NOTICE

All drawings located at the end of the document.

TECHNICAL MEMORANDUM NO. 2

HUMAN HEALTH RISK ASSESSMENT
WALNUT CREEK PRIORITY DRAINAGE
OPERABLE UNIT NO. 6
EXPOSURE SCENARIOS

DRAFT

ROCKY FLATS PLANT

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

ENVIRONMENTAL MANAGEMENT DEPARTMENT

June 1993

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ATTACHMENT A OPERABLE UNIT 6 DOMESTIC WATER SUPPLY SIMULATIONS

This Exposure Assessment Technical Memorandum (EATM) is presented as part of the Baseline Risk Assessment (BRA) for the Walnut Creek Priority Drainage, otherwise known as Operable Unit Number 6 (OU6), 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 exposure scenarios for the HHRA portion of the BRA for OU6. The HHRA will evaluate human health risks for on-site and off-site receptors under current land-use conditions and under probable future land-use conditions, assuming no remedial action takes place at OU6.

This memorandum describes present and potential and reasonable future-use exposure scenarios to be evaluated for OU6 and identifies reasonable maximum intake parameters for estimating chemical intake from various exposure routes. This memorandum is being submitted prior to initiating the HHRA for OU6, as part of the Phase I 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 1991).

1.1 OBJECTIVES

The objectives of this EATM are to identify: (1) human receptor populations that may be exposed to chemicals released from the operable unit, (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 exposure pathway and receptor. This EATM does not quantify chemical intake, which is dependent on the chemical concentration at the exposure points. Exposure point concentrations will be estimated based on the analytical results of the Phase I Remedial Investigation and fate and transport modeling, as appropriate.

1.2 SCOPE

The scope of this technical memorandum is limited to the identification of current and future human exposure scenarios for OU6, including identifying exposure pathways and intake parameters. Potential scenarios are identified according to EPA's 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 exposure pathways are evaluated in Section 4.0 using a conceptual site model (CSM). In the CSM, exposure pathways are classified as significant, relatively insignificant, negligible or incomplete. In this document, incomplete pathways are those in which release and transport to exposure points does not occur; negligible pathways are those that are inconsequential compared to other exposure routes; significant pathways are those that result in comparatively high exposures, depending on exposure point concentration and intake; and relatively insignificant pathways are those that could 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. Both significant and insignificant exposure scenarios will be evaluated quantitatively in the HHRA for OU6. Negligible and incomplete pathways are discussed in this EATM but will not be evaluated quantitatively in the HHRA.

This EATM is organized as follows: Section 2.0, Site Description, describes site characteristics of OU6 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 human 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 OU6 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 intake of chemicals in various media and identifies exposure factors for the calculation of chemical intake by human receptors. Section 6.0 contains the references cited throughout this document.

2.0
SITE DESCRIPTION

The RFP is located on approximately 2,653 hectare (6,550 acres) of federally owned land in northern Jefferson County, Colorado, approximately 26 kilometers (16 miles) northwest of Denver (Figure 2-1). 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-acre) security area surrounded by a buffer zone of approximately 2,489 hectares (6,150 acres). A general description of RFP is presented in this section. For a more detailed description, please refer to the RFI/RI Work Plan for OU6 (EG&G 1992a).

The RFP is a government-owned and contractor-operated facility that is part of the nationwide nuclear weapons production complex. RFP was operated for the U.S. Atomic Energy Commission (AEC) from the RFP's inception in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for RFP was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the Department of Energy (DOE) in 1977. Dow Chemical USA, an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975, when Dow was succeeded by Rockwell International. On January 1, 1990, EG&G Rocky Flats, Inc. succeeded Rockwell International.

RFP's primary mission has been to produce metal components for nuclear weapons. These components are fabricated from plutonium, uranium, and nonradioactive metals (principally beryllium and stainless steel). Parts made at RFP are shipped elsewhere for final assembly. When a nuclear weapon is determined to be obsolete, components of these weapons fabricated at RFP are returned for special processing to recover plutonium. Other activities at RFP include research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics. Both radioactive and nonradioactive wastes are generated in these research and production processes. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed 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 1992 speech given at RFP, Secretary of 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 IHSS's WITHIN OU6

This Phase I RFI/RI EATM addresses OU6, which is the Walnut Creek Drainage located to the north and east of the RFP security area. Twenty-one individual hazardous substances sites (IHSS's) are included in OU6. Figure 2-2 shows the locations of these IHSS's, and the OU6 boundary. Detailed historical information can be found in the Phase I RFI/RI Work Plan (EG&G 1992a). The following IHSS's make up OU6 and will be included in the risk assessment:

- A-Series Ponds (IHSS's 142.1, 142.2, 142.3, 142.4)
- Terminal pond near intersection of Walnut Creek and Indiana Street (IHSS 142.12)
- B-Series Ponds (IHSS's 142.5, 142.6, 142.7, 142.8, 142.9)

- North, Pond and South Area Spray Fields (IHSS's 167.1, 167.2, 167.3)
- East Area Spray Field (IHSS 216.1)
- Trenches A, B, and C (IHSS's 166.1, 166.2, 166.3)
- Sludge Dispersal Area (IHSS 141)
- Triangle Area (IHSS 165)
- Old Outfall (IHSS 143)
- Soil Dump Area (IHSS 156.2)

2.2 PHYSICAL SETTING

The natural environment of RFP 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 and 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 interfluve 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. The flow in Walnut Creek is routed around Great Western Reservoir by the Broomfield Diversion Canal operated by the City of Broomfield. Woman Creek drains the southern portion of the 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 the precipitation, and the remainder is received as light rain and snowfall in the fall. Annually, snowfall averages 216 centimeters (85 inches).

The prevailing wind direction, as shown in Figure 2-3, is from the north and northwest approximately 36 percent of the year. Wind flows from the west-southwest approximately 24 percent of the year. The highest wind velocity is from the northwest and is greater than approximately 56 kilometers per hour (34.5 mph). Therefore, it is likely that atmospheric dispersion from RFP would affect areas to the east and southeast of the plant.

2.4 GEOLOGY

The surficial deposits at OU6 consist of pediment alluvium, colluvium, valley-fill alluvium, and artificial fill that unconformably overlie bedrock. Surficial deposits at RFP are Quaternary and Pleistocene in age (EG&G 1992b). The near-surface bedrock (Arapahoe and Laramie formations), as well as the Rocky Flats Alluvium, are shown on Figure 2-4 and are discussed below. The regional dip of the bedrock is approximately two degrees to the east, in the vicinity of OU6 (EG&G 1992a).

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 (EG&G 1992b). Subsequent dissection and headward erosion by creeks to the south and within OU6 have cut through the alluvium into the underlying bedrock. This dissection has left the base of the alluvium exposed along the valley walls. The Rocky Flats Alluvium is the surficial deposit in the vicinity of the western portion of the North and South Spray Fields, the East Spray Field and Soil Dump Area, Trenches A, B, and C, the Sludge Dispersal Area, and the Triangle Area.

Colluvial materials in OU6 were derived from slope wash and creep of the Rocky Flats Alluvium and from the Arapahoe and Laramie Formations. The colluvium consists of clays, sands, and gravels. Colluvium derived from the Rocky Flats Alluvium characteristically covers the alluvial/bedrock contact along the hillsides, especially near the A and B-series ponds (EG&G 1992b). Artificial fill and disturbed ground occur in localized areas of OU6, especially in the Old Outfall, Soil Dump Area, and the Pond Area Spray Field. Recent valley-fill alluvium occurs in the active stream channels of Walnut Creek and near the Old Outfall. This material is derived from reworked older alluvial and bedrock deposits.

The Cretaceous-age Arapahoe Formation underlies the surficial material at OU6. The Arapahoe Formation 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 Formation occasionally outcrops along the Walnut Creek stream valley and probably underlies the Rocky Flats Alluvium under all of the IHSS's in OU6.

The geology at depth in OU6 is largely unknown or unconfirmed. There is an ongoing Bedrock Characterization Program at Rocky Flats to better define the subsurface geology and reinterpret information from previous studies. Aside from the subsurface investigation conducted during the Phase I RFI/RI for OU6, there has been no subsurface investigation near many of the IHSS's in OU6.

2.5 HYDROLOGY

2.5.1 Groundwater

Groundwater in OU6 is likely to occur under unconfined conditions in the Rocky Flats Alluvium, colluvium, valley fill, and the Arapahoe Formation sandstones in direct contact with the alluvium. In addition, limited areas of subcropping claystone may be saturated, particularly where the claystone is fractured and weathered (EG&G 1991b).

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. Groundwater in the colluvium mantling the valley slopes bordering Walnut Creek will have a localized flow toward the creek.

Eleven wells were installed during Phase I RFI/RI field investigation conducted from in late 1992 to early 1993. The Rocky Flats Alluvium was found to be less than 10 feet thick in those locations. In addition, eight of the eleven wells were dry upon completion. Wells were completed between November 1992 and January 1993. While the wells may contain water during periods of highest groundwater, field results suggest that the Rocky Flats Alluvium in the OU6 area is probably only a seasonal aquifer.

Groundwater does occur in the valley fill material along North and South Walnut Creeks. The extent of the valley fill aquifer is limited to the narrow stream channels in contact with Walnut Creek.

Recharge to the unconfined aquifer 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 (EG&G 1992a).

Groundwater discharge in the unconfined aquifer occurs at seeps and springs at the contact between the Rocky Flats Alluvium and the claystone bedrock. This water is consumed by evapotranspiration or flows downslope through the colluvial deposits where it discharges to Walnut Creek or into the valley fill alluvium.

2.5.2 Surface Water

Surface water at RFP is currently managed and monitored in accordance with the RFP's surface water management plan (EG&G 1991a). 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 due to plant operations.

Walnut Creek flows through a series of detention ponds (A and B series) and is currently diverted around Great Western Reservoir via the Broomfield Diversion Ditch. Walnut Creek and its tributaries are intermittent because of the seasonal response to freezing, spring runoff, and storm events.

Figure 2-2 illustrates the current surface water bodies in the Walnut Creek drainage. Detention Ponds B-1 through B-5 are located on South Walnut Creek and receive storm runoff from the East Spray Field, Soil Dump Area, Triangle Area, and Sludge Dispersal Area. Detention Ponds A-1 through A-4 are located on North Walnut Creek and receive storm runoff from the East Spray Field, Soil Dump Area, Triangle Area, Old Outfall, and South Spray Field. An unnamed tributary to Walnut Creek receives storm runoff from the Trenches, North Spray Field, Pond Area Spray Field, and South Spray Field. Detention Pond IHSS 142.12 receives storm runoff from the eastern-most portion of the Walnut Creek drainage at RFP since it is on the eastern edge of the plant. Surface water held in Ponds A-1, A-2, B-1 and B-2 is generally not discharged to the lower ponds; instead the water is spray evaporated or naturally evaporates from the ponds so that they maintain a relatively constant water level. Pond B-3 receives effluent from the Sewage Treatment Plant and then periodically discharges to B-4. Pond B-4 continuously discharges to Pond B-5 and the water from B-5 is pumped to Pond A-4 where it is treated by granular activated carbon (GAC) prior to discharge downstream. Ponds A-3, A-4, B-3, and B-5 are all sampled for NPDES compliance.

2.5.3 Wells Along the Walnut Creek Drainages

Walnut Creek 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 the Walnut Creek Drainage.

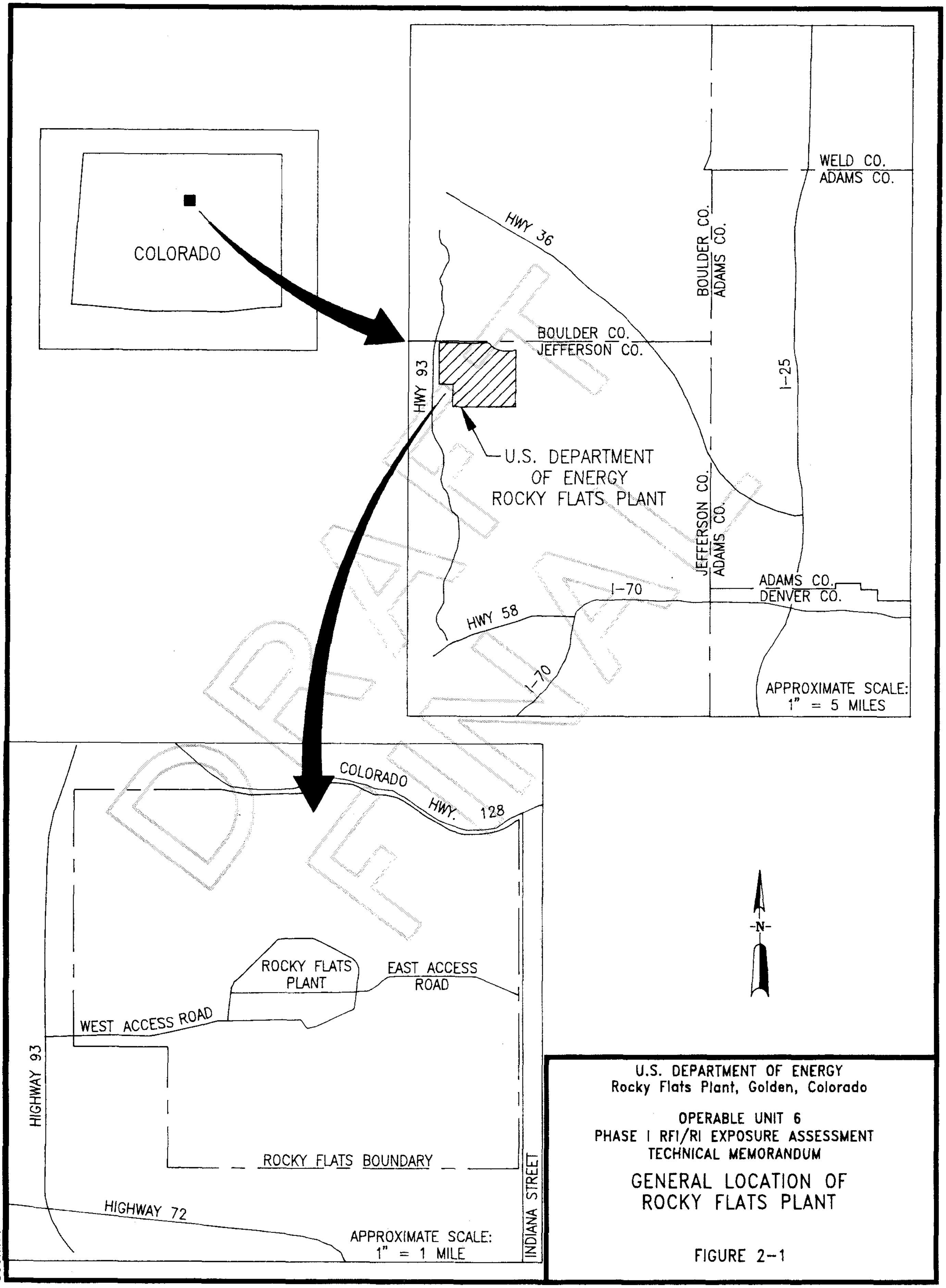
2.6 ECOLOGY

The following section presents a brief summary of biological resources at the RFP. 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.

Plants characteristic of tall-grass prairie, short-grass plains, lower mountain, and foothill ravine regions can be found within the boundaries of RFP. Grasses predominate on the hillsides along Walnut Creek and Woman Creek drainages. The creeks also host grasses, cattails, rushes, and cottonwood trees.

Animals inhabiting RFP and the buffer zone are characteristic of western prairie regions. Mule deer, 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 Walnut Creeks. Minnows have been observed in Walnut Creek, 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 OU6. The western painted turtle and western plains garter snake inhabit the greens near the ponds (DOE 1980).

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 1991c). The wildlife species include the bald eagle, peregrine falcon, whooping crane, and the black-footed ferret (DOE 1991, USFWS 1990). Because of the undisturbed nature of the buffer zone, it is a possible candidate for 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.

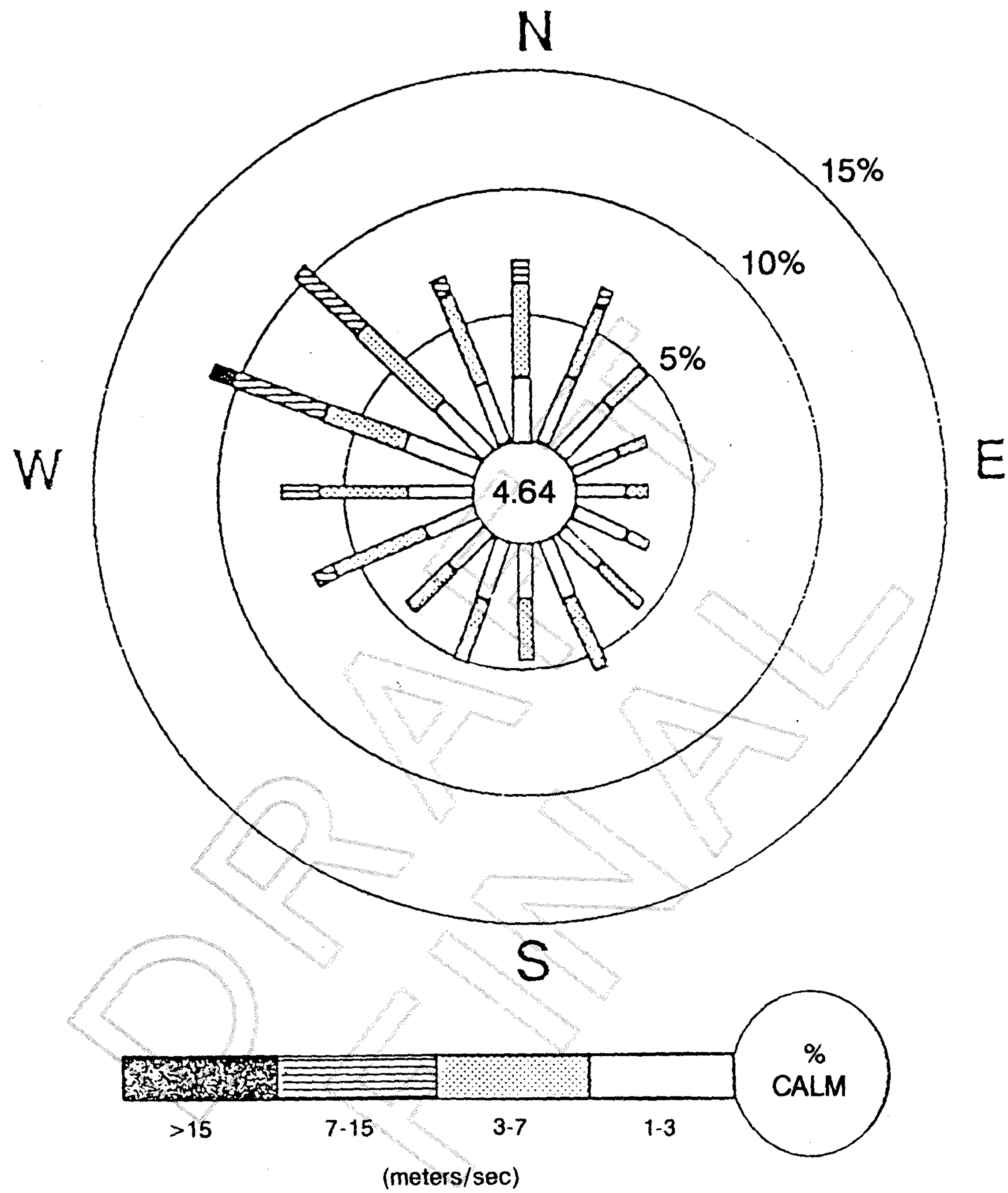


U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

GENERAL LOCATION OF
ROCKY FLATS PLANT

FIGURE 2-1



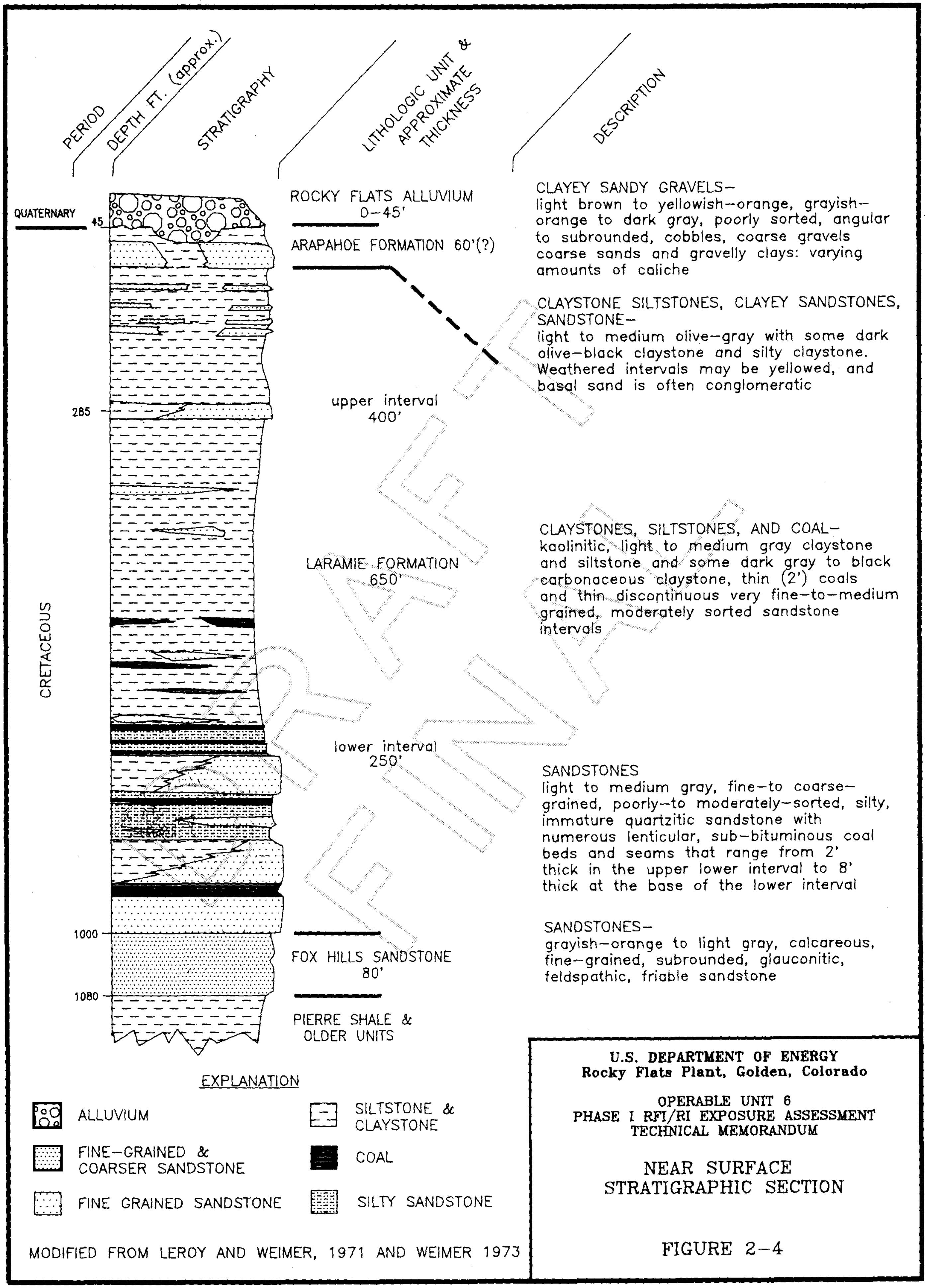
SOURCE: EG&G 1990a.

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

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

WIND ROSE FOR THE
ROCKY FLATS PLANT
1990 ANNUAL

FIGURE 2-3


PERIOD
DEPTH FT. (approx.)
STRATIGRAPHY
LITHOLOGIC UNIT & APPROXIMATE THICKNESS
DESCRIPTION
QUATERNARY
45
ROCKY FLATS ALLUVIUM 0-45'
CLAYEY SANDY GRAVELS– light brown to yellowish-orange, grayish-orange to dark gray, poorly sorted, angular to subrounded, cobbles, coarse gravels coarse sands and gravelly clays: varying amounts of caliche
ARAPAHOE FORMATION 60'(?)
CLAYSTONE SILTSTONES, CLAYEY SANDSTONES, SANDSTONE– light to medium olive-gray with some dark olive-black claystone and silty claystone. Weathered intervals may be yellowed, and basal sand is often conglomeratic
285
upper interval 400'
CRETACEOUS
LARAMIE FORMATION 650'
CLAYSTONES, SILTSTONES, AND COAL– kaolinitic, light to medium gray claystone and siltstone and some dark gray to black carbonaceous claystone, thin (2') coals and thin discontinuous very fine-to-medium grained, moderately sorted sandstone intervals
lower interval 250'
SANDSTONES light to medium gray, fine-to coarse-grained, poorly-to moderately-sorted, silty, immature quartzitic sandstone with numerous lenticular, sub-bituminous coal beds and seams that range from 2' thick in the upper lower interval to 8' thick at the base of the lower interval
1000
FOX HILLS SANDSTONE 80'
SANDSTONES– grayish-orange to light gray, calcareous, fine-grained, subrounded, glauconitic, feldspathic, friable sandstone
1080
PIERRE SHALE & OLDER UNITS
EXPLANATION
ALLUVIUM
SILTSTONE & CLAYSTONE
FINE-GRAINED & COARSER SANDSTONE
COAL
FINE GRAINED SANDSTONE
SILTY SANDSTONE
MODIFIED FROM LEROY AND WEIMER, 1971 AND WEIMER 1973
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM
NEAR SURFACE STRATIGRAPHIC SECTION
FIGURE 2-4

3.0
POTENTIALLY EXPOSED RECEPTOR POPULATIONS

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 OU6 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 a one-mile circumference surrounding 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 1992a). 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, located in Standley Lake Park, is a drinking water supply for the cities of Thornton, Northglenn, Westminster, and Federal Heights, and 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 immediately east and southeast of OU6 includes all of the uses mentioned above, with the predominant uses are open space, single-family detached dwellings, and horse-boarding operations. Cattle are grazed locally on a seasonal basis. Two small cattle herds (approximately 10 to 20 cattle in each herd) have been observed approximately 2-1/2-miles east east and southeast of the Plant. Industrial facilities to the south include the TOSCO laboratory, Great Western Inorganics Plant, and Frontier Forest Products (EG&G 1992a).

3.2.2 Future

Future development is expected to follow 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 because the land is currently undeveloped and therefore costs less, and because of the lower taxes associated with locating in an unincorporated portion of the county. Future improvements in roads and highways may also enhance commercial and industrial development of northeastern Jefferson County.

The 470 highway system has been proposed to encircle the entire Denver metropolitan area including an area near RFP. The proposed W-470 alignment would skirt the southern and eastern boundaries of RFP, although several alignments have been studied. The construction of W-470 has been postponed at this time but could be reconsidered at some time in the future.

Residential development is not as attractive as industrial development of the area because of the proximity to Jefferson County Airport and the industrial land use that is expected to dominate the northeastern portion of Jefferson County.

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. The plan was developed by representatives of Jefferson County, five cities (Arvada, Broomfield, Golden, Superior, and Westminster), and participants from a variety of interest groups including homeowners, businesses, builders/developers, environmentalists, and special districts. The plan identifies 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 OU6 area. The major portion of OU6 is located within the buffer zone, outside of the security fence and protected area (PA). Current activities in OU6 consist of environmental investigations and routine security surveillance.

3.3.2 Future

RFP is currently planning for decontamination and decommissioning, which is expected to begin in the near future. Future plans for RFP activities are discussed in the Nuclear Weapons Complex Reconfiguration Study. The two preferred nuclear weapons complex reconfiguration options identified in the study both include relocation of RFP functions (DOE 1992). Future land-use alternatives are discussed in the "RFP Site-Wide Environmental Impact Statement" (EIS). Four alternatives 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 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 decontamination and decommissioning 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, decontamination and decommissioning of selected facilities, and placement of other facilities into safe storage. This is the preferred alternative at this point.

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 former Secretary of Energy James Watkins. Watkins characterized RFP as an attractive site for manufacturers and other businesses. Private industry could relocate to existing buildings and use existing equipment at RFP, after necessary decontamination is complete. The RFLII is working to achieve this objective at Rocky Flats so that future changes at RFP can be transformed into economic, socioeconomic, educational, land use, environmental, and infrastructural advantages. RFLII is working with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the RFP (RFLII 1992).

Large portions of the buffer zone surrounding the developed portions of the plant could remain open space. 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 adjacent to the plant, it is plausible that the buffer zone and OU6 area will also 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 1992c). 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 the Walnut Creek drainage are not conducive to extensive residential or commercial development. Due to the potential hazards associated with unstable slopes, landslides, and slope failures, Jefferson County emphasizes that development should only occur on slopes with grades of 30 percent or less (Jefferson County 1990). Approximately 25 percent of the land in the eastern portion of the RFP property is 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 EVALUATION OF POTENTIAL RECEPTORS

Current and future human population groups on and near OU6 are potential candidates for evaluation based on 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 current and expected future land-use patterns for off-site and on-site areas are described in Sections 3.2 and 3.3, respectively. For the purpose of a qualitative evaluation of potential receptors, future land-use scenarios have been categorized as either improbable (unlikely to occur because of serious constraints) or credible (expected to occur given the right set of circumstances). Table 3-3 presents the probability classification for the five major land use categories (residential, commercial/industrial, recreational, ecological reserve, and agricultural) and is used to identify potential human receptors for quantitative evaluation in the OU6 HHRA.

Current on-site land uses are industrial and open space. Potential receptors include workers at RFP. Since OU6 is comprised largely of land outside the production areas, security and maintenance workers who visit OU6 during their rounds are the people most likely to be currently exposed to OU6-related chemicals.

Current off-site land use includes residential, commercial/industrial, recreational, and agricultural. Anyone involved in these activities could potentially be exposed to OU6-related chemicals if the chemicals were transported off-site. Residential exposure, because it occurs daily for many years in the same location, is the highest current off-site exposure that is expected to occur.

As shown in Table 3-3, future on-site uses for agriculture and residential communities are classified as improbable because of the increasing public interest in preserving unplowed prairie and wetlands habitats and protecting wildlife. This is evidenced by ongoing acquisition of open space by Jefferson County, Boulder County, and the City of Boulder (including large tracts near RFP) and the recent designation of the Rocky Mountain Arsenal as a wildlife refuge by the U.S. Fish and Wildlife Service. Like RFP, the Arsenal is a large (27-square mile) RCRA/CERCLA site that was protected from grazing or development because of weapons production and the need for an extensive buffer zone. Additionally, agriculture would offer poor economics compared to commercial/industrial development.

Off-site agriculture is considered to be less likely than residential, commercial/industrial, or open-space recreational uses because of economics as well as public and community interest in preserving open space. This is also consistent with existing regional zoning and land use designations, as discussed in Section 3.2 of this technical memorandum and shown in the figures included in that section. Therefore, although agriculture currently occurs in nearby off-site areas, it is anticipated that this use will gradually diminish and eventually disappear from parcels closest to the site.

Use of off-site areas as ecological reserves is considered improbable because most parcels are disturbed by cultivation or heavy grazing and therefore do not provide valuable wildlife habitat and because of the proximity to planned commercial/industrial or mixed commercial/residential uses. Exceptions might be stands of cottonwoods near Standley Reservoir, where bald eagles were observed in the winter of 1992-1993.

Future on-site land uses considered to be credible include commercial/industrial, recreational uses, and the designation of the buffer zone as open space or an ecological reserve. Commercial/industrial uses would be appropriate, at least for the present industrialized area of RFP, because of the existing infrastructure, economic advantages, and reduced liability concerns. On-site recreational and ecological reserves would be consistent with the ecological diversity and scenic quality of the site, the existing wildlife uses and presence of several species of special concern, the increasing regional interest in habitat preservation and undeveloped recreation, and minimal liability issues.

Credible future off-site uses include commercial/industrial, residential, and recreational. All these are consistent with recent growth and development patterns in the northwestern Denver metropolitan area and are projected in various planning documents (see Section 3.2).

3.5 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. The receptor populations selected for evaluation are those most likely to be exposed and be subject to 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 3-4 and include current and hypothetical future off-site residents, hypothetical future on-site residents, current on-site security workers, future on-site office and construction workers, and future on-site ecological researchers. The ecological researcher is used to represent potential outdoor exposures to the Walnut Creek drainage system and ponds. Each of these receptors is described in further detail below. The receptor locations are shown in Figure 3-7. The exposure areas and exposure points shown in Figure 3-7 were selected to reflect the most reasonable locations where chemical exposures could be expected to occur for each of the receptors, and they are consistent with current and future land use at the RFP. The exposure areas and exposure points depict locations where each of the respective human receptors are expected to spend the majority of their time. Using field data and fate and transport modeling, as appropriate, the exposure concentrations will be calculated and used to quantitatively evaluate chemical intakes for each receptor.

3.5.1 Current and Future Residents

Exposure point locations for current and future residents are shown on Figure 3-7. The HHRA will evaluate potential health risks for a current off-site resident at the nearest downwind location to RFP. This is the reasonable maximum exposure scenario for non-RFP personnel because the public is restricted from access to RFP and access to OU6 is limited to authorized on-site workers.

Trespassing is not considered a plausible current-use scenario because of the high level of security at the plant, nor does it represent a reasonable maximum exposure. 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 trespassers on federal property that they are subject to arrest. 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.

Based on the future industrial/commercial land-use plans for the area, exposure to a hypothetical future off-site resident will be quantitatively evaluated at Walnut Creek at Indiana Street. This location corresponds to the reasonable maximum exposure point because of its proximity to the site, the direction of prevailing winds, and the proximity to Walnut Creek as it leaves the RFP. 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.

Although on-site residences are not consistent with future land-use plans, a hypothetical future on-site resident exposure scenario will be evaluated in the health risk assessment. The future on-site resident will be assumed to live within the OU6 area boundary.

3.5.2 Current and Future On-Site Workers

The current RFP workers who spend the greatest amount of time in OU6 are plant security personnel. Guards conduct routine patrols within OU6.

The HHRA will evaluate potential risks to both current and future on-site workers, even though worker health and allowable exposures to potentially hazardous materials are governed by programs and standards outside of the RFI/RI process. The health and safety of on-site workers is presently monitored under a comprehensive health and safety program at RFP. Health and safety 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 1990b). 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 1990b). EG&G has superseded some of the OSHA standards with more stringent policies established by EG&G, DOE, or other governmental agencies (EG&G 1990b).

At RFP, health and safety plans and procedures are written for everyday activities as well as specific projects. All subcontractors to EG&G must prepare their own site or project-specific health and safety plans, and they must require and enforce standards that are at least as stringent as EG&G's requirements (EG&G 1990b). Several programs exist at RFP to support the health and safety programs, including radiation protection, emergency response, occupational safety, vehicular and pedestrian safety, fire protection, and contractor safety (EG&G 1992c). The written plans 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 1992d). 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. Physical and administrative controls also limit worker exposure to potentially hazardous conditions. The health and safety of current workers at RFP is thoroughly monitored with required baseline, annual, and exit physical examinations. Exposure levels of chemicals of concern in the work environment are controlled by monitoring and reporting requirements.

A future on-site worker will also be quantitatively evaluated in the health risk assessment. This worker is assumed to be unprotected and untrained in health and safety matters. Based on the commercial/industrial development plans for the area, the future on-site workers are assumed to be an indoor worker (office worker), and a construction worker. The setting for the office worker is likely to have extensive paved areas and well-maintained landscaping. The location of this receptor is shown in Figure 3-7. The location designated for on-site workers represents a reasonable exposure area for that receptor. The future on-site construction worker is assumed to have direct contact with subsurface soil limited to the duration of construction of a moderate-size commercial building on site.

3.5.3 Future On-Site Ecological Researcher

The future use of the on-site, non-production areas at RFP will most likely involve an open-space or ecological reserve scenario. The receptors in an open-space scenario could include recreational users and researchers conducting ecological studies. Of these two potential receptors, the ecologist is likely to spend more time at the RFP site than recreational users and would come in close contact with the soils, sediments, and surface water. Therefore the ecological researcher would have a greater chance of exposure to contaminants at the site and represents the reasonable maximum exposed individual under open space future land use. The area applicable to this receptor is shown in Figure 3-7 and includes Walnut Creek and the land area surrounding the creek outside the security fence and the PA. Exposures to this receptor will be quantitatively evaluated in the risk assessment.

TABLE 3-1

CURRENT AND PROJECTED POPULATIONS

		Year 1989/2010					
Sector	Location (1)	D	E	F	G	H	I
1	RFP	0/0	0/0	0/0	0/0	0/0	0/0
2	RFP	0/0	0/0	0/0	0/0	0/0	0/0
3	1 mile	0/0	0/0	0/0	17/17	0/0	7/7
4	2 miles	0/14	283/644	46/142	50/50	215/1007	3/3
5	3 miles	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."

(1) Miles shown are distance from RFP boundary.

TABLE 3-2

ROCKY FLATS PLANT
CURRENT SURROUNDING LAND USE IN JEFFERSON COUNTY

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
22009			
44001	Vacant	A-2	Vacant
44002			
44003	Vacant	I-1	Industrial
44004	Vacant	A-2	Vacant
44005			
44006	Vacant	I-3	Industrial
44007	Vacant	A-2	Vacant
45001			
45002	Walnut Creek Unit 1	P-D	Single Family - Detached
45002	Walnut Creek Unit 1	P-D	Retail
45003	Vacant	A-2	Vacant
45004	Single Family - Detached	A-2	Single Family - Detached
45005	Single Family - Detached	A-2	Vacant
45006	Water	A-2	Water
45007	Single Family - Detached	A-2	Single Family - Detached
45007	SF-D	A-2	Farm/Ranching
46005	Vacant	A-2	Single Family - Detached
46006	Triple C Quarter Horses	A-2	Retail
46007	Horse Barn- Boarding & Breeding	A-2	Retail

TABLE 3-2
(Continued)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
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
72009	Vacant - Rocky Flats	A-2	Industrial
72010	Vacant	I-2	Industrial
72011	Northwest Industrial	I-2	Industrial

TABLE 3-2
(Continued)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
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
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

TABLE 3-2
(Concluded)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
101002	Vacant	M-C	Industrial
101003	Vacant	I-2	Industrial
101004	Mine and Water	I-2	Industrial
101005	Northwest Industrial	I-2	Industrial
101006	Vacant	M-C	Industrial
101007	Sanitary Landfill and Gravel	P-DA	Industrial
101008	Rocky Flats Lake	M-C	Water

1 Zoning Abbreviations are 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
M-C	Mineral Conservation
Source:	Jefferson County Planning Department

TABLE 3-3

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

Land Use Category	Current		Future	
	Off Site	On Site	Off Site	On Site
Residential	Yes	No	Credible	Improbable
Commercial/Industrial	Yes	Yes	Credible	Credible[c]
Recreational	Yes	No	Credible	Credible[d]
Ecological Reserve	No	Yes	Improbable	Credible[d]
Agricultural	Yes	No	Improbable	Improbable

[a]Credible is used to indicate scenarios that may reasonably occur.
[b]Improbable is used to indicate scenarios that are unlikely to occur.
[c]Expected in the currently developed area of the plant site.
[d]Expected in the buffer zone.

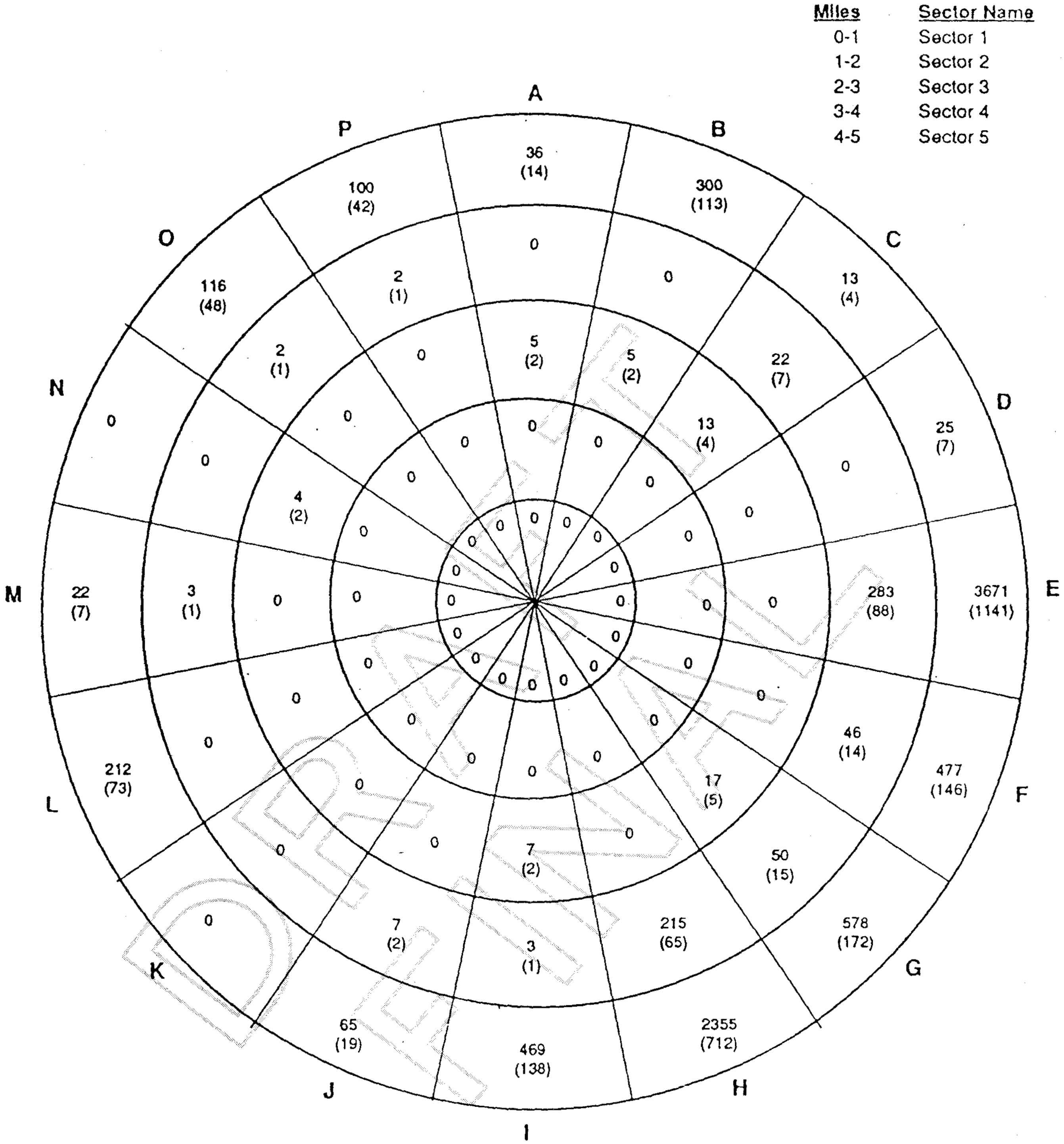
TABLE 3-4

ROCKY FLATS PLANT
OU6
POTENTIALLY EXPOSED RECEPTORS TO BE QUANTITATIVELY EVALUATED

Current Scenario	Future Scenario
On-site worker (security) Off-site resident	On-site worker (commercial/ industrial) On-site construction worker On-site ecological researcher Hypothetical on-site resident (1) Hypothetical off-site resident (2)

(1) A future on-site hypothetical resident will be quantitatively evaluated within the OU6 area.

(2) A future off-site hypothetical resident will be quantitatively evaluated at Walnut Creek and Indiana Street



SOURCE: DOE, 1990.

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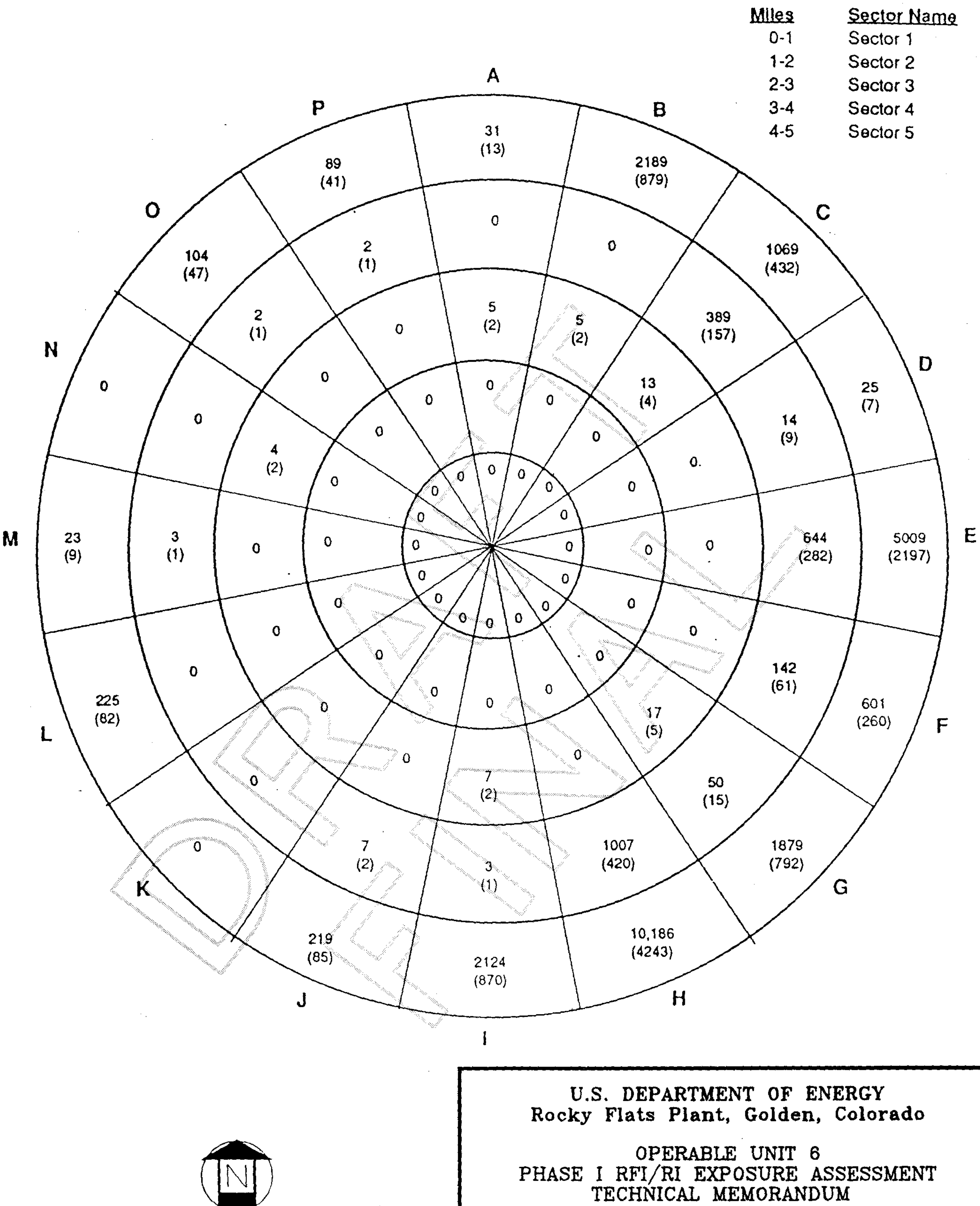
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

1989 POPULATION AND (HOUSEHOLDS) SECTORS 1-5

FIGURE 3-1

23047031



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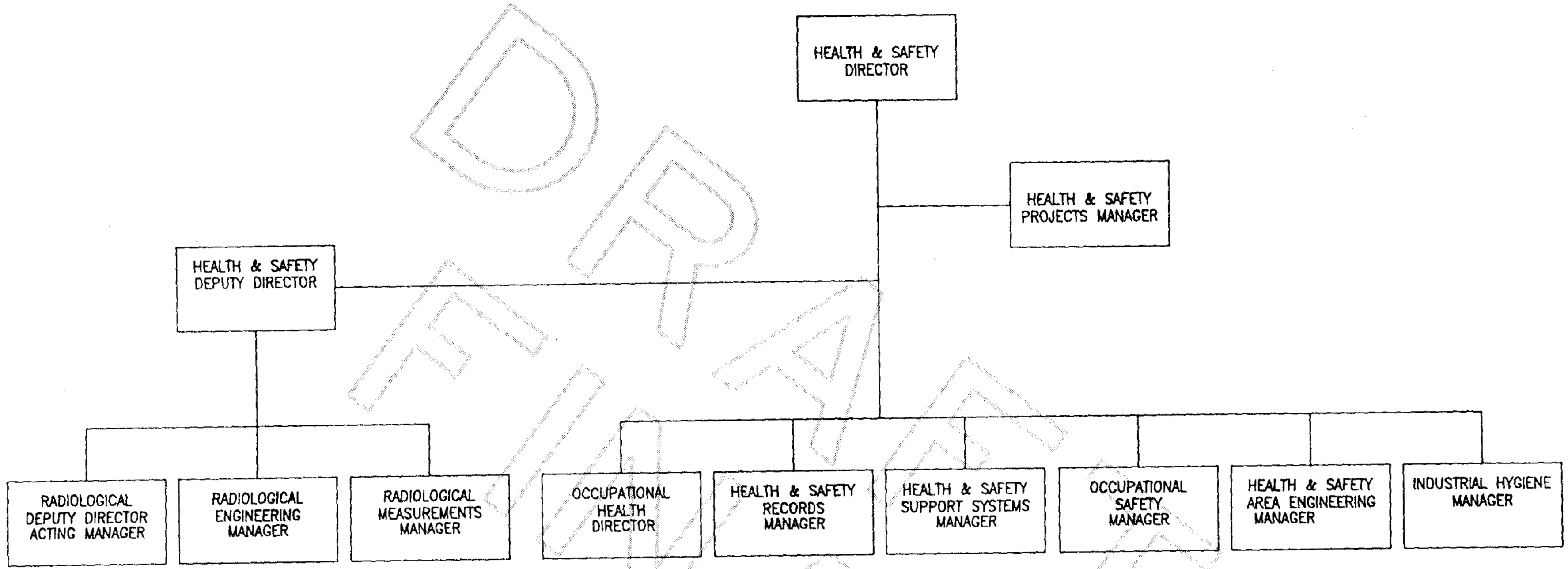
2010 POPULATION AND (HOUSEHOLDS) SECTORS 1–5

SOURCE: DOE, 1990.

FIGURE 3–2

23047032



SOURCE: EG&G, 1990.

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EG&G ROCKY FLATS
HEALTH & SAFETY ORGANIZATION

FIGURE 3-8

APRIL, 1993

4.0
EXPOSURE PATHWAYS

This section discusses the potential release and transport of chemicals from OU6 and identifies exposure pathways by which the receptor populations identified in Section 3.0 could be exposed to OU6-related 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 (e.g., infiltration, wind erosion)
- An environmental transport medium (e.g., groundwater, air)
- An exposure point
- A human intake route (e.g., ingestion, inhalation)

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 pathways will be addressed in the HHRA for OU6. An exposure pathway is considered to be potentially complete if there are potential chemical release and transport mechanisms and identified exposure points, receptors and intake routes for that exposure pathway. A few pathways may be potentially complete for some receptors, but negligible compared to other pathways. Negligible pathways are not evaluated in the quantitative risk assessment. Potentially complete, negligible, and incomplete pathways are identified for each receptor in Section 4.5, Conceptual Site Model.

4.1 CHEMICAL RELEASE SOURCES AND TRANSPORT MEDIA

OU6 encompasses the Walnut Creek Drainage from within the security area eastward to the RFP boundary. The HHRA will evaluate contaminated soil and sediments at OU6 as the primary source of chemical release. A description of historical activities conducted at OU6 was provided in Section 2.1. Chemical release from soils or sediment can occur through mechanisms such as direct contact, wind erosion, infiltration, and storm runoff. Environmental media that may transport chemicals of concern from OU6 to exposure points include air, surface water, and groundwater. These release and transport mechanisms are described in relation to exposure pathways in Section 4.5, Conceptual Site Model.

4.2 POTENTIALLY EXPOSED RECEPTOR POPULATIONS

Potentially exposed receptor populations selected for quantitative assessment in the HHRA were identified in Section 3.0. The following receptors were selected as representing reasonable maximum exposure scenarios under current and probable or hypothetical future uses:

- Current off-site resident
- Current on-site worker (security)
- Future on-site worker (office)
- Future on-site worker (construction)
- Future on-site ecological researcher
- Future off-site resident
- Hypothetical future on-site resident

4.3 EXPOSURE POINTS

An exposure point is a specific location where humans can come in contact with site-related chemicals. Exposure points are selected so that reasonable maximum exposures will be quantitatively evaluated. Evaluation of risks at these reasonable maximum exposure points will bound the risks for receptors at other locations (that is, risks at other locations will not exceed and are expected to be lower than risks at the selected exposure points). The following exposure points were selected for reasonable maximum estimates of risk. These locations are shown in Figure 3-7.

Current Use Scenarios

- Off-site residential receptor. Nearest downwind residence to RFP (located near the southeast corner of the RFP property boundary).

- On-site occupational receptor. Security specialist conducting rounds within the OU6 area.

Future Use Scenarios

- On-site occupational receptor. Office worker working in a building inside the existing security area or in future office buildings in the buffer zone, within OU6.

- On-site construction worker. Excavation worker preparing foundations for new buildings within OU6 both inside the security area and in the buffer zone.

- Ecological researcher. Outdoor on-site exposure, within buffer zone area of OU6, bounded by the unnamed tributary to Walnut Creek and South Walnut Creek.

- Off-site residential receptor. Hypothetical off-site residence at the point at which Walnut Creek intersects the eastern Rocky Flats Plant property boundary (Indiana Street).

- On-site residential receptor. Hypothetical on-site residence within the OU6 area.

4.4 EXPOSURE MEDIA

Exposure media for on- and off-site OU6 exposure scenarios include on-site soils, off-site soils potentially contaminated by deposition of particulate matter, air, and sediments and surface water in the A and B-series ponds and Walnut Creek. Surface water is considered an OU6 exposure media only in so far as it contains chemicals transported from OU6 soils in surface runoff or groundwater, or resuspended from sediments. Surface water is affected by numerous sources outside OU6. Therefore, concentrations of OU6-related contaminants in surface water will be modeled based on transport from soils in runoff or groundwater, and resuspension and transport of sediment to exposure points. Surface water sample results will be used to compare to modeling results and to provide concentrations of total suspended solids for estimating contaminant concentrations resulting from resuspension of sediments.

Groundwater is not an exposure medium for OU6 at this time because its occurrence is very limited. Approximately one-half of the monitoring wells completed during the Phase I field investigation were dry following completion. In addition, the unconfined aquifer does not extend off site (except for the valley fill alluvium) and does not appear to be a sufficient or reliable source of drinking water (Appendix A). This will be evaluated further during RFI/RI Report preparation. The upper unit is thought to discharge from seeps along Walnut Creek. Potential transport of OU6 contaminants in groundwater will be modeled to the seeps and to surface water to evaluate direct contact exposures in surface water.

4.5 HUMAN UPTAKE MECHANISMS

A human uptake mechanism is the route by which a chemical is taken in to the body. There are four basic human uptake mechanisms: (1) dermal absorption of chemicals in soil, sediment, or surface water; (2) inhalation of volatile organic compounds and airborne particulate matter; (3) ingestion of soil or water; and (4) if radionuclides are present, external irradiation. These uptake mechanisms are described further in Section 5.0, Estimating Chemical Intakes.

4.6 CONCEPTUAL SITE MODEL

Figure 4-1 shows a conceptual site model (CSM) of potential human exposure pathways for OU6. 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 needed to quantify potential exposures, and to aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

In the CSM, potentially complete and significant exposure pathways are designated by a black dot. Potentially complete but relatively insignificant exposure pathways are designated by an open circle. Both significant and relatively insignificant exposure pathways will be quantitatively addressed in the risk assessment. Quantitatively addressing significant and relatively insignificant exposure pathways will result in risk estimates that do not underestimate actual potential risks. Negligible exposure pathways and incomplete exposure pathways are designated in the CSM by an N and a dash, respectively, and will not be addressed in the risk assessment. The rationale for eliminating incomplete and negligible pathways from further evaluation is described in Section 4.6.1, Incomplete or Negligible Exposure Pathways for All Receptors. Subsequent sections describe exposure pathways that will be quantitatively evaluated for each receptor.

4.6.1 Incomplete or Negligible Exposure Pathways for All Receptors

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

- Ingestion of fish or other aquatic organisms from Walnut Creek is a negligible pathway for the future on-site resident and an incomplete exposure pathway for all other receptors. Walnut Creek is an intermittent creek. High-flow periods for this creek generally occur from March to June. The amount of flow varies significantly from no-flow in dry years to approximately four times the predicted annual flow (Advanced Sciences, Inc. 1990).

  Due to its intermittent nature, the creek does not support significant numbers of fish. However, it is possible for fish that reside in on-site ponds to migrate from these ponds to Walnut Creek during high-flow periods (WWE 1991; WCC 1992). However, because of the creek's intermittent nature, subsistence fishing is unlikely. Therefore, ingestion of fish is a negligible exposure pathway for future on-site residential receptor.

Because the nearest current off-site resident does not reside on Walnut Creek and does not have access to the ponds and because the creek is intermittent, the fish ingestion pathway is incomplete for the current and future resident. Fish ingestion is also an incomplete exposure pathway for occupational scenarios (current and future on-site workers, the future on-site construction worker and the future ecological researcher) given that these receptors are not expected to conduct subsistence fishing while working at the site, nor does Walnut Creek support subsistence fishing.

- Ingestion of livestock that graze in the area and are watered by Walnut Creek is an incomplete pathway for all receptors. Most livestock in the area surrounding RFP are horses or stock cattle brought in for temporary grazing. These animals are not consumed locally. Specifically, livestock for local consumption are not currently being raised by the nearest off-site resident, nor are there any livestock currently being raised on Walnut Creek. Therefore, ingestion of livestock is an incomplete pathway for the current and future off-site resident.

Ingestion of livestock is not an exposure pathway for current and future on-site workers and the ecological researcher because these receptors will not be raising livestock on-site for consumption.

Future zoning does not indicate that RFP will be used for agricultural purposes. A future on-site resident will probably not be raising farm animals for personal consumption. Therefore, ingestion of livestock is an incomplete pathway for the future on-site resident.

- Ingestion of groundwater for domestic use is an incomplete pathway for all receptors. Under current use, drinking water is supplied to RFP and groundwater is not a source of drinking water for on-site receptors. The upper aquifer does not extend off-site, so current and future off-site receptors cannot come into contact with the groundwater. Preliminary domestic water supply simulations performed on the water-bearing strata beneath OU6 indicate that the yield from the aquifer is insufficient to support one family of four. Therefore future residents would be unable to use it as a drinking water source (Appendix A). Future workers would be expected to be supplied by public or private water systems, as is now done. The ecological researcher is not expected to use groundwater as a drinking water supply.

- Inhalation of chemicals volatilizing from site soils to outdoor air is considered a negligible pathway for all receptors. Based on field screening results that will be reported in the OU6 Phase I RFI/RI Report, there appears to be little or no contamination by volatile organic compounds in OU6 soils. Therefore, considering the effects of dilution and dispersion in the outdoors and the apparent low concentrations of volatile compounds, this pathway is considered negligible and will not be evaluated in the risk assessment.

- Inhalation of chemicals volatilizing from groundwater through the soil column to outdoor air is a negligible pathway because volatile chemicals, if present in and released from groundwater, will be significantly retarded through the vadose zone and diluted in the ambient air.

- Ingestion of homegrown garden produce potentially contaminated by uptake from soil potentially affected, by deposition of airborne particulates is an incomplete pathway for occupational scenarios (current and future on-site workers, the future on-site construction worker and the future ecological worker) since on-site workers will not grow food on the site.

  Ingestion of homegrown garden produce potentially contaminated by uptake from soil potentially affected by deposition of airborne particulates is considered a negligible pathway for current and future off-site residents.

Concentrations resulting from deposition and mixing of OU6 contaminants in off-site residential garden soil would represent a negligible additional exposure because extreme dilution would occur during transport in air from OU6 to the closest off-site resident and because the deposited particulate matter would be mixed into the soil during tilling. Dilution in air due to Gaussian dispersion is expected to result in an annual deposition rate of less than 100 mg/m^2 of OU6 particulates on garden soil at a distance of one mile from the source. Actual values will be calculated in the Phase I RFI/RI Report. Using a tilling depth of 15 cm and a soil density of 1.2 g/cm^3 results in a total mixing factor of at least 1.8 million for each year's deposition. Assuming that deposits of airborne contaminants accumulate at the same rate for a period of 30 years yields a total dilution factor of at least 60,000.

4.6.2 Current Off-Site Resident

The nearest current off-site resident is located on Indiana Avenue south of Mower Reservoir, approximately two miles from OU6 and Walnut Creek. As shown in the CSM (Figure 4-1), wind suspension is the only release mechanism associated with potentially complete exposure pathways for the current off-site resident. Current off-site residents may be directly exposed to airborne particulate matter via inhalation. For the purpose of the risk assessment, it will be conservatively assumed that indoor and outdoor air particulate concentrations are the same. Ingestion of homegrown garden produce potentially contaminated by direct deposition of airborne particulates represents a potentially complete exposure pathways. Likewise, ingestion of and dermal contact with soil that is contaminated by particulate deposition represents potentially complete exposure pathways for the off-site resident. Because the nearest off-site resident does not live in the Walnut Creek drainage and surface water discharges during periods of high flow are regulated under the RFP NPDES permit, direct contact with surface water and sediment by the current off-site resident is a negligible pathway. Groundwater pathway exposures and ingestion of fish or livestock are negligible or incomplete for all receptors, as explained in Section 4.6.1. Ingestion of homegrown garden produce grown in soil potentially contaminated by deposition of airborne particulates is also a negligible pathway for current off-site residents, as explained in Section 4.6.1.

In summary, potentially complete human exposure pathways to be evaluated for the current off-site resident are:

- Inhalation of airborne particulates
- Soil ingestion (following deposition of airborne particulates on residential soil)
- Dermal contact with soil (following deposition of airborne particulates)
- Ingestion of garden produce (following surface deposition of particulates)

4.6.3 Current On-Site Worker

Current RFP employees, such as security personnel and maintenance workers, visit areas within OU6 during the course of their work. For purposes of the risk assessment, the current on-site worker is assumed to work outdoors as a security specialist within the OU6 area. The worker may be exposed to surface soils and airborne contaminants originating in OU6. Therefore, chemical release mechanisms that result in potentially complete exposure pathways are wind suspension, direct contact with soils, and external irradiation. Current on-site workers may be directly exposed to airborne particulate matter via inhalation. Direct contact with soils represents potentially complete ingestion and dermal contact exposure pathways for current workers at the site. External irradiation from decay of OU6-related radioactive compounds in surface soils is also a potentially complete exposure pathway. Exposure to radioactive compounds via inhalation, ingestion, or dermal uptake is accounted for in the other potentially complete exposure pathways described for this receptor.

The current on-site worker is not expected to come into contact with the pond water or sediments. Therefore, pathways related to surface water and sediments are shown as incomplete for this receptor.

Ingestion or dermal contact with OU6 soils that have been contaminated through the deposition of airborne particulates released from site soils are indicated as negligible pathways on the CSM because those exposure routes are covered under direct contact with contaminated soils.

Inhalation of indoor air contaminated by either volatilization of chemicals from subsurface soils or from groundwater is an incomplete pathway because the on-site worker is assumed to be a patrolling security guard who is not working indoors.

In summary, potentially complete human exposure pathways to be evaluated for the current on-site workers are:

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

4.6.4 Future On-Site Worker

The future on-site worker is assumed to work in an office building in OU6. The worker would potentially be exposed to indoor and outdoor air and to OU6 surface soils during time spent outdoors.

Future on-site workers may inhale airborne particulate matter released from surface soil. Volatile chemicals released from groundwater or subsurface soils that migrate through foundations to indoor air represent potentially complete inhalation pathways for the future on-site office workers. However, these pathways are likely to be insignificant because of the general absence of groundwater at OU6 (see Section 2.5) and because contamination by volatile compounds has not been detected in field screening of OU6 soils. Exposures to volatile compounds in outdoor air are considered negligible as explained in Section 4.6.1.

Ingestion and dermal contact with OU6 soils that have been contaminated by deposition of airborne particulate matter released from site soils are indicated as negligible pathways on the CSM because those exposure routes are covered under direct exposure pathways.

Direct contact with surface soil represents potentially complete ingestion and dermal contact exposure pathways for future workers at the site. External irradiation from decay of radioactive materials in contaminated surface soils is also a potentially complete exposure pathway. Exposure to radioactive materials via inhalation, ingestion, or dermal uptake is accounted for in the other potentially complete exposure pathways described for this receptor.

The office worker is not assumed to contact pond water or sediments. Therefore, pathways related to sediments and surface water are shown as incomplete for the future office worker.

In summary, potentially complete human exposure pathways to be evaluated for the future on-site office and industrial workers are:

- Inhalation of volatile compounds released from subsurface soil or groundwater to indoor air
- Inhalation of airborne particulates from surface soil
- Surface soil ingestion
- Dermal contact with surface soil
- External irradiation

4.6.5 Future On-Site Construction Worker

The future on-site construction worker is assumed to be involved in excavation and construction activities during future commercial development in OU6. Wind suspension, direct contact with subsurface soils, and radioactive decay are expected result in potentially complete exposure pathways for this receptor. Pathways associated with surface water and sediments and migration of volatile organics to indoor air are incomplete for this receptor because construction is not likely to occur in the creeks and the construction worker is not exposed to indoor air. Inhalation of chemicals volatilizing from groundwater through the soil column to outdoor air and ingestion of groundwater are negligible or incomplete pathways for all receptors as explained in Section 4.6.1. Inhalation of chemicals volatilizing from site soils to outdoor air is also considered a negligible pathway for all receptors as described in Section 4.6.1.

Future construction workers will be directly exposed to airborne particulates via inhalation. This pathway is likely to be relatively insignificant due to the limited duration of exposure. Ingestion and dermal contact with airborne particulates redeposited on soil is negligible compared to direct contact with the soil itself; therefore those pathways will be accounted for under direct contact with OU6 soils.

As mentioned above, direct contact with soils represents potentially complete ingestion and dermal contact exposure pathways for future construction workers at OU6. Both of the pathways are expected to be relatively insignificant due to short duration of exposure. External irradiation from decay of radioactive compounds in soils is also a potentially complete pathway. Exposure to radioactive compounds in soils or air via inhalation, ingestion, or dermal contact 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 construction workers are:

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

4.6.6 Future On-Site Ecological Researcher

The ecological researcher is identified as a future receptor to account for future exposure in OU6 open space, including the creeks and ponds. Outdoor exposures include exposure to surface soils, air, sediments, and surface water.

If transported by stormwater runoff or groundwater, chemicals in OU6 soils may be released to surface water or sediments. Incidental ingestion of and dermal contact with surface water and sediments are potentially complete, although relatively insignificant, exposure pathways for the ecological researcher who may be wading in Walnut Creek or the A-series or B-series ponds. Suspended particulates in surface water resulting from the disturbance of sediment may be ingested and will be evaluated in the surface water ingestion exposure pathway. Soluble chemicals in sediments may be released to surface water and dermally absorbed; this exposure route will be accounted for in the dermal contact with surface water exposure pathway.

A future on-site ecological researcher may be directly exposed to airborne particulate matter via inhalation, which is considered to be an insignificant but complete pathway. Ingestion of or dermal contact with soil contaminated by redeposition of airborne particulates are shown as negligible pathways on the CSM; these exposure pathways are covered under direct contact with contaminated soils.

Ingestion and dermal contact with surface soils represents potentially complete pathways for future ecological researchers. Ingestion and dermal contact is expected to be a relatively insignificant exposure route for chemicals of concern at OU6.

External irradiation from decay of radioactive compounds in surface soils is also a potentially complete exposure pathway. Exposure to radioactive chemicals via inhalation, ingestion, or dermal uptake is accounted for in the other potentially complete exposure pathways described for this receptor.

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

- Surface water ingestion (suspended sediment and site-related chemicals potentially transported to surface water)
- Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water)
- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation

4.6.7 Future On-Site Resident

The CSM indicates that dissolution and resuspension of sediments, stormwater runoff, infiltration and percolation from soil to groundwater, volatilization, wind suspension, direct contact with soils, external irradiation, and uptake of chemicals in soil by garden produce are the primary chemical release mechanisms from OU6 soils to the environment. All these primary release mechanisms provide potential exposure routes to the future on-site resident.

Chemicals that are transported from OU6 soils in stormwater runoff or groundwater, or from sediment resuspension/dissolution may be released to surface water or sediments in Walnut Creek or the A-series or B-series ponds. Incidental ingestion of and dermal contact with sediments and surface water are potentially complete exposure pathways for the future on-site resident because unrestricted access to the creeks and ponds are assumed for the future on-site resident scenario. Suspended particulates in surface water resulting from the disturbance of sediment may be ingested and will be accounted for in the surface water ingestion exposure pathway. Soluble chemicals in sediments may be released to surface water and dermally absorbed; this exposure route will be accounted for in the dermal contact with surface water exposure pathway. Ingestion of fish or livestock are negligible or incomplete for future on-site residents, as explained in Section 4.6.1.

Volatile chemicals that migrate from site groundwater or subsurface soils to indoor air represent a potentially complete but insignificant inhalation pathway to future on-site residents. Groundwater ingestion is an incomplete pathway, and inhalation of chemicals volatilizing from groundwater or site soils to outdoor air are negligible pathways for all receptors, as explained in Section 4.6.1.

Future on-site residents may be directly exposed to airborne particulate matter via inhalation, which is considered to be a complete and potentially significant pathway. For the purposes of this exposure assessment, the concentrations of particulate matter in outdoor and indoor air are assumed to be the same. Ingestion of homegrown garden produce contaminated by direct deposition of airborne particulates from the site or by uptake from OU6 soils are potentially complete exposure pathways. Ingestion of and dermal contact with soils contaminated by redeposition of OU6 airborne particulates and plant uptake from soils affected by redeposits of airborne particulate matter are shown as negligible pathways on the CSM; these pathways are covered under direct contact with and uptake from OU6 soils.

Ingestion of and dermal contact with OU6 soils represents potentially complete pathways for the future on-site resident. Dermal absorption is expected to be a relatively insignificant exposure route for chemicals in OU6 soils.

External irradiation exposures to future on-site residents are a potentially complete pathway.

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

- Surface water ingestion (suspended sediment and site-related chemicals potentially transported to surface water)
- Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water)
- Inhalation of volatile compounds released from subsurface soils and/or groundwater to indoor air
- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation
- Ingestion of garden produce contaminated by deposition of airborne particulates
- Ingestion of garden produce grown in contaminated soil

4.6.8 Future Off-Site Resident

A future off-site "fenceline" resident is assumed to reside on Indiana Street at Walnut Creek. Exposure pathways for this receptor are the same as for the current off-site resident, with the addition of surface water and sediment ingestion and direct contact exposures. Surface water and sediment exposures will focus on OU6-specific contaminant loads to Walnut Creek.

In summary, potentially complete human exposure pathways for chemicals released from OU6 for the future off-site resident are:

- Surface water ingestion (suspended sediment and site-related chemicals potentially transported to surface water)
- Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water)
- Inhalation of airborne particulates
- Soil ingestion (following deposition of airborne particulates on residential soil)
- Dermal contact with soil (following deposition of airborne particulates)
- Ingestion of garden produce contaminated by airborne particulates

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
OU6
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Off-site resident	Current	Inhalation of airborne particulates Ingestion of soil contaminated with airborne particulates Dermal contact with soil contaminated with airborne particulates Ingestion of vegetables contaminated by airborne particulates
On-site worker	Current	Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay
On-site worker	Future	Inhalation of indoor air with VOCs from groundwater Inhalation of indoor air with VOCs from subsurface soil Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay
On-site construction worker	Future	Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay
On-site ecological researcher	Future	Surface Water Ingestion (suspended sediment and site-related chemicals potentially transported to surface water) Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water) Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay

TABLE 4-1
(Concluded)

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Hypothetical on-site resident	Future	Surface Water Ingestion (suspended sediment and site-related chemicals potentially transported to surface water) Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water) Inhalation of indoor air with VOCs from groundwater Inhalation of indoor air with VOCs from subsurface soil Inhalation of airborne particulates Ingestion of soil Dermal contact with soil Ingestion of garden produce contaminated with airborne particulates External irradiation from radioactive decay Ingestion of garden produce grown in contaminated soils
Hypothetical off-site resident	Future	Surface Water Ingestion (suspended sediment and site-related chemicals potentially transported to surface water) Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water) Inhalation of airborne particulates Ingestion of soil contaminated with airborne particulates Dermal contact with soil contaminated with airborne particulates Ingestion of garden produce contaminated with airborne particulates

5.0
ESTIMATING CHEMICAL INTAKES

This section presents reasonable maximum exposure (RME) factors for each exposure pathway identified in the previous section. Chemical intakes (doses) are not presented in this memorandum since they are dependent on chemical data and fate and transport modeling, as appropriate. The fate and transport models to be used in the OU6 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. Chemical intakes are expressed in terms of milligram (mg) chemical ingested, inhaled, or dermally absorbed per kilogram body weight per day (mg/kg-day). Intakes are calculated following guidance in Risk Assessment Guidance for Superfund (EPA 1989a), the Exposure Factors Handbook (EPA 1989b), Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors (EPA 1991b), other EPA guidance documents as appropriate, and professional judgment regarding probable site-specific exposure conditions. Intakes are estimated using reasonable estimates of body weight, inhalation volume, ingestion rates, soil or food matrix effects, frequency and duration of exposure, and exposure point concentrations of OU6-related chemicals.

Intakes are estimated for 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:

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

with corresponding units of:

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

The variable "averaging time" is expressed in days to calculate daily chemical intake. For noncarcinogenic chemicals, averaging time is the exposure duration (in years) times 365 days/year. Intakes of noncarcinogens are thus the average daily intake over the exposure duration. For carcinogens, averaging time is a 70-year lifetime times 365 days/year. In other words, intakes of carcinogens are calculated by averaging the total received 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 (i.e., a low dose of a carcinogen may produce carcinogenic effects). Therefore, the intake of a carcinogen is averaged over a 70-year lifetime (EPA 1989a). Intake of noncarcinogens is averaged only over the exposure duration because higher daily doses of noncarcinogens may produce toxic effects whereas lower doses may not (i.e., there is a threshold dose below which no adverse effects are expected).

Omitting chemical concentrations from the intake equation yields an "intake factor" that is constant for each exposure pathway/receptor combination. The intake factor can then be multiplied by the exposure point concentration of each chemical to obtain the pathway-specific intake of that chemical. Intake factors are calculated separately for each receptor/exposure pathway that was identified in Section 4.6. Body surface area, food intake and inhalation rates are roughly proportional to body size. Therefore, it is common to use adult exposure factors to represent all age groups, except for soil ingestion (children are assumed to ingest more soil per kg body weight than adults because of their increased mouthing behavior). Although body weight is not exactly proportional to body surface area and age-specific body weight/inhalation rates may vary somewhat, these differences are assumed to be negligible. Therefore, 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 are described in Section 5.1.1. Pathway-specific assumptions are described in later sections (5.1.2 through 5.1.9).

5.1.1 General Exposure Assumptions

- For all exposure scenarios except dermal contact with surface water, the RME exposure frequency is 7 days/week for 50 weeks (350 days) for the current and future on- and off-site residents (EPA 1991b), and 5 days/ week for 50 weeks (250 days) for the current security worker and office workers on site (EPA 1991b). These exposure frequencies assume that exposures occur routinely at OU6 when in fact exposures are not routine and may not occur at all due to precipitation, snow cover, or high winds.

- Residential RME exposure duration is assumed to be 30 years (EPA 1991b).

- Current security worker and future on-site worker RME exposure durations are assumed to be 25 years (EPA 1991b). The future on-site construction worker is assumed to be exposed during building construction for 6 months (130 working days).

- Outdoor exposure frequency and duration for the ecological researcher is 4 hours/day, 5 days/week, 13 weeks/year for 2.5 years.

- Averaging time for chemicals with noncarcinogenic effects is the exposure duration expressed in days.

- Averaging time for carcinogenic effects is 70 years (25,550 days).

- The average adult body weight is assumed to be 70 kg (EPA 1989b). The average child body weight is assumed to be 15 kg (EPA 1991b).

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 parameters 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 workers and the future on-site resident. The following assumptions will be used to estimate exposure to chemicals of concern through inhalation.

- The RME respiratory volume of air for residents and indoor worker receptors is assumed to be 20 m^3/day (0.83 m^3/hr). This rate assumes that all of the exposure time is spent at activities equivalent to walking (EPA 1991b).

- The RME respiratory volume of air for outdoor workers is assumed to be 1.4 m^3/hr. This is the recommended average value for an outdoor worker (EPA 1989b).

- 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. Indoor air particulate concentrations are assumed to be equal to outdoor air particulate concentrations. This is a conservative assumption. It assumes the resident never leaves the home and is breathing air containing outdoor particulate matter 24 hours/day.

- Seventy-five percent of inhaled particles are deposited in the lung; it is further assumed that all chemicals in that fraction are absorbed (MRI 1985).

5.1.3 Soil Ingestion Assumptions

Intake 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 soil particles 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.

Intake factors for exposure via soil ingestion were calculated for an adult resident, a child resident, a future on-site ecological researcher, a future on-site office worker, a future on-site construction worker and a current 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 childhood 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 contacted (FC) from the contaminated source is assumed to be 0.06 for the current on-site worker, 1.0 for the future on-site construction worker, and 0.5 for all other receptors. The FC for the current on-site worker (0.06) is based on the approximate amount of time that a security guard would spend in the OU6 portion of the buffer zone each day (EG&G 1992e). For the future on-site construction worker, 100 percent of the material ingested is assumed to be from contaminated sources in OU6. The FC for all other receptors (0.5) assumes that 50 percent of ingested soil or dust originates from contaminated sources (the remainder originates from uncontaminated sources).

- The matrix effect of soil on bioavailability of ingested contaminants is chemical-specific 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.

5.1.4 Homegrown Produce Ingestion Assumptions

Intake of chemicals via ingestion of homegrown garden produce contaminated by deposition of airborne particulate matter or uptake of chemicals from soil is a function of the ingestion rate, the fraction of homegrown produce ingested, the frequency and duration of exposure, root uptake and air deposition rates, and bioavailability of the chemical adhered to the soil ingested. It is assumed that contamination of homegrown produce may occur by deposition of particulates and by uptake of chemicals from soils. An intake factor for exposure via ingestion of homegrown garden produce was calculated for current and future residential receptors. The following assumptions will be used in estimating intake through this route.

- Current and future residential receptors are assumed to ingest 200,000 mg/day of vegetables and 140,000 mg/day of fruits. Assuming that the "reasonable worst case" proportion that is homegrown is 40 percent for vegetables and 30 percent of fruits (EPA 1991b) results in a total ingestion rate for homegrown produce of 122,000 mg/day.

- It is assumed that homegrown produce is ingested 50 percent of the year. This is a reasonable worst-case assumption for a long growing season or home canning (EPA 1989b).

- Homegrown garden produce is assumed to be potentially contaminated by surface deposition of airborne particulates from OU6 soils, as described in Section 4.0. Modeled wet and dry deposition rates will be applied to reasonable maximum estimates of food surface area, weight, and human consumption rate to estimate chemical intake from this exposure pathway.

- Soil concentrations of chemicals will be multiplied by chemical-specific soil-to-plant partition coefficients to estimate chemical uptake from soil and resulting concentrations in edible portions of produce.

- The food matrix effect on bioavailability of ingested contaminants is assumed to be 1.0 in the RME case unless chemical-specific information is available.

- A 90 percent reduction in chemical concentration on the food surface due to washing of produce will be assumed (EPA 1990b).

5.1.5 Surface Water/Suspended Sediment 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 on- and off-site residential receptors. The following assumptions will be used in estimating intake through this route.

- Both the future ecological researcher and hypothetical on- and off-site residents are assumed to ingest 0.05 liters of surface water per event (50 ml/event) (EPA 1989b).

- The RME exposure frequency is assumed to be 7 events/year for the future ecological researcher and the future hypothetical on- and off-site residents (EPA 1989a).

5.1.6 Dermal Contact with Soil

Uptake of chemicals of concern through dermal contact with 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 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 from strong, stable bonds with other soil constituents that reduce the available concentrations of a dissolved metal. In addition, due to polarity and solubility, metals are not absorbed well across the skin. (EPA 1991a).

It is also Region VIII policy to assess dermal uptake of metals qualitatively. Therefore, dermal uptake of metals is considered negligible and will not be quantitatively evaluated in the human health risk assessment (EPA 1991a). Likewise, 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 surface soil will only be evaluated if sampling demonstrates the presence of organic contaminants. The following assumptions will be used to estimate exposure to chemicals of concern through dermal contact with soil.

- The RME exposed body surface area for all receptors, but not all pathways, is assumed to be 2,910 cm^2/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^2 in the RME case (Sedman 1989).

- The fraction contacted (FC) from the contaminated medium is assumed to be 0.06 in the RME case for the current on-site worker and 1.0 for future on-site construction workers. These values are based on the amount of direct contact with soils at OU6 versus other areas outside OU6 as previously discussed for soil ingestion. An FC of 0.5 is used for all other receptors, assuming that 50 percent of contacted soil originates from contaminated areas in OU6 and that 50 percent originates from uncontaminated areas.

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 absorption of organic 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 on- and off-site residential receptors and the ecological researcher.

- The RME exposed body surface area for future residential receptors and the ecological researcher is assumed to be 4,850 cm^2/day because they may remove their shoes and roll up their pant legs while wading. The reasonable maximum surface area is assumed to be 25 percent of total body surface (equivalent to hands, feet, and lower legs) (EPA 1989b).

- 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 receptors and the 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 receptors (EPA 1989a).

5.1.8 Internal Exposure to Radionuclides

Internal exposure to radionuclides identified as OU6 chemicals of concern will be evaluated in two ways. First, the dose equivalent based on intake of radionuclides via ingestion or inhalation will be calculated and compared to radiation protection standards. The second method for evaluation of internal radionuclide exposure will be conducted by calculating the intake of radionuclides and multiplying that intake by EPA-derived carcinogenic slope factors for each radionuclide of concern (EPA 1989a). The result of this calculation will be the carcinogenic risk associated with ingestion or inhalation of a given radionuclide of concern.

Calculation of intake for radionuclides is conducted in a similar manner as for nonradioactive chemicals of concern. Intake of radionuclides by either ingestion or inhalation is a function of radionuclide concentration, ingestion or inhalation rate, and exposure frequency and duration. The only difference between calculating intake for radionuclides and nonradioactive substances is that the averaging time and body weight are excluded from the intake equation. The intake of radionuclides through inhalation or ingestion can be estimated using the following equation:

$$Intake_{int} = C * IR * EF * ED$$

where:

$Intake_{int}$	=	Internal radionuclide intake via inhalation or ingestion in Becquerels (Bq).
C	=	Concentration of a radionuclide at the exposure point (Bq/m^3, Bq/l, or Bq/kg).
IR	=	Intake rate (breathing rate [m^3/day], ingestion rate [kg/day], or drinking rate [l/day]).
EF, ED	=	Exposure frequency (days/year) and duration (years).

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

5.1.9 External Irradiation

External (ground surface) exposure to radionuclides will be evaluated in a similar manner as internal radionuclide exposure. The equivalent dose (Sv) will first be calculated for comparison with radiation protection standards. The cancer risks for ground surface irradiation will be computed using the EPA-derived external slope factor, the soil concentration, and the frequency and duration of the exposure for each radionuclide per EPA guidance (EPA 1989a).

To estimate the equivalent dose, radionuclide concentrations on the ground surface (Bq/m^2), whether directly measured or predicted by modeling, will be multiplied by the external dose coefficient for specific radionuclides (Sv/hr per Bq/m^2) and the duration of exposure (hours) (EPA 1989a). This will result in an estimate of the equivalent dose, which can then be compared to radiation protection standards. Equivalent doses from external exposure to radioactively contaminated ground surfaces do not require internal adjustment factors, such as uptake rate, bioavailability, or body weight. The equation for estimating equivalent dose from external radiation exposure is as follows:

$$H_{T,ext} = C * EF * ED * DC$$

Where:

$H_{T,ext}$	=	External equivalent dose of radiation received through ground surface exposure (Sv).
C	=	Concentration of a contaminant at the exposure point (Bq/m^2).
EF, ED	=	Exposure frequency (hours/year) and duration (years).
DC	=	Dose coefficient (Sv/hr per Bq/m^2).

The carcinogenic risks for the ground surface pathway will be calculated as the product of the external slope factor (risk/yr per Bq/g soil), the soil concentration (Bq/g soil), and the frequency and duration of the exposure (years) for each radionuclide as indicated below:

$$Risk = C * ET * EF * ED * CSF$$

Where:

Risk = Carcinogenic risk from ground surface exposure (unitless).

C = Concentration of a contaminant at the exposure point (Bq/g soil).

ET, EF = Exposure time (fraction of day/day) and frequency (fraction of year/year).

ED = Exposure duration (years).

CSF = External Cancer Slope Factor (Risk/yr per Bq/g soil).

ET and EF are expressed as fraction of day/day and fraction of year/year so that external irradiation exposure are only calculated for the actual time exposed to the contaminated soil. For example, for the current on-site worker, ET and EF are calculated as follows:

$$ET = ET_A/ET_B * FT * FE$$

$$EF = EF_A/ET_B$$

Where:

ET = Fraction of day/day

ET_A = Exposure time (hours/day), 8 hours

ET_B = Baseline exposure time (hours/day), 24 hours

FT = Fraction of time at OU6 (unitless), 0.06

FE = Fraction exposed at contaminated sources (unitless), 0.5

EF_A	=	Exposure frequency (days/year), 250 days
EF_B	=	Baseline exposure frequency (days/year), 365

Values for ET_A, FT, FE, and EF_A are shown for each on-site receptor in Tables 5-30 through 5-33.

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 5-29. Exposure point concentrations and other chemical-specific factors will be used with these parameters to obtain pathway-specific intakes of each chemical of concern.

TABLE 5-1

INHALATION OF PARTICULATES
CURRENT OFF-SITE RESIDENT

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

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	24
EF =	Exposure frequency (days/year)[3]	350
ED =	Exposure duration (years)[4]	30
DF =	Deposition factor[5]	0.75
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) This RME exposure time assumes that the most sensitive segments of the population, mainly infants and the elderly, are exposed 24 hours per day.

(3) Source: EPA (1991b).

(4) Source: EPA 1991b.

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

TABLE 5-2

SOIL INGESTION
CURRENT OFF-SITE RESIDENT (ADULT AND CHILD)[1]

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

	Parameter	RME Adult	RME Child
IR =	Ingestion rate (mg/day)[1]	100	200
FC =	Fraction contacted from contaminated source[2]	0.5	0.5
ME =	Matrix effect[3]	chemical specific	
EF =	Exposure frequency (days/year)[4]	350	350
ED =	Exposure duration (years)[5]	24	6
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	15
AT =	Averaging time (days)		
	Noncarcinogenic	10,950	
	Carcinogenic	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) (EPA 1991b).

(2) The RME (FI) assumes that 50 percent of the soil ingested is contaminated.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound.

(4) Assumes that residents take 15 days per year vacation (EPA 1991b).

(5) Source: EPA 1991b.

TABLE 5-3

DERMAL CONTACT WITH SURFACE SOIL
CURRENT OFF-SITE RESIDENT

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

	Parameter	RME
SA =	Surface area (cm^2)[(1)]	2,910
AB =	Absorption factor[(2)]	chemical-specific
AF =	Adherence factor (mg/cm^2)[(3)]	0.5
FC =	Fraction contacted from contaminated source[(4)]	0.5
EF =	Exposure frequency (days/year)[(5)]	350
ED =	Exposure duration (years)[(6)]	30
CF =	Conversion factor (kg/mg)	10^{-6}
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) Dermal absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be less than one and will be determined on a chemical-specific basis.

(3) Source: Sedman 1989.

(4) The FC assumes that 50 percent of the soil contacted is contaminated.

(5) Assumes that residents take 15 days per year vacation (EPA 1991b).

(6) Source: EPA 1991b.

TABLE 5-4

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

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

	Parameter	RME
IR:	Ingestion rate (mg/day)[1]	122,000
WO:	Wash-off factor[2]	0.1
ME:	Matrix effect[3]	chemical-specific
EF:	Exposure frequency (days/year)[4]	175
ED:	Exposure duration (years)[4]	30
CF:	Conversion factor (kg/mg)	10^{-6}
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This ingestion rate is based on typical consumption rates for vegetables (200,000 mg/day), and fruits (140,000 mg/day), with the "reasonable worst case" homegrown proportion assumed to be 40 percent for vegetables and 30 percent for fruits (EPA 1991b).

(2) Assumes that 90 percent of surface soil is removed during food preparation (EPA 1990b)

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes reasonable worst-case exposure frequency (for long growing seasons or home canning) of 50 percent of the year (EPA 1989b). Exposure duration is 30 years (EPA 1991b).

TABLE 5-5

INHALATION OF PARTICULATES CURRENT ON-SITE WORKER

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

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[(1)]	1.4
FT =	Fraction of time at OU6[(2)]	0.06
ET =	Exposure time (hours/day)	8.0
EF =	Exposure frequency (days/year)[(3)]	250
ED =	Exposure duration (years)[(4)]	25
DF =	Deposition factor[(5)]	0.75
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) Recommended average value for an outdoor worker (EPA 1989b).

(2) Based on the fraction of time security personnel spend patrolling the OU6 portion of the buffer zone. (OU6 surface area/buffer zone surface area).

(3) Assumes that occupational receptor works 5 days per week for 50 weeks per year (EPA 1991b).

(4) Source: EPA 1991b.

(5) Seventy-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 5-6

SOIL INGESTION
CURRENT ON-SITE WORKER

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

	Parameter	RME
IR =	Ingestion rate (mg/day)[1]	50
FT =	Fraction of time at OU6[2]	0.06
FC =	Fraction contacted from contaminated sources[3]	0.5
ME =	Matrix effect[4]	chemical-specific
EF =	Exposure frequency (days/year)[5]	250
ED =	Exposure duration (years)[6]	25
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) Source: EPA (1991b)
(2) Based on the fraction of time security personnel spend patrolling the OU-6 portion of the buffer zone. (OU6 surface area/buffer zone surface area).
(3) Assumes that 50 percent of the soil ingested is from contaminated areas.
(4) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.
(5) Assumes that occupational receptor works 5 days per week for 50 weeks per year (EPA 1991b).
(6) Source: EPA 1991b.

TABLE 5-7

DERMAL CONTACT WITH SURFACE SOIL
CURRENT ON-SITE WORKER

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

	Parameter	RME
SA =	Surface area (cm^2)[1]	2,910
AB =	Absorption factor[2]	chemical-specific
AF =	Adherence factor (mg/cm^2)[3]	0.5
FT =	Fraction of time at OU6[4]	0.06
FC =	Fraction contacted from contaminated source[5]	0.5
EF =	Exposure frequency (days/year)[6]	250
ED =	Exposure duration (years)[7]	25
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) The surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).
(2) Dermal absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be less than one and will be determined on a chemical-specific basis.
(3) Source: Sedman 1989.
(4) Based on the fraction of time security personnel spend patrolling the OU6 portion of the buffer zone (OU6 surface area/buffer zone surface area).
(5) Assumes that 50 percent of the soil contacted is at contaminated areas.
(6) Assumes that occupational receptor works 5 days per week for 50 weeks per year (EPA 1991b).
(7) Source: EPA 1991b.

TABLE 5-8

INHALATION OF INDOOR AIR VOCs
FUTURE ON-SITE WORKER (OFFICE ONLY)

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

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	8
EF =	Exposure frequency (days/year)[3]	250
ED =	Exposure duration (years)[3]	25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).
(2) The ET is based on an 8-hour workday.
(3) Source: EPA 1991b.

TABLE 5-9

INHALATION OF PARTICULATES
FUTURE ON-SITE WORKERS (OFFICE AND CONSTRUCTION)

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

		RME	
	Parameter	Office	Construction
IR =	Inhalation rate (m^3/hr)	0.83[1]	1.4[2]
ET =	Exposure time (hours/day)	8	8
EF =	Exposure frequency (days/year)	250[3]	130[4]
ED =	Exposure duration (years)	25	1.0
DF =	Deposition factor[5]	0.75	0.75
BW =	Body weight (kg)	70	70
AT =	Averaging time (days)		
	Noncarcinogenic	9,125	365
	Carcinogenic	25,550	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).
(2) Recommended average value for an outdoor worker (EPA 1989b).
(3) Assumes that occupational receptor works 5 days per week for 50 weeks per year (EPA 1991b).
(4) Assumes 130 working days (6 months) of excavation during building construction.
(5) Seventy-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 5-10

SOIL INGESTION
FUTURE ON-SITE WORKERS (OFFICE AND CONSTRUCTION)

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

	Parameter	RME Office	RME Construction
IR =	Ingestion rate (mg/day)[1]	50	50
FC =	Fraction contacted from contaminated source	0.5[2]	1.0
ME =	Matrix effect[3]	chemical-specific	chemical-specific
EF =	Exposure frequency (days/year)	250[4]	130[5]
ED =	Exposure duration (years)	25	1.0
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	70
AT =	Averaging time (days)		
	Noncarcinogenic	9,125	365
	Carcinogenic	25,550	25,550

(1) Source: EPA 1991b (supersedes EPA 1989a).
(2) Assumes that 50 percent of ingested soil or dust originates as contaminated media.
(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.
(4) Assumes that occupational receptor works 5 days per week for 50 weeks per year (EPA 1991b).
(5) Assumes 130 working days (6 months) of excavation during building construction.

TABLE 5-11

DERMAL CONTACT WITH SURFACE SOIL
FUTURE ON-SITE WORKERS (OFFICE AND CONSTRUCTION)

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

	Parameter	RME	
		Office	Construction
SA =	Surface area (cm^2)[1]	2,910	2,910
AB =	Absorption factor[2]	chemical-specific	
AF =	Adherence factor (mg/cm^2)[3]	0.5	0.5
FC =	Fraction contacted from contaminated source	0.5[4]	1.0
EF =	Exposure frequency (days/year)	250[5]	130[6]
ED =	Exposure duration (years)	25	1.0
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	70
AT =	Averaging time (days)		
	Noncarcinogenic	9,125	365
	Carcinogenic	25,550	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) Source: Sedman 1989.

(4) Assumes that 50 percent of soil or dust contacted originates as contaminated media.

(5) Assumes that occupational receptor works 5 days per week for 50 weeks per year (EPA 1991b).

(6) Assumes 130 working days (6 months) of excavation during building construction.

TABLE 5-12

INGESTION OF SURFACE WATER (SUSPENDED SEDIMENT AND CHEMICALS TRANSPORTED TO SURFACE WATER) FUTURE ON-SITE ECOLOGICAL RESEARCHER

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

	Parameter	RME
IR :	Intake rate (l/event)[1]	0.05
EF :	Exposure frequency (events/year)[2]	7
ED:	Exposure duration (years)	2.5
FI:	Fraction ingested from contaminated source	1.0
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	913
	Carcinogenic	25,550

(1) Equivalent to 50 ml of incidental surface water ingestion per day for on-site surface water research (EPA 1989b).

(2) Source: EPA 1989a.

TABLE 5-13

DERMAL CONTACT WITH SURFACE WATER
FUTURE ON-SITE ECOLOGICAL RESEARCHER

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

	Parameter	RME
SA =	Surface area (cm^2)[1]	4,850
PC =	Permeability constant (cm/hr)[2]	chemical-specific
ET =	Exposure time (hours/event)[3]	2.6
EF =	Exposure frequency (events/year)[3]	7
ED =	Exposure duration (year)	2.5
CF =	Conversion factor (l/cm^3)	10^{-3}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	913
	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) Chemical-specific permeability constants will be used, if available, for aqueous solutions.

(3) Source: EPA 1989a.

TABLE 5-14

INHALATION OF PARTICULATES FUTURE ON-SITE ECOLOGICAL RESEARCHER

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

	Parameter	RME
IR =	Inhalation rate (m^3/hr)(1)	1.4
ET =	Exposure time (hours/day)(2)	4
EF =	Exposure frequency (days/year)(2)	65
ED =	Exposure duration (years)(2)	2.5
DF =	Deposition factor (3)	0.75
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	913
	Carcinogenic	25,550

(1) Recommended average value for an outdoor worker (EPA 1989b).

(2) Assumes that ecological research involves a combination of periodic field work coupled with work in the library, office, or laboratory. Field work involves 4 hours per day, 13 weeks per year, over a period of 2.5 years.

(3) Seventy-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 5-15

SOIL INGESTION
FUTURE ON-SITE ECOLOGICAL RESEARCHER

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

	Parameter	RME
IR =	Ingestion rate (mg/day)[(1)]	50
FC =	Fraction contacted from contaminated source[(2)]	0.5
ME =	Matrix effect[(3)]	chemical-specific
EF =	Exposure frequency (days/year)[(4)]	65
ED =	Exposure duration (years)[(4)]	2.5
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	913
	Carcinogenic	25,550

(1) Source: EPA 1991b.

(2) Assumes that 50 percent of ingested soil originates as contaminated media.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that ecological research involves a combination of periodic field work coupled with extensive time in the library, office, or laboratory. Field work involves 4 hours per day, 13 weeks per year, over a period of 2.5 years.

TABLE 5-16

DERMAL CONTACT WITH SURFACE SOIL
FUTURE ON-SITE ECOLOGICAL RESEARCHER

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

	Parameter	RME
SA =	Surface area (cm^2)[(1)]	2,910
AB =	Absorption factor[(2)]	chemical-specific
AF =	Adherence factor (mg/cm^2)[(3)]	0.5
FC =	Fraction contacted from contaminated source[(4)]	0.5
EF =	Exposure frequency (days/year)[(5)]	65
ED =	Exposure duration (years)[(5)]	2.5
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	913
	Carcinogenic	25,550

(1) The surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).

(2) Dermal absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be less than one and will be determined on a chemical-specific basis when data become available.

(3) Source: Sedman 1989.

(4) Assumes that 50 percent of soil contacted originate as contaminated media.

(5) Assumes that ecological research involves a combination of periodic field work coupled with extensive time in the library, office, or laboratory. Field work involves 4 hours per day, 13 weeks per year, over a period of 2.5 years.

TABLE 5-17

INGESTION OF SURFACE WATER (SUSPENDED SEDIMENT AND CHEMICALS TRANSPORTED TO SURFACE WATER) HYPOTHETICAL FUTURE ON-SITE RESIDENT

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

	Parameter	RME
IR :	Intake rate (l/event)[1]	0.05
EF :	Exposure frequency (events/year)[2]	7
ED:	Exposure duration (years)[3]	30
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) Source: EPA 1989a.
(3) Source: EPA 1991b.

TABLE 5-18

DERMAL CONTACT WITH SURFACE WATER
HYPOTHETICAL FUTURE ON-SITE RESIDENT

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

	Parameter	RME
SA =	Surface area (cm^2)[1]	4,850
PC =	Permeability constant (cm/hr)[2]	chemical-specific
ET =	Exposure time (hours/event)[3]	2.6
EF =	Exposure frequency (events/year)[3]	7
ED =	Exposure duration (year)[4]	30
CF =	Conversion factor (l/cm^3)	10^{-3}
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) Chemical-specific permeability constants will be used when available for aqueous solutions.

(3) Source: EPA 1989a.

(4) Source: EPA 1991b.

TABLE 5-19

INHALATION OF PARTICULATES
HYPOTHETICAL FUTURE ON-SITE RESIDENT

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

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	24
EF =	Exposure frequency (days/year)[3]	350
ED =	Exposure duration (years)[4]	30
DF =	Deposition factor [5]	0.75
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).
(2) This RME exposure time assumes that the most sensitive members of the population, mainly infants and the elderly, are at home 24 hours per day.
(3) Assumes that residents take 15 days per year vacation (EPA 1991b).
(4) Source: EPA 1991b.
(5) Seventy-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 5-20

INGESTION OF HOMEGROWN VEGETABLES
HYPOTHETICAL FUTURE ON-SITE RESIDENT

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

	Parameter	RME
IR:	Ingestion rate, vegetables (mg/day)[(1)]	122,000
WO:	Wash-off factor [(2)]	0.1
ME:	Matrix effect[(3)]	chemical-specific
EF:	Exposure frequency (meals/year)[(4)]	175
ED:	Exposure duration (years)[(4)]	30
CF:	Conversion factor (kg/mg)	10^{-6}
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This ingestion rate is based on typical consumption rates for vegetables (200,000 mg/day) and fruits (140,000 mg/day), with the "reasonable worst case" homegrown proportion assumed to be 40 percent for vegetables and 30 percent for fruits (EPA 1991b).

(2) Assumes that 90 percent of surface soil is removed during food preparation (EPA 1990b).

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes reasonable worst-case exposure frequency (for long growing seasons or home canning) of 50 percent of the year (EPA 1989b). Exposure duration is 30 years (EPA 1991b).

TABLE 5-21

INHALATION OF INDOOR AIR VOCs
FUTURE ON-SITE RESIDENTS

$$\text{Intake Factor} = \frac{\text{IR x ET x EF x ED}}{\text{BW x AT}}$$

Parameter		RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	24
EF =	Exposure frequency (days/year)[3]	350
ED =	Exposure duration (years)[3]	30
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) RME exposure time assumes that the most sensitive segments of the population, mainly infants and the elderly, are exposed 24 hours per day.

(3) Source: EPA 1991b.

TABLE 5-22

SOIL INGESTION
HYPOTHETICAL FUTURE ON-SITE RESIDENT (ADULT AND CHILD)[1]

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

Parameter		RME	
		Adult	Child
IR =	Ingestion rate (mg/day)[1]	100	200
FC =	Fraction contacted from contaminated source[2]	0.5	0.5
ME =	Matrix effect[3]	chemical-specific	
EF =	Exposure frequency (days/year)[4]	350	350
ED =	Exposure duration (years)[5]	24	6
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	15
AT =	Averaging time (days)		
	Noncarcinogenic	10,950	
	Carcinogenic	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) (EPA 1991b).

(2) The FC assumes that 50 percent of the soil ingested is contaminated.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that residents take 15 days per year vacation (EPA 1991b).

(5) Source: EPA 1991b.

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TABLE 5-23

DERMAL CONTACT WITH SURFACE SOIL
HYPOTHETICAL FUTURE ON-SITE RESIDENT

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

	Parameter	RME
SA =	Surface area (cm^2)[(1)]	2,910
AB =	Absorption factor[(2)]	chemical-specific
AF =	Adherence factor (mg/cm^2)[(3)]	0.5
FC =	Fraction contacted from contaminated source[(4)]	0.5
EF =	Exposure frequency (days/year)[(5)]	350
ED =	Exposure duration (years)[(6)]	30
CF =	Conversion factor (kg/mg)	10^{-6}
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) Dermal absorption of metals from a soil matrix is assumed to be zero (EPA 1991a). The absorption factor for semivolatile, volatile, and other organics is likely to be less than one and will be determined on a chemical-specific basis.

(3) Source: Sedman 1989.

(4) The FC assumes that 50 percent of the soil contacted is contaminated.

(5) Assumes that residents take 15 days per year vacation (EPA 1991b).

(6) Source: EPA 1991b.

TABLE 5-24

INGESTION OF SURFACE WATER
HYPOTHETICAL FUTURE OFF-SITE RESIDENT

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

	Parameter	RME
IR :	Intake rate (l/event)[1]	0.05
EF :	Exposure frequency (events/year)[2]	7
ED:	Exposure duration (years)[3]	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) Source: EPA 1989a.
(3) Source: EPA 1991b.

TABLE 5-25

DERMAL CONTACT WITH SURFACE WATER HYPOTHETICAL FUTURE OFF-SITE RESIDENT

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

	Parameter	RME
SA =	Surface area (cm^2)[(1)]	2,910
PC =	Permeability constant (cm/hr)[(2)]	chemical-specific
ET =	Exposure time (hours/event)[(3)]	2.6
EF =	Exposure frequency (events/year)[(3)]	7
ED =	Exposure duration (year)[(4)]	30
CF =	Conversion factor (l/cm^3)	10^{-3}
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) Chemical-specific permeability constants will be used when available for aqueous solutions.
(3) Source: EPA 1989a.
(4) Source: EPA 1991b.

TABLE 5-26

INHALATION OF PARTICULATES
HYPOTHETICAL FUTURE OFF-SITE RESIDENT

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

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	24
EF =	Exposure frequency (days/year)[3]	350
ED =	Exposure duration (years)[4]	30
DF =	Deposition factor [5]	0.75
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) This RME exposure time assumes that the most sensitive members of the population, mainly infants and the elderly, are at home 24 hours per day.

(3) Assumes that residents take 15 days per year vacation (EPA 1991b).

(4) Source: EPA 1991b.

(5) Seventy-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 5-27

INGESTION OF HOMEGROWN VEGETABLES
HYPOTHETICAL FUTURE OFF-SITE RESIDENT

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

	Parameter	RME
IR:	Ingestion rate, vegetables (mg/day)[(1)]	122,000
WO:	Wash-off factor [(2)]	0.1
ME:	Matrix effect[(3)]	chemical-specific
EF:	Exposure frequency (meals/year)[(4)]	175
ED:	Exposure duration (years)[(4)]	30
CF:	Conversion factor (kg/mg)	10^{-6}
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This ingestion rate is based on typical consumption rates for vegetables (200,000 mg/day) and fruits (140,000 mg/day), with the "reasonable worst case" homegrown proportion assumed to be 40 percent for vegetables and 30 percent for fruits (EPA 1991b).

(2) Assumes that 90 percent of surface soil is removed during food preparation (EPA 1990b).

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes reasonable worst-case exposure frequency (for long growing seasons or home canning) of 50 percent of the year (EPA 1989b). Exposure duration is 30 years (EPA 1991b).

TABLE 5-28

SOIL INGESTION
HYPOTHETICAL FUTURE OFF-SITE RESIDENT (ADULT AND CHILD)[1]

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

	Parameter	RME	
		Adult	Child
IR =	Ingestion rate (mg/day)[1]	100	200
FC =	Fraction contacted from contaminated source[2]	0.5	0.5
ME =	Matrix effect[3]	chemical-specific	
EF =	Exposure frequency (days/year)[4]	350	350
ED =	Exposure duration (years)[5]	24	6
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	15
AT =	Averaging time (days)		
	Noncarcinogenic	10,950	
	Carcinogenic	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) (EPA 1991b).

(2) The FC assumes that 50 percent of the soil ingested is contaminated.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that residents take 15 days per year vacation (EPA 1991b).

(5) Source: EPA 1991b.

TABLE 5-29

DERMAL CONTACT WITH SURFACE SOIL
HYPOTHETICAL FUTURE OFF-SITE RESIDENT

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

	Parameter	RME
SA =	Surface area (cm^2)[(1)]	2,910
AB =	Absorption factor[(2)]	chemical-specific
AF =	Adherence factor (mg/cm^2)[(3)]	0.5
FC =	Fraction contacted from contaminated source[(4)]	0.5
EF =	Exposure frequency (days/year)[(5)]	350
ED =	Exposure duration (years)[(6)]	30
CF =	Conversion factor (kg/mg)	10^{-6}
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) Dermal absorption of metals from a soil matrix is assumed to be zero (EPA 1991a). The absorption factor for semivolatile, volatile, and other organics is likely to be less than one and will be determined on a chemical-specific basis.
(3) Source: Sedman 1989.
(4) The FC assumes 50 percent of the soil contacted is contaminated.
(5) Assumes that residents take 15 days per year vacation (EPA 1991b).
(6) Source: EPA 1991b.

TABLE 5-30

EXTERNAL IRRADIATION
CURRENT ON-SITE WORKER

$$\text{Intake Factor} = \frac{ET \times EF \times ED \times FT \times FE}{ET_B \times EF_B}$$

	Parameter	RME
ET =	Exposure time (hours/day)[(1)]	8
ET_B =	Baseline exposure time (hours/day)	24
ED =	Exposure duration (yr)[(2)]	25
EF =	Exposure frequency (days/yr)[(3)]	250
EF_B =	Baseline exposure frequency (day/yr)	365
FT =	Fraction of time at OU6[(4)]	0.06
FE =	Fraction exposed at contaminated sources[(5)]	0.5

(1) The ET assumes an 8-hour work day.
(2) Source: EPA 1991b
(3) Equivalent to 5 days/week for 50 weeks per year (EPA 1991b).
(4) Based on the fraction of time security personnel spend patrolling the OU6 portion of the buffer zone (OU6 surface area/buffer zone surface area).
(5) Assumes that 50 percent of exposure in OU6 is at contaminated source areas.

TABLE 5-31

EXTERNAL IRRADIATION
FUTURE ON-SITE WORKER (OFFICE AND CONSTRUCTION)

$$\text{Intake Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

		RME	
	Parameter	Office	Construction
ET =	Exposure time (hours/day)[(1)]	1	8
ET_B =	Baseline exposure time (hours/day)[(2)]	24	24
ED =	Exposure duration	25	1
EF =	Exposure frequency (days/yr)[(3)]	250	130
EF_B =	Baseline exposure frequency (day/yr)[(4)]	365	365
FE =	Fraction exposed from contaminated surfaces[(5)]	0.5	1

(1) The ET assumes that the office worker spends 1 hour outdoors in OU6 each workday and that the construction worker spends 8 hours outdoors in OU6.

(2) Baseline exposure time.

(3) EF assumes that the office worker works 5 days per week for 50 weeks per year (EPA 1991b) and that the construction worker is involved in 130 working days (6 months) of excavation activity.

(4) Baseline exposure frequency.

(5) Assumes that 50 percent (office worker) and 100 percent (construction worker) of outdoor exposure is at contaminated sources.

TABLE 5-32

EXTERNAL IRRADIATION
FUTURE ON-SITE ECOLOGICAL RESEARCHER

$$\text{Intake Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

	Parameter	RME
ET =	Exposure time (hours/day)[1]	4
ET_B =	Baseline exposure time (hours/day)	24
ED =	Exposure duration (yr)[1]	2.5
EF =	Exposure frequency (days/yr)[1]	65
EF_B =	Baseline exposure frequency (day/yr)	365
FE =	Fraction exposed at contaminated surface[2]	0.5

(1) Assumes that ecological research involves a combination of periodic field work coupled with work in the library, office, or laboratory. Field work involves 4 hours per day, 13 weeks per year, over a period of 2.5 years.

(2) Assumes that 50 percent of exposure in OU6 is at contaminated areas.

TABLE 5-33

EXTERNAL IRRADIATION
HYPOTHETICAL FUTURE ON-SITE RESIDENT

$$\text{Intake Factor} = \frac{ET \times EF \times ED \times FE}{ET_B \times EF_B}$$

	Parameter	RME
ET =	Exposure time (hours/day)[1]	0.5
ET_B =	Baseline exposure time (hours/day)	24
ED =	Exposure duration (yr)[2]	30
EF =	Exposure frequency (days/yr)[2]	350
EF_B =	Baseline exposure frequency (day/yr)	365
FE =	Fraction exposed at contaminated surface[3]	0.5

(1) Based on an estimated 3 hours per week outdoor exposure at one's residence (EPA 1989b).
(2) Source: EPA 1991b.
(3) Assumes that 50 percent of exposure is to contaminated areas.

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ATTACHMENT A

OPERABLE UNIT 6 DOMESTIC WATER SUPPLY SIMULATIONS

Results of domestic water production simulations of subsurface hydrostratigraphic units beneath Operable Unit 6, Rocky Flats Plant, Golden, Colorado

This work was performed by the Geosciences Division for the Remediation Program Management in support of risk analysis studies.

June 2, 1993

INTRODUCTION

Several transient-pumping numerical simulations were performed To assess the water production capabilities of the near surface hydrostratigraphic units beneath Operable Unit 6 (OU-6) at the Rocky Flats Plant. These simulations are designed to assess the ability of these units to produce a sufficient ground water quantity for a hypothetical four-member household from the vicinity of a "typical" Individual Hazardous Substance Site (IHSS) in OU-6 (Figure 1). A total daily water requirement of 240 gallons is assumed based on a daily water requirement of 60 gallons per person.

The upper hydrostratigraphic unit beneath OU-6 is composed of four lithologically distinct units. These units are the Rocky Flats Alluvium, the hillslope colluvium, the upper sandstone unit of the Arapahoe Formation (designated the #1 sandstone), and the valley fill alluvium. Independent simulations were performed for the four units. The Rocky Flats Alluvium and the hillslope colluvium are not considered reliable water supply sources because of their low hydraulic conductivities and thin saturated thicknesses. Plant activities have impacted these units, making it necessary to simulate them. Of the claystones and sandstones that comprise the Arapahoe Formation, the sandstone unit is considered the best prospect for water production from the Arapahoe Formation because of its greater hydraulic conductivities and large saturated thicknesses. The Arapahoe Formation sandstones in this area are believed to be discontinuous pods and lenses. The Arapahoe Formation claystones are not considered good prospects for a water supply because of their low hydraulic conductivities and therefore, are not modeled. The valley fill alluvium is another apparent prospect for water production because of its large hydraulic conductivity.

METHOD

Simulations were performed using the U.S. Geological Survey's MODFLOW groundwater flow simulation package (McDonald and Harbaugh, 1988). Input parameters and their associated values common to all simulations are presented in Table 1. Separate simulations are performed for the Rocky Flats Alluvium, the hillslope colluvium, the Arapahoe Formation sandstone unit, and the valley fill alluvium. A listing of the input parameters and their associated values for these respective simulations is presented in Tables 2 through 5. Simulations were run with a daily time-frame until the pumping well cell went dry or the end of the simulation (365 days) was reached.

Each day of the transient simulation is divided into two periods with each period divided into three timesteps. The first 2.7 hours of each day are the pumping period. It is assumed that the household maintains water storage capabilities and that the water storage system is replenished during this time. The pumping rate is 1.5 gallons per minute (gpm), which is less than the 3 to 5 gpm rate commonly used for domestic wells. The lower pumping rate used in the simulations a conservative value because it would create smaller drawdowns in the well (thereby lessening the possibility of desaturation of the pumping well). The pumping period is based on the total daily water requirement (240 gallons) and the pumping rate (1.5 gpm):

$$240 \text{ gal.}/(1.5 \text{ gpm} * 60 \text{ min/hr}) = 2.7 \text{ hours}$$

Water level recovery takes place during the remaining 21.3 hours of each day.

The pumping well is located at the center of the model grid. A variable grid spacing ranging from 5 feet at the well to 50 feet at the model boundaries provides realistic drawdown conditions near the well. Grid spacings for the four models are presented in Tables 2 through 5 and is shown in Figure 2.

Boundary conditions are either simulated as constant head (equal to the initial head) or as no-flow conditions depending on the simulation. Constant head boundaries are used at all model edges for the Rocky Flats Alluvium, the hillslope colluvium, and the valley fill simulations. For the Arapahoe sandstone unit simulation, the modeling grid is intended to represent a discontinuous channel sand deposit. No-flow boundaries are placed along two parallel sides of the grid with constant head boundaries along the other two sides to simulate a channel sand deposit.

ROCKY FLATS ALLUVIUM SIMULATION

The modeling grid for this simulation consists of a 19 by 19 cell array with the pumping well at the center of the grid and constant head boundaries (equal to the initial head) along each edge of the grid. Grid spacing in feet for the x and y directions increases from the well as follows: 5_{well}-7-10-15-25-35-50-50-50-$50_{boundary}$ (Figure 2).

The hydraulic conductivity value used in the simulation is the geometric mean of results from aquifer tests performed in the OU-6 alluvium (or from nearby areas). The specific yield value is from example literature values for fine-grained geologic materials (Fetter, 1980). Initial saturated thicknesses represents the historical averages for wells present in or near OU-6 (2286, 5887, 6087, 6187, 9287, 6387, 6487, 6587, 6687, 6787, 6887, and B206489). Based on site observations, this unit is considered unconfined and is modeled as such. Specific parameters and their associated values for the Rocky Flats Alluvium are presented in Table 2.

Results

For the simulation of the OU-6 Rocky Flats Alluvium, the pumping well cell became dry between two and three hours on the fourth day of the simulation. The length of time to desaturate the simulated pumping well is a reflection of the large hydraulic conductivity and saturated thickness of the alluvium in this area.

HILLSLOPE COLLUVIUM SIMULATION

The modeling grid for this simulation consists of a 19 by 19 grid cell array with the pumping well at the center of the grid and constant head boundaries (equal to the initial head) along each edge of the grid. Grid spacing in feet for the x and y directions increases from the well as follows: 5_{well}-7-10-15-25-35-50-50-50-$50_{boundary}$ (Figure 2).

Because aquifer test results are apparently unavailable for the colluvium in OU-6, values obtained from OU-5 were used. The hydraulic conductivity value used in the modeling is the geometric mean of results from OU-5 aquifer tests. The specific yield value is from example literature values for fine-grained geologic materials (Fetter, 1980). Initial saturated thickness represents the historical averages for wells present near the OU-6 IHSS's (2986, 7087, 7287). Based on site observations, the hydrologic system is modeled as unconfined. Specific parameters and their associated values for the hillslope colluvium are presented in Table 3.

Results

For the OU-6 hillslope colluvium simulation, the pumping well cell became dry within the first hour on the first day of the simulation. The length of time to desaturate the well is a reflection of the small saturated thickness and the simulated hydraulic conductivity of the colluvium in this area.

ARAPAHOE FORMATION SANDSTONE SIMULATION

The model for this simulation consists of a 13 row by 21 column grid with the pumping well at the center. The rectangular shape of the modeling grid represents the elongate physical shape of the sandstone unit as reconstructed from borehole information. It should be noted that the sandstone units in this area are clay-rich and discontinuous. The modeling grid represents a continuous channel-like sandstone body, which may not reflect reality. The model grid, however, is considered conservative because it represents a greater saturated volume than potentially exists (and therefore provides more water). Constant head boundaries (equal to the initial head) are used along the first and last columns of the gird with no-flow boundaries set along the other two edges. Grid spacing in feet for the x and y directions increases from the well as follows: 5_{well}-7-10-15-25-35-50-50-...-$50_{boundary}$ (Figure 2).

The hydraulic conductivity value is derived from the greatest reported value for aquifer tests performed in the Arapahoe Formation at OU-6. This value is believed to represent sand-rich units present in the Arapahoe Formation beneath OU-6. The specific yield/storage value is assumed to be similar to literature values for fine-grained materials. This is considered reasonable due to the great clay content of the discontinuous sand units beneath OU-6. Initial saturated thickness (10 feet) is based on the reported thickness of the sand unit in the southern part of OU-6 (EG&G, 1991). Initial water levels are based on the historical averages for wells B206189, B206289, and B206589. Because the average bedrock water levels are at or near the top of bedrock reported for B206489 (EG&G, 1991), the sand unit hydrologic system is considered confined. The sand unit, however, was simulated as a convertible hydrologic system (from confined to unconfined and vice versa) to account for dewatering effects from the pumping well. It should be noted that the sand unit in this area is apparently extremely clay rich (based on the boring logs for B206289,B206489, and B206589, which are supposedly within the sand body). Specific parameters and their associated values for the sandstone unit are presented in Table 4.

Results

For the Arapahoe Formation sandstone simulation, the simulated pumping well became dry between two and three hours on the first day.

VALLEY FILL SIMULATION

The modeling grid for this simulation consists of a 7 rows by 19 columns with the pumping well at the center of the grid. The rectangular shape of the modeling grid represents the elongate physical shape of the valley fill unit as it is constrained by the Walnut Creek valley. Constant head boundaries (equal to the initial head) are used around the entire edge of the model. Grid spacing in feet for the x and y directions increases from the well as follows: 5_{well}-7-10-15-25-35-50-50-...-$50_{boundary}$ (Figure 2).

The hydraulic conductivity value is derived from the geometric mean of OU-6 valley fill aquifer test results. The specific yield value is assumed to be similar to literature values for fine-grained materials. Initial saturated thickness (4 feet) is based on the estimated average thickness of the valley fill alluvium from various geologic cross sections. It is assumed that the entire thickness of the valley fill alluvium is saturated. The hydrologic system is considered unconfined.

Specific parameters and their associated values for the hillslope colluvium are presented in Table 5.

Results

For the simulation of the valley fill in the Walnut Creek drainage, the simulated pumping well became dry within one hour after pumping was initiated in the simulation.

SUMMARY

Based on the results of groundwater flow simulations, the Rocky Flats Alluvium, the hillslope colluvium, the Arapahoe Formation sandstone unit, and the valley fill alluvium within OU-6 cannot produce sufficient water to support a four-member household consuming 240 gallons per day. An alluvial well would be pumped dry within 4 days, and the colluvial, sandstone, and valley fill wells would be pumped dry within a day, when pumped at 1.5 gpm for 2.7 hours per day.

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Table 1
OU-6 Domestic Water Supply Simulations
Modeling Parameters Common to All Simulations

PARAMETER	VALUE	SOURCE
Water Requirement	240 gpd	Based on 60 gpd/person
Pumping Rate	1.5 gpm	Assumed
Pumping Time Per Day	2.7 hours	Based on Pumping Rate
X:Y Anisotropy	1.0 (isotropic)	Assumed

Table 2
OU-6 Domestic Water Supply Simulations
Modeling Parameters for Rocky Flats Alluvium

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	1.69 ft.day	*OU-6 Aquifer Tests*
Specific Yield	0.10	Literature Values
Grid Spacing (Variable)	from 5 to 50 feet	Assumed
Hydrogeologic Unit Condition	Unconfined	On-site Observation
Initial Saturated Thickness	9.7 feet	Observation Wells
Boundary Conditions	Constant Head	Assumed

Table 3
OU-6 Domestic Water Supply Simulations
Modeling Parameters for Hillslope Colluvium

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	0.232 ft.day	OU-5 Aquifer Tests
Specific Yield	0.10	Literature Values
Grid Spacing (Variable)	from 5 to 50 feet	Assumed
Hydrogeologic Unit Condition	Unconfined	On-site Observation
Initial Saturated Thickness	2.11 feet	Observation Wells
Boundary Conditions	Constant Head	Assumed

Table 4
OU-6 Domestic Water Supply Simulations
Modeling Parameters for Arapahoe Sandstone

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	0.0703 ft.day	OU-6 Aquifer Tests
Specific Yield	0.10	Literature Values
Grid Spacing (Variable)	from 5 to 50 feet	Assumed
Hydrogeologic Unit Condition	Confined/Unconfined	On-site Observation
Initial Saturated Thickness	10.0 feet	Observation Wells
Boundary Conditions	Constant Head & No Flow	Assumed

Table 5
OU-6 Domestic Water Supply Simulations
Modeling Parameters for Valley Fill Alluvium

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	0.1163 ft.day	OU-6 Aquifer Tests
Specific Yield	0.10	Literature Values
Grid Spacing (Variable)	from 5 to 50 feet	Assumed
Hydrogeologic Unit Condition	Unconfined	On-site Observation
Initial Saturated Thickness	4.00 feet	Estimated from Geologic Cross Sections
Boundary Conditions	Constant Head	Assumed

OU-6 Domestic Water Supply Simulations

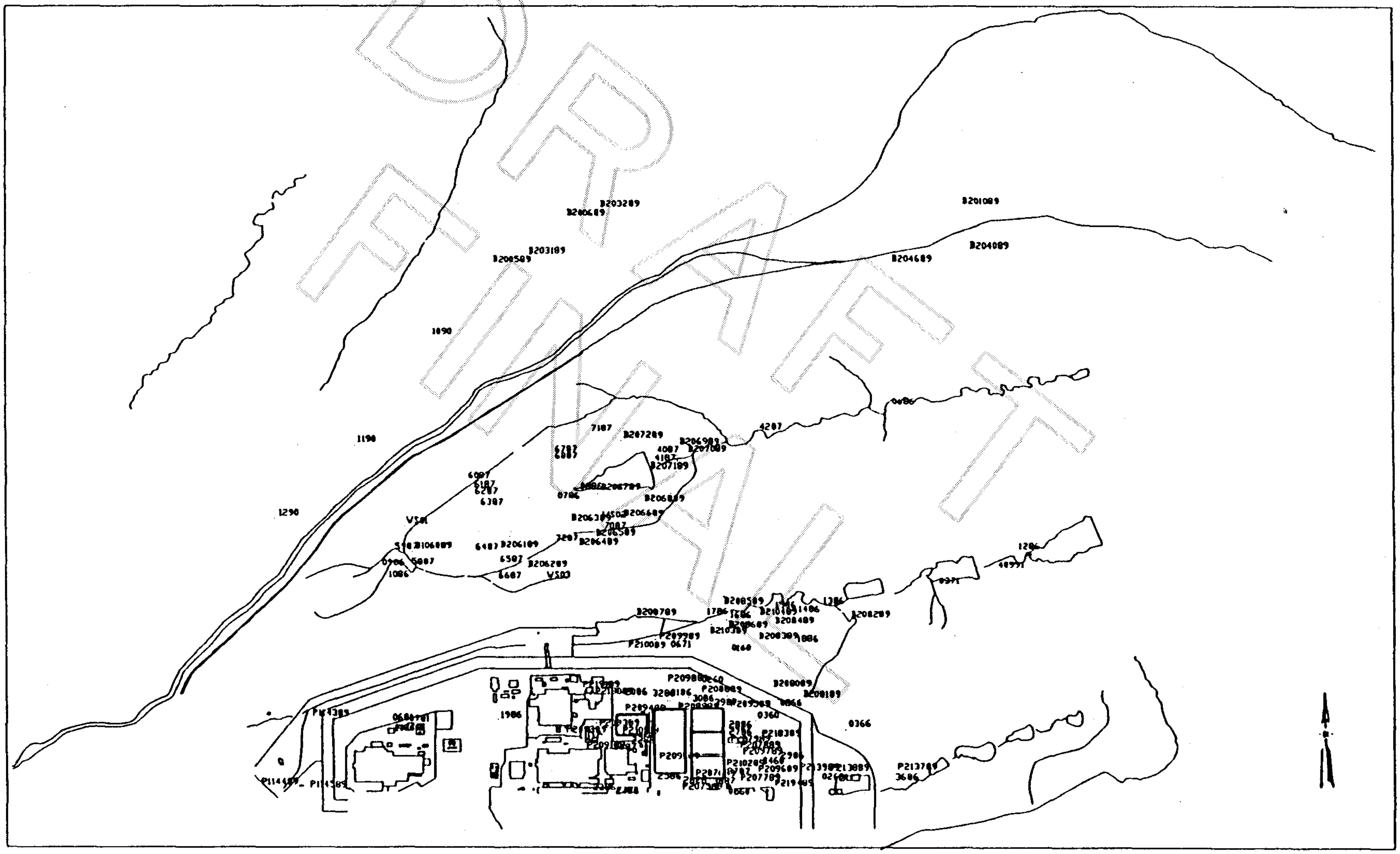


Figure 1. Well Location Map.

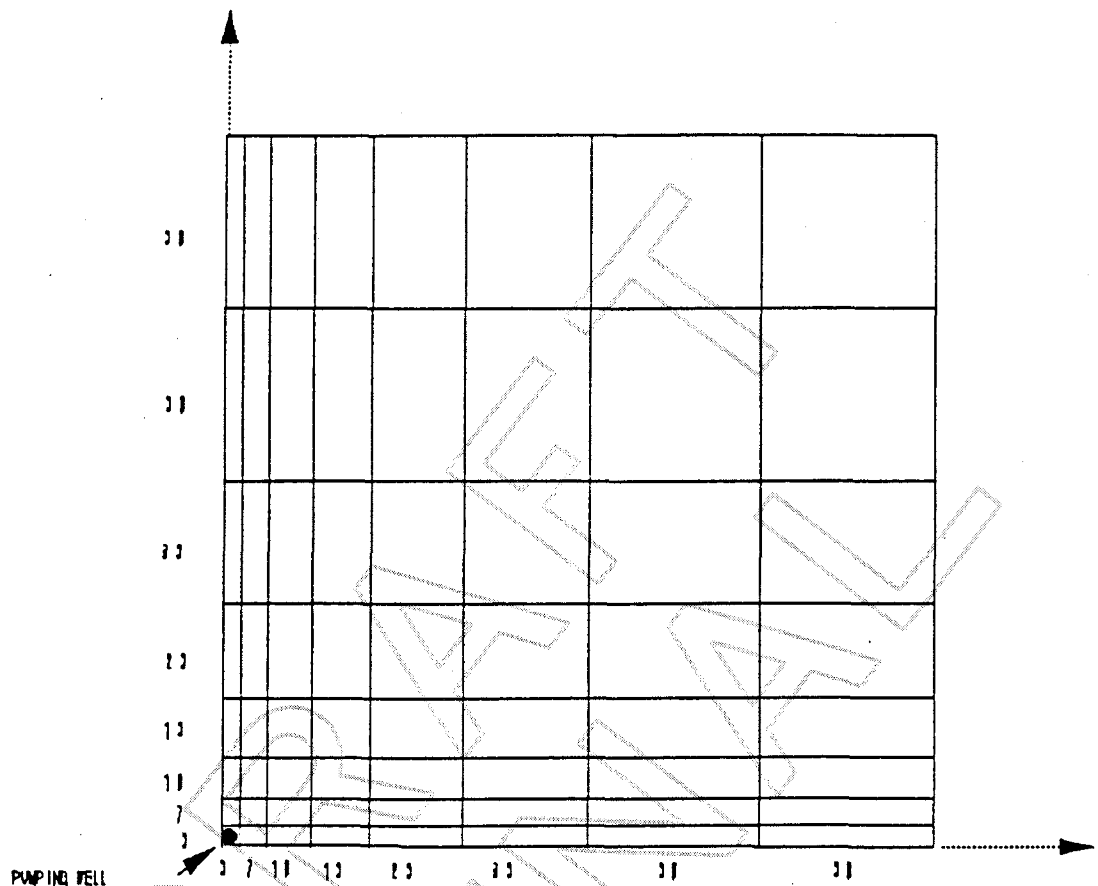
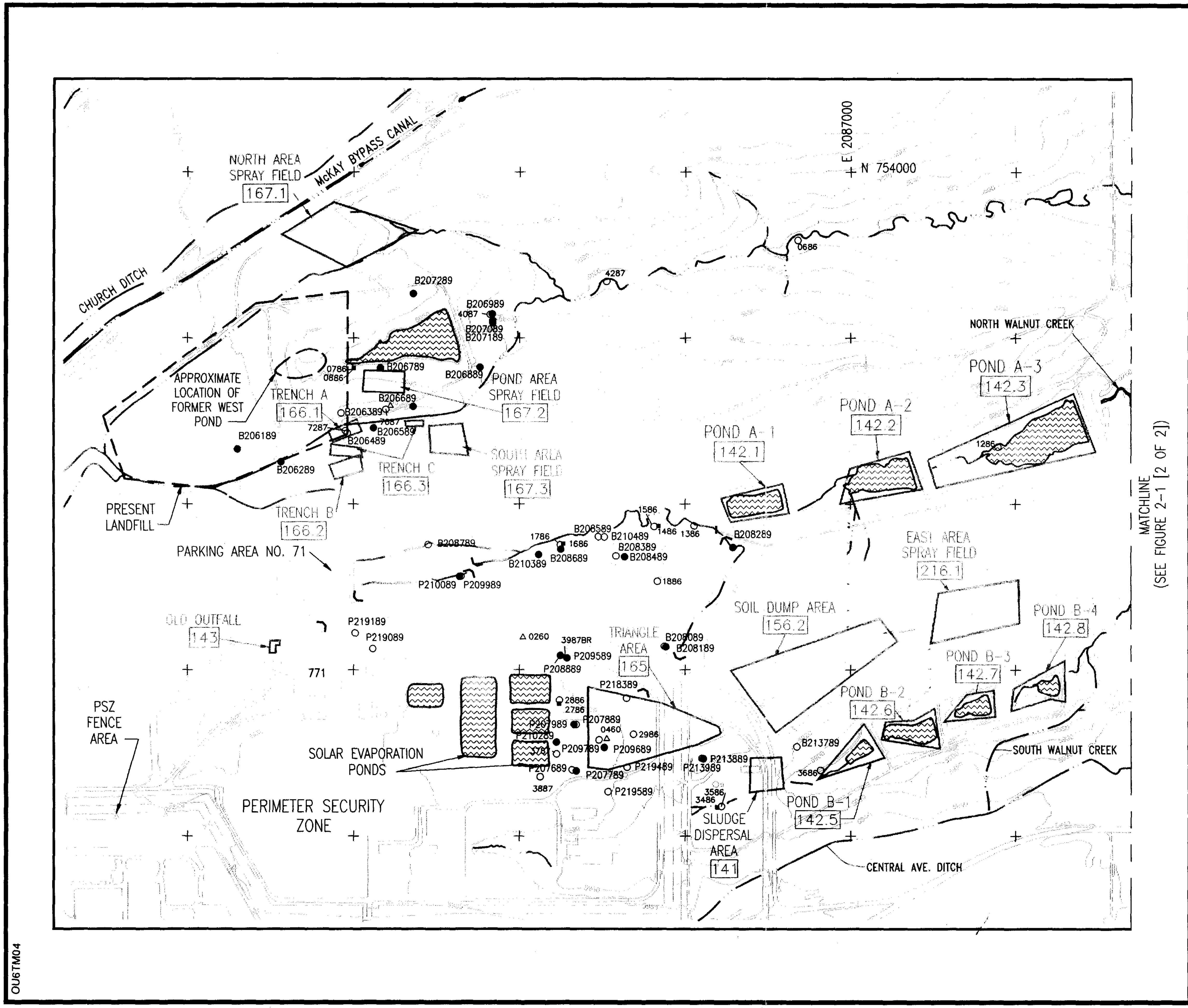


Figure 2. Upper right-hand quadrant of an example model grid, with the pumping well in the center of the grid. Not to scale.

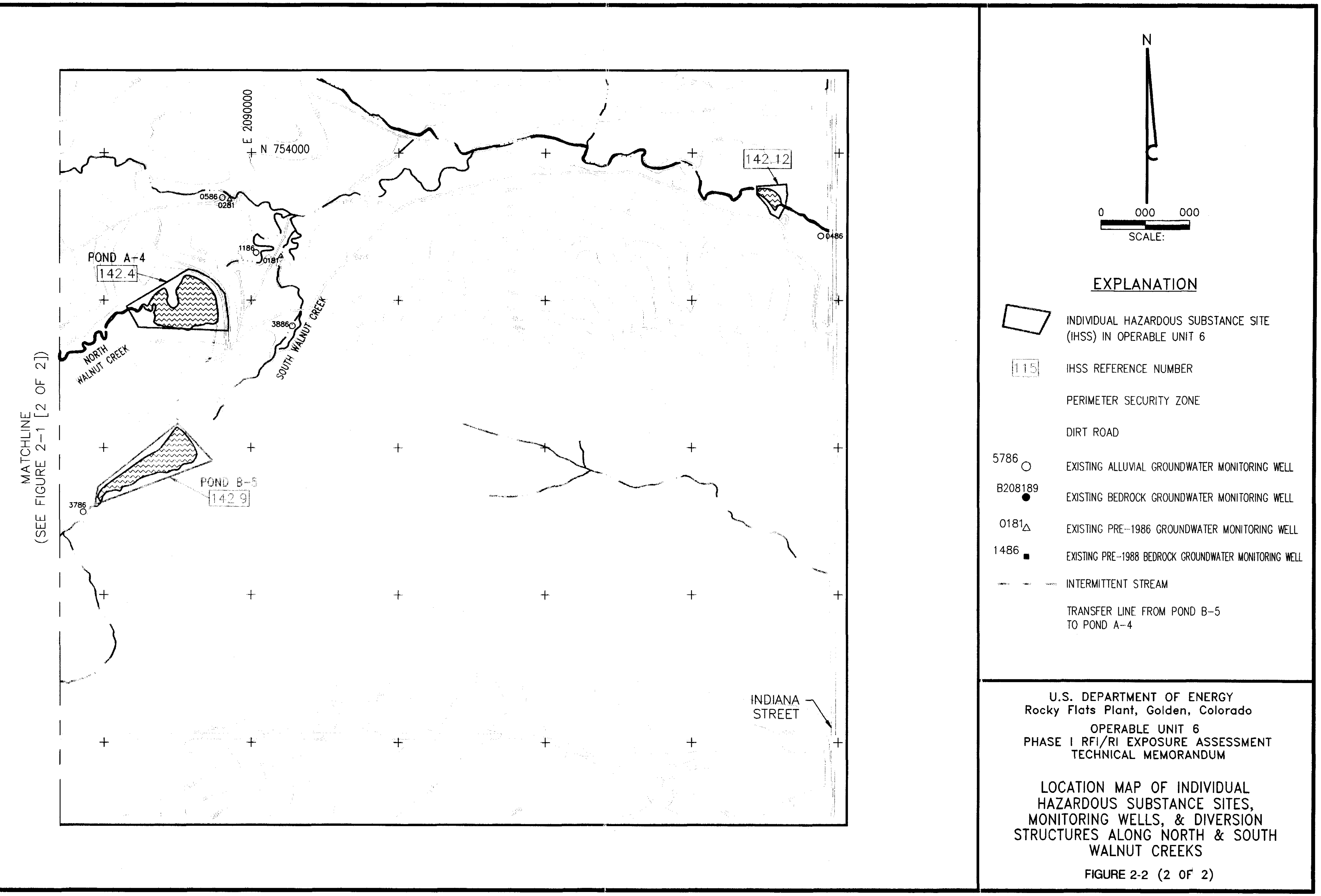


U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

LOCATION MAP OF INDIVIDUAL HAZARDOUS SUBSTANCE SITES, MONITORING WELLS, & DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS

FIGURE 2-2 (1 OF 2)



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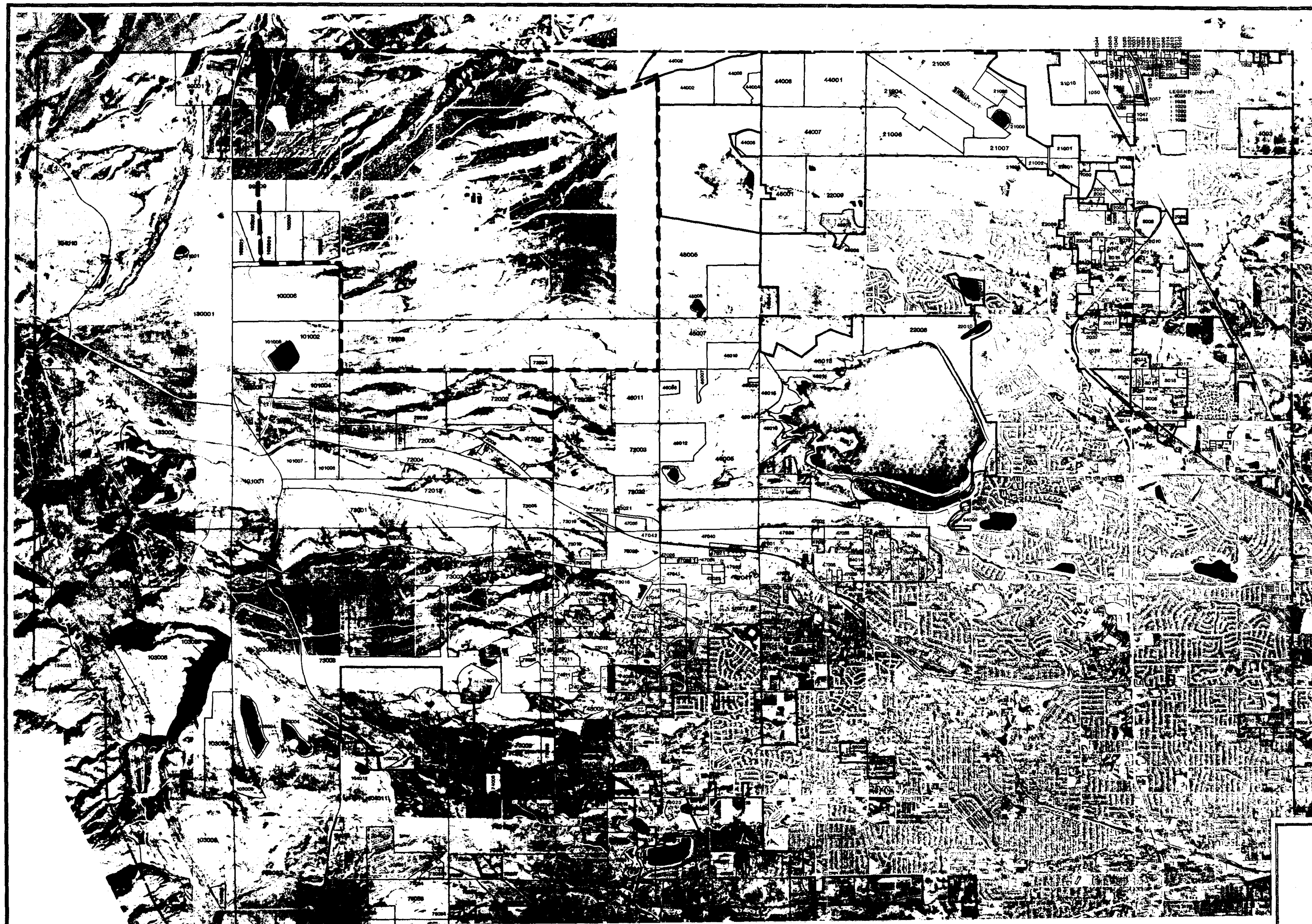
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

LOCATION MAP OF INDIVIDUAL HAZARDOUS SUBSTANCE SITES, MONITORING WELLS, & DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS

FIGURE 2-2 (2 OF 2)

OU6TM05



SOURCE: JEFFERSON COUNTY LAND USE INVENTORY MAP.

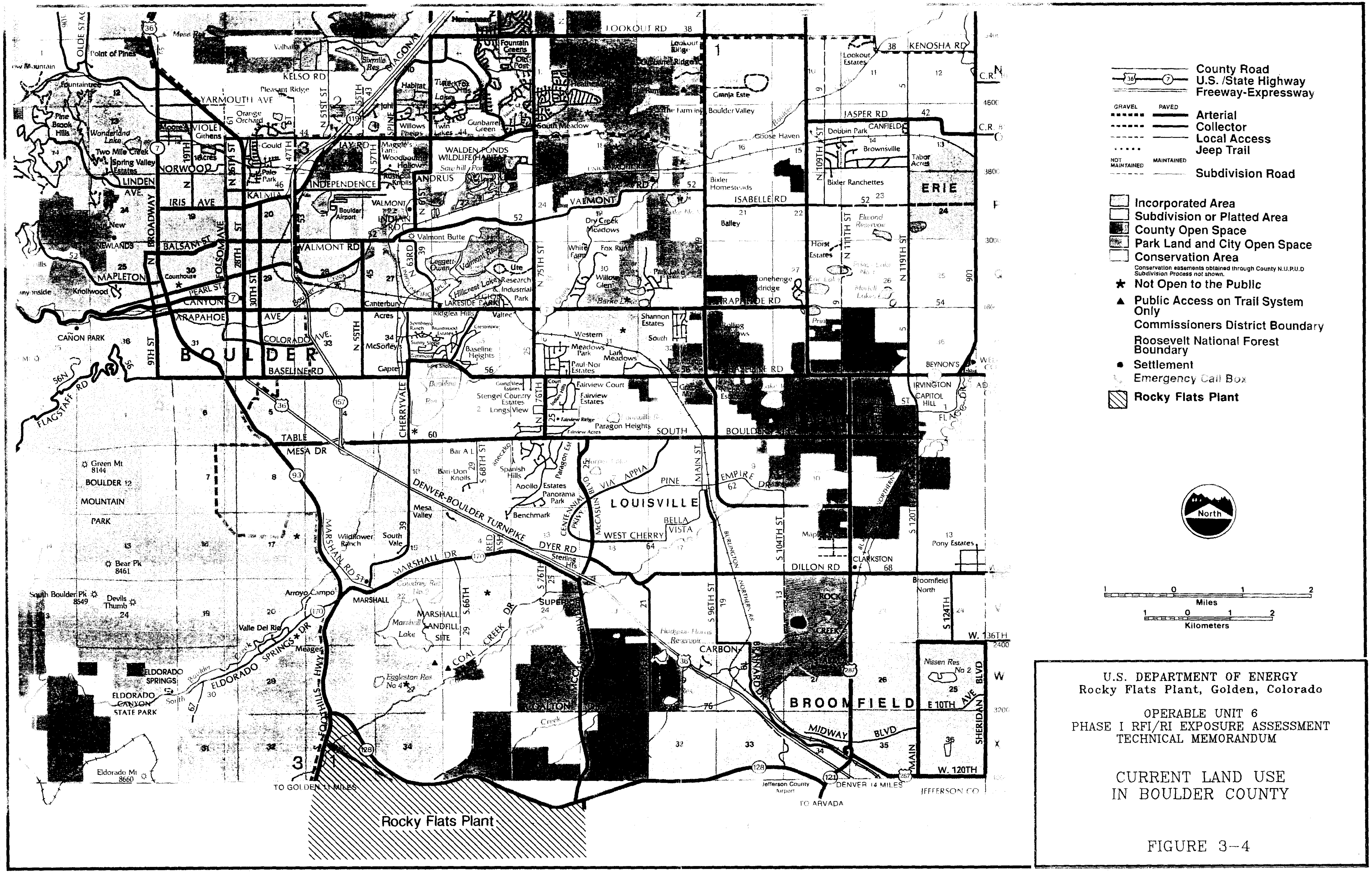
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

CURRENT LAND USE
IN JEFFERSON COUNTY

FIGURE 3–3

23047033



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Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

CURRENT LAND USE
IN BOULDER COUNTY

FIGURE 3-4

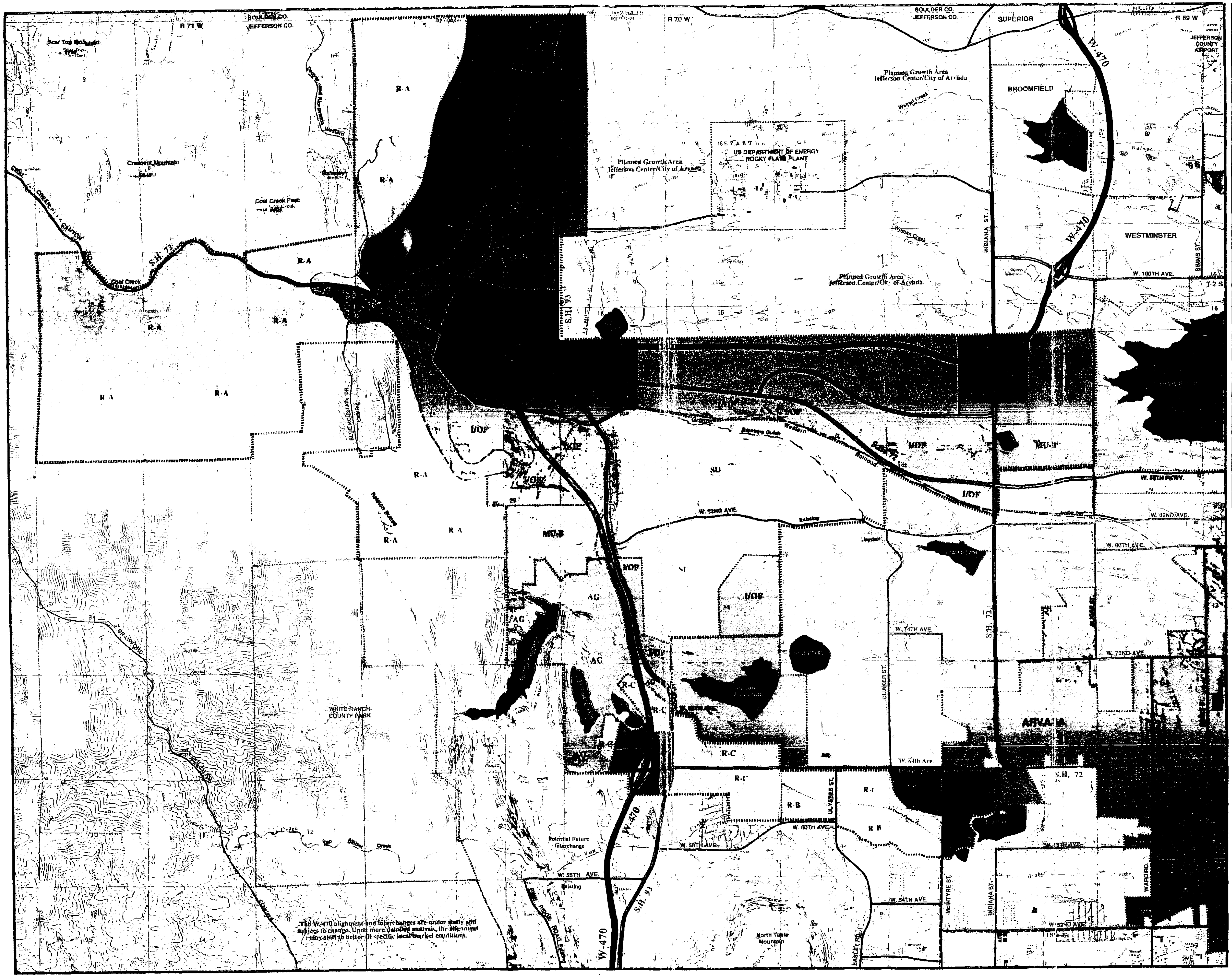
2304703

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

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

FUTURE LAND USE
IN JEFFERSON COUNTY

FIGURE 3-5



JEFFERSON COUNTY

City of Arvada

JCMD NO. 1

Jefferson Center Metropolitan District No. 1

Jefferson CENTER Associates

Jefferson Center Comprehensive Development Plan

FIGURE 3-6

Legend

- Commercial and Office
- Industrial and Office
- Mixed-Use: A B or C
- R Residential (A, B or C)
- AG Agricultural
- OS Open Space
- SU Special Use
- W-470
- Arterial Roadways
- Collector Roadways
- Existing Roadways
- Jefferson Center Development Area

SOURCE: DOE 1992.

Approval

Jefferson County
By: [signature] Date: 9/15/89
Title: Chairman of the Board of the County Commissioners

ATTEST:
By: [signature] Deputy Date: 8-15-89
Title: County Clerk and Recorder

City of Arvada
By: [signature] Date: 8-14-89
Title: Mayor

ATTEST:
By: [signature] Date: 8-14-89
Title: City Clerk

Jefferson Center Metropolitan District No. 1
By: [signature] Date: 8/17/89
Title: President

ATTEST:
By: [signature] Date: 8-9-89
Title: Secretary

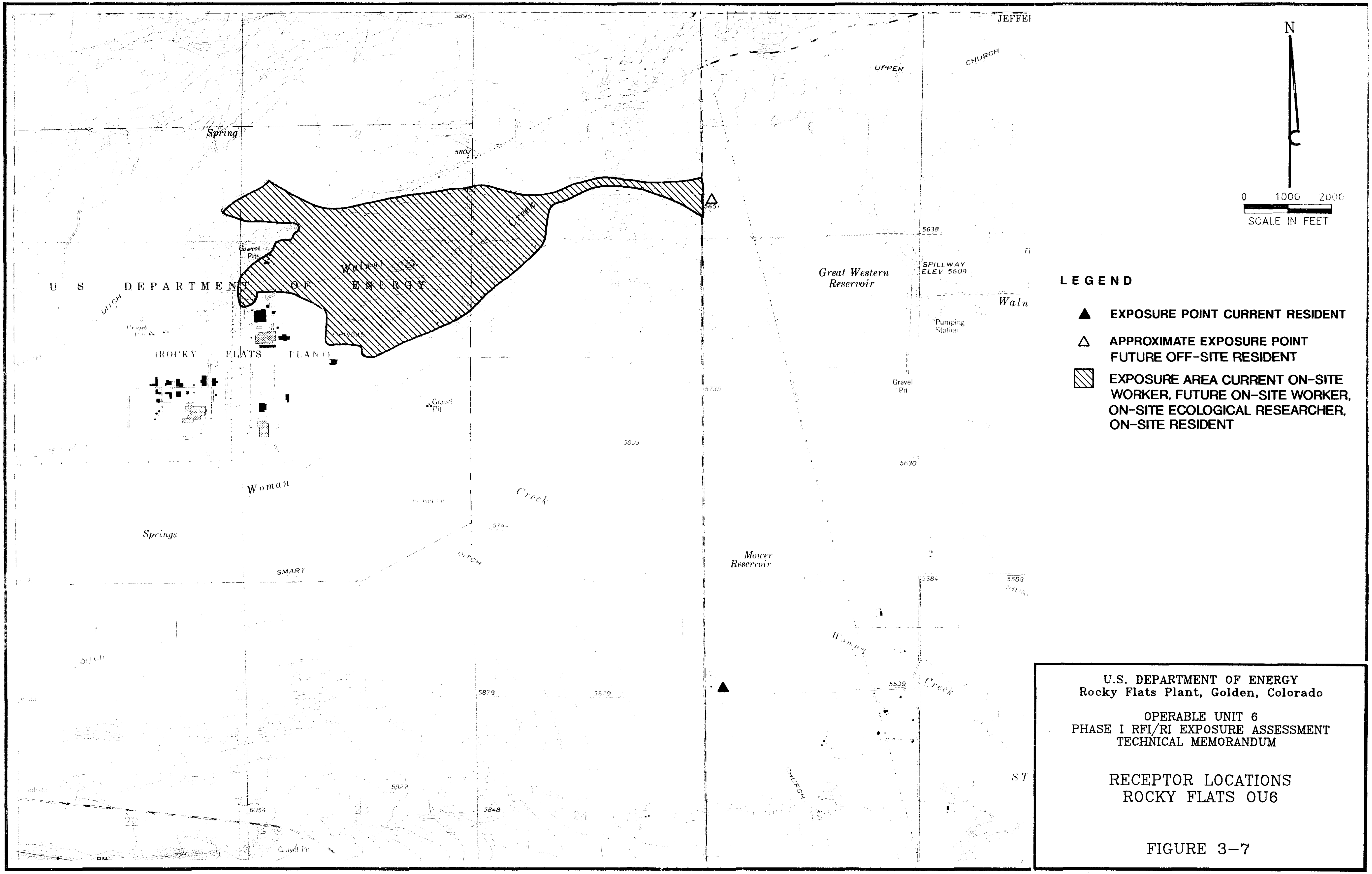
Jefferson Center Associates
By: [signature] Date: 8/17/89
Title: President

ATTEST:
By: [signature] Date: 8/14/89
Title: Vice President

NORTH

0 1,000 2,000

Scale: 1" = 2000'-0"

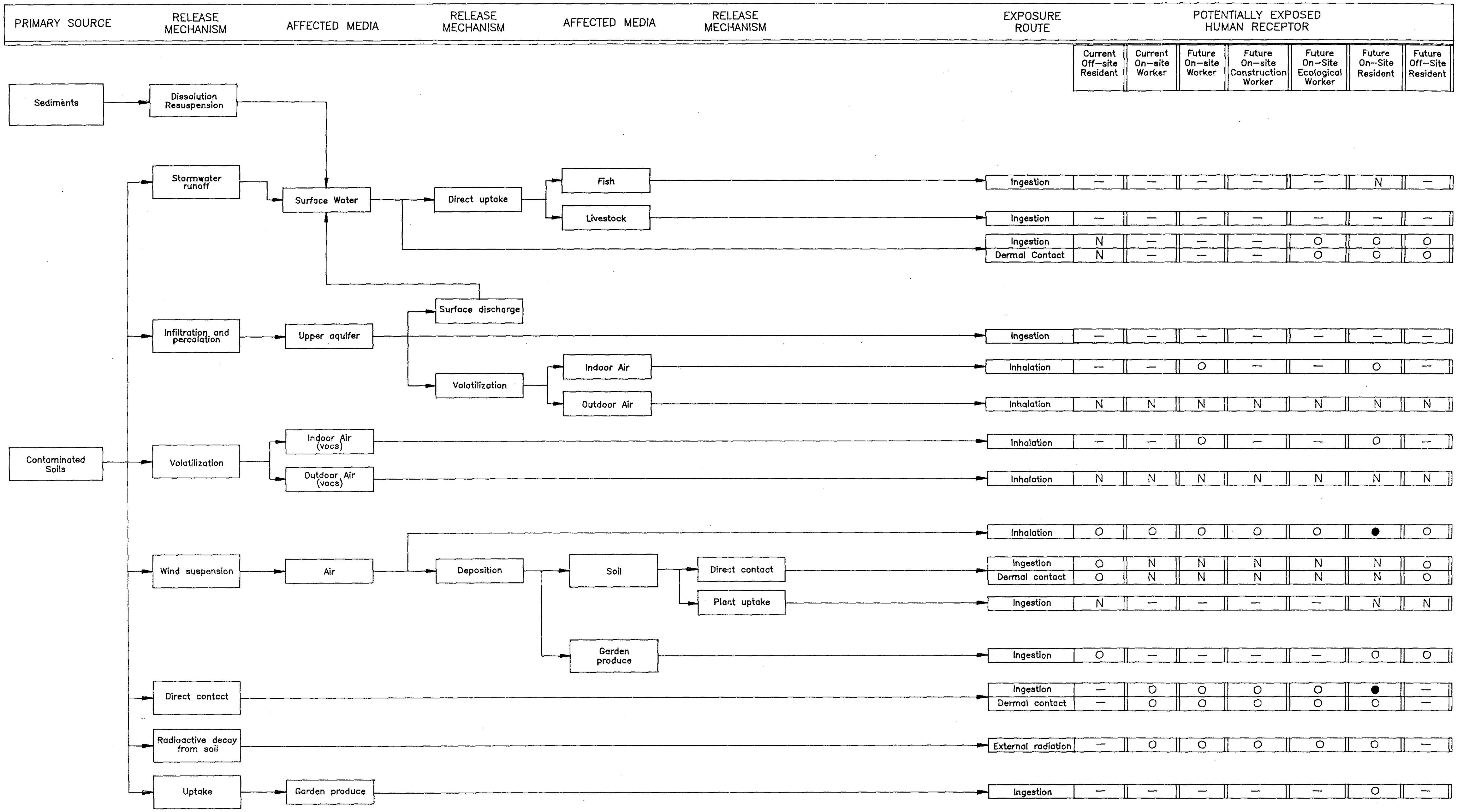


U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

RECEPTOR LOCATIONS
ROCKY FLATS OU6

FIGURE 3–7



Pathway	Exposure Route	Current Off-site Resident	Current On-site Worker	Future On-site Worker	Future On-site Construction Worker	Future On-Site Ecological Worker	Future On-Site Resident	Future Off-Site Resident
Surface Water → Direct uptake → Fish	Ingestion	—	—	—	—	—	N	—
Surface Water → Direct uptake → Livestock	Ingestion	—	—	—	—	—	—	—
Surface Water	Ingestion	N	—	—	—	O	O	O
	Dermal Contact	N	—	—	—	O	O	O
Upper aquifer	Ingestion	—	—	—	—	—	—	—
Upper aquifer → Volatilization → Indoor Air	Inhalation	—	—	O	—	—	O	—
Upper aquifer → Volatilization → Outdoor Air	Inhalation	N	N	N	N	N	N	N
Volatilization → Indoor Air (vocs)	Inhalation	—	—	O	—	—	O	—
Volatilization → Outdoor Air (vocs)	Inhalation	N	N	N	N	N	N	N
Wind suspension → Air	Inhalation	O	O	O	O	O	●	O
Air → Deposition → Soil → Direct contact	Ingestion	O	N	N	N	N	N	O
	Dermal contact	O	N	N	N	N	N	O
Air → Deposition → Soil → Plant uptake	Ingestion	N	—	—	—	—	N	N
Air → Deposition → Garden produce	Ingestion	O	—	—	—	—	O	O
Direct contact	Ingestion	—	O	O	O	O	●	—
	Dermal contact	—	O	O	O	O	O	—
Radioactive decay from soil	External radiation	—	O	O	O	O	O	—
Uptake → Garden produce	Ingestion	—	—	—	—	—	O	—

LEGEND
- ● Significant Potential Exposure Pathway
- O Insignificant Potential Exposure Pathway
- N Negligible Exposure Pathway
- — Incomplete Exposure Pathway

NOTE:
Significant and insignificant potential exposure pathways will be evaluated in the risk assessment.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 6
PHASE I RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM
CONCEPTUAL SITE MODEL
POTENTIAL HUMAN EXPOSURE PATHWAYS
ROCKY FLATS OU6
FIGURE 4-1

RFOU6