PUBLIC HEALTH RISK ASSESSMENT
881 HILLSIDE AREA (OU1)
TECHNICAL MEMORANDUM NO. 6
EXPOSURE SCENARIOS

Revision 4.0

Department of Energy
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM

June 1992

EXECUTIVE SUMMARY

This Exposure Scenario Technical Memorandum is presented as part of the Public Health Evaluation (PHE) of the Baseline Risk Assessment (BRA) for the 881 Hillside Area Operable Unit #1 (OU1) at the Rocky Flats Plant (RFP). It does not include the Environmental Evaluation (EE) portion of the BRA. The purpose of this technical memorandum is to describe "present, potential, and reasonable use [scenarios] with a description of the assumptions made and the use of data" as specified in the Interagency Agreement (IAG 1991). The objective is to present information on current and future land use to enable selection of reasonable scenarios to be used for the PHE. Potential scenarios are identified according to the Environmental Protection Agency (EPA) concept of reasonable maximum exposure (RME), defined as conservative, but within a realistic range of exposures, and are "reasonably expected to occur at a site" (EPA 1990b). The term "potential" is used to mean " a reasonable chance of occurrence within the context of the reasonable maximum exposure scenario" (EPA 1990a). Using this approach, the potential or likelihood of a scenario occurring is classified as improbable, plausible, or credible; defined in this document as 1) improbable - unlikely to occur, 2) plausible - conceivable, though not expected, and 3) credible - believable with reasonable grounds.

The physical environment of RFP is important in assessing the key mechanisms by which contaminants may be transported from sources to receptor populations. The climate is characterized as semi-arid, receiving approximately 0.38 meters [m] (15 inches) of precipitation annually. Winds blow predominantly from the northwest quadrant to the southwest, and exceed 15 meters per second [m/s] (34 miles per hour [mph]) approximately 5% of the year. The predominant geologic units at OU1 include the Rocky Flats Alluvium, colluvium, valley-fill alluvium and the Arapahoe and Laramie Formations. The water table at OU1 fluctuates seasonally by several feet. Groundwater flow is generally to the south and southeast and occurs in colluvium and weathered bedrock. The French drain was designed to capture shallow ground water at OU1. This physical environment includes a riparian habitat

and is part of a unique grassland community, providing protection for such animals as deer, coyotes, rabbits, many varieties of birds, and several types of reptiles.

RFP is located approximately 26 kilometers [km] (16 miles) northwest of Denver, Colorado and approximately 16 km (10 miles) south of Boulder. The 881 Hillside Area is located to the south and southeast of the center of the plant and is separated from the southern and eastern plant boundaries by approximately 1.6 km (1 mile) of undeveloped Department of Energy (DOE)-owned buffer zone. Approximately 9,000 people live within an 8-km (5-mile) radius from the center of the plant, with most of these located to the south and east between 6.4 and 8 km (4 and 5 miles) away. The majority of the population beyond a 6.4-km (4-mile) radius receives its water from public utilities, while the smaller population (684 people) closer to RFP, 3.2 - 6.4 km (2-4 miles), is potentially supplied by domestic water wells.

Current off-site land use includes residential, commercial/industrial, limited agricultural, and recreational uses, and current on-site use is restricted to RFP personnel or visitors. According to the plans of Jefferson County and of a group of area landowners, Jefferson Center Associates, credible future uses of off-site land include 1) commercial/industrial uses adjacent to RFP, and 2) residential and recreational uses further away. Due to commercial land development pressures and limited water supplies, it is improbable that future off-site use will include agricultural land use. As the land manager responsible for determining future onsite use, DOE must consider existing policies and potential liabilities. Future on-site use as an ecological reserve is credible and consistent with Atomic Energy Commission (AEC) and DOE policy and is allowed under DOE Order 4300.1B; commercial/industrial use in the areas currently developed for operations is also credible. Due to potential liabilities and the ecological reserve policy, it is improbable that future land uses will include agricultural or residential uses. However, at the request of EPA and the Colorado Department of Health (CDH), residential use will be quantitatively evaluated. The most likely time that the site would be available for alternative use is the year 2047, allowing 20 years for relocation of special nuclear materials (SNM) and SNM production and 35 years for decontamination and decommissioning (D&D). Because it is possible the site could become available before 2047, the target date of the year 2020 set by Energy Secretary Admiral James D. Watkins for completion of Environmental Restoration (ER) is proposed by DOE to evaluate risks related to future potential use. However, at the request of EPA and CDH, the hypothetical future resident will be assumed to reside at OU1 under conditions that exist now, coexisting with the adjacent special nuclear materials and production facilities.

Future land uses that are credible or additional land uses that have been specifically requested by EPA and CDH will be used for quantitative exposure assessment, while those that are less likely will not be evaluated. The land use scenarios selected for quantitative exposure assessment are 1) current off-site residential, 2) current on-site commercial/industrial (requested by EPA and CDH), 3) future on-site residential (requested by EPA and CDH), 4) future on-site commercial/industrial, and 5) future on-site ecological reserve. For those scenarios that will be quantitatively assessed, complete exposure pathways and exposure parameters have been identified. Quantitative exposure assessment of these RME scenarios will be conducted as part of the PHE portion of the BRA.

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ACRONYMS

AEC	Atomic Energy Commission
BRA	Baseline Risk Assessment
CDH	Colorado Department of Health
D&D	decontamination and decommissioning
DOE	Department of Energy
DRCOG	Denver Regional Council of Governments
EE	Environmental Evaluation
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ER	environmental restoration
IAG	Interagency Agreement
IHSS	Individual Hazardous Substance Site
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PEIS	Programmatic Environmental Impact Statement
PHE	Public Health Evaluation
RAGS	Risk Assessment Guidance for Superfund
RFP	Rocky Flats Plant
RI	Remedial Investigation
RME	reasonable maximum exposure
SNM	special nuclear material
TLV	threshold limit value
TWA	time weighted average

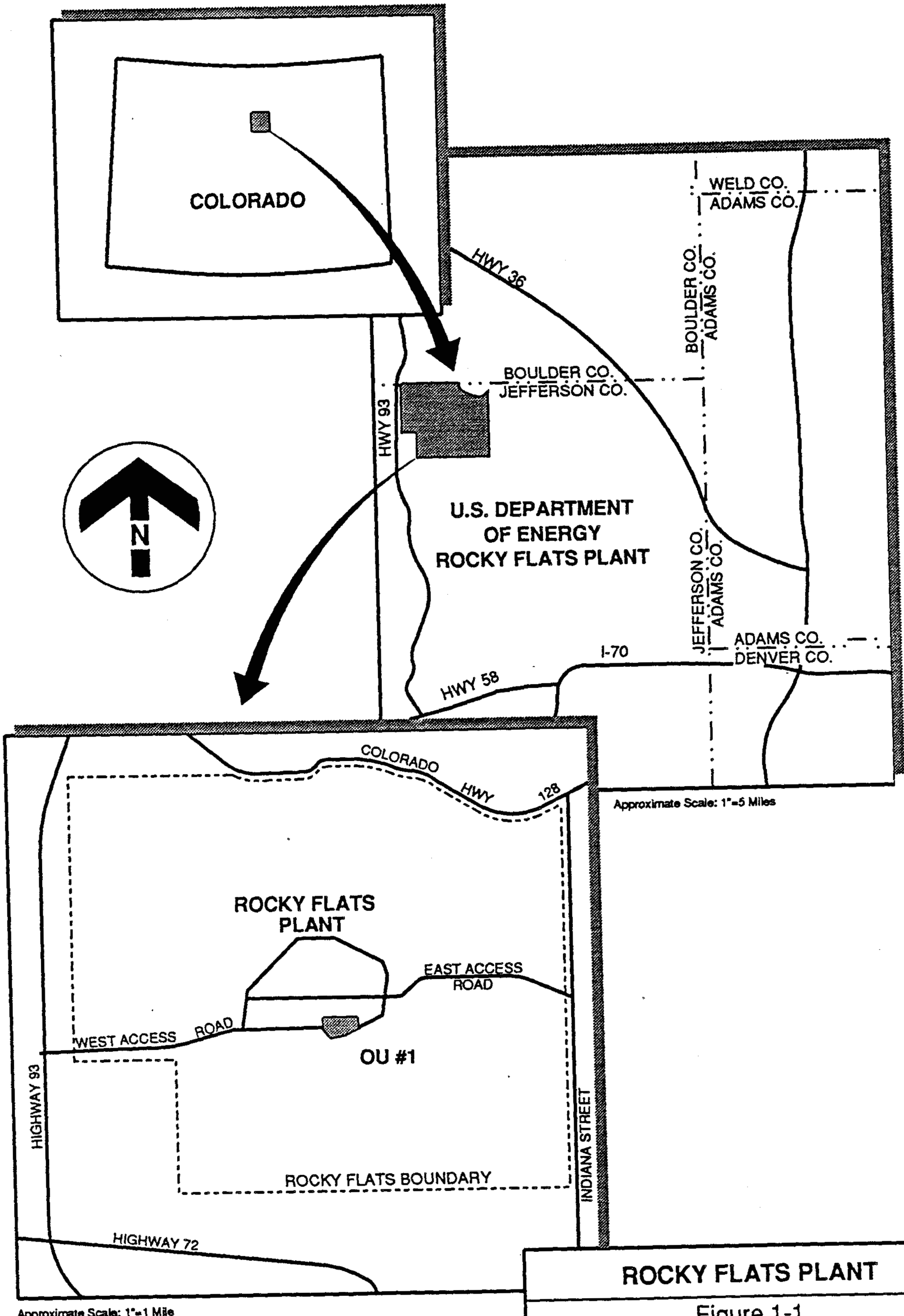
1.0 INTRODUCTION

1.1 Purpose

This Exposure Scenario Technical Memorandum is presented as part of the Public Health Evaluation (PHE) of the Baseline Risk Assessment (BRA) for the 881 Hillside Area Operable Unit #1 (OU1) located at the Rocky Flats Plant (RFP) (Figure 1-1). This technical memorandum outlines present and future reasonable land use scenarios along with applicable exposure parameters. The purpose of this technical memorandum is to describe "the present, potential, and reasonable use with a description of the assumptions made and the use of data" as specified in Attachment 2, Section VII.D of the Interagency Agreement (IAG 1991). Applicable exposure scenarios will be used to estimate intakes of contaminants by receptor populations during the Exposure Assessment phase of the PHE. This memorandum is being submitted prior to the required submittal of the BRA for OU1 as specified in Attachment 2, Section VII.D of the IAG.

1.2 Scope

The scope of this Technical Memorandum is limited to the identification of current and future land use and human exposure scenarios for OU1, including identifying exposure pathways and intake and exposure values. Potential scenarios are identified according to the Environmental Protection Agency (EPA) concept of reasonable maximum exposure (RME), defined as conservative, but within a realistic range of exposures, and are reasonably expected to occur at a site (EPA 1990b). The term "potential" is used to mean " a reasonable chance of occurrence within the context of the reasonable maximum exposure scenario" (EPA 1990a). Using this approach, the potential or likelihood of a scenario occurring is classified as improbable, plausible, or credible. In this document, "improbable" is used to indicate scenarios that are unlikely to occur. "Plausible" is used to indicate scenarios that are conceivable, though not expected, and "credible" is used to designate scenarios that are believable with reasonable grounds. Thus, in order of increasing credence,



ROCKY FLATS PLANT

Figure 1-1
General Location of
Rocky Flats Plant

the terms range from improbable (unlikely to occur) through plausible (conceivable, though not expected) to credible (believable with reasonable grounds).

In general, land uses that are likely to occur will be considered for quantitative exposure assessment, while those that are less likely are qualitatively discussed or dismissed from further consideration.

2.0 PHYSICAL ENVIRONMENT

The physical environment is described in the OU1 work plan (EG&G 1991b). The following is a summary of the information describing climate, geology, hydrology, and biota.

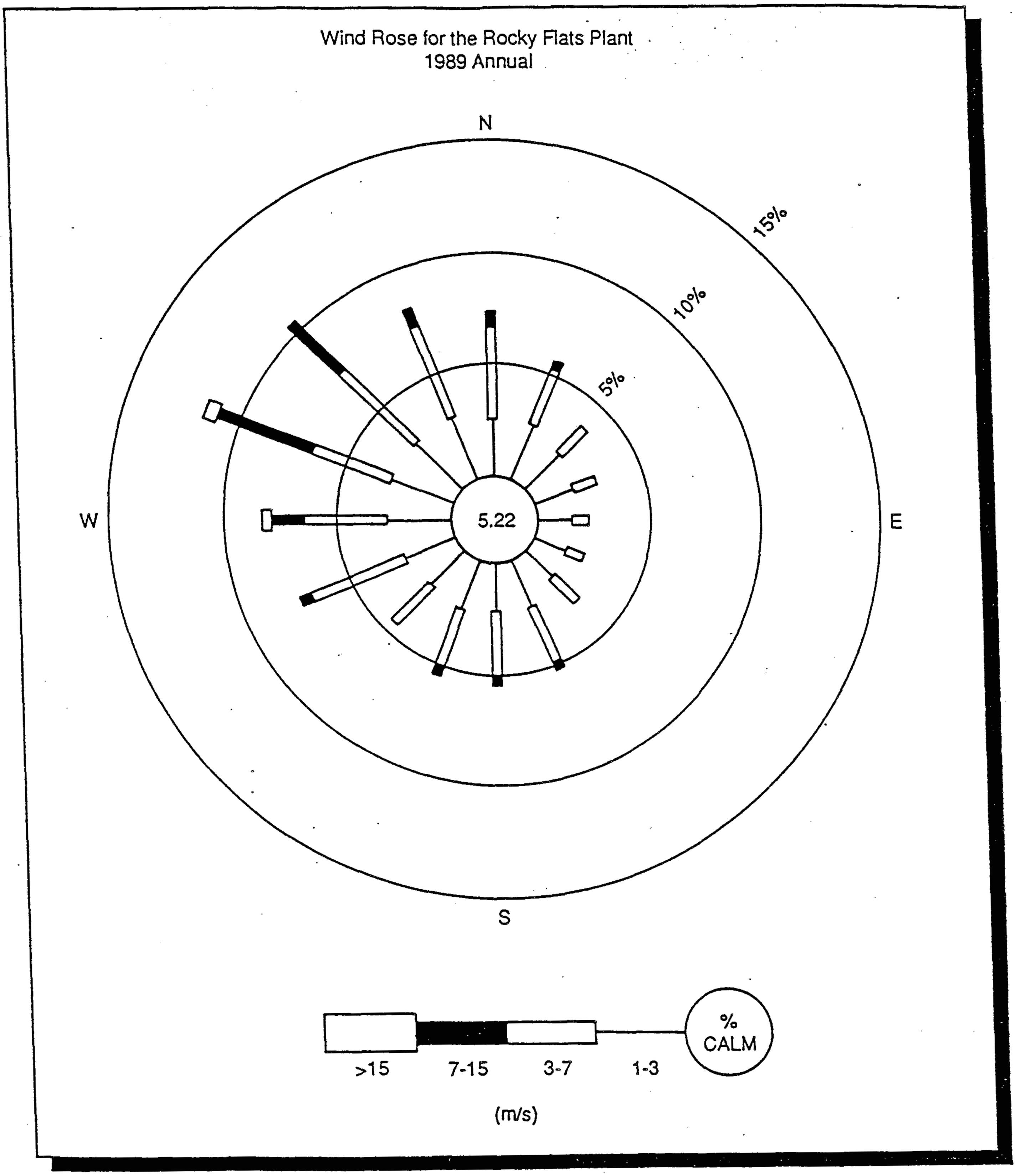
2.1 Climate

The area has a semi-arid climate and receives approximately 0.38 meters (15 inches) of precipitation annually. Approximately half of this moisture is received during the winter and spring as snowfall, approximately 30 percent falls during summer thunderstorms, and the remainder is received as light rain during the spring, summer, and fall. Annual free-water evaporation is approximately 1.1 meters (45 inches), substantially greater than the amount of annual precipitation.

The general annual wind pattern (Figure 2-1) for RFP indicates that winds flow from the northwest quadrant approximately 46 percent of the year. Outside of the northwest quadrant, the next largest wind rose component is due to wind from the west-southwest, which occurs approximately 7.2 percent of the year. The highest velocity winds (>15 meters per second [m/s]) (>34.5 miles per hour [mph]) are generally from the northwest. Topographical conditions specific to OU1 may cause local variations in wind direction; however, the annual averages are not expected to be significantly different from those for the entire RFP site. Based on the above information, the general area from the east-northeast to the south of RFP could be impacted by atmospheric dispersion from RFP.

2.2 Geology

The geologic units at OU1 include the Rocky Flats Alluvium, colluvium, valley-fill alluvium, terrace alluvium, and artificial fill that unconformably overlie the Arapahoe and Laramie Formations of the Cretaceous Age (EG&G 1991b, EG&G 1992). The Arapahoe Formation occurs only at the top of the slope of the hillside. The majority of OU1 is



Wind Rose for the Rocky Flats Plant
1989 Annual
N
15%
10%
5%
W
5.22
E
S
%
CALM
>15
7-15
3-7
1-3
(m/s)

FIGURE 2-1

underlain by the Laramie Formation. There are also isolated exposures of bedrock at OU1. The 881 Hillside Area is south-facing and slopes towards Woman Creek, south of RFP and Building 881.

The Rocky Flats Alluvium, a series of coalescing alluvial fans deposited by braided streams (Hurr 1976), is the oldest alluvium at RFP and caps the top of the 881 Hillside. A four- to twenty-foot thick layer of colluvium and weathered bedrock mantles the slope of the Woman Creek drainage. The colluvium materials were deposited by slope wash and creep of the Rocky Flats Alluvium and weathered bedrock. The colluvium consists mainly of clay with common occurrences of sandy clay and gravel. Artificial fill and disturbed surficial materials are present around building 881 and extend down-slope to the south interceptor ditch. The colluvium is covered by fill at Individual Hazardous Substance Site (IHSS) 130, and surficial materials have been disturbed near IHSSs 119.1 and 119.2. Valley-fill alluvium, derived from reworked older alluvial deposits and bedrock, occurs along Woman Creek. The valley fill consists of poorly sorted cobbles, pebbles, and gravels in a silty sand matrix. Terrace alluvium, composed of very poorly sorted gravelly sand, is present along the north side of the Woman Creek valley fill alluvium (EG&G 1991b).

The surficial materials at OU1 are underlain by the Laramie Formation of Cretaceous age and consist of claystones with interbedded lenticular sandstones, siltstones, and occasional lignite deposits. The bedrock dips at approximately two degrees to the east under RFP (EG&G 1990). Sandstones were deposited in stream channels and in overbank splays. Claystones were deposited in the floodplain and in backswamp areas. A generalized stratigraphic column is available for review in Figure B-1 in Appendix B.

2.3 Hydrology

Shallow ground water occurs in surficial materials and in subcropping Laramie Formation sandstones at OU1. This ground water is unconfined and flows to the southeast from areas of higher elevation towards Woman Creek. Ground water may also exist in deeper sandstone units in the Laramie Formation; however, the hydraulic connection of the shallow groundwater flow system to these deeper sandstone units is not fully understood (EG&G 1991b).

Recharge to the unconfined system occurs by infiltration of incident precipitation and by seepage from ditches, creeks, and retention ponds. The elevation of the water table fluctuates seasonally by several feet, with the highest levels occurring during the spring and early summer months of May and June when precipitation and runoff is large and evapotranspiration is small. Water levels generally decline and many wells in the unconfined flow system go dry during late summer and fall. Seeps commonly occur at the contact between the Rocky Flats Alluvium and outcropping claystone of the Arapahoe Formation at the top of the hillside. The French drain was designed to capture shallow ground water at OU1.

The surface water at the OU1 is ephemeral because of the seasonal response to spring runoff and storm events. Seeps and springs occur on the far eastern portion of OU1 during these events. A small drainage ditch near IHSS 102 also has intermittent flow into the south interceptor ditch (EG&G 1991a).

2.4 Biota

The 881 Hillside Area is part of a diverse and unique grassland community and hosts a riparian habitat in lower-lying areas. Flora representative of tall-grass prairies, short-grass prairies, and foothills regions can be found within the plant boundary. The more steeply sloped areas of the hillside are predominantly covered with grasses, while surface-water drainage areas such as Woman Creek are host to grasses, cattails, rushes, and cottonwood trees. As evidenced by the presence of disturbance-sensitive grasses like big bluestem and sideoats, restricted site access has facilitated vegetative recovery from common human activities along the Front Range such as burning, grazing, and road-building. In addition, restricted access provides protected nesting areas and habitats which help support animal populations in adjacent areas.

Animal life inhabiting RFP and its buffer zone consists of species associated with western prairie regions. Mule deer are the most common large mammals, with approximately 125 permanent residents. Smaller animals include carnivores, such as the coyote and red fox, omnivores, such as the striped skunk, and herbivores, such as rabbits, meadow voles, and gophers. Throughout the hillside area, birds such as western meadowlarks, mourning doves, and vesper sparrows are quite common, while birds of prey such as great horned owls, and ferruginous and American rough-legged hawks are observed less frequently. A variety of ducks, killdeer, and redwing blackbirds may be seen near the ponds along Woman Creek. Reptiles such as the western painted turtle and the western plains garter snake also inhabit the areas near the ponds, while bull snakes and rattlesnakes may be infrequently observed throughout the hillside area.

Impact to ecological receptors will be evaluated in the Environmental Evaluation (EE) portion of the BRA. EE and PHE are parallel activities in the evaluation of hazardous waste sites, and although different processes, they share certain information needs and will generally use some of the same data and similar future use scenarios. The scope of this document is limited to PHE and will discuss exposure scenarios from that perspective. The compatibility and likelihood of PHE and EE exposure scenarios will be considered by risk management during the development of remediation goals. In some cases, future land uses assessed as credible for PHE may have severe impact on ecological scenarios (e.g., future commercial development of the 881 Hillside Area could necessitate destruction of local ecological habitats).

3.0 POTENTIALLY EXPOSED POPULATIONS

Potentially exposed populations are characterized using information developed by the Denver Regional Council of Governments (DRCOG) in the demographics study *1989 Population, Economic, and Land Use Data for Rocky Flats Plant* (DOE 1990). Section 3.1 contains a summary of some relevant aspects of that document, including the presence of sensitive subgroups, current and projected activity patterns, and the location of each relative to the site. Information on current zoning and land use is available in the Jefferson County Northeast Land Use Inventory (JEFFCO 1989). Plans for future off-site land uses are indicated in the North Plains Community Plan (JEFFCO 1990) and the Jefferson Center Comprehensive Development Plan, which is Exhibit B of the Intergovernmental Agreement (IGA 1989). Future on-site land use is discussed in an Environmental Statement completed in 1972 when the land in the buffer zone was acquired by the Atomic Energy Commission (AEC) (AEC 1972). Further information on future plans for RFP is given in the Nuclear Weapons Complex Reconfiguration Study (DOE 1991a), the RFP Sitewide Environmental Impact Statement (EIS) (in production), and the Environmental Restoration and Waste Management Five-Year Plan (DOE 1991c).

3.1 Location

RFP is located approximately 26 km (16 miles) northwest of Denver and approximately 16 km (10 miles) south of Boulder. The site is located on a high arid plain at about 1,800 m (6,000 feet) above sea level. The area west of RFP is primarily mountainous, sparsely populated and government-owned (e.g., National Forest), while the area east of RFP is primarily a high arid plain, densely populated, and privately owned. Most 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 to the year 2010.

As illustrated by Figure 3-1 (DOE 1990), there is minimal residential and commercial development within a 6.4-km (4-mile) radius from the center of RFP. Between 6.4 and 16 km (4 and 10 miles) from the center of RFP, development gradually increases to the extent that approximately 316,000 people live within the 16-km (10-mile radius). Beyond the 16-km (10-mile radius), the Denver area lies to the southeast. Presently, the most significant development within the 16-km (10-mile) radius has occurred towards the east-southeast in the cities of Westminster, Arvada, and Wheat Ridge. Additional significant development within 16 km (10 miles) includes the cities of Boulder, Louisville, Lafayette, Broomfield, and Golden.

Sensitive subpopulation facilities (e.g., schools, nursing homes, and hospitals) are located beyond the 8-km (5-mile) radius shown in Figure 3-1. Ninety-three schools, eight nursing homes, and six hospitals are located within the 8- to 16-km (5- to 10-mile) radius of RFP. Over half of the schools are located in the southeast quadrant in the cities of Westminster, Arvada, and Wheat Ridge. Boulder, Arvada, and Wheat Ridge each contain one or more nursing homes. The six hospitals contain a total of approximately 900 beds and are located in the cities of Boulder, Louisville, Wheat Ridge, and Westminster.

The expected trend in population growth in the vicinity of RFP has been projected by DRCOG and is summarized in a recent Department of Energy (DOE) demographics study (DOE 1990). This report considers expected variations in population density by comparing the current (1989) setting to population projections for the year 2010. A 21-year profile of projected population growth in the vicinity of RFP can thus be examined.

Expected population density and distribution around RFP for the year 2010 is shown in Figure 3-2. Table 3-1 summarizes the population data presented in Figures 3-1 and 3-2. Sectors 3, 4, and 5 depicted in these figures are relevant to off-site exposure scenarios, while Sectors 1 and 2 represent property within RFP boundaries. In addition, only radial segments D through I are likely to be relevant to the 881 Hillside Area based on distance and pathway direction. These segments represent the predominant down-wind and downstream

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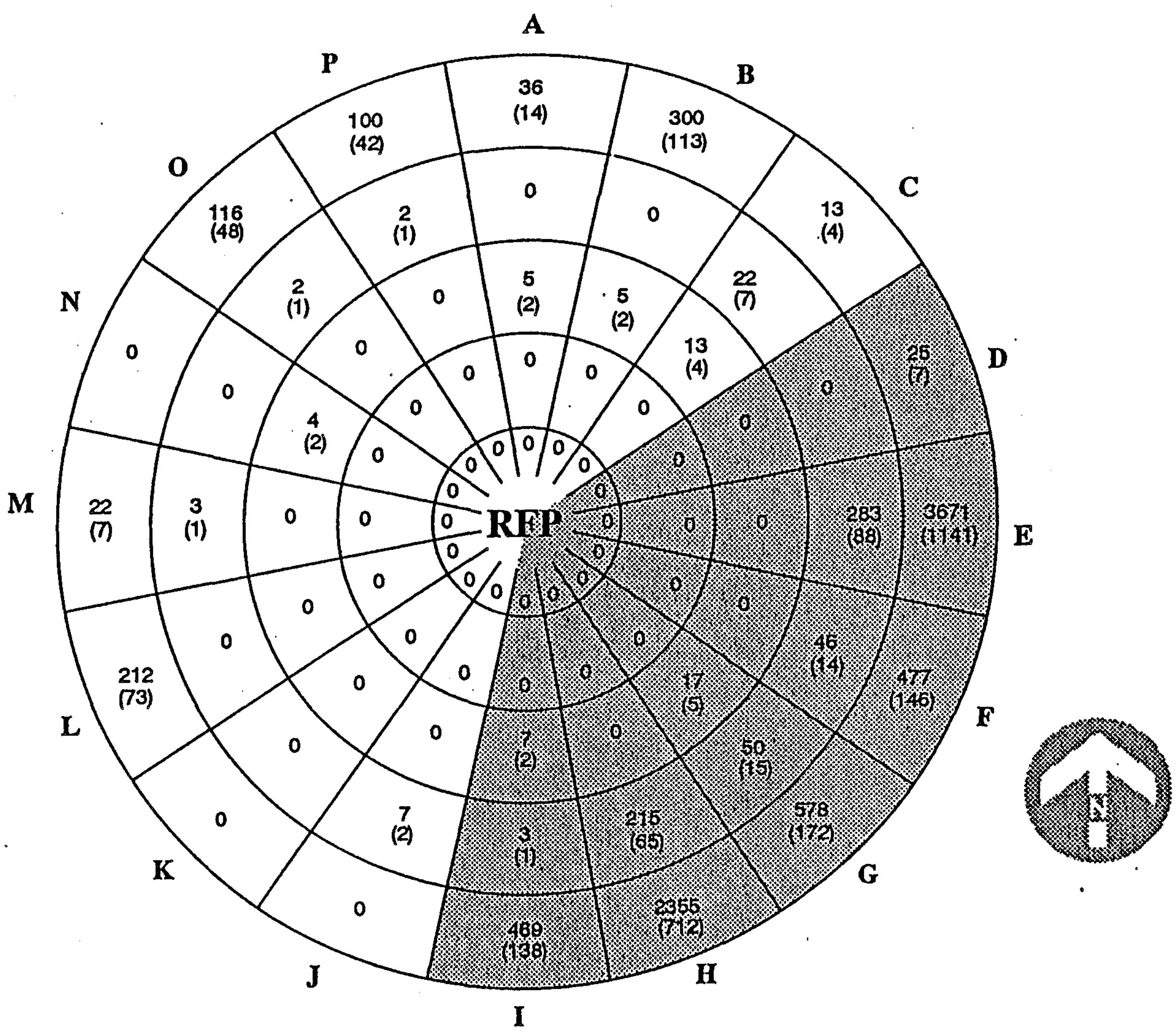


KILOMETERS	(MILES)	SECTOR NUMBER
0-1.6	0-1	SECTOR 1
1.6-3.2	1-2	SECTOR 2
3.2-4.8	2-3	SECTOR 3
4.8-6.4	3-4	SECTOR 4
6.4-8.0	4-5	SECTOR 5

LEGEND

SHADED AREAS INDICATE REGIONS IN THE PREDOMINANT DOWNWIND DIRECTIONS FROM THE ROCKY FLATS PLANT (RFP).

NOTE:

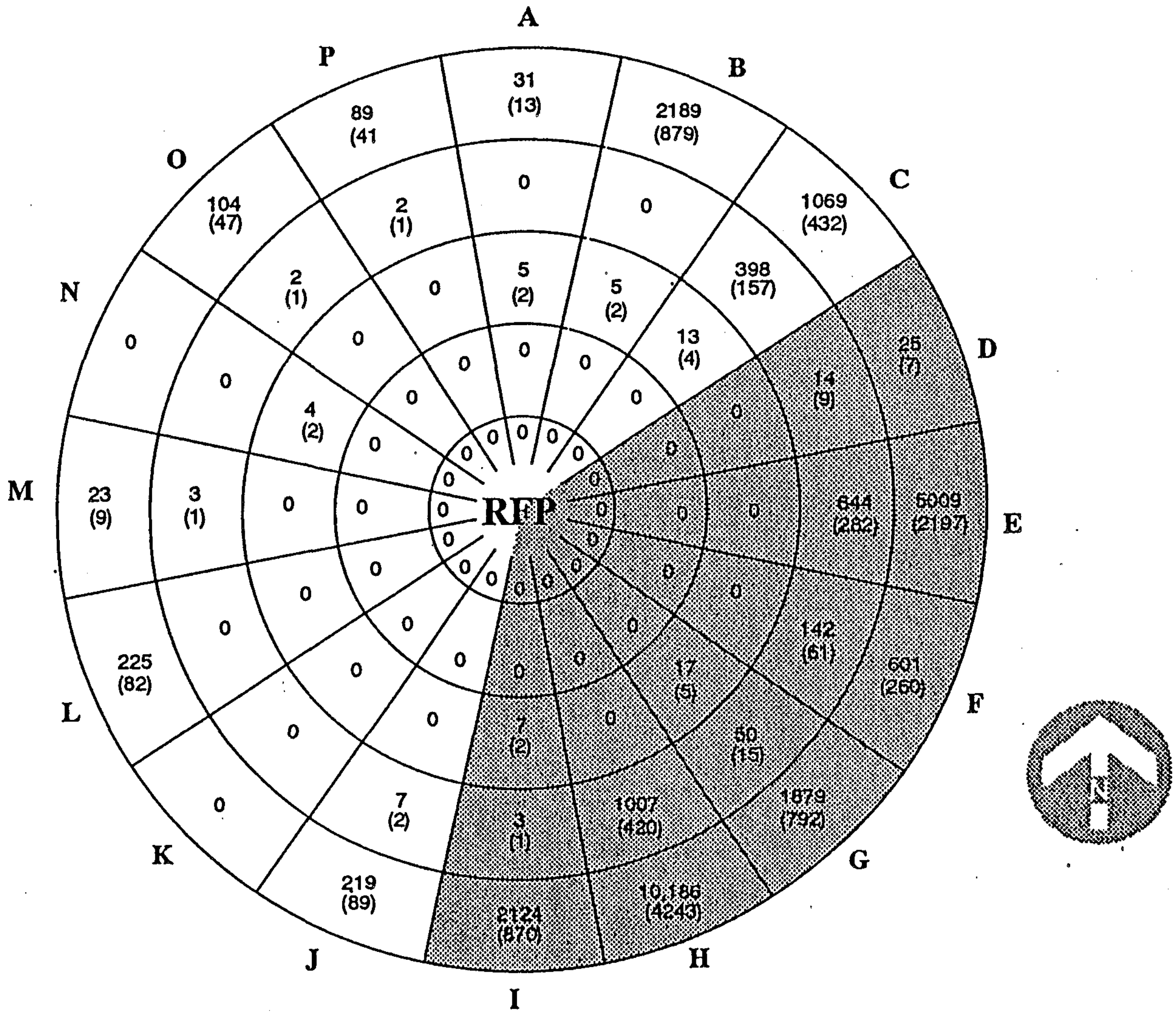
THERE ARE NO SENSITIVE SUBPOPULATION FACILITIES LOCATED WITHIN THIS 8-KILOMETER (5-MILE) RADIUS.

SOURCE:

DOE, "1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT" (DOE, 1990).

FIGURE 3-1

1989 POPULATIONS AND (HOUSEHOLDS), SECTORS 1-5



KILOMETERS	(MILES)	SECTOR NUMBER
0-1.6	0-1	SECTOR 1
1.6-3.2	1-2	SECTOR 2
3.2-4.8	2-3	SECTOR 3
4.8-6.4	3-4	SECTOR 4
6.4-8.0	4-5	SECTOR 5

LEGEND

SHADED AREAS INDICATE REGIONS IN THE PREDOMINANT DOWNWIND DIRECTIONS FROM THE ROCKY FLATS PLANT (RFP).

NOTE:

THERE ARE NO SENSITIVE SUBPOPULATION FACILITIES LOCATED WITHIN THIS 8-KILOMETER (5-MILE) RADIUS.

SOURCE:

DOE, "1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT" (DOE, 1990).

FIGURE 3-2

2010 POPULATIONS AND (HOUSEHOLDS), SECTORS 1-5

areas that are located closest to RFP. Review of Table 3.1 and Figures 3-1 and 3-2 suggests the following relative to future populations:

- Sector 3, the 3.2- to 4.8-km (2- to 3-mile) band from the center of RFP, contains the nearest resident (approximately 1.2 km [3/4 of a mile] east-southeast from the point where Woman Creek crosses under Indiana Avenue). There is no projected population growth in this sector over the next 20 years. Currently, a total of 24 residents reportedly live in Sector 3, Segments D, E, F, G, H, and I.

TABLE 3-1
CURRENT AND PROJECTED POPULATION IN THE VICINITY OF THE ROCKY FLATS PLANT

Sector	D	E	F	G	H	I	Sum
Year: 1989							
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	17	0	7	24
4	0	283	46	50	215	3	597
5	25	3,671	477	578	2,355	469	7,575
SUM	25	3,954	523	645	2,570	479	8,196
Year: 2010							
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	17	0	7	24
4	0	644	142	50	1,007	3	1,846
5	25	5,009	601	1,879	10,186	2,124	19,824
SUM	25	5,653	743	1,946	11,193	2,134	21,694

Source: DOE (1990)

- Population growth in Sectors 4 and 5, 4.8 to 8 km (3 to 5 miles) from the center of RFP is expected to be substantial through the year 2010. Most of this projected increase is anticipated in northern and southern areas. Within Segments D, E, F, G, H, and I, the population is expected to increase from 8,172 to 21,670.

These observations suggest that, while the population in the vicinity of RFP is expected to grow in the next 20 years, the dynamics of growth will not substantially encroach on the areas where contaminants from the 881 Hillside would likely impact (Sectors 2E, F, G, 3E, F, G).

3.2 Current Off-site Land Use

In addition to the location of populations discussed in Section 3.1, information on present zoning and land uses around RFP is available in the Jefferson County Northeast Land Use Inventory (JEFFCO 1989). The results are summarized in the Jefferson County Land Use Inventory map (Figure 3-3). Considering this information, current off-site land use includes each of the land use categories identified by the Environmental Protection Agency (EPA 1991):

- Residential
- Commercial/Industrial
- Recreational
- Agricultural

FIGURE 3-3 JEFFERSON COUNTY LAND USE INVENTORY

Water is a limited resource in this semi-arid climate, and as such, the economic availability influences land use decisions. Water supply for the off-site area originates from two primary sources, public utilities and private wells. The residential developments apparent on the Jefferson County Land Use Inventory map (Figure 3-3) are served by municipal water systems from the cities of Westminster and Arvada. Between the RFP boundary and the residential developments, private wells are assumed to provide water for domestic use (Appendix B). To the southeast of RFP, near Woman Creek, there are 14 wells permitted for domestic use. Actual sustained well-yields (gallons per minute) are difficult to obtain, but personnel in the Colorado State Engineers Office indicate that while a well generally provides sufficient yield for a residence, the yield is usually insufficient to supply an agricultural irrigation system. In the future, it is expected that public water supply systems will continue to be expanded to accommodate development, thereby eliminating the need for private wells.

Because residents are more likely to spend the greatest amount of time at or near home, the residential land use category will be the most conservative for exposure assessment purposes. Commercial/industrial populations would not be expected to spend as much time per day in a potential exposure area or have the same extent of direct contact with soils, sediments, and surface water as residential receptors. Since the evaluation of the potential risk to a residential receptor is expected to bound the potential risk to a commercial/industrial receptor, the off-site commercial/industrial scenario will not be considered further, while the off-site residential scenario is evaluated further in Section 4.

To illustrate the relative magnitude of the potential risks for residential and recreational receptors, information available from previous calculations at another RFP OU is used. Off-site risks have been evaluated in a preliminary manner for OU 3. Two separate documents, the *Past Remedy Report, Operable Unit No. 3 — IHSS 199* (DOE 1991e) and the *Historical Information Summary and Preliminary Health Risk Assessment, Operable Unit No. 3* (DOE 1991f), were submitted to EPA and approved. In both documents, potential risks to an off-site recreational receptor are evaluated using assumptions that yield a reasonable maximum risk estimate.

The Past Remedy Report calculated potential risks to recreational and residential land-use scenarios due to inhalation and ingestion of ^{239}Pu in soils. For soil concentrations of 1, 10, and 100 pCi/gm, the total incremental cancer risks associated with the recreational use exposure scenario were estimated as 7.0E-08, 7.0E-07, and 7.0E-06, respectively. Using a 10 pCi/gm soil concentration, comparison of the estimated total incremental cancer risk for the residential scenario (2.2E-06), with that for the recreational scenario (7.0E-07), indicates that the risk to a recreational receptor is expected to be less than the risk to a resident. Another relevant point of interest in that study is that for the recreational use scenario, the estimated risk due to ingestion of soil was calculated to be one order of magnitude less than that due to inhalation of dust.

Similar to the Past Remedy Report, the Historical Information Summary and Preliminary Health Risk Assessment estimated potential risk to a recreational receptor for hypothetical concentrations of ^{239}Pu in sediments. For a 10 pCi/gm sediment concentration, the total risk was calculated to be 4.6E-07. Furthermore, inhalation of resuspended exposed sediments was found to contribute 98 percent of the risk, while ingestion of surface water and sediments constitutes the other 2 percent.

The preliminary risk calculations in these two documents support two important conclusions. For a given sediment concentration, the potential risk to a hypothetical resident exceeds the potential risk to a recreational receptor. Also, for the recreational receptor, the inhalation pathway dominates the risk. Thus, assessment of the risk to the hypothetical resident bounds the risk to the recreational receptor, and risk management practices established to protect the resident will also adequately protect the recreational receptor. Because these conclusions are driven by assumed exposure times and uptake factors, rather than site-specific concentration or dispersion data, the same relative risk relationships should be applicable for OU1. Consequently, the current off-site recreational scenario will not be further considered.

Based on reconnaissance conducted within approximately a 6.4-km (4-mile) radius of RFP and on information in the Jefferson County Land Use Inventory map, there is little agricultural use of land in the area in the form of farming or raising of livestock for human consumption (a small herd was observed approximately 6.4 km [4 miles] south of RFP). Predominant downgradient (with respect to water flow and predominant wind direction) use is presently single-family dwellings and horse boarding operations. The prevalent use of downgradient land for boarding horses has resulted in overgrazing, thereby making the land less suitable for other types of agricultural use. Thus, although this land is zoned for agricultural use, the actual observed uses resemble a residential scenario more than a farm family scenario (EPA 1991). The current use of off-site land for this type of limited agricultural activity is discussed further in Section 4.

3.3 Current On-site Land Use

The area encompassing OU1 is essentially devoid of Rocky Flats production and maintenance activities. A large portion of the OU is actually located outside the security fence and technically within the buffer zone. As a result, under the no action conditions of the BRA, Rocky Flats workers are not expected to be within OU1. However, the area is subject to routine security surveillance as part of the overall RFP security program. Security surveillance includes periodic vehicular drives through the area on established roadways. The opportunity for significant inhalation exposure during these surveillance tours is very small, as indicated by a conservative screening assessment. A screening assessment involves preliminary calculations to estimate the magnitude of an exposure or risk, which can then be used to determine the relative importance of exposure pathways or scenarios. The results of the screening assessment presented in Appendix A are summarized in Tables 3-2 and 3-3.

TABLE 3-2
ESTIMATED ANNUAL EFFECTIVE DOSES FOR A SECURITY SPECIALIST

Radionuclide	Mean Soil Concentration (pCi/g)	Estimated Effective Annual Dose (mrem/yr)	Annual Dose Limit (mrem/yr)
U-234 + 235	9	0.19	5,000
U-238	287	5.3	5,000
Pu-239	0.1	0.1	5,000
Total Dose		5.6	5,000

TABLE 3-3
ESTIMATED TIME WEIGHTED AVERAGE (TWA) CONCENTRATIONS FOR A SECURITY SPECIALIST

Metal	Mean Soil Concentration (mg/g)	TWA Air Concentration (mg/m^3)	Threshold Limit Value (TLV) (mg/m^3)
Cadmium	0.003	2E-7	0.05
Chromium III	0.012	8E-7	0.5
Beryllium	0.0009	6E-7	0.002

The conservatively estimated summed annual effective dose equivalent of 5.6 mrem/year is insignificant relative to background (300 mrem/year) (NCRP 1987) or relative to the annual effective dose equivalent limit of 5000 mrem/year. Similarly, the estimated time-weighted average (TWA) concentrations are each several orders of magnitude below the threshold limit values (TLV) (ACGIH 1991-1992). This screening assessment indicates that intermittent exposure to hazardous substances identified at the site are well within acceptable guidelines for security personnel performing routine surveillance functions in OU1.

Security personnel at RFP are required to participate in medical monitoring programs designed to clinically screen for potential trace amounts of radionuclides and hazardous substances. Components of the monitoring programs include: (1) baseline, annual, and exit physical examinations, (2) bioassay programs to detect potential intake of radionuclides and hazardous substances, and (3) additional diagnostic procedures such as lung function tests to identify potential impacts of exposure to environmental contaminants. These monitoring programs are designed in accordance with DOE Orders, Occupational Health and Safety Administration (OSHA) requirements, and good occupational health practice.

In addition to the presence of those involved with the operation and support of RFP, possible exposure of the public while on-site must be considered. Because site access is restricted, any members of the public at the 881 Hillside Area must be either 1) members of an RFP-organized tour or function, or 2) unauthorized intruders. Compared to the screening assessment regarding routine surveillance tours through the 881 Hillside Area, members of a public tour would only be exposed once or twice a year, resulting in a substantially lower risk than the low risk to the security specialist. Intruders could be children at play, adults as hunters, hikers, or activists. Present levels of security include secure fencing, frequent armed security patrols, and modern electronic security systems. Fencing is posted to warn intruders that they are trespassing on federal property and, if caught, will be arrested. Plant security reports that there have been no incidents of trespassing in the buffer zone in the past seven years.

Therefore, based on the discussion above, the security specialist provides the bounding current on-site land use scenario. Although the screening assessment indicates that intermittent exposure to hazardous substances identified at the site are well within occupational guidelines, EPA and CDH have requested quantitative risk assessment for the current on-site commercial/industrial scenario be included in the PHE.

3.4 Future Off-site Land Use

Future off-site land uses are illustrated in the North Plains Community Plan Study Area Map (Figure 3-4) and the map of the Jefferson Center Comprehensive Development Plan (Figure 3-5). Jefferson County and five area cities (Arvada, Broomfield, Golden,

FIGURE 3-4 NORTH PLAINS COMMUNITY PLAN STUDY AREA SUMMARY MAP

FIGURE 3-5 JEFFERSON CENTER COMPREHENSIVE DEVELOPMENT PLAN MAP

Superior, and Westminster) have conducted a review of present land uses in the area and participated in a cooperative planning process. Results are summarized results presented in the North Plains Community Plan Study Area Map (Figure 3-4). Similar to the North Plains Community Plan Study Area Map, the map of the Jefferson Center Comprehensive Development Plan represents the plans of Jefferson Center Associates, a group of area landowners, to develop areas outside the protected area of RFP.

As illustrated by the maps, areas closest to RFP are planned for industrial or office space, while residential development is planned for areas further from RFP. Coupled with the historical pattern of growth and DRCOG projections of continued future growth, it is likely that demands on finite resources such as water and land will result in increasing costs for these commodities. At some point in the foreseeable future, these increasing costs, combined with past overgrazing practices at horse boarding operations, will render agricultural use of the land impractical. Based on this information, future off-site land uses and their likelihood of occurrence include:

- Residential (credible)
- Commercial/Industrial (credible)
- Recreational (plausible)
- Ecological Reserve (improbable)
- Agricultural (improbable)

Of the credible or plausible land uses, residential use is expected to involve greater exposure duration and frequency than commercial/industrial or recreational uses. Thus, evaluation of the potential risk to a residential receptor is expected to bound the risk to commercial/industrial or recreational receptors. Between the two risk assessment scenarios bounded by residential use potential risk, recreational use is likely to involve less exposure than commercial/industrial use due to shorter exposure duration and less exposure frequency. A commercial/industrial worker may be potentially exposed throughout the work-year, while a recreational user exposure is typically limited to a fraction of the day and seasonally to 6 to 9 months.

Since future on-site scenarios involve exposures significantly closer to the contaminant sources, they are expected to provide the greatest potential exposure and to bound the off-site scenarios. Consequently, future off-site scenarios will not be further evaluated.

3.5 Future On-site Land Use

Future plans for RFP are discussed in the Nuclear Weapons Complex Reconfiguration Study (DOE 1991a). This is a nationwide study investigating options to reconfigure the aging weapons complex to meet today's needs. Of the two preferred reconfiguration options discussed in the study, both dictate relocation of RFP functions. A final decision on reconfiguration is not likely until a Programmatic Environmental Impact Statement (PEIS) is developed to analyze the consequences of alternative configurations for the weapons complex. As of this writing, the PEIS is scheduled for completion in August, 1993.

While the PEIS addresses the consequences of reconfiguration alternatives on the entire weapons complex, the RFP Site-Wide EIS focuses on the consequences of future alternatives specific to RFP. The alternatives are considered within five- and ten-year time frames, corresponding closely to the period prior to implementation of the Reconfiguration decisions. Depending on decisions made by Energy Secretary Admiral James D. Watkins, these alternatives may be subject to change. Currently, there are four alternatives being considered in the draft implementation plan, including the no action alternative:

- The no action alternative includes completing nuclear production upgrades, maintaining production standby, and complying with IAG environmental restoration (ER) commitments.

- Alternative 1 includes nuclear production activities at reduced levels, complying with IAG ER commitments, and placing surplus facilities into safe storage.

- Alternative 2 includes nuclear production at up to 1989 levels, increased non-nuclear production, completion of ER by 2020, and placing surplus facilities into safe storage.

- Alternative 3 includes transition to no production of nuclear or non-nuclear components, completion of ER by 2020, decontamination and decommissioning (D&D) of selected facilities, and placing other facilities into safe storage for deferred D&D.

Examination of these alternatives indicates ER of the buffer zone may be completed by 2020, but there is no specific time frame for discontinuing production or D&D. It is possible that ER of the 881 Hillside area could be completed before Reconfiguration is complete. However, as long as special nuclear materials (SNM), e.g. ^{239}Pu, are present at RFP, it is improbable that the buffer zone would be released for alternative use. Only after completion of ER, removal of SNM, and D&D of the facilities, does alternative use of the buffer zone become plausible.

For relocation of RFP, the entire process of site evaluation and selection, development of new process technologies, detailed design of facilities, staging of construction projects for affordability, parallel operation for certification, and final production transition will probably require up to 20 years (DOE 1991a). It is important to note that reconfiguration plans are not tied to definite time deadlines; instead they will be addressed as funds are appropriated by Congress. Thus, considering the potential large size of the appropriations necessary for Reconfiguration, the 20-year timeframe for relocating RFP operations is a minimum.

DOE weapons production sites have been in existence for 50 years or less and have only been considered for D&D in the past decade. Consequently, there are no historical precedents of unrestricted release of a site contaminated with transuranic waste material. Selection of a date for alternative use of the 881 Hillside Area is a function of the following factors:

- The time required for ER
- The time required for relocation of nuclear production
- The time required for D&D

Environmental restoration plans are discussed in detail in the Environmental Restoration and Waste Management Five-Year Plan (DOE 1991c). In this document, Energy Secretary Admiral James D. Watkins reaffirms that he is committed to the 30-year cleanup goal for all DOE sites. As discussed above, relocation of nuclear production is likely to take more than 20 years after plans are finalized. The time necessary to remove SNM and complete D&D activities is uncertain, but considering the size and number of facilities involved, a minimum of 35 years is reasonable. Thus, the best estimate of a date for alternative use of the 881 Hillside Area is 20 + 35 = 55 years, or the year 2047. However, for purposes of the BRA, Energy Secretary Admiral James D. Watkins' ER cleanup goal of the year 2020 will be considered the earliest date that the 881 Hillside Area would be available for alternative use.

Preservation of the undeveloped land surrounding the production area, including the 881 Hillside Area and the buffer zone, was discussed when much of this land was acquired in two increments from private owners by the AEC in the early seventies. With residential and commercial development expanding towards the plant, the land acquisition was, in part, "aimed at preserving a substantial band of that unoccupied land in an open, undeveloped state... [as] an open space or 'green belt' ...... [to] encourage increased growth of vegetation, and provide shelter for animal life" (AEC 1972). Because the land was not ceded by local government, DOE is the land manager and is responsible for determining and providing for future land use of the site. Such future use decisions must balance the public's needs and desires with potential risk liabilities. The original DOE policy of preserving the buffer zone environment is still valid and may be expanded to include the entire RFP site. As indicated in a DOE memorandum concerning a draft paragraph to be included in the RFP Site-specific Plan, it is consistent with DOE's policy to secure the future land use of the RFP for an ecological preserve (DOE 1991b). Furthermore, such use is allowed by DOE Order 4300.1B, Chapter VIII, Section (4), which states, "Suitable DOE-owned or -leased land may be designated as a national environmental research park. Property holdings will be reviewed periodically and may be set aside for the exclusive use of nonmanipulative environmental research for definite or indefinite periods of time" (DOE 1987).

Consistent with the present uses of open space land in the region (hiking and nature trails), it is plausible that the entire site may be used for low-impact recreation. This use is similar to the ecological reserve in that both involve keeping the 881 Hillside Area undeveloped. An open space area and an ecological preserve would also involve some form of walking, either a day-hiker in the open space area or a research biologist walking during field activities. However, because a research biologist is likely to spend much more time at the site than a day-hiker and to be in close contact with soils and sediments during specimen observation and collection, the potential for exposure to a research biologist is greater than that of a day-hiker. Therefore, evaluation of potential exposure to a research biologist is judged to bound the potential exposure to a day-hiker.

Although written DOE policy does not indicate future use of the RFP site for commercial/industrial development, as recently as June 12, 1992, Admiral James D. Watkins, Secretary of Energy, introduced his plan to develop the RFP site as an industrial park. In this event, potential exposures to a commercial/industrial worker are expected to be less than those considered for a research biologist. This is due to the greatly reduced potential to be in close contact for long duration with soils, resuspended dust, surface water, and sediments. A research biologist is likely to conduct field research for one or two full days each week and spend the remainder of the week at an office or lab located away from the 881 Hillside Area. Field work may involve kneeling or lying on bare ground or vegetation, and soiling the hands and arms with soil, sediments, or surface water during specimen collection. By contrast, a commercial/industrial worker is likely to be indoors most of the time, and when outdoors, is likely to be surrounded by landscaped lawns, sidewalks, and paved parking areas that decrease the opportunity for resuspending particulates and direct contact with soil.

The sources and economic availability of an adequate water supply must be examined in light of the potential influence on future land uses and potential risks. Presently, water at RFP is supplied by the Denver Water Board, with existing facilities capable of handling two million gallons per day. With distribution facilities already in place, it is likely that future land uses would utilize this system. Since off-site wells presently exist that are capable of limited water production, OU1 area well production characteristics were evaluated and the details are provided in Appendices B and C.

As presented in Appendix B, on-site wells would not produce adequate yield to support a family of four unless drilled to deeper confined water-bearing units, such as the Laramie/Fox Hills Aquifer. This is evident when considering monitoring wells completed in the Arapahoe and Laramie Formations at the RFP. Several of these wells are routinely bailed dry during normal sampling activities and may require several days to recover. This exemplifies the slow recharge rates for these units. The slow recharge rates can be attributed to both small hydraulic conductivity and recharge available at the RFP. Conversely, off-site wells are believed (discussed in more detail in Appendix B) to be screened in the basal conglomeratatic sandstone of the Arapahoe Formation and have a potentially large source of recharge from Standley Lake and nearby ditches and canals feeding Standley Lake or conveying water through the area (Appendix B).

In addition, a pump test analysis was conducted at OU1. The results, presented in Appendix C, indicate that the upper and shallow lower hydrostratigraphic units at the 881 Hillside are not reliable sources of ground water for normal domestic purposes. Without an economical source of ground water, it is very likely that the existing treated water supply system would continue to be used.

Considering the discussion above along with growth pressures of planned off-site development illustrated in the North Plains Community Plan Study Area Map and Jefferson Center Comprehensive Development Plan maps, the likelihood of uses of the land surrounding the production area is evaluated as:

- Ecological Reserve (credible)
- Commercial/Industrial (credible)
- Recreational (plausible)
- Residential (improbable)
- Agricultural (improbable)

Exposure potential for the credible land uses, ecological reserve, and commercial/industrial are considered further in Section 4. At the request of EPA and CDH, the potential risk for a future on-site residential scenario will also be considered further. The potential risk for recreational land use is plausible for the area, however low-impact hiking is bounded by the potential risk for the ecological reserve scenario, and will not be further evaluated. The last type of land use listed, agricultural, is unlikely to be present in the future due to the development pressures discussed in Section 3.4; therefore, future on-site agricultural land use will not be further evaluated.

4.0 LAND USE SCENARIOS

An exposure scenario is defined by exposure pathways from the source to a human receptor, along with assumptions on the frequency and duration of exposure. The exposure scenarios developed in this Technical Memorandum are based on RME. EPA defines "reasonable maximum" such that only potential exposures likely to occur will be included in the assessment of exposures (EPA 1990b). EPA further states that "in general, the baseline risk assessment will look at a future land use that is both reasonable, from land use development patterns, and may be associated with the highest (most significant) risk, in order to be protective" (EPA 1990a). To assess whether a scenario is reasonable or likely to occur, historical precedents, and site and community planning documents must be considered. Based on the concept of RME, the scenarios identified are classified as improbable, plausible, or credible events as defined in Section 1.2. To summarize in order of increasing credence, the terms range from improbable (unlikely to occur) through plausible (conceivable, though not expected) to credible (believable with reasonable grounds).

The present pattern of land use and information concerning likely future land uses (reconfiguration plans, environmental remediation plans, policy to use the site as an ecological preserve, and development plans for off-site land) are discussed in Section 3. Table 4-1 provides a summary analysis of current and future land uses.

TABLE 4-1
ANALYSIS OF CURRENT AND FUTURE LAND USE

Land Use Classification or Category	Current		Future	
	Off-site[1]	On-site[2]	Off-site[3]	On-site[4]
Residential	Yes	No	Credible[5]	Improbable
Commercial/Industrial	Yes	Yes	Credible	Credible
Recreational	Yes	No	Credible	Plausible
Ecological Reserve	No	No	Improbable[6]	Credible
Agricultural	Yes	No	Plausible[7]	Improbable

(1) Current off-site land uses are discussed in Section 3.2.

(2) Current on-site land uses are discussed in Section 3.3.

(3) Plans for future off-site land uses are discussed in Section 3.4.

(4) Plans for future on-site land uses are discussed in Section 3.5.

(5) "Credible" is used in this document to indicate scenarios offering reasonable grounds to be believed.

(6) "Improbable" is used in this document to indicate scenarios that are unlikely to occur.

(7) "Plausible" is used in this document to indicate scenarios that are conceivable, though not expected.

Exposure scenarios that have a higher degree of likelihood are candidates for quantitative assessment in the BRA, while scenarios that appear improbable in light of existing information are generally not candidates for quantitative assessment. In the case of projected future land uses, more than one alternative may be credible. In some cases, significant differences in exposure duration and contact rates makes it unnecessary to evaluate each alternative, because the scenarios with less potential exposure are bounded by those with greater potential exposure. Quantitative assessment of the scenario with greater potential exposure will yield sufficient information for PHE. Methods of evaluation or assessment for each scenario are presented in Table 4-2.

TABLE 4-2
METHOD OF EVALUATION OR ASSESSMENT

Land Use Classification or Category	Current		Future	
	Off-site	On-site	Off-site	On-site
Residential	Quantitative	None	None	Quantitative(1)
Commercial/Industrial	None(2)	Quantitative(3)	None	Quantitative
Recreational	None(2)	None	None	None(4)
Ecological Reserve	None	None	None	Quantitative
Agricultural	None(5)	None	None(6)	None

(1) Although future on-site residential use is improbable, requests of EPA and CDH will be followed and risks to hypothetical future on-site residential receptors will be quantitatively assessed.

(2) Examination of exposure duration and contact rates indicates that the potential increased cancer risk to an off-site recreational receptor or commercial/industrial receptor will be less than potential risks to an off-site resident. Quantitative assessment of the risk to an off-site resident is judged to bound these other scenarios.

(3) Quantitative analysis requested by EPA and CDH.

(4) Examination of exposure duration and contact rates indicates that the potential risk to a research biologist will be greater than the potential risk to a recreational receptor. Quantitative assessment of the risk to a research biologist will bound the recreational scenario.

(5) Observed downgradient current off-site agricultural use consists of horse boarding operations and is expected to have approximately the same potential risk as current off-site residential land use.

(6) Growth pressures of Front Range development coupled with finite supply and increasing costs of land and water indicate that future agricultural land use is not expected.

4.1 Scenarios Selected for Quantitative Evaluation

4.1.1 Current Off-site Residential Scenario

Information presented in Section 3 shows that there is current residential off-site land use, and this is projected by DRCOG to continue to the year 2010. Consequently, potential exposure and risk will be quantitatively assessed in the PHE. Both adult and child (0-6 yrs) receptors will be considered. The following exposure assumptions will govern this analysis:

- A hypothetical resident is assumed to live from birth to age 30 (EPA 1991) at a location 1.2 km (0.75 miles) southeast of the site boundary.
- This individual may come in direct contact with soil during outdoor activities. Some of this soil may be ingested.
- The individual may come in contact with surface water and sediments while wading in Woman Creek. Some of this may be ingested.
- Currently, the individual consumes all of his water from an uncontaminated residential well.
- The individual spends a majority of time at home, breathing air potentially influenced by the site. Inhalation exposure away from home is assumed to be negligible.
- The individual regularly eats fruits and vegetables raised in a backyard garden.

4.1.2 Current On-site Commercial/Industrial Land Use

The category of RFP personnel that spend the greatest amount of time in OU1 are the security specialists on routine patrol. The following exposure assumptions concerning this type of commercial/industrial use are:

- A security worker conducts routine vehicular patrols within OU1 for 30 minutes per day, over a period of 25 years.
- This individual occasionally leaves the patrol vehicle for closer visual inspections. During some of these excursions, he comes in direct contact with soil, surface water and sediments. Some of this soil is inadvertently ingested through failure to wash before eating, etc.
- The individual uses water supplied by the Denver Water Board for washing and drinking.
- The individual spends 30 minutes per workday at OU1, breathing air potentially influenced by OU1. Inhalation exposure away from the site is negligible.

4.1.3 Future On-site Residential Land Use

Both adult and child (0-6 yrs) receptors are considered. The following exposure assumptions govern this analysis:

- A hypothetical resident lives from birth to age 30 (EPA 1991b) at a location within the OU1 boundary.
- This individual comes into direct contact with soil during outdoor activities, and some of this soil is ingested.
- The individual comes in contact with surface water and sediments while wading in Woman Creek, and some of this is ingested.
- The individual spends a majority of time at home, breathing air potentially influenced by the site. Inhalation exposure away from home is negligible.
- The individual uses water supplied by the Denver Water Board for washing and drinking. Further discussion of the availability of ground water at OU1 is provided in Appendices B and C.
- The individual spends a typical workday at the site, breathing air potentially influenced by the site. Inhalation exposure away from the site is assumed to be negligible.

4.1.4 Future On-site Commercial Industrial Land Use

Current and projected development patterns in the area do not favor heavy industry, thus the term "industry" refers to light industry. The following exposure assumptions concerning commercial/industrial use are:

- A hypothetical worker works a typical work-year for 25 years.
- This individual comes in direct contact with soil during operation and maintenance activities. Some of this soil is ingested through failure to wash before eating, etc.

- The individual uses water supplied by the Denver Water Board for washing and drinking. Further discussion of the availability of ground water at OU1 is provided in Appendices B and C.

- The individual spends a typical workday at the site, breathing air potentially influenced by the site. Inhalation exposure away from the site is negligible.

4.1.5 Future On-site Ecological Reserve Land Use

Use of the site as an ecological reserve, potentially involving exposure to a hypothetical research biologist, is based on the following exposure assumptions:

- The hypothetical research biologist works in the field five days per week, on average, for 25 years (250 days per year over all four seasons).

- This individual comes in direct contact with soil during field activities, and some of this is ingested through failure to wash before eating, etc.

- The individual comes in direct contact with surface water and sediments during field activities, and some of the surface water and sediments are ingested.

- The individual uses water supplied by the Denver Water Board for washing and drinking. Further discussion of the availability of ground water at OU1 is provided in Appendices B and C.

- The individual spends a typical workday at the site, breathing air potentially influenced by the site. Inhalation exposure away from the site is negligible.

5.0 EXPOSURE PATHWAYS

Once potentially exposed populations and exposure scenarios have been identified and characterized, exposure pathways can be traced from the source to the receptor. An exposure pathway generally consists of five elements:

- A source of contaminants
- A contaminant release mechanism
- A medium (or media) to transport contaminants
- A point of contact between the contaminated medium and the receptor
- An exposure route (intake into the body, direct exposure, etc.)

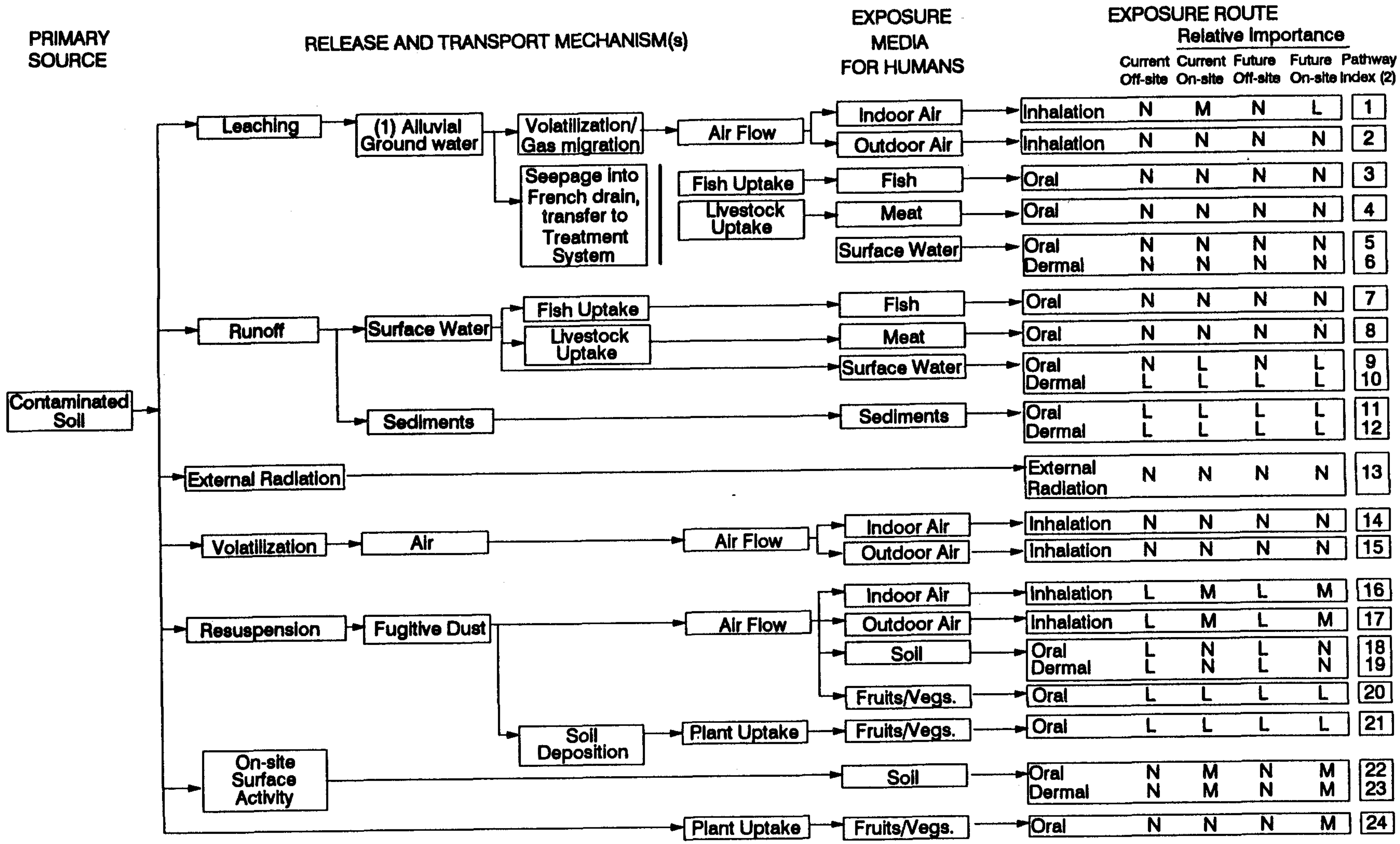
The field investigations conducted during Phases I and II of the Remedial Investigation (RI) have indicated contamination in unconfined ground water, soil, sediments, and surface water. Contaminants include chlorinated aliphatic hydrocarbon solvents, potentially toxic metals, pesticides, polychlorinated biphenyls, and radionuclides including actinides. These contaminants may be released to transport media by leaching, volatilization, resuspension of particulates by the wind, etc. Transport media may include surface water, ground water, air, soil, or biota. After transport to the location of the receptor, contact between the exposure media and the receptor (e.g., exposure to airborne particulate contamination) may occur. To complete the pathway, an exposure route into the body such as ingestion, inhalation, or dermal contact must occur. A conceptual model of theoretical exposure pathways is shown in Figure 5-1.

5.1 Complete Pathways for Quantitative Analysis

Table 5-1 lists potentially complete pathways for the current land use scenarios involving off-site residential use and on-site commercial/industrial use. The pathways with non-negligible potential for exposure are those associated with inhalation, and with direct contact and consumption by the receptor.

FIGURE 5-1

881 HILLSIDE AREA (OU-1) EXPOSURE PATHWAY CONCEPTUAL MODEL



(1) - The on-site alluvial groundwater system does not yield sufficient quantity of water to support residential use. See appendices B and C. On-site water is supplied by public water systems. Future off-site water is expected to be supplied by public water systems.

(2) - Pathways in Tables 5-1 through 5-2 have been indexed to Figure 5-1 for convenience.

N=NEGLIGIBLE; L=LOW; M=MEDIUM; H=HIGH

EXPPW-6.DRW

TABLE 5-1
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - CURRENT LAND USE
(Page 1 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
Off-site Resident	Inhalation of contaminated soil/dust particulates	Yes	Site contaminants may be blown off-site as fugitive dust.	16, 17
Off-site Resident	Inhalation of chemicals volatilized on site	No	Volatile chemicals near the soil surface were previously volatilized and no longer remain as supported by field instrument readings.	14, 15, 2
Off-site Resident	Inhalation of chemicals volatilized from ground water during home use	No	Off-site residential wells are not known to be contaminated.	None
Off-site Resident	Ingestion of contaminated well water	No	Off-site residential wells are not known to be contaminated.	None
Off-site Resident	Ingestion of wind-deposited soil	Yes	Children playing at home may be exposed to soil contaminated with fugitive dust associated with OU1.	18
Off-site Resident	Ingestion of contaminants that have accumulated in fish	No	Woman Creek flow east of RFP is negligible, and would not support development of sufficient aquatic species. There is currently no off-site contaminated surface water associated with OU1.	7
Off-site Resident	Ingestion of contaminated garden-grown fruits and vegetables	Yes	Plants may be grown in soil contaminated from fugitive dust.	20, 21

TABLE 5-1
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - CURRENT LAND USE
(Page 2 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
Off-site Resident	Ingestion of plants grown on-site	No	*Site access is restricted.*	20, 21, 24
Off-site Resident	Ingestion of livestock watered by surface water	No	Woman Creek flow east of RFP is negligible and low, and would not support use for this application. There is currently no off-site contaminated surface water associated with OU1.	8
Off-site Resident	Ingestion of surface water	No	There is currently no off-site contaminated surface water associated with OU1.	9
Off-site Resident	Ingestion of sediments	No	There is currently no off-site contaminated surface water associated with OU1.	11
Off-site Resident	Direct contact with contaminants in soil on the site	No	Site access is restricted. No credible means of exposing current off-site residents has been identified.	23
Off-site Resident	Dermal contact with potentially contaminated soils	Yes	Children playing at home may be exposed to soil contaminated with fugitive dust	
Off-site Resident	Dermal exposure to surface water	No	There is currently no off-site contaminated surface water associated with OU1.	10

TABLE 5-1
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - CURRENT LAND USE
(Page 3 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
Off-site Resident	Dermal exposure to sediments	No	There is currently no off-site contaminated surface water associated with OU1.	12
Off-site Resident	External radiation from on-site soils	No	Site access is restricted.	13
On-site Commercial/ Industrial Worker (Security Specialist)	Inhalation of chemicals volatilized from alluvial ground water.	No	Volatile chemicals in alluvial ground water could migrate upward, but would be significantly diluted outdoors.	1
On-site Commercial/ Industrial Worker	Inhalation of contaminated soil/dust particulates.	Yes	Valid while workers are on-site.	16, 17
On-site Commercial/ Industrial Worker	Inhalation of chemicals volatilized from soils.	No	Volatile near surface chemicals have been previously volatilized.	14, 15
On-site Commercial/ Industrial Worker	Ingestion of soil.	Yes	Workers may come into contact with contaminated soil.	22
On-site Commercial/ Industrial Worker	Ingestion of sediments	Yes	Workers may come into contact with contaminated sediments.	11
On-site Commercial/ Industrial Worker	Ingestion of surface water	Yes	Workers may come into contact with surface water	9
On-site Commercial/ Industrial Worker	Ingestion of contaminants that have accumulated in fish located in on-site ponds.	No	Workers are not expected to catch or eat fish from on-site ponds.	7

TABLE 5-1
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - CURRENT LAND USE
(Page 4 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
On-site Commercial/ Industrial Worker	Ingestion of fruits and vegetables grown on-site.	No	Workers are not expected to grow or eat vegetables from on-site.	20, 21, 24
On-site Commercial/ Industrial Worker	Ingestion of livestock or animals raised on-site.	No	Consumption of livestock or animals raised on-site is unlikely.	8
On-site Commercial/ Industrial Worker	Direct contact with contaminants in soil on the site.	Yes	Workers may come into contact with contaminated soil.	19, 23
On-site Commercial/ Industrial Worker	Dermal contact with sediments	Yes	Workers may come into contact with sediments	12
On-site Commercial/ Industrial Worker	Dermal contact with surface water	Yes	Workers may come into contact with surface water	10
On-site Commercial/ Industrial Worker	External radiation from radionuclides in soil.	No	Significant levels above natural background variation have not been observed.	13

These include inhalation of suspended particulates, and direct contact with or ingestion of surface water, sediments, and soil. Several pathways have little potential for exposure under present conditions. These include all on-site pathways that involve violating site security.

Potentially complete future pathways for the scenarios selected for quantitative assessment are listed in Table 5-2. These include potential exposure to a future on-site research biologist, future on-site commercial/industrial worker, and future on-site resident. Each pathway will be used in combination with specific exposure parameters to quantitatively assess potential exposure.

5.2 Exposure Parameters

Exposure parameters for each assumed scenario are listed in Tables 5-3 through 5-6. The values used are consistent with the concept of RME. The RME approach supersedes the previous method of determining an average and a worst-case exposure. The intent of the RME concept is to present exposure scenarios that are conservative yet credible and to avoid overly conservative exposure scenarios resulting from what McKone and Bogen (1991) refer to as the "creeping conservatism." According to EPA, the RME exposure scenario is reasonable because it is a product of factors, such as concentration and exposure frequency and duration, that are an approximate mix of values that reflect averages and 95th percentile distributions (EPA 1990b). Some of the values for an RME scenario are based on averages (e.g., body weights) while others are upper-bound values (e.g., intake/contact rates). The parameter values listed were extracted from the Risk Assessment Guidance for Superfund (RAGS) Volume 1 (EPA 1989), RAGS Supplemental Guidance "Standard Default Exposure Factors (EPA 1991)," and other relevant risk assessment literature.

TABLE 5-2
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - FUTURE LAND USE
(Page 1 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
On-site Research Biologist	Inhalation of contaminated soil/dust particulates	Yes	Valid while researchers on-site.	16, 17
On-site Research Biologist	Outdoor inhalation of chemicals volatilized from alluvial ground water.	No	Volatile chemicals in alluvial ground water could migrate upward, but would be significantly diluted outdoors.	2
On-site Research Biologist	Outdoor inhalation of chemicals volatilized from soils.	No	Volatile near surface chemicals have been previously volatilized.	15
On-site Research Biologist	Ingestion of surface water	Yes	While wading, incidental surface water ingestion may occur.	9
On-site Research Biologist	Ingestion of contaminants that have accumulated in fish located in on-site ponds	No	The researcher may collect fish for research, but will not eat them.	7
On-site Research Biologist	Ingestion of soil	Yes	Valid for inadvertent hand-to-mouth transfer due to soiled hands.	22, 18
On-site Research Biologist	Ingestion of animals grown on-site	No	Animal specimens may be collected for research, but will not eaten.	8
On-site Research Biologist	Ingestion of sediments	Yes	Ingestion of sediments from Woman Creek is possible.	11

TABLE 5-2
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - FUTURE LAND USE
(Page 2 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
On-site Research Biologist	Direct contact with contaminants in soil on the site	Yes	Contact possible during field and lab work.	19, 23
On-site Research Biologist	Dermal exposure to surface water	Yes	Contact with surface water from Woman Creek is possible.	10
On-site Research Biologist	Dermal exposure to sediments	Yes	Contact with sediments from Woman Creek is possible.	12
On-site Research Biologist	External radiation from radionuclides in soil	No	Significant levels above natural background variation have not been observed.	13
On-site Commercial/Industrial Worker	Indoor inhalation of chemicals volatilized from alluvial ground water.	Yes	Volatile chemicals in alluvial ground water could migrate upward and be concentrated indoors.	1
On-site Commercial/Industrial Worker	Inhalation of contaminated soil/dust particulates	Yes	Valid while workers are on-site.	16, 17
On-site Commercial/Industrial Worker	Inhalation of chemicals volatilized from soils	No	Volatile near surface chemicals have been previously volatilized.	14, 15
On-site Commercial/Industrial Worker	Ingestion of soil	Yes	Workers may come into contact with contaminated soil.	18, 22
On-site Commercial/Industrial Worker	Ingestion of contaminants that have accumulated in fish located in on-site ponds	No	Consumption of fish caught on-site is unlikely.	7

TABLE 5-2
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - FUTURE LAND USE
(Page 3 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
On-site Commercial/Industrial Worker	Ingestion of fruits and vegetables grown on-site	No	Consumption of produce grown on-site is unlikely.	20, 21, 24
On-site Commercial/Industrial Worker	Ingestion of livestock raised on-site	No	Consumption of livestock raised on-site is unlikely.	8
On-site Commercial/Industrial Worker	Direct contact with contaminants in soil on the site	Yes	Workers may come into contact with contaminated soil.	19, 23
On-site Commercial/Industrial Worker	External radiation from radionuclides in soil	No	Significant levels above natural background variation have not been observed.	13
On-Site Resident	Indoor inhalation of chemicals volatilized from alluvial ground water	Yes	Volatile chemicals may migrate through soils and concentrate indoors	14
On-Site Resident	Inhalation of contaminated soil/dust particulates	Yes	Site contaminants may be resuspended as fugitive dust	18
On-Site Resident	Ingestion of soil	Yes	Children or adults may come in contact with contaminated soil.	18, 22
On-Site Resident	Ingestion of surface water	Yes	While wading, incidental surface water ingestion may occur	9
On-Site Resident	Ingestion of sediments	Yes	Ingestion of sediments for Woman Creek is possible	11

TABLE 5-2
POTENTIALLY COMPLETE EXPOSURE PATHWAYS - FUTURE LAND USE
(Page 4 of 4)

Potentially Exposed Population	Exposure Route, Medium, and Exposure Point	Pathway Selected for Quantitative Evaluation?	Reason for Selection or Exclusion	Pathway Index to Figure 5-1
On-Site Resident	Ingestion of contaminants that have accumulated in fish located in on-site ponds	No	Consumption of fish caught on-site is unlikely	7
On-Site Resident	Dermal contact with potentially contaminated soils	Yes	Children or adults may come in contact with contaminated soil	19, 23
On-Site Resident	Dermal exposure to surface water	Yes	Contact with surface water from Woman Creek is possible	10
On-Site Resident	Dermal exposure to sediments	Yes	Contact with sediments from Woman Creek is possible	12
On-Site Resident	External radiation from radionuclides in soil	No	Significant levels above natural background variation have not been observed	13

TABLE 5-3
CURRENT AND FUTURE RESIDENTIAL OCCUPANT EXPOSURE ASSUMPTIONS

Parameter	Adult Value	Child Value	Reference	Variable Rating
Ingestion - soil and sediments	100 mg/day	200 mg/d 0-6 y	EPA 1991	C
Ingestion - fruits and vegetables [a]	0.08 kg/day	0.042 kg/day[d]	EPA 1990b	C
Inhalation	20 m^3/day	9.6 m^3/d[e]	RHH 1984	T
Adherence factor	0.6 mg/cm^2	0.9 mg/cm^2	EPA 1992	T
Dermal absorption factor	0.001 metals, 0.4 organics	0.001 metals, 0.4 organics	EPA 1992	T
Body weight	70 kg	15 kg	EPA 1989	T
Body surface area	3000 cm^2	1400 cm^2	EPA 1990b	T
Exposure duration	16 hr/day - 350 days/yr	24 hr/day - 350 d/y	EPA 1991	C
Exposure time - surface water	2.0 hr/event [c]	2.6 hr/event	EPA 1991	C
Exposure frequency - surface water	7 events/y	7 events/y	EPA 1991	T
Ingestion – surface water	50 ml/event	50 ml/event	EPA 1989	C
Matrix Factor[b]	0.15	0.15	Poiger and Schlatter 1980	T
Averaging Time (carcinogenic effects)	70 y	N/A	EPA 1989	C
Chronic Exposure Period	30 y	6 y	EPA 1989	C
Bio-availability- soil and sediments	0.9	0.9	Professional Judgement	C

T Typical
C Conservative
a Used for Current Off-site Residential Land Use
b This factor quantifies the effect of soil matrix to reduce dermal absorption of chemicals.
Poiger and Schlatter (1980) determined that the soil matrix decreases the dermal absorption of chemicals (TCDD).
c Adult exposure was assumed to be less than child's
d value for child (0-10) is assumed to be 1/2 the adult value
e age-weighted average

TABLE 5-4
CURRENT COMMERCIAL/INDUSTRIAL WORKER (SECURITY SPECIALIST) EXPOSURE ASSUMPTIONS

Parameter	Adult Value	Reference	Variable Rating
Ingestion- soil and sediments	50 mg/day	EPA 1991	C
Inhalation	18 m^3/workday	EPA 1991	T
Adherence factor	0.6 mg/cm^2	EPA 1992	T
Dermal absorption factor	0.001 metals, 0.4 organics	EPA 1992	T
Body surface area	3000 cm^2	EPA 1990b	T
Body weight	70 kg	EPA 1989	T
Exposure duration	0.5 hr/day - 250 day/yr - 25 yrs	EPA 1989	C
Matrix factor[(a)]	0.15	Poiger and Schlatter 1980	T
Exposure time (surface water)	2.0 hr/event	EPA 1989	C
Exposure frequency (surface water)	7 events/y	EPA 1989	T
Ingestion- surface water	0.02 ml/event[(b)]	Professional Judgement	C
Bio-availability	0.9	Professional Judgement	C
Averaging Time (carcinogenic effects)	70 y	EPA 1989	C
Chronic Exposure Period	25 y	EPA 1991	C

T Typical
C Conservative
a This factor quantifies the effect of soil matrix to reduce dermal absorption of chemicals.
Poiger and Schlatter (1980) determined that the soil matrix decreases dermal absorption of chemicals.
b Amount of water contained in 50 mg of saturated sediments, assuming wet density of 1.4 g/cm^3 and porosity of 50 percent.

TABLE 5-5
FUTURE ECOLOGICAL RESERVE RESEARCH BIOLOGIST EXPOSURE ASSUMPTIONS

Parameter	Adult Value	Reference	Variable Rating
Ingestion– soil and sediments	100 mg/day	EPA 1991	C
Inhalation	18 m^3/workday	EPA 1991	T
Adherence factor	0.6 mg/cm^2	EPA 1992	T
Dermal absorption factor	0.001 metals, 0.4 organics	EPA 1992	T
Body surface area	3000 cm^2	EPA 1990b	T
Body weight	70 kg	EPA 1991	T
Exposure duration	7, 100, 250 days - 8 hr/day - 250 day/yr - 25 yrs - 2 days/wk	EPA 1991	C
Matrix factor[(a)]	0.15	Poiger and Schlatter 1980	T
Exposure time (surface water)	2.6 hr/event	EPA 1989	C
Exposure frequency (surface water)	7 events/y	EPA 1989	T
Ingestion – surface water	0.02 ml/event[(b)]	Professional Judgement	C
Averaging Time (carcinogenic effects)	70 y	EPA 1989	C
Chronic Exposure Period	25 y	EPA 1991	C

T Typical
C Conservative
a This factor quantifies the effect of soil matrix to reduce dermal absorption of chemicals.
Poiger and Schlatter (1980) determined that the soil matrix decreases the dermal absorption of chemicals.
b Amount of water contained in 50 mg of saturated sediments, assuming wet density of 1.4 g/cm^3 and porosity of 50% .

TABLE 5-6
FUTURE COMMERCIAL/INDUSTRIAL WORKER EXPOSURE ASSUMPTIONS

Parameter	Adult Value	Reference	Variable Rating
Ingestion- soil and sediments	50 mg/day	EPA 1991	T
Inhalation	18 m^3/workday	EPA 1991	T
Adherence factor	0.6 mg/cm^2	EPA 1992	T
Dermal absorption factor	0.001 metals, 0.4 organics	EPA 1992	T
Body surface area	3000 cm^2	EPA 1991	T
Body weight	70 kg	EPA 1989	T
Exposure duration	8 hr/day - 250 day/yr - 25 yrs	EPA 1989	C
Matrix factor[(a)]	0.15	Poiger and Schlatter 1980	T
Bio-availability	0.9	Professional Judgment	C
Averaging Time (carcinogenic effects)	70 y	EPA 1989	C
Chronic Exposure Period	25 y	EPA 1991	C

T Typical
C Conservative
a This factor quantifies the effect of soil matrix to reduce dermal absorption of chemicals.
Poiger and Schlatter (1980) determined that the soil matrix decreases dermal absorption of chemicals.

6.0 SUMMARY

Exposure scenarios have been identified based on an inventory of current land uses and available information on DOE policy and community plans. Based on the concept of RME, the scenarios identified are classified as improbable, plausible, or credible events, defined in this document as 1) improbable - unlikely to occur; 2) plausible - conceivable, though not expected; and 3) credible - believable with reasonable grounds. In general, land uses that are more likely to occur will be used for quantitative exposure assessment. Two scenarios, current on-site commercial/industrial use and future on-site residential use, have been included at the request of EPA and CDH.

The land use scenarios selected for quantitative exposure assessment are:

- Current Off-site Residential Use
- Current On-site Commercial/Industrial Use
- Future On-site Residential Use
- Future On-site Commercial/Industrial Use
- Future On-site Ecological Reserve Use

For those scenarios that will be quantitatively assessed, complete exposure pathways and exposure parameters have been identified. As suggested by the EPA, a combination of exposure parameters have been identified that will result in an RME estimate. Quantitative exposure assessment of these RME scenarios will be conducted as part of the PHE portion of the BRA.

7.0 REFERENCES

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APPENDIX A

RISK SCREENING ASSESSMENT

RISK SCREENING ASSESSMENT

A.1 Objective

The objective of this risk screening assessment is to evaluate the potential impacts to workers from radioactive and hazardous substances during expected activities in OU-1 under the "No Action" alternative of the BRA.

A.2 Approach

The approach involves comparison of estimated external and internal exposures to potential contaminants at the site with established acceptable doses and airborne concentrations. External doses and airborne concentrations will be estimated using existing soil characterization data and conservative resuspension and exposure factors.

A.3 Assumptions

The exposed individual is assumed to be a RFP Security Specialist who routinely drives a vehicle along the Buffer Zone road in OU-1. The roadway travel distance is conservatively estimated to be 1.6 km (1 mile). At a rate of 6.4 kilometers per hour (kph) (4 mph), the estimated time period in OU-1 is 15 minutes per trip. Assuming 2 trips per 8-hour workday, a conservatively estimated exposure period of 30 minutes per day is derived. It is further assumed that no airborne contaminant concentration reduction is afforded by the being inside the vehicle. A conservative value of 1 mg/m^3 is assumed for steady-state particulate concentration, and a typical value of 10 m^3/8 hours is assumed for the inhalation rate.

A.4 Radioactive Dose Estimates

Mean soil radionuclide concentrations are given in Technical Memorandum #5, Draft Surface Soil Sampling and Analysis Plan for Operable Unit #1 (DOE 1992):

U 233+234:	9 pCi/g
U 238:	287 pCi/g
Pu 239:	1.5 pCi/g

The mean aerosol radionuclide concentration may be determined by multiplying the mean soil activity concentration by the concentration of particulates present in air and a unit conversion factor:

U 233+234:	(9 pCi/g)(1 mg/m^3)(0.001 g/mg) = 0.009 pCi/m^3
U 238:	(287 pCi/g)(1 mg/m^3)(0.001 g/mg) = 0.287 pCi/m^3
Pu 239:	(1.5 pCi/g)(1 mg/m^3)(0.001 g/mg) = 0.0015 pCi/m^3

Annual doses may be estimated by finding the product of the dose-per-unit-activity conversion factors, the concentration in air, the annual volume of air inhaled, and several unit conversion factors. Dose conversion factors are given in *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion* (EPA 1988):

U 233+234:	3.66E-5 Sv/Bq
U 238:	3.2E-5 Sv/Bq
Pu 239:	1.16E-4 Sv/Bq

U-233 + 234

$$\left[\frac{3.66E^{-}5\ Sv}{Bq}\right]\left[\frac{0.009\ pCi}{m^3}\right]\left[\frac{0.037\ Bq}{pCi}\right]\left[\frac{10\ m^3}{day}\right]\left[\frac{1\ day}{8\ hr}\right]\left[\frac{0.5\ hr}{day}\right]\left[\frac{250\ days}{yr}\right]\left[\frac{1.0E5\ mrem}{Sv}\right] = 0.19\frac{mrem}{yr}$$

U-238

$$\left[\frac{3.2E^{-}5\ Sv}{Bq}\right]\left[\frac{0.287\ pCi}{m^3}\right]\left[\frac{0.037\ Bq}{pCi}\right]\left[\frac{10\ m^3}{day}\right]\left[\frac{1\ day}{8\ hrs}\right]\left[\frac{0.5\ hr}{day}\right]\left[\frac{250\ days}{yr}\right]\left[\frac{1.0E5\ mrem}{Sv}\right] = 5.3\frac{mrem}{yr}$$

Pu-239

$$\left[\frac{1.16E-4\ Sv}{Bq}\right]\left[\frac{0.0015\ pCi}{m^3}\right]\left[\frac{0.037\ Bq}{pCi}\right]\left[\frac{10\ m^3}{day}\right]\left[\frac{1\ day}{8\ hrs}\right]\left[\frac{0.5\ hr}{day}\right]\left[\frac{250\ days}{yr}\right]\left[\frac{1.0E5\ mrem}{Sv}\right] = 0.1\ \frac{mrem}{yr}$$

Results are summarized in Table A-1 and compared to DOE annual effective dose equivalent limits for occupational workers (DOE 1989).

TABLE A-1
ESTIMATED EFFECTIVE ANNUAL DOSES FOR A SECURITY SPECIALIST

Radionuclide	Mean Soil Concentration (pCi/g)	Estimated Effective Annual Dose (mrem/yr)	Annual Dose Limit (mrem/yr)
U-234 + 235	9	0.19	5,000
U-238	287	5.3	5,000
Pu-239	0.1	0.1	5,000
Total Dose		5.6	5,000

A.5 Hazardous Chemical Breathing Zone Concentration Estimates

Mean soil metal concentrations are given in the Plan for Prevention of Contaminant Dispersion (DOE 1991):

Cadmium:	0.003 mg/g
Chromium III:	0.012 mg/g
Beryllium:	0.0009 mg/g

The 8-hour time-weighted-average (TWA) of the breathing zone concentration is the product of the particulate air concentration, the mean soil concentration, a unit conversion factor, and the time-fraction. Results are summarized in Table A-2 and compared to the American Council of Governmental Industrial Hygienists occupational threshold limit value (TLV) for each contaminant (ACGIH 1991-1992).

$$TWA = (1\ mg/m^3) \left[\frac{.003\ mg}{g}\right] \left[\frac{1\ g}{1000\ mg}\right] \left[\frac{0.5\ hr}{8\ hr}\right] = 1.8E\text{-}\ 7\ mg/m^3$$

$$TWA = (1\ mg/m^3) \left[\frac{0.012mg}{g}\right] \left[\frac{1\ g}{1000\ mg}\right] \left[\frac{0.5\ hr}{8\ hr}\right] = 7.5E{-}7\ mg/m^3$$

$$TWA = (1\ mg/m^3) \left[\frac{0.0009mg}{1000mg}\right] \left[\frac{1\ g}{1000\ mg}\right] \left[\frac{0.5\ hr}{8\ hr}\right] = 5.6E{-}8\ mg/m^3$$

TABLE A-2
ESTIMATED TIME WEIGHTED AVERAGE (TWA) CONCENTRATIONS FOR A SECURITY SPECIALIST

Metal	Mean Soil Concentration (mg/g)	TWA Air Concentration (mg/m^3)	TLV (mg/m^3)
Cadmium	0.003	2E-7	0.05
Chromium III	0.012	8E-7	0.5
Beryllium	0.0009	6E-8	0.002

A.6 Finding

Estimated exposure levels for a security specialist traveling through OU-1 on routine surveillance are several orders of magnitude below accepted occupational limits for both radionuclide and hazardous contaminants.

REFERENCES

ACGIH, 1991-1992. *Threshold Limit Values and Biological Exposure Indices for 1991-1992*. American Conference of Governmental Industrial Hygienists. Cincinnati, Ohio.

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APPENDIX B

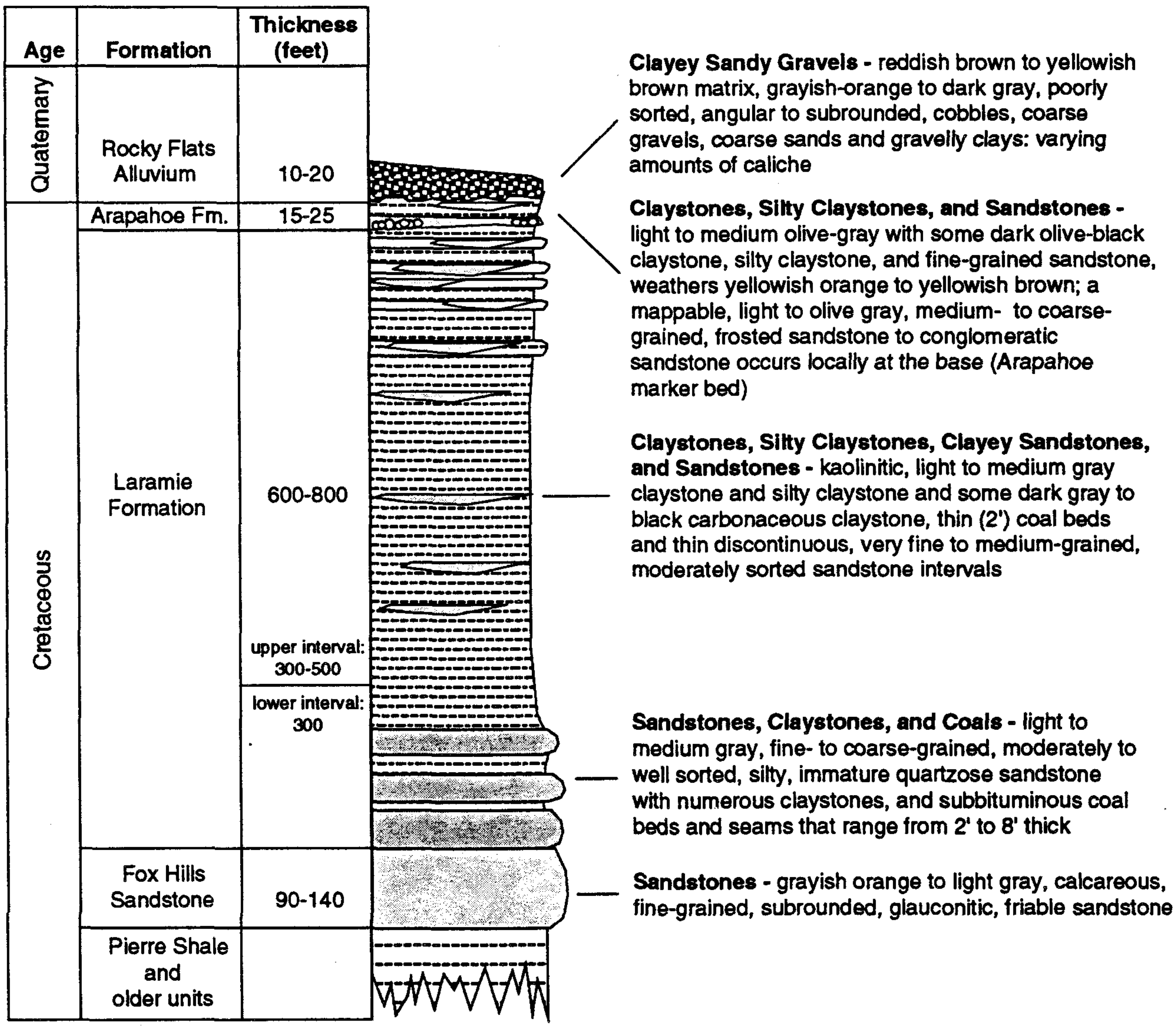
INVESTIGATION AND SIMULATION OF WATER PRODUCTION CAPABILITIES

B.1 Simulation Introduction

In order to investigate the water production capabilities of several hydrostratigraphic units beneath the Rocky Flats Plant, transient pumping simulations for these units were performed. These simulations were designed to estimate whether the hydrostratigraphic units beneath the 881 Hillside area could produce sufficient water to supply a four-member household. A daily pumping requirement of 3.03 cubic meters per day [800 gallons per day (gpd)] was used based on the Denver Metro area average water requirement of 0.76 cubic meters per day (200 gpd)/person (discussion with the Denver Water Board, 1991). Simulations were done for the Rocky Flats Alluvium and for a confined sandstone unit in bedrock. Figure B-1 (generalized stratigraphic section of the Central portion of the Rocky Flats Plant) identifies the hydrostratigraphic units considered in this investigation. The Rocky Flats Alluvium is not considered a reliable water source but was included in the simulations since it is the uppermost hydrostratigraphic unit and portions of it have been affected by activities at the plant. The bedrock sandstone unit was included because it was considered to be the best prospect for producing water from the Arapahoe or Laramie Formations. The claystones and siltstones of the Arapahoe and Laramie were considered poor prospects due to their low hydraulic conductivities ($\sim 2 \times 10^{-4}$ ft/day as measured from on-site packer tests) and were not simulated.

B.2 Simulation Findings

Based on ground-water flow simulation results neither the Rocky Flats Alluvium nor the sandstone units are capable of producing sufficient water to support a four-member household. Using a nine-hour daily pumping period and a rate of 0.34 cubic meters per hour [1.5 gallons per minute (gpm)], both the alluvium and the Arapahoe wells would be pumped dry within two months. For the sandstone unit, simulations of a single sandstone unit were done. This is based on borehole lithologic data which indicate that the Arapahoe and Laramie sandstone units are not laterally (perpendicular to the long dimension) or vertically continuous. Although unlikely, if a second similar sandstone unit was encountered,



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

After EG&G 1992

Generalized Stratigraphic Section for the Central Portion of Rocky Flats Plant

Figure B-1

water production rates would be increased. Considering the length of the estimated times, as well as the conservative pumping rate, 0.34 cubic meters per hour (1.5 gpm), it is unlikely that realistic variations in the model input parameters would significantly affect these findings. Specifically, the model results (Table B-1) indicate that the Rocky Flats Alluvium would be pumped dry in approximately 11 days; the sandstone unit would be pumped dry after approximately 67 days. The first stratigraphic interval likely capable of producing a sufficient quantity of water is the Lower Laramie Formation/Fox Hills sandstone interval which is between 152 to 213 meters (500 to 700 feet) deep beneath the 881 Hillside.

These findings are also supported by the following observations:

- Arapahoe and Laramie sandstone units beneath the Rocky Flats Plant (RFP) subcrop in local drainages. This limits the areal extent of sandstone units from which water can be pumped.

- The Laramie sandstone units beneath OU1 are known to be of limited extent (in addition to outcrops and subcrops). The sandstones are typically lenticular in form due to the depositional environment in which they were deposited. The sandstone units are thus of limited lateral extent perpendicular to the long dimension of the units. Therefore, water storage capacity in the Laramie sandstone units beneath OU1 is limited.

- The geometric-mean hydraulic conductivity of the Laramie sandstone units beneath OU1 is 0.068 ft/day (this is the geometric mean of values listed in Table 2-6 of the Phase III Work Plan (EGG&G 1991b). This value is nearly one order of magnitude smaller than the value of 0.5 ft/day used in the model (Table B-2). Furthermore, typical aquifers used for water supply have transmissivities of 14,000 ft^2/day (Freeze and Cherry 1979), which is nearly four orders of magnitude larger than the estimated maximum transmissivity (6.84 ft^2/day of Arapahoe sandstone units beneath OU1 (based on the maximum

Table B-1
Summary of Simulation Results

Unit	Days to Dry
Rocky Flats Alluvium	11
sandstone unit	67

Table B-2
Modeling Parameters For Sandstone Unit

Parameter	Value	Source
Hydraulic Conductivity	1.8×10^{-4} cm/s (0.5 ft/day)	On-site testing. High value within range in Table 3, Geologic Characterization, 1991. EG&G Rocky Flats.
Specific Yield	0.30	GPMPP* Table 2-11
Grid Spacing (uniform)	4.6 m (15 ft)	Based on width of sandstone unit
Hydrogeologic Unit Character	Confined	GPMPP* page 2-23
Hydrogeologic Unit Thickness	0.6 to 3.0 m (2 to 10 ft)	Well Logs
Channel Width	78 m (255 ft)	Estimated**
Initial Piezometric Head	6.1 m (20 ft)	Assumed
Boundary Conditions	Constant head & No flow	Assumed based on channel geometry

* Ground-water Protection and Monitoring Program Plan, November, 1991
** Based on Plate 4 from July, 1991 Rocky Flats Plant Geologic Characterization

values of 0.57 ft/day for hydraulic conductivity and 12 feet of saturated thickness).

- Several monitoring wells completed in the Arapahoe or Laramie Formations are routinely bailed dry during normal sampling activities and may require several days to recover. During the most recent sampling activity at RFP, 34% of the wells required 2 days to sample (due to slow recharge rates) and 8% could not be sampled due to lack of water. This indicates the low recharge rates and low permeability of bedrock. Although a production well with a larger diameter would have greater storage and would recharge at a slightly higher rate, it is unlikely that a suitable water yield could be maintained for a domestic well. Further, a larger diameter production well would be impractical, due to the excessive depth and casing requirements.

A domestic well completed in the Laramie/Fox Hills Aquifer may be capable of producing 800 gpd; however, this appears highly impractical as supported by the following points:

- The RFP is located near a portion of the recharge area of this aquifer. Therefore, confining pressures would be smaller than those further downgradient from the RFP. Small confining pressures result in smaller amount of available water in the aquifer. A lower confining pressure would also limit the water level rise in the well, reducing the volume of water stored in the well.

- To access the Laramie/Fox Hills Aquifer from the OU1, a well of approximately 500 to 800 feet would be necessary. A domestic water well of this depth would probably not be an economically viable alternative.

This model is based on data collected from on-site boreholes. Section B.3 provides details of modeling methodology.

B.3 Simulation Method

Simulations were performed using the U.S. Geological Survey MODFLOW ground-water flow simulation package (McDonald and Harbaugh 1988). Input parameters common to all simulations are listed in the Table B-3. Separate simulations were done for the Rocky Flats Alluvium and for the sandstone unit. A listing of the input parameters for these simulations is given in Tables B-4 and B-2. Simulations were run using a daily time-frame until the pumping well went dry or the end of the simulation (120 days) was reached.

Each day of the transient simulation was divided into two periods. The first nine hours of each day was used as a pumping period. It was assumed that the household maintained water storage capabilities and that this pumping period was used to replenish the water storage system. This scenario allows low pumping rates which should allow a larger volume of water to be extracted before desaturating the well. A pumping rate of 0.34 cubic meters per hour (1.5 gpm) was used. This rate is below the 0.68 - 0.91 cubic meters per hour (3-4 gpm) rate normally required for domestic wells [conversations with the Jefferson County Health departments indicated 0.68 cubic meters per hour (3 gpm), and the Federal Housing Authority 0.91 cubic meters per hour (4 gpm)] and, as such, is conservative. The remaining 15 hours of each day allowed water level recovery to take place.

The pumping well was located at the center of a 19 by 19 grid cell array. The grid spacings for each scenario are given in Tables B-4 and B-2.

Boundary conditions were either constant head (equal to the initial head) or no-flow, depending on the scenario. A conservative value for the range of known hydraulic conductivities in each formation was used to provide estimates of the longest possible period of time before the pumping well would go dry (that is, the results are designed to over estimate the time required to dry up the ground-water source). For the Rocky Flats Alluvium scenario a constant head boundary was used at all boundaries. The sandstone unit was intended to represent a channel-sand deposit. To implement this, no-flow boundaries

Table B-3
Modeling Parameters Common to All Scenarios

Parameter	Value	Source
Water Requirement	3.0 m^3/d (800 gpd)	City of Denver Water Board*
Pumping Rate	0.34 m^3/h (1.5 gpm)	Assumed
Pumping Time per Day	9 hrs	Based on pumping rate
X to Y Anisotropy	1 (isotropic)	Assumed
Number of Rows	19	Assumed
Number of Columns	19	Assumed

* Aggregate Denver Metro Area Average of 200 gpd/person

Table B-4
Modeling Parameters For Rocky Flats Alluvium

Parameter	Value	Source
Hydraulic Conductivity	$8.8X10^{-4}$ cm/s (2.5 ft/day)	On-site testing. High value within range in Table 3, Geologic Characterization, 1991. EG&G Rocky Flats.
Specific Yield	0.30	GPMPP* Table 2-11
Grid Spacing (uniform)	6.1 m (20 ft)	Assumed
Hydrogeologic Unit Character	Unconfined	On-site observation
Initial Saturated Thickness	1.5 m (5 ft)	Observation wells
Boundary Conditions	Constant head	Assumed

* Ground-water Protection and Monitoring Program Plan, November, 1991

were placed along two parallel sides of the grid (parallel to the long dimension of the sandstone unit) with constant head boundaries along the other two sides. Logs from bedrock wells on the 881 Hillside area indicate most sandstone units consist of intervals from 0.3 to 3 meters (1 to 10 feet) in thickness and are generally clayey-to-silty in nature. For this simulation a composite thickness of 3 meters (10 feet) was estimated to be the most likely expected thickness. To simulate a channel geometry, the thickness of the sandstone unit varied from 3 meters (10 feet) at the center to 0.6 meters (2 feet) along the sides adjacent to the no-flow boundaries.

B.4 Area Water Supply

Water is supplied to the Rocky Flats Plant (RFP) by the Denver Water Board. There is currently a supply system (i.e., pumps, pipes, and related utilities) capable of handling two million gallons per day. Any future use of the RFP site is likely to utilize this system. Consequently, there is not a reasonable chance that an on-site future use scenario would: 1) fail to access the readily available water supply, and 2) install a ground-water well into the unreliable alluvium or upper Arapahoe Formation.

The cities of Westminster and Arvada provide water to developed areas located approximately 6.4 kilometers (4 miles) east and southeast of the center of RFP. A public water source is not currently available in immediately adjacent areas south and east of the RFP. Historically, municipalities in the area have provided water to emerging residential and commercial developments. As these off-site areas are developed, it is likely that a public water supply will eventually be provided. Meanwhile, these areas must depend upon water supply from other sources, including water wells.

B.5 Area Wells

Within an 8.3 kilometer (5 mile) radius to the south and east of the plant, 146 well permits are registered with the Colorado State Engineer's office (Figure B-2). Table B-5 is derived from a microfiche data base and retains English units used by the Colorado State Engineers Office. Actual well existence can not be inferred from the table; this list merely denotes that permit applications have been filed with the State Engineer's Office. The yields listed in Table B-5 indicate maximum permissible pumping rates and have no relation to sustainable yields (well permits for low-yield wells do not require any testing to estimate actual sustainable yield). The permit applicant states a planned well completion depth, and this is accepted or rejected by the State Engineer's Office.

The majority of the 146 wells are located 5 kilometers (3 miles) or more from the plant (Figure B-3) and range in depth from 3.0 to 396.2 meters (10 to 1300 feet) below ground surface. Figure B-4 shows that over 80 percent of the wells are less than 121.9 meters (400 feet) deep. Sixty four percent of the wells are permitted to yield under 3.4 cubic meters per hour (15 gpm) and thus are classified[1] as domestic wells by the Colorado State Engineer's office.

B.6 Wells Near Standley Lake

Off-site wells adjacent to RFP and down-gradient from OU1 are of particular interest (Figure B-5). Table B-6 lists information from well completion reports[2] for the 14 wells near Standley Lake. These values represent observations and measurements during installation. Yields specified in Table B-6 are pumping rates which drillers recorded during well development. They are not indicative of sustainable pumping rates (well completion reports do not indicate water level recovery rates after pumping). At the pumping rates

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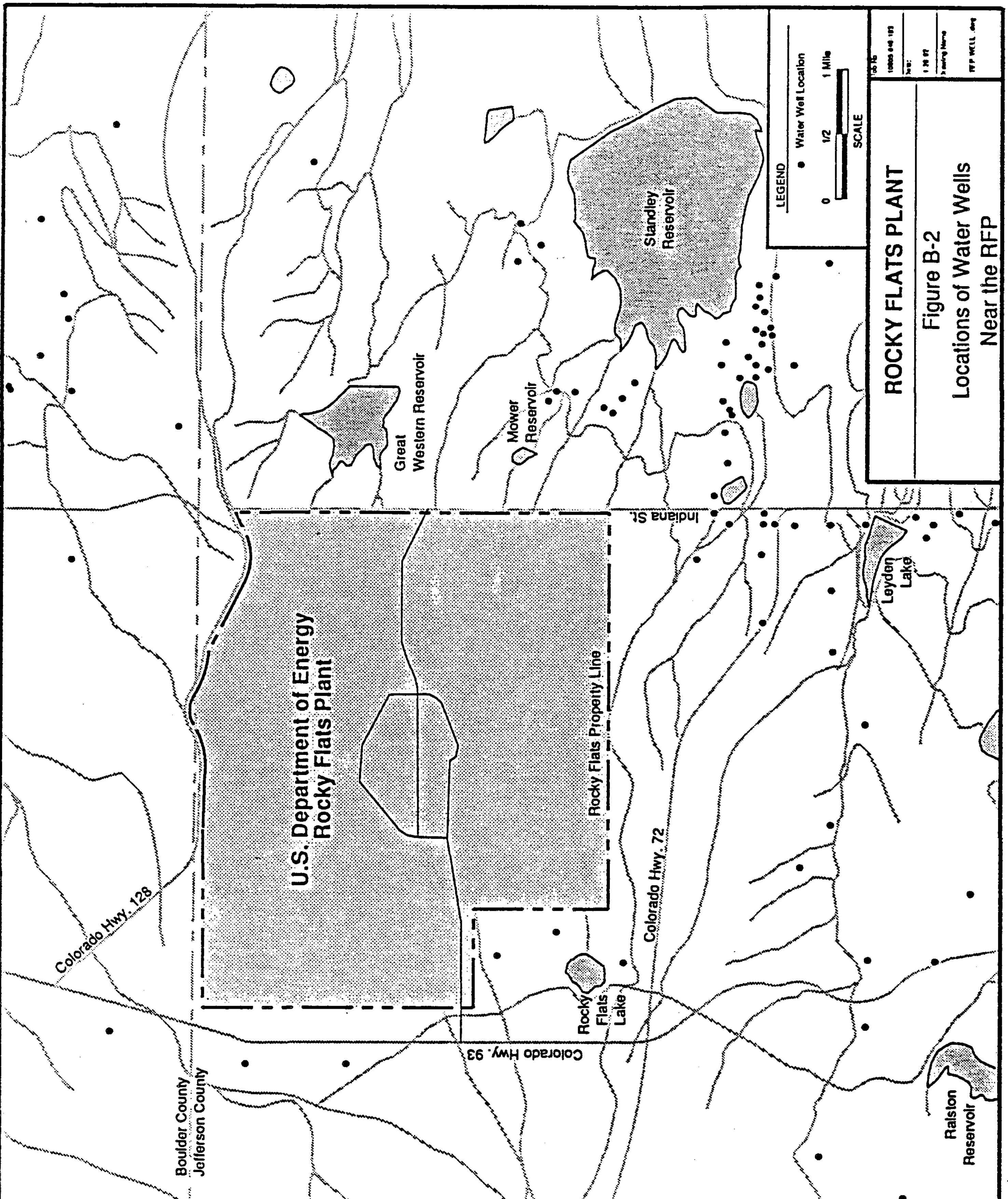
[1]Classification is not indicative of actual well yields or usage.

[2]Drillers file these reports after completing well installation. Along with permit applications, these are on file at the Colorado State Engineer's Office.



ROCKY FLATS PLANT

Figure B-2
Locations of Water Wells
Near the RFP

Table B-5 Well Permits in the Vicinity of Rocky Flats *

Permit No.	Use	Permitted Yield (gpm)	Permitted Well Depth (ft bls)	Coordinates		QTRS	Section	Township	Range	Distance (mi)
6711F	I	4525.9	390			SWS	29	1S	69W	
25514	D	7	360			NWN	30	1S	69W	
34317F	M	1	365	50N	260E	NWN	30	1S	69W	
35470F	M	23	597	820N	1525E	NWN	30	1S	69W	
35471F	M	23	790	570N	490E	NEN	30	1S	69W	
36154F	M	25	830	2390S	1740E	NWS	30	1S	69W	
48196	D	15	610			NESE	30	1S	69W	
8273	D	20	185			SEN	30	1S	69W	
24243	D	25	800			SWS	31	1S	69W	
29289	DS	25	800			SWS	31	1S	69W	
34582	D	7	333			SWSE	31	1S	69W	
44374	D	13	80			NEN	31	1S	69W	
100277	D	15	635	476N	2180W	NEN	32	1S	69W	
2600	D	10	410	350BN	2250E	NWN	32	1S	69W	
33093	D	12	825			SENE	33	1S	69W	
5414F	N	10	850			NEN	33	1S	69W	
37464	D	5	109			SWN	16	2S	69W	5
38163	D	15	53			SWN	16	2S	69W	5
13494	D	20	142			SENE	17	2S	69W	4
15044R	N	5	182			SWN	17	2S	69W	4
30030	D	20	182			NESE	17	2S	69W	4
666	D	10	95			NESE	17	2S	69W	4
80021	D	15	300	2295S	100E	NESE	17	2S	69W	4
955	D	20	85			NESE	17	2S	69W	4
103583	D	15	125	1000S	610E	SESE	18	2S	69W	3
132562	S	15	10	730S	573E	SESE	18	2S	69W	3
132563	DS	5	10	744S	384E	SESE	18	2S	69W	3
29620	D	15	112			NESE	18	2S	69W	3
52028	D	8	122	44		NESE	18	2S	69W	3
96282	H	14	125	1800S	400E	NESE	18	2S	69W	3
1246	D	15	67			NEN	19	2S	69W	4
138834	D	15	71	1200N	100E	NEN	19	2S	69W	4
139972	D	4	375	250S	1300E	SESE	19	2S	69W	4
14820	D					NEN	19	2S	69W	4
15251	D	20	86			SWS	19	2S	69W	4
15252	D	20	86			SWS	19	2S	69W	4
18383	D	12	75			NEN	19	2S	69W	4
19069	D	6	100			NEN	19	2S	69W	4
223	D	6	110			SWSE	19	2S	69W	4
26	D	15	125	100N	1200E	NEN	19	2S	69W	4
32467	D	8	115			SESE	19	2S	69W	4
32849	D	14	80			NEN	19	2S	69W	4
45855	D	15	110			NEN	19	2S	69W	4
65747	DS	15	120	450S	1700E	SWSE	19	2S	69W	4
8117	D	12	70			NEN	19	2S	69W	4
83981	D	5	305	590S	1520W	SESW	19	2S	69W	4
87059	D	5	140	250S	1220E	SESE	19	2S	69W	4
89558	D	15	150	400N	13300E	NEN	19	2S	69W	4
25429	D	4	40			SENE	20	2S	69W	4
29754	D	20	240			SWS	20	2S	69W	4
39001	D	15	170			SWS	20	2S	69W	4
556	D	20	185			SWS	20	2S	69W	4
85531	D	2.5	385	550S	1500W	SESW	20	2S	69W	4

Table B-5 Well Permits in the Vicinity of Rocky Flats *

Permit No.	Use	Permitted Yield (gpm)	Permitted Well Depth (ft bls)	Coordinates		QTRS	Section	Township	Range	Distance (mi)
11621	D	10	375	700N	1330W	NEN	29	2S	69W	5
14099	D	7	265			SWN	29	2S	69W	5
155357	H	5	400	1154N	2090W	NEN	29	2S	69W	5
2049	D	6	72			NESE	29	2S	69W	5
25218	D	12	305			NWN	29	2S	69W	5
37296	D	15	207			NWN	29	2S	69W	5
52877	D	15	300			NWN	29	2S	69W	5
54046	D	15	270			NWN	29	2S	69W	5
55735	D	7	365	775S	92E	NESE	29	2S	69W	5
61192	D	14	300			NEN	29	2S	69W	5
63995	D	15	330	840N	1536E	NWN	29	2S	69W	5
66103	D	1	320	115N	115W	NWN	29	2S	69W	5
66359	D	10	320	50S	100E	NWN	29	2S	69W	5
70958	D	12	340	650N	250W	NWN	29	2S	69W	5
73291	H	12	300	350N	1000W	NWN	29	2S	69W	5
73870	H	10	300	1000N	2580W	NEN	29	2S	69W	5
75034	H	10	300	750N	2250E	NWN	29	2S	69W	5
76567	H	10	300	1230N	545W	NWN	29	2S	69W	5
81924	D	13	310	1030N	1760W	NEN	29	2S	69W	5
82491	H	15	300	1152N	1876W	NEN	29	2S	69W	5
89110	D	3	296	720NN	1490E	NEN	29	2S	69W	5
12664	D	4	30			SWSE	4	2S	69W	5
28779	D	1	50			SWS	6	2S	69W	3
9126	D	20	50			NEN	7	2S	69W	3
26667	DS	8	27			SENE	9	2S	69W	5
15314	D	12	615			swsw	29	1S	69w	
128433	D	5	12	1798S	2W	NWS	30	1S	70W	
36497	D	40	22			NWS	30	1S	70W	
3714	D	10	23			NWS	30	1S	70W	
2862	D	1	74			SWN	33	1S	70W	
15060	D	1	100			NWN	36	1S	70W	
17190F	C	150	604	1440S	1150E	NESE	16	2S	70W	2
10467TH	O		50			SENE	18	2S	70W	4
11877	D	6	325			SWN	19	2S	70W	5
13018	D	1	110			SWS	19	2S	70W	5
13439F	M	17	465			SWS	19	2S	70W	5
28408	D	1	308			SESW	19	2S	70W	5
33695	D		80			SWS	19	2S	70W	5
35711	D	4525.9	410			SWS	19	2S	70W	5
45022	D	9	230			NWS	19	2S	70W	5
53597	D	6	200			SWS	19	2S	70W	5
67546	D	7	253	2150N	50W	SWN	19	2S	70W	5
72601	H		260	2270N	1640W	SEN	19	2S	70W	5
3257	D	15	430			NWN	21	2S	70W	3
10003F	N	30	1090			NWS	22	2S	70W	3
20196	DS	16	101			NWS	24	2S	70W	3
2679F	N	50	500			SWN	24	2S	70W	3
34955	D	15	405	1240S	190E	SESE	24	2S	70W	3
17337	D	20	170			SESE	25	2S	70W	4
18722	D	22	1050			SESE	25	2S	70W	4

Table B-5 Well Permits in the Vicinity of Rocky Flats *

Permit No.	Use	Permitted Yield (gpm)	Permitted Well Depth (ft bls)	Coordinates		QTRS	Section	Township	Range	Distance (mi)
25117	D	20	190			NESE	25	2S	70W	4
2925f	C	20	812			SESW	25	2S	70W	4
34149	D	4525.9	80			NWN	25	2S	70W	4
34541	D		115			NWN	25	2S	70W	4
35405	D	4525.9	100			NWN	25	2S	70W	4
37604	D	6	70			SWSE	25	2S	70W	4
41313	D	25	1060			SESE	25	2S	70W	4
4746	D	4525.9	200			NES	25	2S	70W	4
61190	D	2	320	800N	230E	NEN	25	2S	70W	4
7548	D	30	1220			SENE	25	2S	70W	4
82199	D	8	28	212S	247E	SESE	25	2S	70W	4
97839	D	2	320	1210N	705E	NEN	25	2S	70W	4
13663F	C	160	862			SESW	26	2S	70W	4
2867F	C	550	715			SESW	26	2S	70W	4
34970	D	5	50			NESE	26	2S	70W	4
39737	D	20	30			SESE	26	2S	70W	4
7619F	M	30	16			SESE	26	2S	70W	4
78493	S	15		1430N	2550W	SEN	26	2S	70W	4
24583F	C	20	879	2130N	1770W	SEN	27	2S	70W	4
2868F	C	600	784			NWS	27	2S	70W	4
139259	D	15	30			SWS	28	2S	70W	4
139260	S	5	18	1200S	875W	SWS	28	2S	70W	4
21762	D	20	50			SWSE	28	2S	70W	4
150955	D		1300	2560S	1000W	NWS	29	2S	70W	4
31673	D	15	500	300N	50W	NWN	30	2S	70W	5
38979	D	10	230			NWN	30	2S	70W	5
22212	D	6	181			NEN	31	2S	70W	5
31260	D	7	165			NEN	31	2S	70W	5
50216	DS	10	10			SWN	32	2S	70W	5
18401	D	10	20			SWN	33	2S	70W	5
3315F	C	600	1038			NWS	34	2S	70W	5
139692	D	15	15			SENE	36	2S	70W	5
139693	D	15		1280MN	400E	NEN	36	2S	70W	5
14107	D	13	365	2400S	250E	NESE	36	2S	70W	5
30764	D	8	115			SESE	36	2S	70W	5
32710	D	30	102			SENE	36	2S	70W	5
33300	D	6	170			NEN	36	2S	70W	5
92330	D	15	105	1700N	1200E	SENE	36	2S	70W	5
2651F	N	100	18			SWN	5	2S	70W	
3338	D	10	50			SENE	5	2S	70W	
91184	H	15	105	325S	230W	SWS	7	2S	70W	4
42120	D	20	200			NEN	8	2S	70W	3
28915	S	2	18			NWS	9	2S	70W	2

These wells were selected from the available database based upon the criteria that either the depth or yield of the well was available. This does not mean that wells in the area are functioning. Field verification may be the only method that would provide exact information concerning operable wells. This list does not include wells that have a use listed as "other" and a permit no. ending with an "m". These are consided to be monitoring wells.

* Source: State Engineer's Office

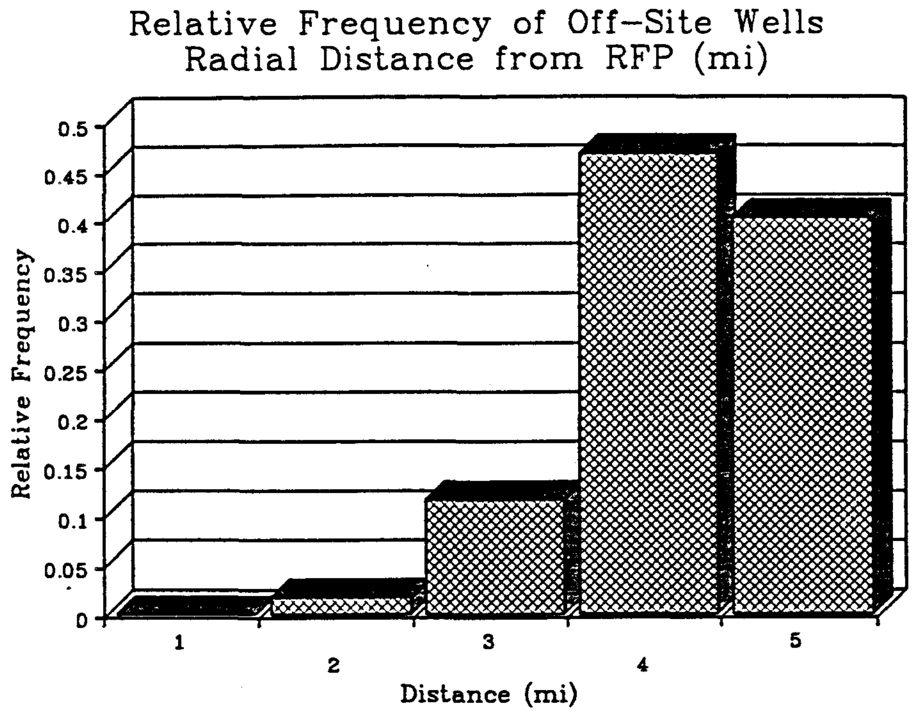


Figure B-3 Frequency of Radial Distance From RFP

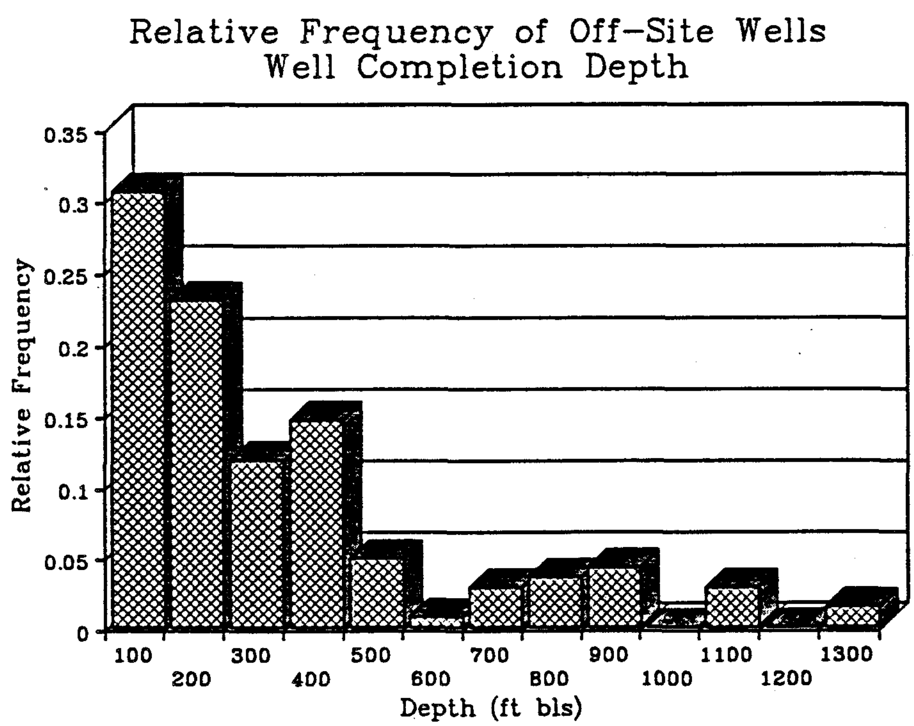
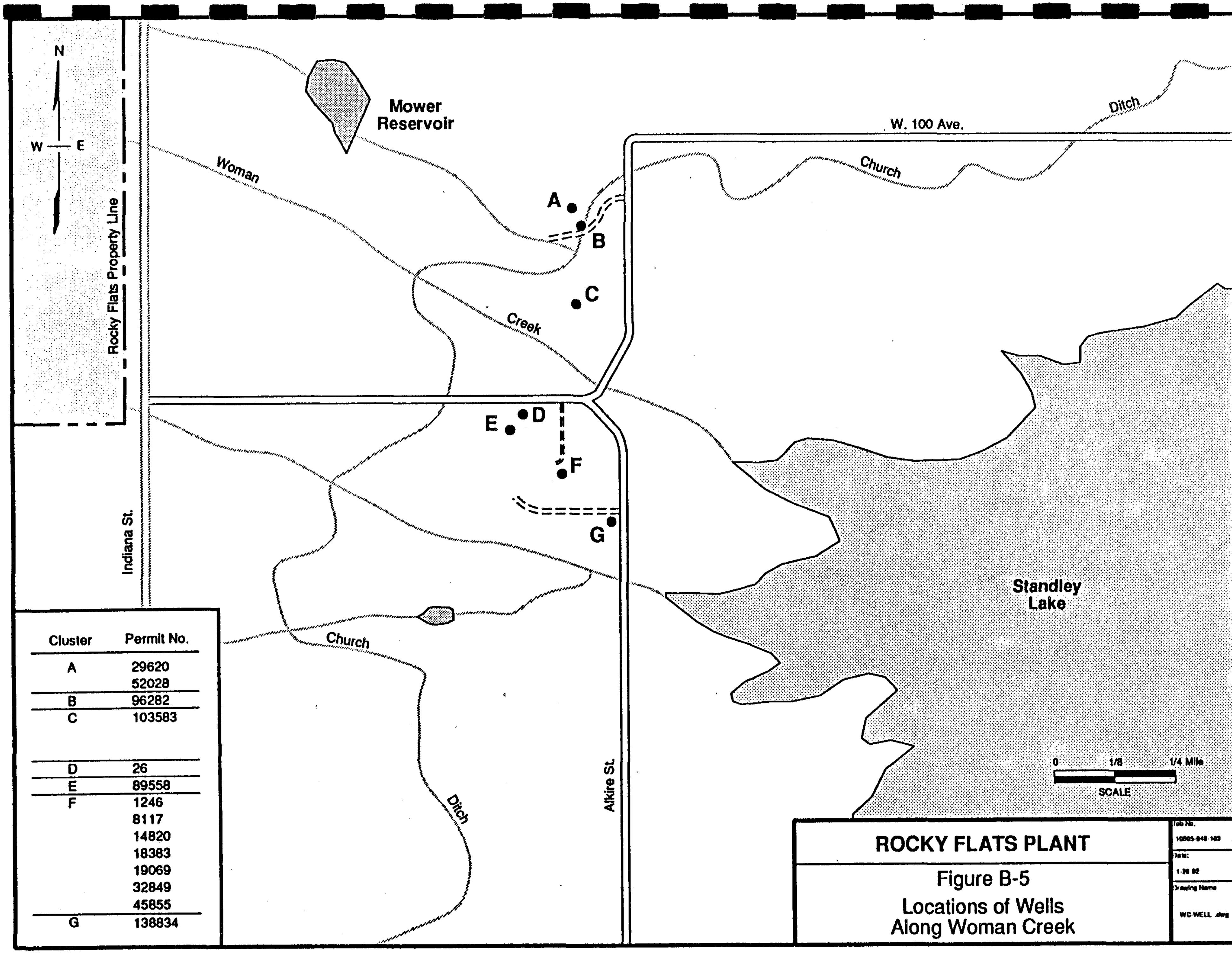


Figure B-4 Depth Frequency From Well Permit Information



ROCKY FLATS PLANT

Figure B-5
Locations of Wells
Along Woman Creek

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

Table B-6

Wells Near Woman Creek *

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

* Source: State Engineer's Office

** Based on drillers' observations. Does not indicate sustainable well yields.

specified, most of the domestic wells were pumped dry within a few hours.[3] The water acquired in this time period, however, could sustain the average consumption rate of a 240 gpd for four-member household. Therefore, it is possible that wells near Standley lake provide Figure B-3 and Figure B-4 water to individual households and/or stock in the area.

The lower Arapahoe Formation contains a basal conglomeratic sandstone. A conglomeratic sandstone out crops on the southern shoreline of Standley Lake (therefore in hydraulic connection with Standley Lake) and is recognized as the basal Arapahoe conglomerate (EG&G 1992). This conglomeratic sandstone is not encountered beneath OU1 (EG&G 1991; EG&G 1992) and is not evident in the off-site logs, suggesting lateral discontinuity of sandstone units between OU1 and Standley Lake off-site. The basal Arapahoe conglomeratic sandstone is likely to have a larger hydraulic conductivity due to its coarse-grained texture compared to very fine-grained sandstone units encountered beneath OU1, which typically exhibit hydraulic conductivities of 1×10^{-6} cm/sec (2.8×10^{-3} ft/day) or less.

The most permeable unit that is likely tapped by wells near the Standley Lake is the basal conglomeratic sandstone of the Arapahoe Formation. OU1 is underlain by the Laramie Formation (EG&G 1992) thus, there is no plausible hydraulic connection between sandstones beneath OU1 and wells near Standley Lake. The location of the basal Arapahoe conglomeratic sandstone, water levels in Standley Lake, and well screened intervals suggest that Standley Lake is a possible recharge source for the nearby wells. Alternatively, recharge may be contributed from the several unlined ditches that cross the area. Therefore, unlike conditions at the RFP, the off-site wells have potentially large sources of recharge in a more permeable sandstone.

[3]Colorado State Engineer's Office. Individual well completion reports. A few hours refers to 1 to 4 hours of pumping.

B.7 Summary

An investigation of the water production capabilities of alluvium and sandstone units was conducted to assess the ability to produce adequate quantities of water for domestic uses. A ground-water flow model of a bedrock sandstone unit was constructed based on the data that has been collected as part of the hydrogeologic characterization of the OU1 site and as part of RFP-wide investigations. The results of the model suggest that the sandstone units beneath the OU1 site would not be capable of producing an adequate supply of water. This results from the small hydraulic conductivity and limited areal extent of the sandstone units.

Ground-water availability from nearby off-site wells was also investigated. Data obtained from the files of the Colorado State Engineers office indicate there are 14 wells near Standley Lake that may use the Basal Conglomerate of the Arapahoe Formation as a source of water. Based on the analysis of well logs at the RFP site, off-site well logs, and the outcropping of the Basal Arapahoe Conglomerate at Standley Lake, hydrogeologic conditions at the RFP and off-site are significantly different. The data analyzed indicate lateral discontinuity between sandstone units beneath OU1 (Laramie sandstones) site and off-site wells. The available data also suggests the off-site wells may be hydraulically connected to Standley Lake, a large source of potential recharge.

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APPENDIX C

881 HILLSIDE (OU1) WELL PRODUCTION TEST RESULTS

881 HILLSIDE (OU1) WELL PRODUCTION TEST RESULTS
ROCKY FLATS PLANT
GOLDEN, COLORADO

C.1 Objective

The purpose of the tests was to evaluate the well yield characteristics of the upper hydrostratigraphic unit (HSU) and shallow lower HSU for potential future development as a domestic water supply source. Specifically the tests were conducted to determine whether or not individual wells situated on the 881 Hillside were capable of producing the 240 gallons per day required to support a family of four persons (as recommended by CDH and the Colorado Water Quality Control Division). These tests were performed as part of the Phase III Public Health Evaluation.

C.2 Test Methodology

Basically, the tests were designed to simulate the operation of a domestic well insomuch that the principal objective was maximizing well yield rather than determining aquifer properties, such as transmissivity and hydraulic conductivity. This objective was achieved by pumping a selected number of wells with a Grunfos Redi-flo 2 submersible pump set at the bottom of the well and maintaining maximum drawdown conditions for the duration of the test. Because of the low well yield conditions encountered during the tests, it was not practical to maintain a constant pumping rate, so the wells were pumped until dry, allowed to recover about 0.5 gallons (2 to 3 foot recovery), and the cycle was repeated. The estimated recovery volume of 0.5 gallons was determined to be about the *minimum* amount (head) of water required to start and operate the pump. Attempts at pumping lower volumes (head) generally proved inadequate to prime the pump. Average flow rates shown on the pump test data sheets were calculated by first measuring pump discharge in a graduated bucket for the pumping portion of each pumping and recovery cycle. This volume was then divided by the total elapsed time of the pumping and recovery portions of the pumping and recovery cycle to give the flow rate. Water level measurements were limited to the recovery phase of the test because of water level probe access problems associated with the limited annular space created by the pump lines in the 2-inch diameter casing of the wells. Recovery data was collected to provide information on the approximate drawdown conditions existing in the well during the last few pump cycling periods.

C.3 Well Selection

A total of 51 monitoring wells, completed in the shallow geologic materials directly underlying the majority of OU1 (colluvium and Arapahoe/Laramie bedrock), were evaluated for testing based on recent data provided by Ebasco as part of the Phase III investigation and other sources. Of these wells, 26 were dry and 8 were destroyed or obstructed leaving 10 colluvial and 7 shallow bedrock available for testing. Two wells completed in upper HSU colluvium (0487 and 37191) and one well completed in the shallow lower HSU bedrock (6286) materials were selected for testing based on consideration of lithology, hydraulic conductivity, saturated thickness and well design. Well development, ground-water sampling and well hydrograph records were also examined during the selection process. Wells having the most promising yield characteristics were systematically chosen from the information presented in Table 1. Deep bedrock wells completed within the OU1 boundary, such as 4587, and wells completed in the Rocky Flats and valley fill alluviums (37591 and 6486, respectively) were not evaluated because of their hydrologic positions relative to OU1. These wells were excluded because 1) Rocky Flats alluvial wells are located primarily upgradient of contamination at OU1; 2) valley fill alluvial wells, located downgradient of OU1, are hydrologically isolated by the French drain; and 3) deep bedrock HSUs are stratigraphically separated from the upper and shallow lower HSUs by low permeability confining claystone layers.

Generally, preference was given to wells with the highest hydraulic conductivities, fastest recharge rates and greatest saturated thicknesses. For example well 6286 was selected for testing instead of 39291 based on comparison of recharge rates measured during well

TABLE 1
SELECTION CRITERIA USED FOR 881 HILLSIDE COLLUVIAL AND SHALLOW BEDROCK WELL PRODUCTION TESTS

Well Number	Test Interval (ft)	Saturated[1] Thickness (ft)	Hydraulic Conductivity (cm/sec)	10 Minute[2] Recharge Rate (ft)	Lithology	Comments
Upper Hydrostratigraphic Unit						
5886	-	0	-	-	-	Dry
5986	-	-	-	-	-	Destroyed
6386	-	0	-	-	-	Dry
6986	-	-	-	-	-	Destroyed
0187	3.4 - 11.8	5.5	n/d	0.64	C, SiltC	
0287	-	-	-	-	-	Destroyed
0487	3.5 - 19.5	6.9	5×10^{-4}	1.1	C, CG, GC	Selected for Testing
0687	-	-	-	-	-	Destroyed
4387	3.5 - 12.3	3.3	n/d	0.70	SilC	
4487	-	0	-	-	-	Dry
4787	-	0	-	-	-	Dry
4887	-	0	-	-	-	Dry
4987	-	0	-	-	-	Dry
5087	-	0	-	-	-	Dry
5187	-	0	-	-	-	Dry
5287	3.5 - 20.5	10	2.1×10^{-4}	n/d	SanC, G	Alternate Test Well
5387	3.5 - 9.1	5.6	n/d	1.01	C, CG	
5487	1.3 - 4.5	2.7	n/d	0.45	C	
5587	-	0	-	-	-	Dry
30991	-	0	-	-	-	Dry
31491	-	0	-	-	-	Dry
31791	-	0	-	-	-	Dry
32591	-	0	-	-	-	Dry
33491	-	0	-	-	-	Dry
33691	-	0	-	-	-	Dry
33891	-	0	-	-	-	Dry
34591	-	0	-	-	-	Dry

TABLE 1. (continued)

Well Number	Test Interval (ft)	Saturated[1] Thickness (ft)	Hydraulic Conductivity (cm/sec)	10 Minute[2] Recharge Rate (ft)	Lithology	Comments
34791	6.2 - 7.7	5.2	1×10^{-5} to 1×10^{-6}	1.40	SilS, G	
35391	-	0	-	-	-	Dry
35691	-	-	-	-	-	Obstructed
35991	-	0	-	-	-	Dry
36191	9.7 = 14.4	5	1×10^{-6}	n/d	Sand, G	
36391	-	0	-	-	-	Dry
36691	-	0	-	-	-	Dry
36991	-	0	-	-	-	Dry
37191	11.3 - 20.9	13.3	1×10^{-4} to 4×10^{-5}	n/d	GSanC	Selected for testing
37691	-	0	1×10^{-5} to 2×10^{-6}	-	-	Dry
38191	10.1 - 14.9	6.4	-	0.22	Sand, SilC, G	
38291	-	0	-	-	-	Dry
39691	-	0	-	-	-	Dry
IHSS 119.1	n/d	n/d	n/d	n-/d	-	Not Fully Functional
Lower Hydrostratigraphic Unit						
0387	-	-	-	-	-	Destroyed
0587	-	-	-	-	-	Destroyed
0687	-	-	-	-	-	Destroyed
6286	25.2 - 35.2	9.0	3×10^{-5} to 6×10^{-6}	4.1	CS, SanS	Selected for Testing
31891	16.8 - 18.4	1.3	2×10^{-4}	n/d	SanCS, CSan	Limited Test Interval
37891	43.4 - 53.0	11.6	1×10^{-6} to 6×10^{-7}	0.67	SilCS, CSilS	
37991	45.4 - 55.0	7.7	7×10^{-6}	1.64	CS, SanS, C SilS	
38991	27.0 - 36.6	10.0	1×10^{-6}	1.02	CS, SilS	
39191	33.0 - 42.6	6.9	2×10^{-5}	0.14	C SilS, SilCS	
39291	34.2 - 43.8	13.4	3×10^{-5}	0.93	CS, SilCS, CSilStone	

<u>Legend</u> 1) Determined January 1992 — n/d - Not Determined
2) Recharge Rate Data Collected from Well Development and Sampling Forms

SilS - Silty Sand
SilCG - Silty Clayey Gravel
SilC - Silty Clay
SilCS - Silty Claystone
SanC - Sandy Clay
SanCG - Sandy Clay Gravel
SanS - Sandstone
SanCS - Sandy Claystone
CSilStone - Clayey Siltstone
CG - Clayey Gravel
GC - Gravelly Clay
CS - Claystone
CS - Claystone
GSanC - Gravelly Sandy Clay
CSan - Clayey Sandstone
G - Gravel
C - Clay

development and sampling (10 minute rate of 4.1 feet in 6286 versus 0.9 feet in 39291), and instead of 31891 based on saturated thicknesses, despite the location of 6286 outside the OU1 boundary (see discussion in section below concerning 31891). It was necessary in some cases to choose an alternate well because the primary choice had been destroyed during construction of the French drain (i.e. well 6986). Plans to test the IHSS 119.1 collector well as suggested by the EPA were delayed because of current equipment limitations at this well, specifically the lack of an automatic liquid level controller and an in-line flow meter. Discussions with operations personnel indicate that this well has a very slow recharge rate commensurate with the results of the monitoring well tests.

C.4 Test Results and Interpretation

Table 2 presents the results of well production testing at OU1. The final sustainable well yield values for the three wells ranged from about 0.026 to 0.055 gallons per minute (gpm), or 36 to 79.2 gallons per day (gpd), after 2 hours of pumping (1.5 hours for 0487). These values were adjusted to approximate the higher yield expected from a larger diameter well using the method described in Driscoll (1986, p. 449). A conservative estimate of Re (effective radius of influence) equal to 25 feet was used in the calculations. Larger Re values, such as 400 feet used in the Driscoll example, would have resulted in smaller increases in well yield (Driscoll, 1986) and are unrealistic considering upper HSU hydrologic conditions. Calculations for both the well (borehole) radius and effective well radius were made for each monitoring well to compensate for the equivalent radii of the IHSS 119.1 collector well. The calculations indicate that increasing the monitoring well radii to that of the existing collector well would theoretically increase the yield of these wells by factors ranging from 1.33 to 1.47 depending on the well tested. The adjusted well yields therefore range from 0.037 gpm (53.3 gpd) to 0.073 gpm (101 gpd). The theoretical increase in well yield for 4 and 6-inch wells normally drilled for domestic purposes would be less, and probably closer to the actual results determined from the monitoring well tests. Attachment A contains the records of each individual pumping test.

TABLE 2.
881 HILLSIDE COLLUVIAL AND SHALLOW BEDROCK WELL PRODUCTION TEST RESULTS

Well Number	Length of Test (hrs	Initial Saturated Thickness (ft)	Final Average Drawdown (ft)	Final Average Discharge (gpm)	Estimated Specific Capacity (gpm/ft)	Casing Radius (ft), r_c	Borehole Radius (ft), r_w	Effect. Casing Radius (ft), r_{ce}	Log R_e/r_w	Est Well Yld (gpm) for r_w=1.25	Log R_e/r_{ce}	Est Well Yield (gpm) for R_{ce}=0.802
0487	1.66	12.00	9.92	0.044	0.0044	0.083	0.312	0.184	1.9037	0.064	0.064	0.063
37191	1.98	17.25	14.53	0.055	0.0038	0.083	0.458	0.260	1.7371	1.7371	0.073	0.073
6286	2.22	10.44	8.19	0.026	0.0032	0.083	0.302	0.179	1.9179	1.9179	0.0382	0.037
IHSS 119.1	n/d	n/d	n/d	n/d	n/d	0.5	1.25	0.802	1.3010	1.3010	N/A	N/A

Legend:

1) Estimated from Recovery Data
2) r_{ce} = [(1 - n)r $_c$2+nr 1$_w$2 1/2
3) R_e = 25 feet
4) Theoretical Well Yield Estimated for Monitoring Well Radius Equal to IHSS 119.1

n = 0.30
n/d - Not Determined

Further review of the well development forms during well test interpretation and report preparation revealed that, although no recharge rate was measured for 31891, this well was capable of producing a short term (1.2 hour) average yield of about 0.11 gpm when developed on October 16, 1991. This rate translates to 158.4 gpd, or approximately 210 gpd corrected to the radius of the IHSS 119.1 collector well (factor of 1.33 based on 31891 rw equal to 0.458 feet). The reason for this unexpected yield value is not evident from the lithologic log which indicates the presence of sandy clay and clayey sandstone in the completion interval. The yield is still considered to be very low compared to rates normally sought when drilling a typical domestic well. Well 31891 is located outside of the OU1 boundary next to the South Interceptor Ditch and downgradient of the French drain. Subcropping sandstones such as that found at 31891 were only detected downslope of the OU1 boundary based on information provided by Ebasco, and apparently are not representative of hydrogeologic conditions at the contaminated areas of the hillside.

Results of the pump testing represent conservative estimates of sustainable well yield for several reasons. Firstly, the results are representative of short term well yields only. The longer term yield of these wells will continue to decline until a steady state condition is reached that is consistent with continuous well usage. This decline is caused by the increasing drawdown in the well created during expansion of the cone of depression to a steady state condition. Secondly, the tests were conducted during the spring recharge period when the aquifer is at or near its maximum saturated thickness. Lower well yields can be expected later in the year when ground-water levels decline to their seasonal lows, as shown in most well hydrographs. Seasonal water table fluctuations ranging from 3 to 5 feet are evident in the hydrographs for 0487 and 37191. The yield for these wells could decline by as much as 50 and 35 percent, respectively, during low water table conditions based on estimates generated from the specific capacity values contained in Table 2. Finally, many upper HSU wells on the 881 Hillside are dry or have limited saturated thicknesses. The two colluvial wells tested represent a selection of the "wettest" areas of the upper HSU. The limited extent and patchy occurrence of saturated colluvium indicates a finite saturated volume with limited ground-water available for exploitation. Constant pumping of wells in areas of a limited upper HSU saturated volume, such as found at 37191, may accelerate drawdowns as the cone of depression reaches the aquifer boundaries (thus decreasing the well yield) and could eventually dewater that portion of the upper HSU pumped by the well.

C.5 Conclusion

The results of the pump test analysis indicate that the upper and shallow lower HSUs at the 881 Hillside are not reliable sources of ground-water for normal domestic purposes given the 240 gpd requirement for a family of four persons (based on the 60 gpd per person criteria). The modeling runs previously performed by EG&G (1992) and the CDH (1992) actually appear to have been overly conservative in light of the field testing results and consideration of upper HSU dynamics. These results support the modeling results and interpretation (presented in Appendix B) that the upper and shallow lower HSUs are not viable sources of groundwater.

Reference

Colorado Department of Health, 1992, personal communication between E. Pottorff, CDH, and B. Roberts, EG&G, regarding CDH model runs.

Driscoll, F., 1986, Groundwater and Wells, 2nd Edition, Johnson Division, St. Paul, Minnesota.

EG&G, 1992, Technical Memorandum #6, Public Health Risk Assessment, Exposure Scenarios; OU1, Appendix B.

ATTACHMENT A
PUMP TESTING DATA SHEETS

AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA R. Smith - EG&G

WELL # 0487 (881 HILLSIDE)

HYDROSTRATIGRAPHIC UNIT Colluvium

SCREENED INTERVAL 9.94 ft to 21.49 ft from TOC-SS (SATURATED SCREENED INTERVAL)

STATIC WATER LEVEL 9.94 ft @ TOC-SS PUMPING WELL I.D. 2 in (CASING)

DISTANCE TO PUMPING WELL N/A ft WELL T.D. 21.94 ft @ TOC-SS

PUMP INTAKE DEPTH 21.17 ft

TEST START TIME 13 : 19 : 55 INITIAL SATURATED THICKNESS 12.00 ft

ELAPSED TIME (Units) (min)	Pump ON/OFF	VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft)
0.0	ON				9.94
1.22	OFF	3.05	1.22	2.5	
3.22	ON				
4.08	OFF	0	(pump	NOT PRIMING)	
8.58	ON				
9.15	OFF	0.75	7.93	0.09	
11.08	ON				
12.58	OFF	0	(pump	NOT PRIMING)	
16.08	ON				
17.53	OFF	0.5	8.38	0.060	
24.58	ON				
26.42	OFF	0.5	8.89	0.056	
34.58	ON				

AQUIFER PUMPING TEST DATA SHEET

DATE 5 \21 \92 PERSON RECORDING DATA ______________

WELL # 0487

HYDROSTRATIGRAPHIC UNIT ________ (see Page 1)

SCREENED INTERVAL ______ft to ______ft

STATIC WATER LEVEL ______ft PUMPING WELL I.D. __________in

DISTANCE TO PUMPING WELL ______ft

TEST START TIME ____:____:____

	ELAPSED TIME (Units) (min)	Pump on/off	~~WATER LEVEL~~ VOLUME PUMPED (gals) (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft)
	36.05	OFF	0.5	9.63	0.052	
	45.58	ON				
	46.77	OFF	0.5	10.72	0.047	
	56.92	ON				
	57.30	OFF	0.45	10.53	0.043	
	68.58	ON				
	70.16	OFF	0.5	12.86	0.039	
	82.75	ON				
	84.50	OFF	0.6	14.34	0.042	
	97.58	ON				
END OF TEST)	99.42 (0)	OFF	0.65	14.92	0.044	
	101.25 (1.83)		(RECOVERY DATA)			21.28
	102.33 (2.91)		↓			20.98

AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA ____________________

WELL # 0487

HYDROSTRATIGRAPHIC UNIT ____________________ (see Page 1)

SCREENED INTERVAL ________ ft to ________ ft

STATIC WATER LEVEL ________ ft PUMPING WELL I.D. ____________ in

DISTANCE TO PUMPING WELL ________ ft

TEST START TIME ____:____:____

ELAPSED TIME (Units) (min)	ELAPSED RECOVERY TIME	Pump on/off	~~WATER LEVEL~~ VOLUME PUMPED (gals) (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft.)
103.42	(4.0)		(RECOVERY DATA)			20.65
104.42	(5.0)					20.40
105.42	(6.0)					20.10
106.42	(7.0)					19.86
107.42	(8.0)					19.59
108.42	(9.0)					19.32
109.42	(10.0)					19.06
110.42	(11.0)					18.81

AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA R. Smith - EG&G

WELL # 37191 (881 Hillside)

HYDROSTRATIGRAPHIC UNIT Colluvium

SCREENED INTERVAL 13.9 ft to 23.8 ft from TOC-PVC

STATIC WATER LEVEL 7.55 ft @ TOC-PVC PUMPING WELL I.D. 2 in (casing)

DISTANCE TO PUMPING WELL N/A ft

WELL T.D. 25.80 ft @ TOC-PVC

Pump INTAKE DEPTH 25.03 ft

TEST START TIME 09 : 38 : 25

INITIAL SATURATED THICKNESS 17.25 ft

ELAPSED TIME (Units) (min)	Pump ON/OFF	VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft)
0.0	ON				7.55
2.5	OFF	3.0	2.5	1.20	
4.5	ON				
5.5	OFF	1.2	3.0	0.40	
7.5	ON				
8.25	OFF	1.0	2.75	0.36	
10.25	ON				
11.41	OFF	0.5	3.16	0.10	
14.41	ON				
15.24	OFF	0.4	3.83	0.10	
19.24	ON				
19.74	OFF	0.4	4.50	0.09	
24.74	ON				

AQUIFER PUMPING TEST DATA SHEET

DATE 5 \ 21 \ 92 PERSON RECORDING DATA __________

WELL # 37191

HYDROSTRATIGRAPHIC UNIT __________ (SEE Page 1)

SCREENED INTERVAL ______ ft to ______ ft

STATIC WATER LEVEL ______ ft PUMPING WELL I.D. ______ in

DISTANCE TO PUMPING WELL ______ ft

TEST START TIME ____:____:____

ELAPSED TIME (Units) (min)	Pump ON/OFF	VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (FT)
25.07	OFF	0.3	5.33	0.056	
33.07	ON				
33.66	OFF	0.5	8.59	0.058	
39.66	ON				
40.32	OFF	0.5	6.66	0.075	
47.33	ON				
48.25	OFF	0.4	7.93	0.050	
57.25	ON				
58.16	OFF	0.55	9.91	0.055	
67.16	ON				
68.07	OFF	0.5	9.91	0.050	
78.08	ON				
78.86	OFF	0.5	10.79	0.046	

AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA ____________

WELL # 37191
HYDROSTRATIGRAPHIC UNIT ____________ (see page 1)
SCREENED INTERVAL ______ft to ______ft

STATIC WATER LEVEL ______ft PUMPING WELL I.D. ______in

DISTANCE TO PUMPING WELL ______ft

TEST START TIME ____:____:____

ELAPSED TIME (Units) (min) ↓ ELAPSED RECOVERY TIME	Pump ON/OFF	~~WATER LEVEL~~ VOLUME PUMPED (gals) (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft)
90.87	ON				
91.87	OFF	0.6	13.01	0.046	
104.87	ON				
105.87	OFF	0.75	14.00	0.054	
116.87	ON				
(END OF TEST) 118.55 (0)	OFF	0.70	12.68	0.055	
119.83 (1.28)		(RECOVERY DATA) ↓			24.40
120.83 (2.28)					23.71
121.83 (3.28)					23.19
122.83 (4.28)					22.79
123.83 (5.28)					22.36
124.83 (6.28)					22.08
125.83 (7.28)					21.75

AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA ____________

WELL # 37191
HYDROSTRATIGRAPHIC UNIT ____________ (see Page 1)
SCREENED INTERVAL ______ft to ______ft

STATIC WATER LEVEL ______ft PUMPING WELL I.D. ______in

DISTANCE TO PUMPING WELL ______ft

TEST START TIME ____:____:____

ELAPSED TIME (Units) (min) (ELAPSED RECOVERY TIME)	Pump ON/OFF	VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft)
126.83 (8.28)		(RECOVERY	DATA)		21.57
127.83 (9.28)					21.49
128.83 (10.28)					21.43
130.83 (12.28)					21.09

AQUIFER PUMPING TEST DATA SHEET

DATE 5\22\92 PERSON RECORDING DATA R. Smith - EG&G

WELL # 6286 (881 HILLSIDE)
HYDROSTRATIGRAPHIC UNIT UPPER LARAMIE SANDSTONE
SCREENED INTERVAL 26.43 ft to 36.40 ft from TOC-SS

STATIC WATER LEVEL 26.41 ft @ TOC-SS PUMPING WELL I.D. 2 in (CASING)

DISTANCE TO PUMPING WELL N/A ft WELL T.D. 36.85 ft @ TOC-SS
PUMP INTAKE DEPTH 36.08 ft

TEST START TIME 09 : 18 : 50 INITIAL SATURATED THICKNESS 10.44 ft

ELAPSED TIME (Units) (min)	Pump ON/OFF	VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft)
0.0	ON				26.41
2.0	OFF	2.3	2.0	1.15	
11.66	ON				
13.58	OFF	0.55	11.58	0.047	
25.83	ON				
26.32	OFF	0.5	12.74	0.039	
36.83	ON				
38.58	OFF	0	(Pump NOT PRIMING)		
38.74	ON				
39.25	OFF	0.45	12.93	0.035	
51.17	ON				
51.50	OFF	0.45	12.25	0.037	
63.67	ON				

AQUIFER PUMPING TEST DATA SHEET

DATE 5\22\92 PERSON RECORDING DATA ____________

WELL # 6286
HYDROSTRATIGRAPHIC UNIT ____________ (see page 1)
SCREENED INTERVAL ______ft to ______ft

STATIC WATER LEVEL ______ft PUMPING WELL I.D. ______in

DISTANCE TO PUMPING WELL ______ft

TEST START TIME ___:___:___

ELAPSED TIME (Units) (min)	Pump ON/OFF	VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft)
64.88	OFF	0.4	13.38	0.030	
66.00	ON				
77.12 ~~67.12~~	OFF	0.4	12.24	0.033	
89.25	ON				
89.83	OFF	0.35	12.71	0.028	
101.33	ON				
102.03	OFF	0.2	12.20	0.016	
117.67	ON				
118.10	OFF	0.45	16.07	0.028	
132.66	ON				
END OF TEST 133.23 (0)	OFF	0.4	15.13	0.026	
135.08 (1.85)		(RECOVERY	DATA)		35.51
136.23 (3)		↓			35.25

AQUIFER PUMPING TEST DATA SHEET

DATE 5 \22 \92 PERSON RECORDING DATA ____________

WELL # 6286
HYDROSTRATIGRAPHIC UNIT ____________ (See Page 1)
SCREENED INTERVAL ______ft to ______ft

STATIC WATER LEVEL ______ft PUMPING WELL I.D. ______in

DISTANCE TO PUMPING WELL ______ft

TEST START TIME ____:____:____

ELAPSED TIME (Units) (min)	Pump on/off	VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units)	ΔT (min)	AVERAGE Q (pumping well) (Units) (gpm)	WATER LEVEL (ft.)
137.23 (4)		(RECOVERY	DATA)		35.02
138.23 (5)					34.87
139.23 (6)					34.72
140.23 (7)					34.60
141.23 (8)					34.49
142.23 (9)					34.40
143.23 (10)					34.31
144.23 (11)					34.22
145.23 (12)					probe failure (unable to ~~desensitize~~ probe)