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ATTACHMENT
for Work Plan OU-5 Woman Creek Priority Drainage

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Any questions please call Carlotta Muheim at 966-3893.

TITLE: Preliminary Site Characterization

Approved By: [signature] 2/24/92
Name (Date)

2.0 PRELIMINARY SITE CHARACTERIZATION

Ten Individual Hazardous Substance Sites (IHSSs), geographically located along or within the drainage areas of Woman Creek (Figure 2-1), have been designated as Operable Unit 5 (OU5). These IHSSs are identified in the Environmental Restoration Interagency Agreement (IAG), dated January 22, 1991, as the Original Landfill (IHSS 115), Ash Pits, Incinerator area, and Concrete Wash Pad (IHSSs 133.1 through 133.6), Detention Ponds C-1 and C-2 (IHSSs 142.10 and 142.11), and a Surface Disturbance (IHSS 209). Ponds C-1 and C-2 are the only IHSSs located on Woman Creek. The remaining eight IHSSs are located along the banks and/or upland areas that drain into Woman Creek or into the South Interceptor Ditch (SID). In addition to these ten IHSSs, two additional surface disturbances will be investigated in the Phase I OU5 investigation, a surface disturbance west of IHSS 209 and a surface disturbance south of the Ash Pits (133).

The initial step in the development of the OU5 work plan was a review of existing information. Available historical and background data for each IHSS were collected through a literature search, which included references at the Rocky Flats Public Reading Room and various libraries within the Rocky Flats Plant, and a review of the RFEDS. Information concerning existing alluvial and bedrock groundwater monitoring wells within the Woman Creek drainage have been collected for this work plan (Table 2-1). Personal communications with plant personnel were also used as a source of information during the background data review so that each IHSS could be better described.

The ten IHSSs are discussed in detail in the following subsections. The location and description of each IHSS, the history of use, surface drainage, nature of contamination, previous investigations conducted at or near the individual IHSSs, geology, and hydrology are discussed. The Ash Pits, Incinerator, and Concrete Wash Pad are grouped together in the following discussions, as are Ponds C-1 and C-2, since these units have interrelated and similar histories. The areal extent and boundary of each IHSS is based on a preliminary review of historical aerial photographs (U.S. EPA 1988b) and the historical operations of the unit. The boundaries for each IHSS in this work plan are the same as those established in the IAG except for the Original Landfill (IHSS 115) and the Surface Disturbance (IHSS 209). The southern boundary of the Original Landfill has been extended approximately 300 feet toward the south across the SID based on a site reconnaissance. The Surface Disturbance boundary was extended to the north and southwest based on a site reconnaissance and aerial photographs. Several investigations are ongoing within the Woman Creek drainage, including surface water, groundwater and sediment sampling and investigations at OUs 1 and 2. Where previous or ongoing investigations have been conducted at or near an IHSS, some of the analytical data are included for reference in the following sections. The inclusion of these data is for informational purposes only. No conclusions are made in this work plan regarding the presence or absence of contamination based on these data. The geology underlying each IHSS has been characterized by the ongoing geologic characterization program in progress by EG&G at Rocky Flats (EG&G 1990b). This program includes conducting a comprehensive literature search, reprocessing and describing previously obtained core samples, reprocessing previously obtained seismic data, and collecting and analyzing selected sample for grain size analyses. The geologic characterization program will incorporate all geologic information Plant-wide for continued refinement of the working geologic model. The referenced report is a draft internal working document. Data and results of this characterization that are pertinent to Operable Unit 5 are presented in this work plan. In addition to the review of each IHSS, a generic conceptual model for the IHSSs of OU5 has been developed. The generic model will be refined and modified appropriate to each IHSS in the RFI/RI Report.

Also discussed in the following section is the Woman Creek drainage system adjacent to the plant site. Woman Creek is the drainage system that provides a common physical setting for all the IHSSs in OU5.

2.1 WOMAN CREEK AND DIVERSION STRUCTURES

The Rocky Flats Plant is geographically located on a plateau and is bounded on the south by the Woman Creek drainage (Figure 2-1). Woman Creek flows from west to east through the Rocky Flats facility and into Stanley Lake Reservoir and Mower Reservoir about 1½ miles from the facility's eastern boundary (Figure 1-2). Woman Creek originates near Coal Creek approximately 1½ miles to the west of Highway 93. Near the west boundary of the plant facility, within the buffer zones, Woman Creek crosses under the South Boulder diversion canal. The canal cross over is constructed of wood and presently contributes water to Woman Creek due to leakage. Other waters which enter into Woman Creek within the buffer zone include upstream runoff and water released from the Rocky Flats Lake. Water is released from Rocky Flats Lakes into Woman Creek by a local rancher as part of his water rights agreement. This flow is diverted out of Woman Creek to Mower Reservoir below Pond C-2.

The natural drainage of Woman Creek has been somewhat modified in the OU5 area by the construction of Ponds C-1 (IHSS 142.10) and C-2 (IHSS 142.11) and the SID south of the plant site. Currently, Woman Creek flows eastward through OU5 in its natural stream channel to Detention Pond C-1 (IHSS 142.10) (Figure 2-1). The purpose of Detention Pond C-1 is for stormwater management and for sampling and monitoring of the water upstream in Woman Creek. Water is rarely retained within this pond as the outlet or gate is usually open and the water is allowed to flow through the pond. The water consequently flows in its natural channel until just west of Pond C-2 where it is diverted around Pond C-2 by a diversion canal. Downgradient and to the east of Pond C-2, approximately two thirds of the water is diverted from Woman Creek's main channel into an unnamed ditch to Mower Reservoir. The remaining flow continues to flow downstream in Woman Creek and into Stanley Lake Reservoir.

characteristic of the deposition of Rocky Flats Alluvium on the surface of the Arapahoe Formation. The geology beneath the surface disturbance west of IHSS 209 has also been characterized based on its geographical location, as no wells or borings have been drilled in this area. Therefore, the surficial geologic unit beneath this unit is likely to be Rocky Flats Alluvium underlain by the Arapahoe Formation. Further characterization of the lithology of these formations is, however, needed.

The characteristics of the hydrologic system(s) are unknown beneath these surface disturbances because of the lack of nearby wells. Groundwater probably occurs at the base of the Rocky Flats Alluvium just above the less-permeable Arapahoe Formation; however, further characterization of the nature of the Rocky Flats Alluvium and Arapahoe Formation is needed.

2.6 METEOROLOGY, CLIMATOLOGY, AND AIR QUALITY

The area surrounding the Rocky Flats Plant has a semiarid climate characteristic of much of the central Rocky Mountain region. Approximately 40 % of the 15-inch annual precipitation falls during the spring season, much of it as snow. Thunderstorms (June to August) account for an additional 30% of the annual precipitation. Autumn and winter are drier seasons, accounting for 19% and 11% of the annual precipitation, respectively. Snowfall averages 85 inches per year, falling from October through May (U.S. DOE, 1980). Temperatures are moderate: extremely warm and cold weather is usually of short duration. On the average, daily summer temperatures range from 55°F to 85°F, and winter temperatures range from 20°F to 45°F. The low average relative humidity (46%) is due to the blocking effect of the Rocky Mountains.

Wind, temperature, and precipitation data are collected on the plant site and summarized annually. Table 2-8 presents the 1990 annual summary of the percent frequency of wind directions (16 compass points) divided into 6 speed categories. These frequency values are represented graphically in Figure 2-10. Winds at the Rocky Flats Plant are predominantly northwesterly. Winds greater than 4.18 meters per second (m/s) (9.2 miles per hour [mph]) with easterly components occur with a low frequency. The Pasguill Stability Class D represents the prevailing meteorological conditions for the Rocky Flats Plant (EG&G, 1991), and average downwind directional frequencies.

Special attention has been focused on dispersion meteorology surrounding the Plant due to the remote possibility that significant atmospheric releases might affect the Denver metropolitan area, which is located in the predominant downwind direction (southeast). Studies of air flow and dispersion characteristics (e.g., Hodgin, 1983 and 1984) indicate that winds come down from the mountains to the west, turn and move toward the north and northeast along the South Platte River valley and pass to the west and north of Brighton, Colorado (U.S. DOE, 1980), which is just north of Denver.

TABLE 2-8

ROCKY FLATS METEOROLOGICAL MONITORING STATION
60 METER TOWER

January 1, 1990 –December 31, 1990

Wind Frequency Distribution by Percent –Stability Class D

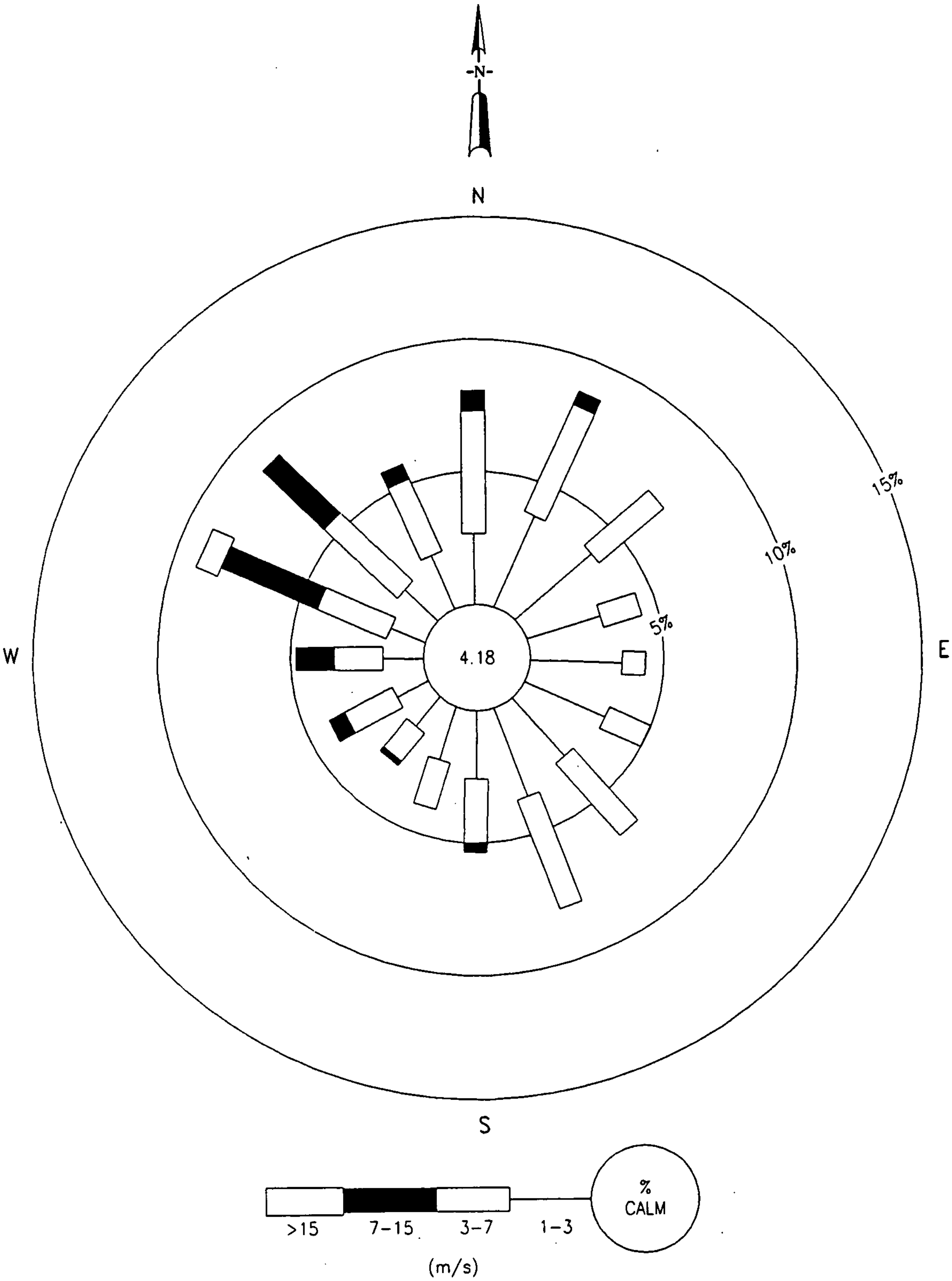
10 Meter Level

WIND SPEED CLASSES (KNOTS)

Wind Direction	<3.0	3.0 - <6.0	6.0 - <10.0	10.0 - <16.0	16.0 - <21.0	≥21.0	Class[a]	Total[b]
N	0.8	2.9	3.4	1.6	0.2	0.2	9.29	9.25
NNE	1.1	3.5	2.9	1.0	0.0	0.0	8.52	8.49
NE	1.1	3.3	1.6	0.3	0.0	0.0	6.31	6.29
ENE	1.0	2.3	0.8	0.1	0.0	0.0	4.20	4.19
E	1.4	3.0	0.7	0.0	0.0	0.0	5.06	5.04
ESE	0.9	2.7	1.9	0.1	0.0	0.0	5.60	5.58
SE	0.9	3.5	3.6	0.6	0.0	0.0	8.57	8.54
SSE	0.8	2.5	2.6	0.6	0.1	0.0	6.66	6.64
S	0.7	2.0	1.5	0.5	0.1	0.0	4.79	4.78
SSW	0.5	1.2	1.0	0.3	0.1	0.0	3.09	3.08
SW	0.3	1.2	1.2	0.4	0.1	0.0	3.29	3.28
WSW	0.4	1.1	1.2	1.0	0.4	0.3	4.25	4.24
W	0.5	1.1	1.1	1.6	1.1	1.5	6.89	6.87
WNW	0.5	1.3	1.5	3.0	1.8	1.6	9.59	9.56
NW	0.7	1.6	2.1	2.3	0.7	0.2	7.54	7.51
NNW	0.6	1.9	2.6	1.1	0.1	0.0	6.34	6.32
All	12.1	35.0	29.7	14.6	4.7	3.9.00	100.00	99.64

[a] Total percent for this stability class.
[b] Total percent relative to all stability classes (A through F).

Total number of invalid observations in this stability class = 18
Total number of valid observations in this stability class = 18,240
Joint data recovery rate = 99.9%



U.S. DEPARTMENT OF ENERGY Rocky Flats Plant Golden, Colorado	1990 ANNUAL WIND ROSE FOR THE ROCKY FLATS PLANT	FIGURE 2-10

R33176.MB021292

An extensive air monitoring network known as the Radioactive Ambient Air Monitoring Program (RAAMP) is maintained at the Plant in order to monitor particulate emissions from the Plant facilities. Historically, the particulate samplers located immediately east, southeast, and northeast of the 903 Pad site have shown the highest plutonium concentrations. This finding is corroborated by the results of soil surveys that indicate elevated plutonium concentrations to the east, particularly southeast of the site. However, the RAAMP has found ambient air samples for plutonium to be well within the DOE guidelines of 20.0×10^{-6} pCi/l established for the protection of human health (Rockwell International, 1987a).

Figure 2-11 shows the locations of the RAAMP ambient air samplers associated with OU5, and Table 2-9 presents the plutonium concentrations detected at those stations during 1990. Prior to January 1990, the biweekly filters from these onsite samplers and others were analyzed for total long-lived alpha activity only. If results exceeded the Rocky Flats Plant guideline of 10×10^{-6} pCi/l, specific plutonium analysis was performed. Data collected at ambient stations 10, 11, 13, 14, 23, 32, and 37 during 1986 through 1989 did not exceed this screening value; therefore, plutonium-specific analyses were not performed.

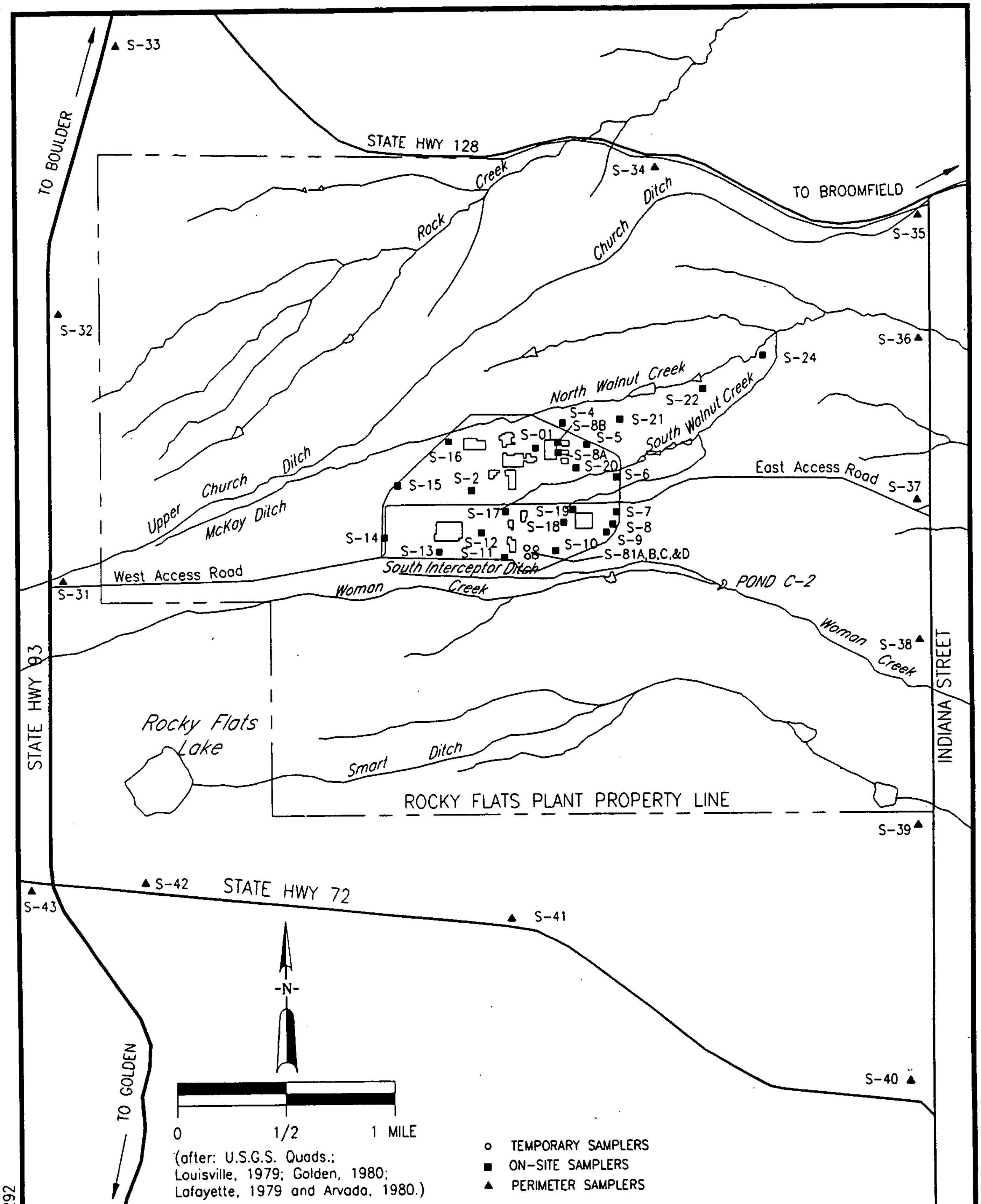
2.7 SITE CONCEPTUAL MODELS

A Site Conceptual Model of contaminant exposure pathways from the types of potential contaminant sources within OU5 is presented in this section. This Site Conceptual Model identifies all elements of an exposure pathway (contaminant source, primary release mechanisms, transport media, secondary release mechanisms, and exposure route) that were considered in the development of the Phase I Field Sampling Plan. After Phase I data is collected, IHSS-specific conceptual models can be developed and provide the basis for the BRA.

The primary purpose of the Site Conceptual Model is to aid in identifying exposure pathways by which populations may be exposed to contaminants from the IHSSs. The EPA defines an exposure pathway as "...a unique mechanism by which a population may be exposed to the chemicals at or originating from the site..." (EPA, 1989c). As shown in Figure 2-12, an exposure pathway must include a contaminant source, a release mechanism, a transport medium, an exposure route, and a receptor. An exposure pathway is not complete without each of these five components. The individual components of the exposure pathway are defined as follows:

- **Contaminant Source:** For the purposes of the OU5 conceptual model, the contaminant sources are waste and/or contaminated media that may be present at each IHSS. These sources include buried wastes and contaminated surface soils and sediments.

- **Release Mechanism:** Release mechanisms are physical and/or chemical processes by which contaminants are released from the source. The conceptual model for OU5 identifies mechanisms that release contaminants directly from the source and those that release contaminants from transport media (i.e., secondary release mechanisms). Numerous potential direct release mechanisms and secondary release mechanisms for OU5 are discussed in the conceptual model.



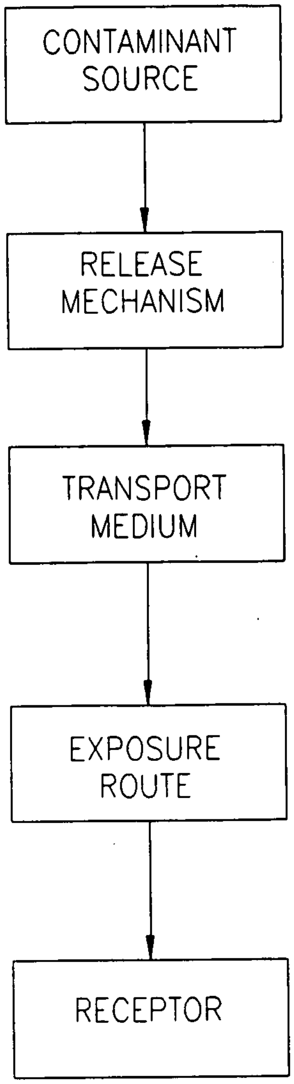
U.S. DEPARTMENT OF ENERGY Rocky Flats Plant Golden, Colorado	LOCATION OF ON-SITE AND PLANT PERIMETER AMBIENT AIR SAMPLERS	FIGURE 2-11

TABLE 2-9

PLUTONIUM CONCENTRATIONS IN AIR AT OU 5 DURING 1990

OU 5 PLUTONIUM-239 CONCENTRATIONS PRESENTED IN pCi/m³							
	1990						
	Station-10	Station-11	Station-13	Station-14	Station-23	Station-32	Station-37
JANUARY	0.000002	0.000006	0.000003	0.000001	0.000001	0.000000	0.000003
FEBRUARY	0.000007	0.000005	0.000001	0.000002	0.000003	0.000001	0.000002
MARCH	0.000016	0.000008	0.000004	0.000003	0.000005	0.000001	0.000003
APRIL	0.000004	0.000004	0.000005	0.000001	0.000002	0.000002	0.000002
MAY	0.000005	0.000006	0.000008	0.000001	0.000003	0.000002	0.000007
JUNE	0.000008	0.000004	0.000002	0.000002	0.000003	0.000002	0.000004
JULY	0.000007	0.000007	0.000008	0.000002	0.000003	0.000000	0.000002
AUGUST	0.000005	0.000007	0.000002	0.000003	0.000005	0.000000	0.000000
SEPTEMBER	0.000005	0.000007	0.000002	0.000002	0.000006	0.000003	0.000001
OCTOBER	0.000003	0.000001	0.000001	0.000004	0.000001	0.000002	0.000003
NOVEMBER	0.000004	0.000003	0.000007	0.000006	0.000002	0.000002	0.000002
DECEMBER	0.000002	0.000000	0.000001	0.000000	0.000001	0.000001	0.000005
Annual Ave.	0.000006	0.000005	0.000004	0.000002	0.000003	0.000001	0.000003
Max. Value	0.000016	0.000008	0.000008	0.000006	0.000006	0.000003	0.000007

pCi/m^3 = picoCurie/cubic meter



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

COMPONENTS OF A COMPLETED EXPOSURE PATHWAY

FIGURE 2-12

- **Transport Medium:** Transport media are the environmental media into which contaminants are released from the source and from which the contaminants are in turn released to a receptor (or to another transport medium by a secondary release mechanism). Potential transport media for OU5 include, air, soils, sediment, surface water, groundwater, and biota (both flora and fauna).

- **Exposure Route:** Exposure routes are avenues through which contaminants are physiologically incorporated by a receptor. Exposure routes for receptors at OU5 are inhalation, ingestion, dermal contact, and external exposure to radiation from radionuclides.

- **Receptor:** Receptors are human or environmental populations that are affected by the contamination released from a site. Environmental receptors include biota (both flora and fauna) indigenous to the OU5 environs.

2.7.1 Contaminant Source Descriptions

2.7.1.1 Original Landfill (IHSS 115)

Most of the limited data available for IHSS 115 suggests the possibility of a wide range of chemicals in the refuse in the landfill. In addition, depleted uranium is likely present in the landfill, and it is possible plutonium contaminated materials are present. Several radioactive anomalies have been identified at the perimeter of the landfill where it slopes down to the SID. Nonradioactive contaminants associated with the landfill likely include, volatile organics, semi-volatile organics and inorganic ions. The landfill is currently covered with a thin clay cap of presumably clean fill. However, there are several locations where the cover has slumped downslope and refuse is exposed.

2.7.1.2 Incinerator, Ash Pits, and Concrete Wash Pad (IHSS 133)

The incinerator (IHSS 133.5) was used to burn general plant wastes from the 1950s to 1968. Depleted uranium is also believed to have been burned in the incinerator (Rockwell 1988). Ashes from the incinerator were placed into the Ash pits (IHSS 133.1 through 133.4) or were pushed over the side of the hill into the Woman Creek drainage and/or onto the Concrete Wash Pad (IHSS 133.6). After the incinerator was closed in 1968, the ash pits were covered with fill. The Concrete Wash Pad appears to have been used to dispose of waste concrete and truck washdown water from construction activities at Rocky Flats Plant. Results from sampling a monitoring well downgradient of the Ash Pits indicate elevated levels of metal and radionuclides. However, due to the limited characterization of the site, it is possible that other contaminants are present at this location.

2.7.1.3 Detention Ponds C-1 and C-2 (IHSS 142)

Detention Ponds C-1 and C-2 (IHSSs 142.10 and 142.11) along the Woman Creek drainage and the SID are used primarily to capture and control surface water runoff. Pond C-1 receives water from Woman Creek, while Pond C-2 receives water from the SID, which in turn collects surface water runoff from the southern part of the production facilities (see Subsection 2.4). Historically, water and sediment samples from these ponds have occasionally contained low concentrations of radionuclides, VOCs, base neutral compounds, pesticides and metals.

2.7.1.4 Surface Disturbances (IHSS 209)

The surface disturbances are thought to be old borrow pits to provide fill for other parts of the Rocky Flats Plant. Although there is no information that indicates that hazardous wastes have been disposed of in these locations, it is possible such activities occurred in the past.

2.7.1.5 Area South of OU5 to the Property Boundary

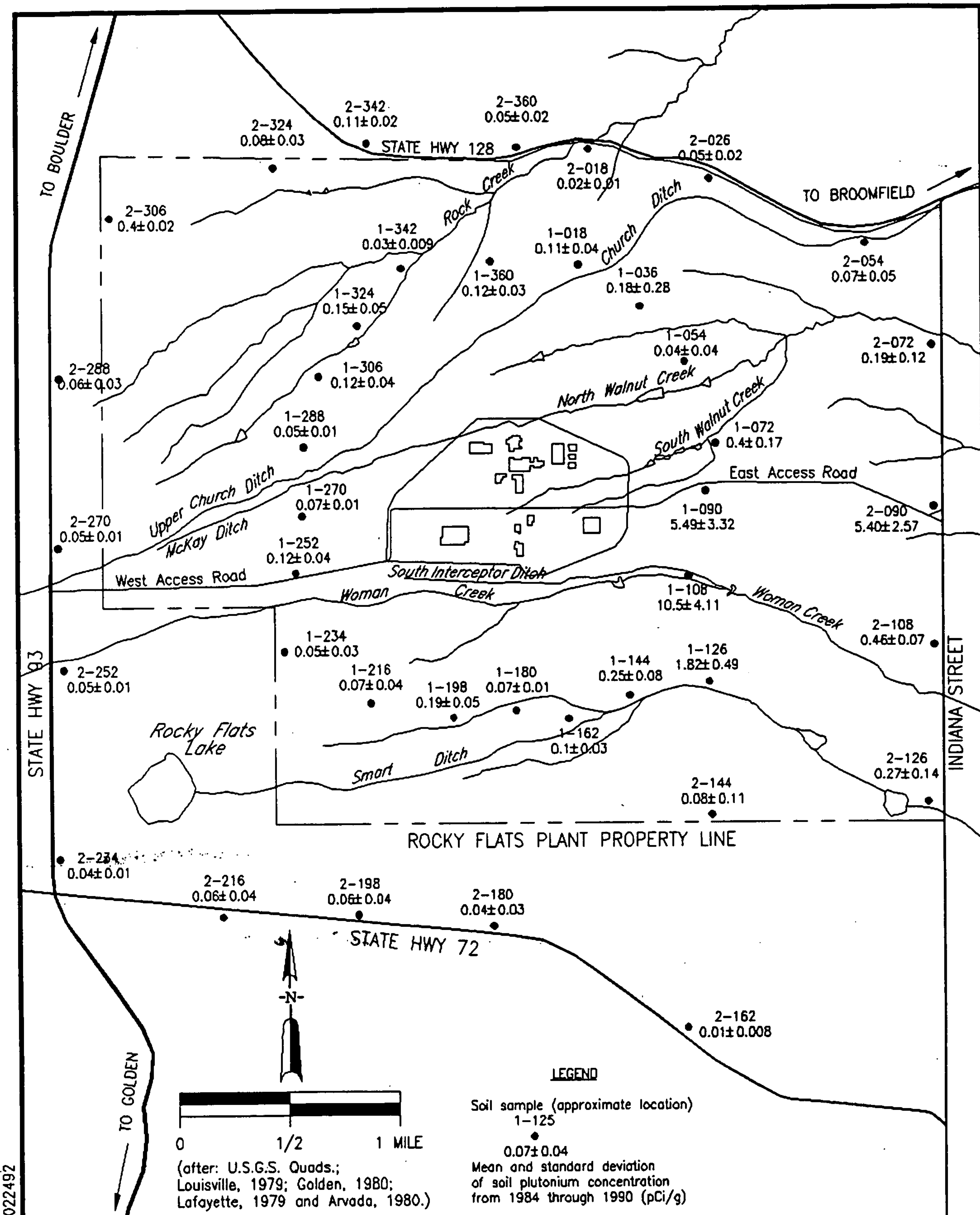
The area south of OU5 to the property boundary was deliberately excluded from the list of OUs and IHSSs in the IAG due to lack of known sources of contamination. Surface soil sampling for plutonium was previously conducted in this area. There were only two sampling locations with levels slightly in excess of the CDH Construction Standard of 0.9 pCi/g (Figure 2-13). Surface soil sampling for plutonium and other radionuclides may be performed in this area pending further data evaluation. This is discussed in Subsection 7.2.4.1. Until more detailed site characterization information is available, it is assumed that no significant exposure to contaminants occurs via this area.

2.7.2 Primary Release Mechanisms and Transport Media

There are a number of mechanisms by which contaminants are released into environmental media. As shown in Figures 2-14 and 2-15, all primary release mechanisms apply to contaminated surface soils and sediments fugitive dust wind erosion; surface runoff; volatilization; infiltration/percolation; biotic uptake; and tracking. Volatilization, infiltration/percolation and tracking also apply to buried wastes.

Once contaminants are released from a source, they will enter an environmental medium where contaminants will be transported either to a point of exposure or be released (secondary release mechanism) to another environmental medium (and subsequently transported to a point of exposure). The transport medium a contaminant enters is determined by the primary release mechanism. For example, volatilization or fugitive dust wind erosion will result in contaminant release to the air. Surface runoff will transport contaminants to surface water while infiltration/percolation results in contaminant transport to groundwater. Contaminants entering biota is simply due to biotic uptake.

The physical and chemical properties of a contaminant determine the tendency of a contaminant to be



U.S. DEPARTMENT OF ENERGY Rocky Flats Plant Golden, Colorado	SOIL SAMPLING LOCATIONS	FIGURE 2-13

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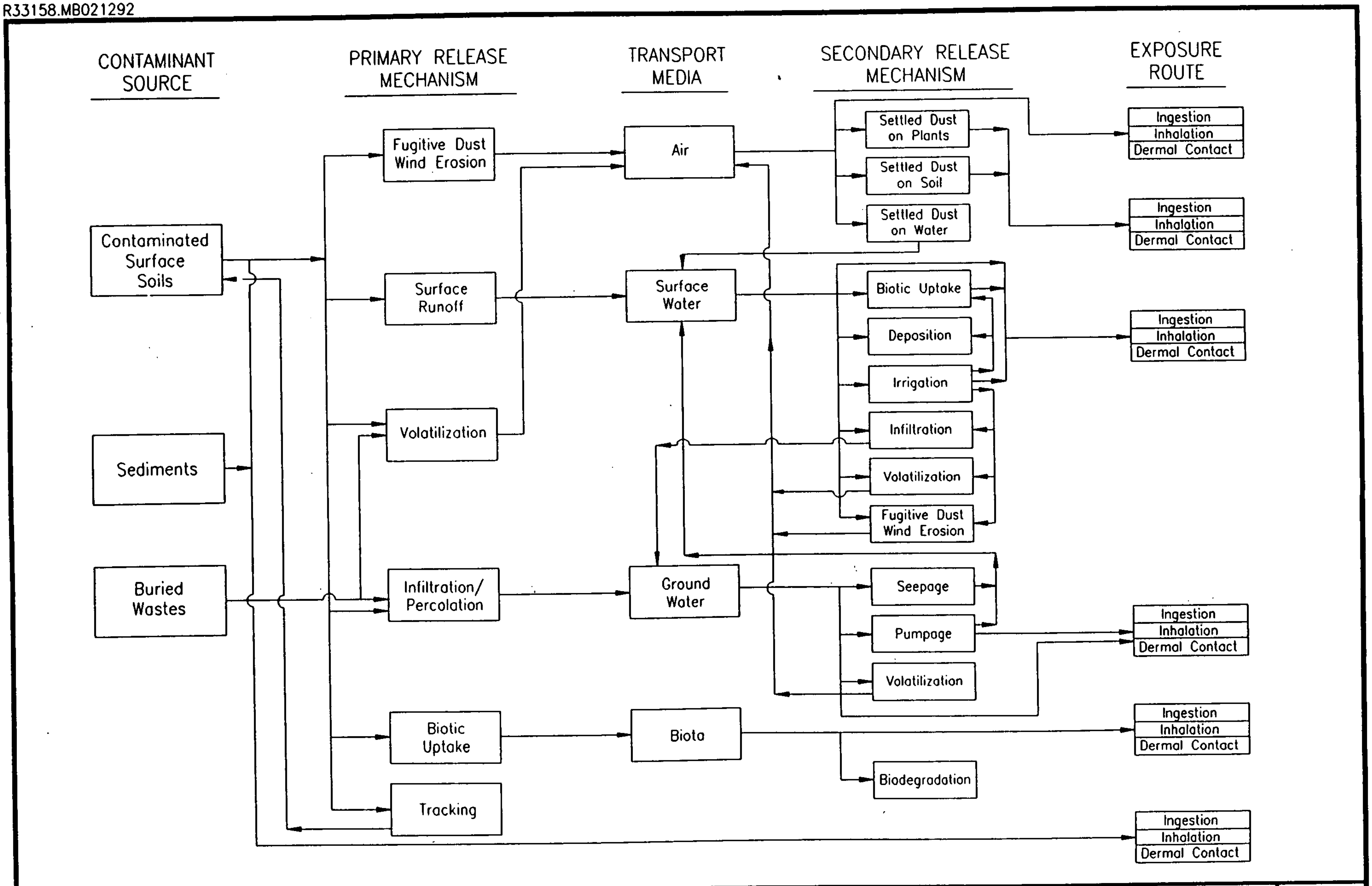

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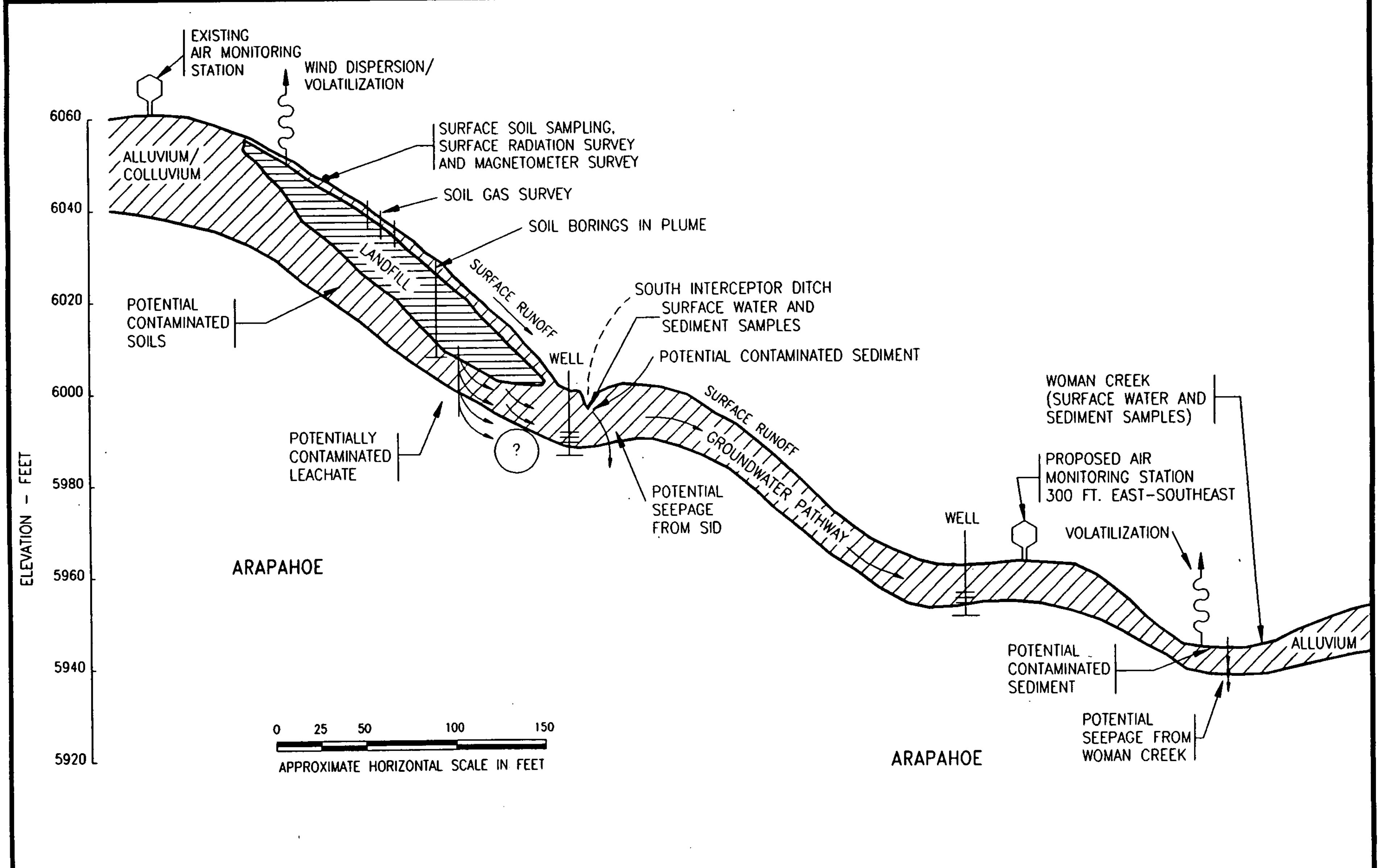
Golden, Colorado

RISK ASSESSMENT CONCEPTUAL MODEL

FIGURE 2-14



U.S. DEPARTMENT OF ENERGY Rocky Flats Plant Golden, Colorado	SAMPLING PROGRAM AND PATHWAY ANALYSES ORIGINAL LANDFILL	FIGURE 2-15

released from a source, and the fate and mobility in a transport medium once released. The following subsections provide a brief summary of these contaminant properties.

2.7.2.1 Organic Contaminants

Table 2-10 presents some of the relevant chemical/physical parameters that control the environmental fate and transport of representative organic chemicals. Because two IHSSs at OU5 accepted a wide range of materials, further investigation may identify additional organic chemicals not present on this list.

TCL Volatiles

TCL volatiles are generally more mobile in the environment than other chemicals (Table 2-10). Volatiles are generally characterized by relatively high water solubility (greater than 100 mg/l) and volatility (vapor pressures greater than 1.0 mm Hg and Henry's Law Constants greater than 0.1). Volatiles can be expected to migrate through soils, sediment and groundwater in both liquid and vapor phase and to be transported in surface water and groundwater as neutral solutes. This is denoted by retardation factors (Rd) between 1 and 50 (Chemical migration velocity = water migration velocity/Rd). The Henry's Constants of volatiles suggest a tendency to volatilize from aqueous systems (including soil/water) to the atmosphere and, therefore, are unlikely to be detected in sediments and soils.

TCL Semivolatiles and Pesticides/PCBs

Semivolatile compounds and pesticides/PCBs typically are much less mobile than volatile compounds (Table 2-10). The retardation factors for semivolatiles and pesticides/PCBs range from approximately 100 to over 180,000,000 with the exception of the phenolic compounds. Phenols are relatively mobile because of their high water solubility. Semivolatiles and pesticides/PCBs exhibit low to negligible volatility as indicated by the low vapor pressures and Henry's Constants. This suggests a low propensity for volatilization of these compounds to the atmosphere from soil and surface water.

2.7.2.2 Radionuclides and Metals

Table 2-11 summarizes the distribution coefficients for radionuclides and inorganic elements. A distribution coefficient (K_d) is the ratio of the concentration of a compound in the solid phase to its concentration in solution at equilibrium. The distribution coefficients are considered empirical and are strongly influenced by the environmental conditions existing where the experiments are performed. Inorganic compounds differ from organic compounds in that they can be present in solution in a number of different forms or species. The form of an inorganic chemical is important in evaluating that chemical's mobility. Each species or complex may have different solubilities and the concentration of each can be related to several factors including pH and oxidation/reduction potential (E_h).

TABLE 2-10

CHEMICAL/PHYSICAL PARAMETERS AFFECTING ENVIRONMENTAL FATE AND TRANSPORT FOR ORGANICS

Chemical	Molecular Weight (g/mole)	Specific Gravity (g/cc)	Vapor Pressure (mmHg)	Henry's Constant (Dimensionless)	Water Solubility (mg/l)	Log Kow (c/c)	Log Koc (ml/g)	Saturated Zone Rd	Mobility Index MI	Env. Mobility
TCL VOLATILE ORGANICS										
Ketones & Aldehydes Acetone	55.1	0.1	270.00	0.013	60000.0	-0.24	-0.43	1.0	8	Extremely Mobile
Monocyclic Aromatics										
Benzene	78.1	0.9	76.00	0.182	1780.0	2.13	1.81	6.8	3	Very Mobile
Toluene	92.1	0.9	22.00	0.214	515.0	2.79	2.48	28.0	2	Very Mobile
Ethyl Benzene	106.2	0.9	7	0.266	152.0	3.34	3.04	100.0	-0	Slightly Mobile
Xylene	106.2	0.9	10	0.380	152.0	3.13	2.11	12.6	1	Very Mobile
Chlorinated Aliphatics										
Carbon Tetrachloride	153.8	1.6	90.00	0.960	785.0	2.96	2.64	40.5	2	Very Mobile
Trichloroethene	131.4	1.5	60.00	0.390	1100.0	2.42	2.10	12.3	3	Very Mobile
Chloroform	119.4	1.5	160.00	0.130	8000.0	1.97	1.64	4.9	4	Very Mobile
1,1,1,2-Trichloroethane	167.9	1.6	5.00	0.016	2900.0	2.39	2.07	11.6	2	Very Mobile
SEMIVOLATILE ORGANICS										
Acid Extractables (Phenolics)										
Phenol	94.1	1.1	0.20	1.2E-04	8200.0	1.46	1.15	2.3	2	Very Mobile
Pentachlorophenol	266.4	2.0	1.1E-0.	1.1E-04	14.0	5.18	4.72	4771.3	-8	Immobile
2,4-Dinitrophenol	184.1	1.7	1.5E-05	2.7E-08	5600.0	1.54	1.22	2.5	-2	Slightly Immobile
2,4,6-Trichlorophenol	197.5	1.5	0.012	1.6E-04	800.0	3.61	3.30	181.0	-2	Slightly Immobile
Base-Neutral Extractables										
Bis(2-ethylhexyl)phthalate	391.1	1.0	2.7E-07	4.4E-06	1.3	9.61	9.30	1.8E+08	-16	Very Immobile
Chrysene	228.2	1.3	1.0E-11	6.9E-08	0.0	5.61	5.30	1.8E+04	-19	Very Immobile
1,2,4-Trichlorobenzene	181.5	1.5	0.29	9.6E-02	30	4.28	3.96	8.3E+02	-3	Slightly Immobile
1,3-Dichlorobenzene	147.0	1.3	2.28	1.5E-01	123	4.28	3.96	8.3E+02	-2	Slightly Immobile
Naphthalene	128.2	1.0	0.087	1.9E-02	31.7	3.29	2.97	8.6E+01	-3	Sightly Immobile
Benzo(a)pyrene	252.0	1.4	5.6E-09	2.0E-05	3.8E-03	6.06	6.74	5.0E+05	-17	Very Immobile

eg&g\ou5\tbl-2-10.feb

TABLE 2-10

CHEMICAL/PHYSICAL PARAMETERS AFFECTING ENVIRONMENTAL FATE AND TRANSPORT FOR INORGANICS (Concluded)

Chemical	Molecular Weight (g/mole)	Specific Gravity (g/cc)	Vapor Pressure (mmHg)	Henry's Constant (Dimensionless)	Water Solubility (mg/l)	Log Kow (c/c)	Log Koc (ml/g)	Saturated Zone Rd	Mobility Index MI	Env. Mobility
PCBs AND PESTICIDES										
PCBs										
PCB-1248	299.5	1.4	4.9E-04	1.5E-01	0.054	5.76	5.44	24931.0	-10	Immobile
PCB-1254	328.4	1.5	7.7E-05	4.6E-02	0.0	6.03	5.72	47233.7	-11	Very Immobile
PCB-1260	375.7	1.6	4.1E-05	2.8E-01	0.0	7.15	6.82	594625.1	-14	Very Immobile
Chlorinated Pesticides										
Dieldrin	381.0	1.8	1.8E-07	1.9E-05	0.2	3.54	3.23	153.8	-11	Very Immobile
DDT	375.7	1.6	1.9E-07	7.1E-04	5.5E-03	6.91	6.59	350141.6	-16	Very Immobile
Heptachlor	375.0	1.6	3.0E-04	3.4E-02	0.18	4.4	4.1	1081.0	-8	Immobile
Lindane	291.0	1.6	2.5E-05	2.5E-04	1.6	3.9	3.6	343.0	-8	Immobile
Chlordane	409.8	1.6	1.0E-05	4.0E-03	0.056	5.5	5.1	12601.0	-11	Very Immobile
Toxaphene	414.0	1.6	0.3	1.4E+01	0.5	3.3	3.0	87.8	-4	

Source: EG&G, 1990e

TABLE 2-11

DISTRIBUTION COEFFICIENTS FOR RADIONUCLIDES AND METALS ELEMENTS

Chemical	Representative Value[1]	Summary Range Low	Summary Range Maximum
Radionuclide			
Americium-241	700	0[4]	47,230[1]
Bismuth-214	200		
Cadmium-109	6.5	1.26[1]	50[3]
Cesium-143	850	3.0[4]	300,000[2]
Cesium-137	1,000	1.3[4]	52,000[1]
Cobalt-60	45	0.2[1]	23,624[4]
Lead-212-Bismuth	900	4.5[1]	7,640[1]
Plutonium-238	4,500	0.4[4]	8.7E7[4]
Potassium-40	5.5	2.0[1]	9.0[1]
Radium-288	450	200[1]	467[4]
Strontium-90	35	0.15[1]	4,300[4]
Thorium-228	1,500	5[4]	1E6[4]
Uranium-234	1,500	0[1]	4,400[1]

[1]U.S. Department of Energy, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmental Released Radionuclides through Agriculture.
[2]U.S. Department of Energy, 1980, Determination of Distribution Coefficients for Plutonium, range of results for a variety of sediments in the Enewetak Lagoon using Lab and Field experiments; Transuranic Elements in the Environment, Technical Information Center.
[3]Couphtrey, P.J. and Thorne, M.C., 1983, Radionuclide Distribution and Transport in *Terrestrial and Aquatic Ecosystems*, A *Compendium of Data*.
[4]ACS Symposium Series, 1979, Radioactive Waste in Geologic Storage (Abyssal Red Clay)
Conc=1E3-1E8 mg/atom/ml in 0.68N NaCl Soin Distributed Coefficient for CS pH2.7-8.0 Figure 1; for Cd pH 5.3 Figure 3; for Sr Phy.1-73; for Ba pH 2.6-8.3 Figure 2; for Ce pH 5.8-8.0 Figure 4.

TABLE 2-11

DISTRIBUTION COEFFICIENTS FOR RADIONUCLIDES AND METALS ELEMENTS (Continued)

Chemical	Representative Value[1]	Summary Range Low	Summary Range Maximum
Metals			
Aluminum	1,500	0[4]	122.8[4]
Antimony	45	1.0[5]	18[5]
Arsenic	200	5[4]	30,000[4]
Barium	60		
Beryllium	650		
Boron	3	1.26[1]	50[4]
Cadmium	6.5		
Chromium	850	0.2[1]	3,800[1]
Cobalt	45	1.4[1]	333[1]
Copper	35	4.5[1]	7,640[1]
Lead	900	0.2[1]	10,000[1]
Manganese	65	30[7]	82,800[7]

[1]U.S. Department of Energy, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmental Released Radionuclides through Agriculture.
[4]Radionuclide Interactions with Soil and Rock Media Volume 1: Processes Influencing Radionuclide Mobility and Retention, Element Chemistry and Geochemistry, Conclusions and Evaluation, Battelle Pacific Northwest Labs, Richland, WA EPA No. 6078-007, August 1978.
[5]Dragun, 1988, The Soil Chemistry of Hazardous Materials, Dragun, 1988, Ranges of Kd for various Elements in Soils and Clays, Table 4.2, pg 158.

TABLE 2-11

DISTRIBUTION COEFFICIENTS
FOR RADIONUCLIDES AND METALS ELEMENTS
(Continued)

Chemical	Representative Value[1]	Summary Range Low	Summary Range Maximum
Mercury	10	0.37[1]	400[1]
Molybdenum	20	200[7]	300,000[7]
Nickel	150		
Selenium	300		
Silicon	30	10[1]	1,000[1]
Silver	45		
Thallium	1,500		
Titanium	1,000		
Vanadium	1,000		
Zinc	40	0.1[1]	8,000[1]

[1]U.S. Department of Energy, 1984, A Review and Analysis of Parameters for Assessing Transport of Environmental Released Radionuclides through Agriculture.
[7]EPRI, 1984, Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration Volume I. A Critical Review. Battelle Pacific Northwest Laboratories, Richland, WA. EPRI EA-3356, Kd for Ba in River Sediments; Kd for Me= pH=6.6 with Bentonite, Kd-82800 Ph-5.95 for Iron Oxide; Kd=200 for Ni in seawater with Clay pH=8; with Mn Oxide Kd=300,000 pH=8.

Radionuclides

The limited data available for OU5 indicates that depleted uranium is a buried waste at two IHSSs, and plutonium contaminated wastes may also be present. Americium is also likely to occur either from in situ ingrowth from the plutonium or from direct disposal of americium contaminated material.The following discussions focus on characteristics of uranium and plutonium which may affect their fate and mobility in the environment (Table 2-11). Numerous studies of uranium and plutonium fate and mobility are incorporated by reference into the discussions. Much less information is available on the nature of americium in the environment. Americium has essentially the same characteristics in the environment as plutonium and is considered insoluble under typical environmental conditions.

Uranium

Uranium has 14 isotopes that decay to other elements at half-lives of minutes to 4.5 billion years. Natural uranium is comprised mainly of U-238 (99.27%) with some U-235 (0.72%) and minor amounts of U-234 (0.0057%) (Table 2-12). Enriched uranium contains a higher percentage of the fissile U-235 isotope. Depleted uranium, a potential contaminant at OU5, contains less U-235 and U-234, and more U-238. Uranium-234 is a daughter product of U-238.

Thermodynamic data (Langmuir 1978) indicates that most uranium in natural waters exists in the U(IV) or U(VI) oxidation state. Uranium in both oxidation states exhibits a strong affinity to complex with available anions in natural waters as either uranous (U^{4+}) or uranyl (UO_2^{+2}) ion. Because U(IV) species tend to precipitate as insoluble uraninite or coffinite (Langmuir, 1978); uranyl ion is the mobile species for most oxidizing groundwaters. More importantly, UO_2^{+2} is mobile over a relatively wide pH range. Depending on the ligands available and the pH, uranyl ion will form soluble complexes in oxidizing waters. Thus, uranyl will be soluble and hence mobile in most oxidizing groundwaters that contain common ligands. Oxidizing conditions probably exist in all alluvial/colluvial materials and extend at least into shallow bedrock as indicated by iron-oxidation staining in numerous drill logs. Therefore, uranium migration via surface water and groundwater is likely given adequate leaching, and, therefore, uranium should be analyzed when characterizing these transport media.

Uranium has a lower K_d than plutonium or americium (Table 2-11). However, under reducing conditions (such as high-organic, fine-grained, bed sediments deposited in the deeper layers of sediments) uranium is immobilized and becomes part of the sediments. Yang and Edwards (1984) documented the fate and transport of uranium and its daughter product, radium-226, in dissolved form, and in both suspended and bed sediments, from above the Schwartzwalder (uranium) Mine adjacent to Ralston Creek several miles southwest of the Rocky Flats Plant. Uranium is present in dissolved and solid phases. Concentrations range from 4 μg/l dissolved in the creek water above the mine to 100 μg/l in Ralston reservoir below the mine. Uranium occurred as both a discrete mineral and as partially entrapped colloidal iron and manganese coatings on suspended and bed sediments.

TABLE 2-12

ISOTOPIC COMPOSITION OF ROCKY FLATS URANIUM

	Relative Weight (%)		Relative Activity* (pCi/μg)	
Isotopic	**Natural Uranium**	**Depleted Uranium**	**Natural Uranium**	**Depleted Uranium**
U-232	0	Trace	0	Trace
U-233	0	Trace	0	Trace
U-234	0.0057	0.002	0.35	.124
U-235	0.72	0.3	0.015	.006
U-236	0	0.0003	0	.0002
U-238	99.27	99.7	0.33	.332

* Relative activity is obtained by multiplying the percentage by weight by the specific activity.
pCi/μg = picoCurie/microgram.

Plutonium

There are 15 known isotopes of plutonium that decay into other elements at half-lives ranging from hours to 387,000 years (Ames and Rai, 1978). At the Rocky Flats Plant, plutonium exists primarily as Pu-239 and Pu-240 (Table 2-13).

Plutonium specification in the environment is heavily influenced by hydrogen ion concentration (pH) and oxidation-reduction capacity (Eh). Typical environmental conditions are pH in the range of 5 to 8 and a positive Eh (greater than 0.05 volts) (Brownlow, 1979). Under these conditions, plutonium species will most likely be found in the following order of occurrence: $Pu^{+4} > PuO_2 > Pu^{+3} > PuO^{+1}$ (Ames and Rai, 1978).

As shown above, the most probable species in the environment is the plus 4 valence (oxidation state) species, which will exist either as plutonium dioxide (PuO_2) or as a solid hydroxide $Pu(OH)_4$ (Brookins, 1984; Dragun, 1988). The assertion is based on the assumption that the pH of the environmental system is near neutral and that the system is in an oxidative state (Eh >0).

Plutonium shows a very strong tendency to adsorb to clays, metal dioxides, and organic matter in soils and thus has a very low migration potential in the environment (CSU, 1974; Brookins, 1984). The distribution coefficient (K_d), for plutonium is 10^3- 10^6 (Allard and Rydberg, 1983), meaning that the ratio of plutonium bound to soil to plutonium dissolved in water would be expected to vary from 1000:1 to 100,000:1. The EPA (1990b) gives a K_d of 2×10^3 for plutonium. At a minimum, analysis of surface water samples should include total plutonium because plutonium may be present in the suspended fraction. Although plutonium is not expected to migrate readily in groundwater, its common occurrence in soil and surface water, and the lack of initial data suggest the Phase I RFI/RI include plutonium analysis for groundwater samples.

Metals and Major Ions

In general, the solubility of metals and major ions in natural water situations are very sensitive to pH and Eh conditions as are the radionuclides. Based on their physical properties (Table 2-11), they can form complexes and potentially move relatively rapidly within the hydrosphere. There is also a tendency for the ions to be incorporated into new minerals, to be adsorbed on to mineral surfaces, ion exchange or to be coprecipitated. Because initial data on source characterization is limited, the Phase I RFI/RI should include metals analysis in waste, soils, and water.

TABLE 2-13

ISOTOPIC COMPOSITION OF ROCKY FLATS PLUTONIUM

Isotopic	Relative Weight (percent)	Specific Alpha Activity (Curies/gram)	Specific Beta Activity (Curies/gram)	Relative[a] Activity (Curies/gram)
Pu-238	0.01	17.1	--	0.00171
Pu-239	93.79	0.0622	--	0.056834
Pu-240	5.80	0.228	--	0.01322
Pu-241	0.36	—	103.5	0.37260
Pu-242	0.03	0.00393	--	1.18×10^{-6}
Am-241	--[b]	3.42	--	--

Source: Rockwell, 1985b.

[a]Relative activity is obtained by multiplying the percent by weight by the specific activity.
Total activity for the plutonium isotopes is:
Alpha 0.0732 curries/gram
Alpha plus Beta 0.446 curies/gram

[b]Am-241 daughter from decay of Pu-241.

2.7.3 Secondary Release Mechanisms and Exposure Routes

As shown in Figure 2-14, there are numerous secondary release mechanisms and exposure routes for contaminants that may be released from OU5 sources. This figure shows all potential pathways; however, the actual pathways of significance will be determined during the risk assessment.

2.7.4 Receptors

The point of exposure includes the source material or any point within a transport media that is contaminated. Whether the human receptor is a resident or visitor there is the potential for direct exposure through multiple pathways. Biota may also be present and be potential receptors. The potential for exposure and the magnitude of risk will be assessed during the risk assessment.

2.7.5 Exposure Pathway Characterization

The elements of the Site Conceptual Model described above are cross referenced to the FSP for characterization details in Table 2-14 through 2-17 for each IHSS. Site sampling based upon the site conceptual model will improve the characterization of contaminant pathways for each IHSS. As additional information is obtained, the overall model and specific portion of the model may be refined or expanded to address the issues of concern.

TABLE 2-14

OU5 PHASE I SITE CHARACTERIZATION OF EXPOSURE PATHWAYS: ORIGINAL LANDFILL (IHSS 115)

Contaminant Source	Primary Release Mechanism	Transport Media	Secondary Release Mechanism
Buried Waste Table 7-1 (1,2,3,4,5,8,11,12,13,14, 15)	Fugitive Dust Wind Erosion Table 7-1 (6) Section 7.2.5	Air Section 7.2.5	Settled Dust on Plants – Phase II
Contaminated Surface Soil Table 7-1, (2,5,7) Table 7-4	Air Sampling Table 7-1, (6)	Surface Water Table 7-1, (10,14,15) Table 7-4 Table 7-4, (2-4)	Settled Dust on Soil Section 7.2.5 Table 7-1, (7) Table 7-4, (2,3,4)
	Surface Runoff Table 7-1, (10) Table 7-4 (2-4)	Groundwater Table 7-1, (3,4,8,11,12,13)	Settled Dust on Water Table 7-1, (10) Table 7-4, (2,3,4)
	Volatilization Table 7-1, (5,10)	Biota Section 9	Biotic Uptake Section 9
	Infiltration Percolation Table 7-1, (3,4,8,11,12,13)		Deposition Table 7-1, (10) Table 7-4, (2-4)
			Irrigation OU 3 Work Plan
	Biotic Uptake Section 9.0		Infiltration Table 7-1, (8,9,12,13) Table 7-4, (2-4)
	Tracking Section 9.0		Volatilization Table 7-1, (7); 7-4, (2-4)
			Fugitive Dust Wind Erosion Table 7-1, (10); 7-4, (2-4)
			Seepage Table 7-1 (12,13)
			Pumpage Table 7-1; OU 3 Work Plan
			Volatilization Table 7-1, (7,13), 7-4, (2-4)
			Biodegradation-Phase II

TABLE 2-15

OU5 PHASE I SITE CHARACTERIZATION OF EXPOSURE PATHWAYS: INCINERATOR, ASH PITS AND CONCRETE WASH PAD (IHSS 133)

Contaminant Source	Primary Release Mechanism	Transport Media	Secondary Release Mechanism
Buried Waste Table 7-2 (1,2,3,4,5,6,7) Contaminated Surface Soil Table 7-2, (2,3,4,5) Table 7-4 (1)	Fugitive Dust Wind Erosion Table 7-2 (5) Section 7.2.5 Air Sampling Table 7-2, (5) Surface Runoff Table 7-2, (5) Table 7-4 (1) Volatilization Table 7-1, (15) Infiltration Percolation Table 7-2, (3,4,6,7) Biotic Uptake Section 9.0 Tracking Section 9.0	Air Section 7.2.5 Surface Water Table 7-2, (5) Table 7-4, (1) Groundwater Table 7-2, (7) Biota Section 9	Settled Dust on Plants – Phase II Settled Dust on Soil Section 7.2.5 Table 7-2, (5) Table 7-4, (1) Settled Dust on Water Table 7-2, (5) Table 7-4, (1) Biotic Uptake Section 9 Deposition Table 7-2, (5) Table 7-4, (1) Irrigation OU 3 Work Plan Infiltration Table 7-2, (3-7) Volatilization Table 7-2, (5), 7-4, (1) Fugitive Dust Wind Erosion Table 7-2, (5), 7-4, (1) Sec. 7.2.5 Seepage Table 7-2, (6,7) Pumpage OU 3 Work Plan Volatilization Table 7-2, (5); 7-4, (1) Biodegradation-Phase II

TABLE 2-16

OU5 PHASE I SITE CHARACTERIZATION OF EXPOSURE PATHWAYS: C-SERIES DETENTION PONDS (IHSS 142.10-11)

Contaminant Source	Primary Release Mechanism	Transport Media	Secondary Release Mechanism
Buried Waste Table 7-3, (1,2,3,4,5)	Fugitive Dust Wind Erosion Section 7.2.5	Air Section 7.2.5	Settled Dust on Plants – Phase II
Contaminated Surface Soil Table 7-3, (1,2,4,5)	Air Sampling Table 7-3, (2,4,5)	Surface Water Table 7-3, (2)	Settled Dust on Soil Section 7.2.5 Table 7-3, (4,5)
	Surface Runoff Table 7-3, (2,3,4,5) Table 7-4, (1-6)	Groundwater Table 7-3, (6)	Settled Dust on Water Table 7-3, (2,3,4,5)
	Volatilization Table 7-3	Biota Section 9	Biotic Uptake Section 9
	Infiltration Percolation Table 7-3		Deposition Table 7-3, (2,3,4,5)
	Biotic Uptake Section 9.0		Irrigation OU 3 Work Plan
	Tracking Section 9.0		Infiltration Table 7-3, (6)
			Volatilization Table 7-3
			Fugitive Dust Wind Erosion Table 7-3 Sec. 7.2.5
			Seepage, Table 7-3 Phase II
			Pumpage Table 7-6; OU 3 Work Plan
			Biodegradation-Phase II