RME
IR	Ingestion rate, vegetables (mg/day) <sup>(1)</sup>	8E + 04
FI	Fraction ingested from contaminated source	1 0
ME	Matrix effect	1 0
EF	Exposure frequency (meals/year) <sup>(2)</sup>	350
ED	Exposure duration (years)	30
CF	Conversion factor (kg/mg)	10 <sup>-6</sup>
BW	Body weight (kg)	70
AT	Averaging time (days)	
	Noncarcinogenic	10 950
	Carcinogenic	25,550

<sup>(1)</sup> This ingestion rate is based on the typical consumption value of vegetables (200 000 mg/day) with the reasonable worst case proportion that is homegrown assumed to be 40 percent (EPA 1991b)

<sup>(2)</sup> EPA 1991b

TABLE 5 16

INHALATION OF PARTICULATES  
HYPOTHETICAL FUTURE OFF SITE RESIDENT

Intake Factor = $\frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$		
Parameter		RME
IR =	Inhalation rate (m <sup>3</sup> /hr) <sup>(1)</sup>	0 83
ET =	Exposure time (hours/day) <sup>(2)</sup>	24
EF =	Exposure frequency (days/year) <sup>(3)</sup>	350
ED =	Exposure duration (years) <sup>(3)</sup>	30
DF =	Deposition factor <sup>(4)</sup>	0 25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10 950
	Carcinogenic	25,550

- (1) This is equivalent to 20 m<sup>3</sup>/day (EPA 1991b)  
 (2) This RME exposure time assumes that 24 hours per day is spent at home (EPA 1991b)  
 (3) EPA 1991b  
 (4) Twenty five percent of inhaled particles are deposited and remain in the lung it is assumed that all chemicals in that fraction are absorbed (MRI 1985)

**TABLE 5 17**

**SURFACE WATER INGESTION  
HYPOTHETICAL FUTURE OFF SITE RESIDENT**

---


$$\text{Intake Factor} = \frac{\text{IR} \times \text{EF} \times \text{ED} \times \text{FI}}{\text{BW} \times \text{AT}}$$


---

Parameter		RME
IR	Intake rate (l/event) <sup>(1)</sup>	0.05
EF	Exposure frequency (events/year) <sup>(2)</sup>	7
ED	Exposure duration (years) <sup>(3)</sup>	30
FI	Fraction ingested from contaminated source	1.0
BW	Body weight (kg)	70
AT	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

---

- (1) Equivalent to 50 ml of incidental surface water ingestion per day (EPA 1989b)
- (2) EPA 1989a
- (3) EPA 1991b

TABLE 5 18

DERMAL CONTACT WITH SURFACE SOIL  
HYPOTHETICAL FUTURE OFF SITE RESIDENT

Intake Factor = $\frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$	
Parameter	RME
SA = Surface area (cm <sup>2</sup> ) <sup>(1)</sup>	2 910
AB = Absorption factor <sup>(2)</sup>	chemical specific
AF = Adherence factor (mg/cm <sup>2</sup> ) <sup>(3)</sup>	0 5
FC = Fraction contacted from contaminated source <sup>(4)</sup>	0 5
EF = Exposure frequency (days/year) <sup>(5)</sup>	350
ED = Exposure duration (years) <sup>(5)</sup>	30
CF = Conversion factor (kg/mg)	10 <sup>-6</sup>
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	10,950
Carcinogenic	25 550

- (1) The RME surface area is equivalent to face forearms, and hands, or 15 percent of total body surface (EPA 1989b)
- (2) Absorption of metals from a soil matrix is assumed to be zero The absorption factor for semivolatile volatile and other organics is assumed to be 0 1 The actual value is likely to be lower (EPA 1991b)
- (3) Sedman 1989
- (4) The FC assumes that residents are in contact with chemical-containing media 50 percent of their time at home
- (5) EPA 1991b

**TABLE 5 19**

**DERMAL CONTACT WITH SURFACE WATER  
HYPOTHETICAL FUTURE OFF SITE RESIDENT**

---

Intake Factor =  $\frac{SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$

---

Parameter	RME
SA = Surface area (cm <sup>2</sup> ) <sup>(1)</sup>	4,850
PC = Permeability constant (cm/hr) <sup>(2)</sup>	8 0E 04
ET = Exposure time (hours/event) <sup>(3)</sup>	2 6
EF = Exposure frequency (events/year) <sup>(3)</sup>	7
ED = Exposure duration (year) <sup>(4)</sup>	30
CF = Conversion factor (l/cm <sup>3</sup> )	10 <sup>3</sup>
BW = Body weight (kg)	70
AT = Averaging time (days)	
Noncarcinogenic	10 950
Carcinogenic	25 550

---

- (1) The RME surface area is equivalent to hands, feet and lower legs or 25 percent of total body surface (EPA 1989b)
- (2) The permeability constant of water is used but chemical specific permeability constants will be used when available for aqueous solutions
- (3) EPA 1989a
- (4) EPA 1991b

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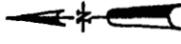
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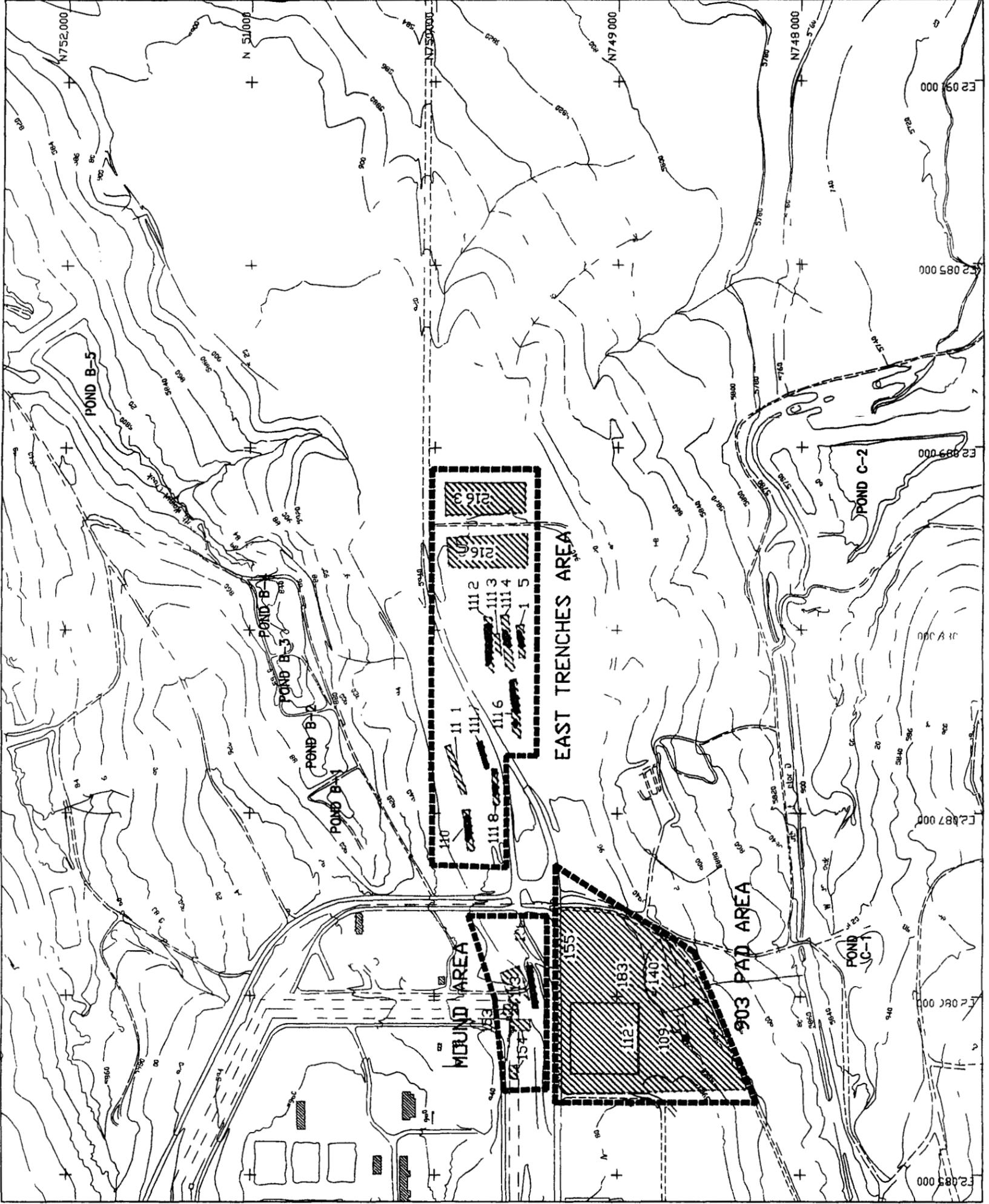
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EXPLANATION

-  INDIVIDUAL HAZARDOUS SUBSTANCE SITE AND HSS DESIGNATION
-  LOCATION OF BARRELS DETERMINED BY VISUAL INSPECTION OR MAGNETOMETER SURVEY
-  SOURCE AREAS



Scale 1 = 600  
 0' 300' 600'  
 CONTOUR INTERVAL = 20'



U. S. DEPARTMENT OF ENERGY  
 Rocky Flats Plant Golden Colorado  
 OPERABLE UNIT 2  
 PHASE II RFI/RI  
 EXPOSURE ASSESSMENT  
 TECHNICAL MEMORANDUM

REMEDIATION INVESTIGATION AREAS AND  
 INDIVIDUAL HAZARDOUS SUBSTANCE SITES

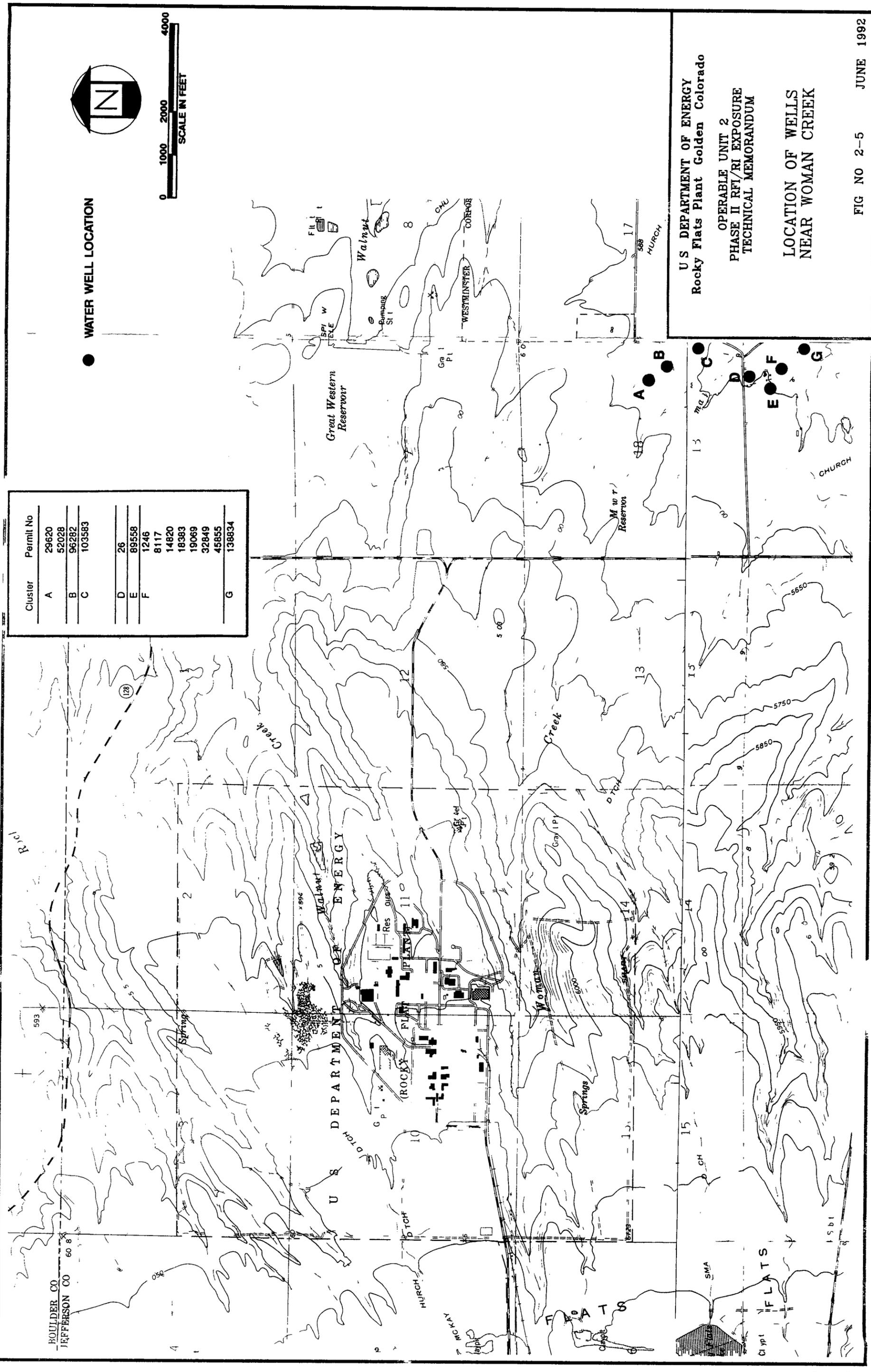
FIGURE 2.2

BOULDER CO  
JEFFERSON CO



● WATER WELL LOCATION

Cluster	Permit No
A	29620
B	52028
C	96282
C	103583
D	26
E	89558
F	1246
	8117
	14820
	18383
	19069
	32849
	45855
G	138834



U S DEPARTMENT OF ENERGY  
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2  
PHASE II RFI/RI EXPOSURE  
TECHNICAL MEMORANDUM

LOCATION OF WELLS  
NEAR WOMAN CREEK



LEGEND

--- ROCKY FLATS PLANT  
BOUNDARY

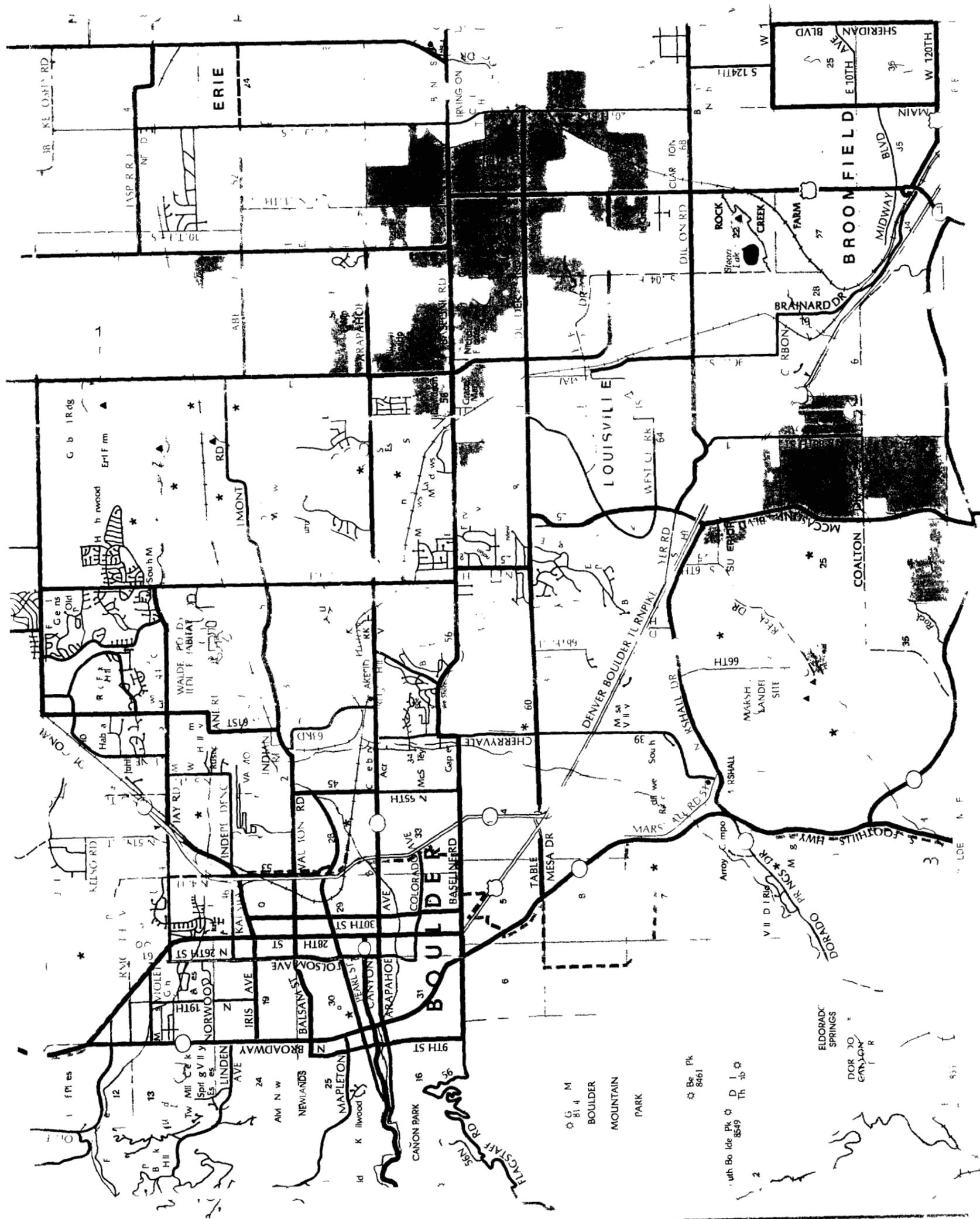


U S DEPARTMENT OF ENERGY  
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2  
PHASE II RFI/RI EXPOSURE  
TECHNICAL MEMORANDUM

CURRENT LAND USE  
IN JEFFERSON COUNTY

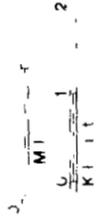
SOURCE JEFFERSON COUNTY LAND USE INVENTORY MAP



20 Interstate  
 15 US State Highway  
 10 Freeway Expressway  
 Arterial  
 Collector  
 Local Access  
 Jeep Trail  
 Subdivisor Road

Incorporated Area  
 Subdivision or Platted Area  
 County Open Space  
 Park Land and City Open Space  
 Conservation Area

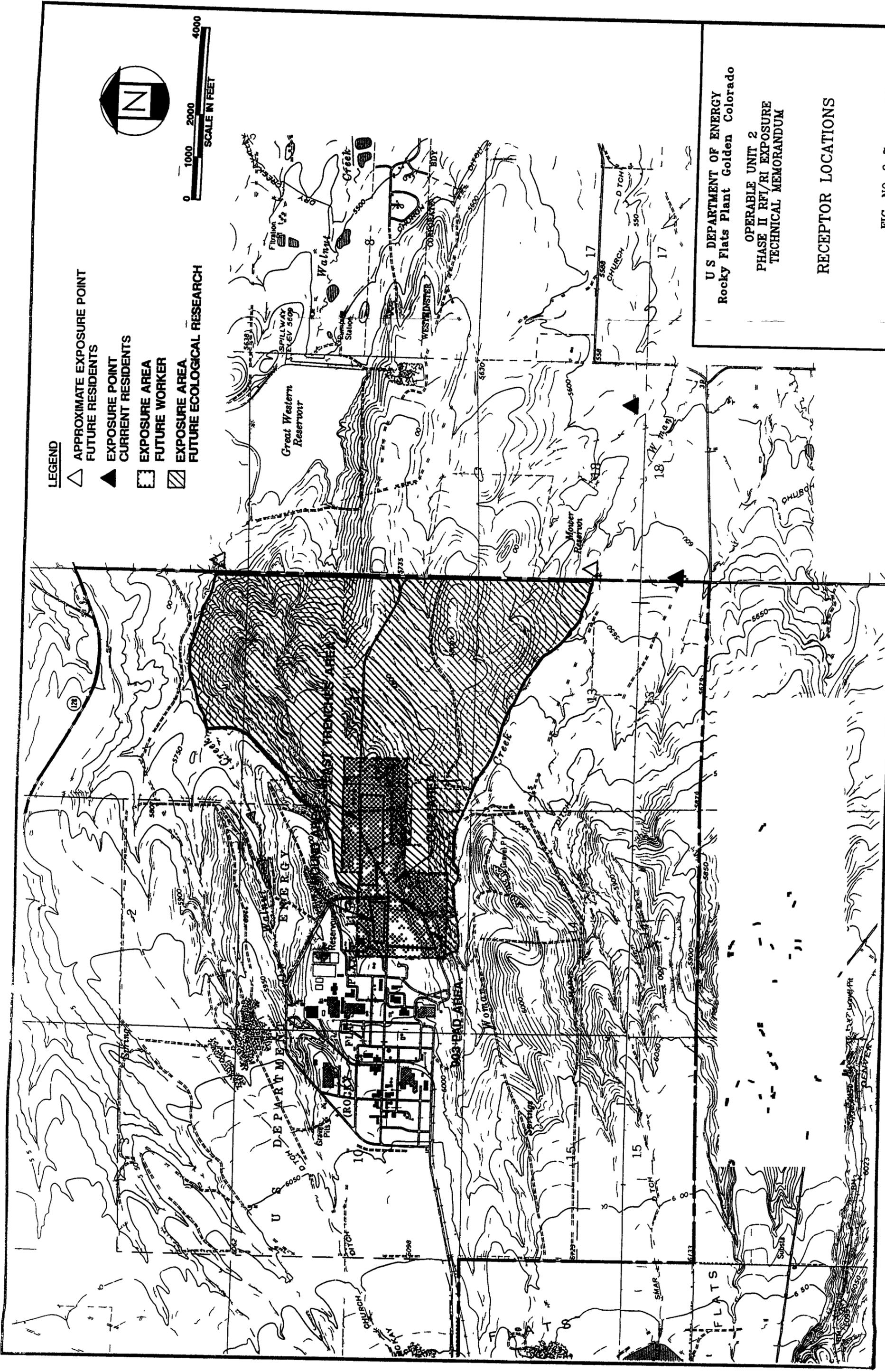
Not Open to the Public  
 Public Access on Trail System Only  
 Commissioner's District Boundary  
 Roosevelt National Forest Boundary  
 Boundary  
 Settlement



COLORADO  
 DEPARTMENT OF ENERGY  
 Rocky Flats Plant Colden Colorado  
 OPERABLE UNIT 2  
 PHASE II REFINERY EXPOSURE  
 TECHNICAL MEMORANDUM  
 CURRENT LAND USE  
 IN BOULDER COUNTY







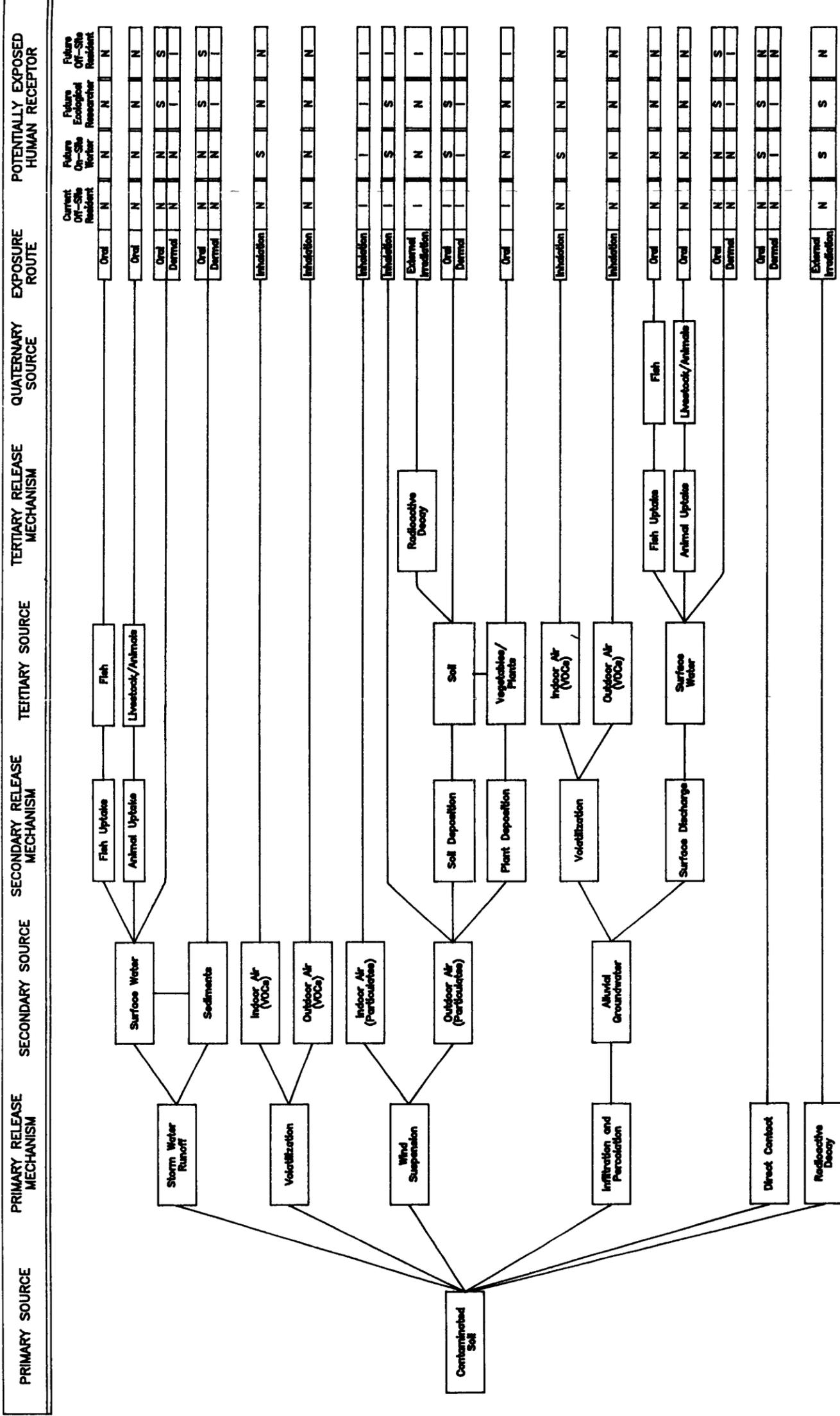
- LEGEND**
- △ APPROXIMATE EXPOSURE POINT  
FUTURE RESIDENTS
  - ▲ EXPOSURE POINT  
CURRENT RESIDENTS
  - ▨ EXPOSURE AREA  
FUTURE WORKER
  - ▩ EXPOSURE AREA  
FUTURE ECOLOGICAL RESEARCH



U S DEPARTMENT OF ENERGY  
Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2  
PHASE II RFI/RI EXPOSURE  
TECHNICAL MEMORANDUM

RECEPTOR LOCATIONS



**LEGEND**

- S Significant Potential Exposure Pathway
- I Insignificant Potential Exposure Pathway
- N Negligible or Incomplete Exposure Pathway

U S DEPARTMENT OF ENERGY  
 Rocky Flats Plant, Golden Colorado  
 OPERABLE UNIT 2  
 PHASE II RFI/RI EXPOSURE ASSESSMENT  
 TECHNICAL MEMORANDUM  
 CONCEPTUAL SITE MODEL  
 FOR ROCKY FLATS OU2