FINAL
PROPOSED ACTION MEMORANDUM
HOT SPOT REMOVAL

Rocky Flats Environmental Technology Site
(Operable Unit No 1)

U S DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden Colorado

September 1994

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF ACRONYMS

AEA	Atomic Energy Act
Am	americium
ARA	Accelerated Response Action
ARAR	Applicable or Relevant and Appropriate Requirements
Be	beryllium
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CHWA	Colorado Hazardous Waste Act
DAC	Derived Airborne Concentration
DOE	Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
EPA	Environmental Protection Agency
FIDLER	Field Instrument for the Detection of Low Energy Radiation
FGSS	Field Gamma Spectroscopy System
gpm	gallons per minute
HPGe	High Purity Germanium Detector
HSP	Health and Safety Plan
IAG	Inter Agency Agreement
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
mg/m^3	milligram per cubic meter
NCP	National Contingency Plan
nCi/g	nanoCuries per gram
NPL	National Priorities List
OU	Operable Unit
PAH	Polynuclear or Polycyclic Aromatic Hydrocarbon
PAM	Proposed Action Memorandum
PCB	polychlorinated biphenyl
PCE	tetrachloroethene or perchloroethene
pCi/g	picoCuries per gram
PGSS	portable gamma spectroscopy system
PPCD	Plan for the Prevention of Contaminant Dispersion
Pu	Plutonium
QQRS	quantitative and qualitative radiological survey
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RFP	Rocky Flats Plant
RI	remedial investigation
SAP	Sampling and Analysis Plan

LIST OF ACRONYMS (Continued)

U	uranium
UV	ultraviolet
µg/kg	micrograms per kilogram
yd^3	cubic yard

1 0 PURPOSE

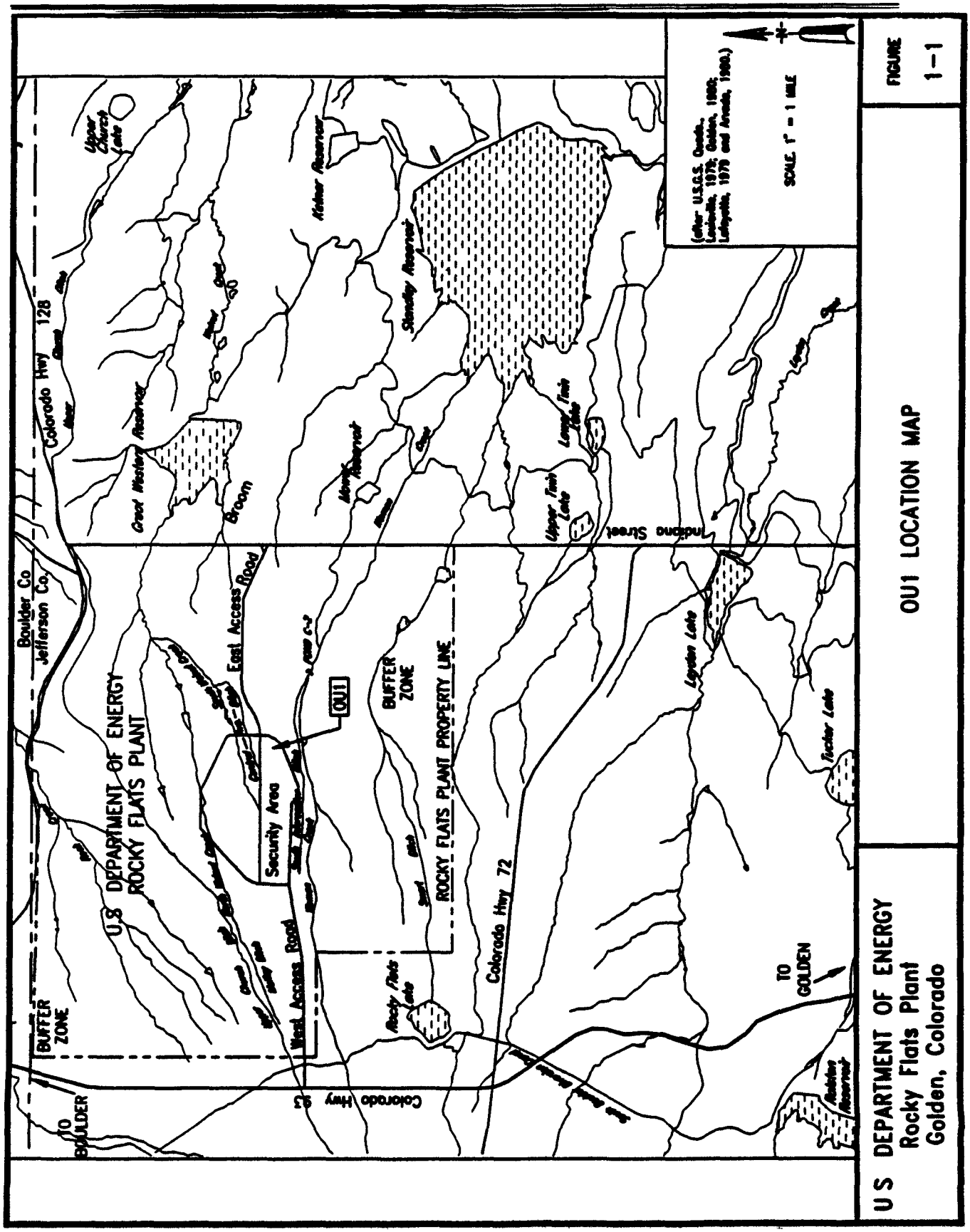
The purpose of this Proposed Action Memorandum (PAM) is to request and document approval of the Department of Energy s (DOE s) proposed Accelerated Response Action (ARA) to remove radionuclide-contaminated soils (hot spots) at six specific locations within the Individual Hazardous Substance Site (IHSS) 119 1 and near IHSS 119 2 at the Rocky Flats Environmental Technology Site (RFETS) located in Golden, Colorado These IHSSs are located within Operable Unit No 1 (OU1) (Figure 1 1) Contaminated soils approximately 3 feet in diameter and approximately 2 feet in depth at each of the six locations contain substantial activities of either plutonium (Pu)/americium (Am) or uranium (U), as well as traces of several organic compounds This ARA will include excavating, containerizing, and storing the contaminated soils from these hot spots The objective of this ARA is to significantly reduce potential risks to workers and the public posed by the radionuclides present in the hot spots The ARA should be consistent with future long term cleanup plans for OU1 because it permanently reduces health risks and contaminant migration potential at OU1

The hot spot removal is an ARA as defined in the proposed language to modify the current Inter Agency Agreement (IAG) i e a remedial response action that all parties (DOE Environmental Protection Agency Region VIII [EPA], and Colorado Department of Health [CDH]) agree is necessary and appropriate to mitigate a threat or potential threat to public health or environment and can be implemented in 6 months The PAM is the primary document used by DOE in making its decision to undertake the action and, therefore, substantiates the need for the action and the selected cleanup method

2 0 SITE BACKGROUND

RFETS is a government-owned contractor operated facility that is part of the nationwide nuclear weapons production complex Until January 1992 RFETS was operated as a nuclear weapons research development and production complex RFETS fabricated nuclear weapons components from plutonium, uranium, beryllium (Be) and stainless steel Support activities included chemical recovery purification of recyclable transuranic radionuclides and research and development of metallurgy machining nondestructive testing coatings remote engineering chemistry and physics The RFETS is currently a Resource Conservation and Recovery Act (RCRA) hazardous waste treatment/storage facility RFETS is in transition from a defense production facility to a facility that will be used for such future missions as environmental restoration waste management maintaining production contingency and eventually decontamination and decommissioning

The IAG signed by the DOE, the EPA, and the CDH in 1991, grouped RFETS-contaminated areas into 16 OUs The IAG requires the investigation study and remediation of OU1 as well as the other OUs at RFETS



R74302A.PJCW-071194

2 1 SITE DESCRIPTION

IHSSs 119 1 and 119 2 at OU1 have historically (1968–1971) been used for temporary storage of drums of wastes containing radionuclides solvents and oils A combined RCRA Facility Investigation (RFI)/Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Remedial Investigation (RI) was conducted in three phases to evaluate the nature and extent of contamination resulting from releases of hazardous substances at IHSSs 119 1/119 2 and other IHSSs at OU1 The Phase III Final RFI/RI Report was submitted to EPA and CDH in June 1994 (DOE 1994) The RFI/RI confirmed the presence of soil and groundwater contaminated by radionuclides and/or organic chemical compounds The soil and groundwater contamination at IHSS 119 1 described in the Phase III RFI/RI report was consistent with leaks from drums containing radionuclide-contaminated lathe coolant or other process wastes generated by historical operations at RFETS

A detailed radiological survey identified the hot spots which are discrete areas of soil contaminated with uranium plutonium and americium (see Section 2 4 1) These areas are identified in the RFI/RI report as locations SS100193 SS100293 SS100393 SS100493 881 16/17 and 881 18/19 Five of these contaminated areas are clustered within a small area in IHSS 119 1 The sixth contaminated area is located near IHSS 119 2 (Figure 2 1)

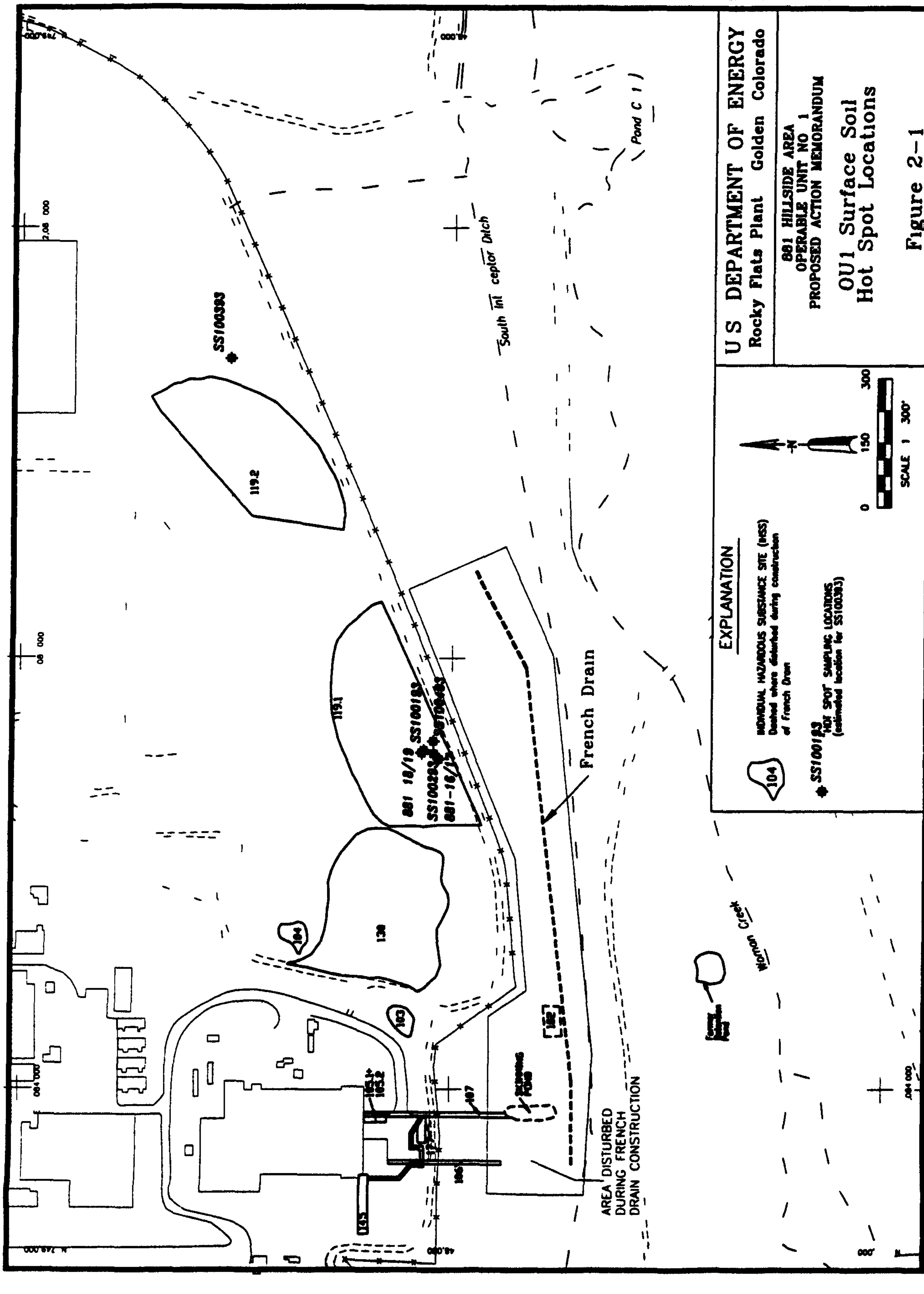
2 2 PHYSICAL LOCATION AND LAND USE

RFETS is located in rural northern Jefferson County approximately 16 miles northwest of Denver Cities within a 10-mile radius from the center of RFETS include Boulder to the northwest Broomfield Lafayette and Louisville to the northeast Westminster to the east, Arvada to the southeast, and Golden to the south Approximately 50% of the area within 10 miles of RFETS is in Jefferson County, 40% in Boulder County and 10% in Adams County

RFETS consists of approximately 6 500 acres of federally owned land in Township 2 South Range 70 West Sections 1 to 4 and 9 to 15 6th Principal Meridian (T2S R70W 1-4 9 15 6PM) A secured area of approximately 400 acres is centrally located within RFETS The secured area is surrounded by a buffer zone of approximately 6 150 acres in area OU1 is located in the southeast portion of the secured area adjacent to its southern boundary (Figure 1 1)

There is little residential or commercial development within a 4 mile radius of the center of RFETS Approximately 9 100 people reside within a 5 mile radius Approximately 316,000 people reside within a 10-mile radius The population within a 50-mile radius is approximately 2 2 million

Generally, those areas closest to RFETS are zoned for industrial development and those farther away are zoned for residential development Since 1973, several new residential subdivisions



U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO 1
PROPOSED ACTION MEMORANDUM
OU1 Surface Soil
Hot Spot Locations
Figure 2-1
EXPLANATION
INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) Dashed where disturbed during construction of French Drain
SS100183 "HOT SPOT" SAMPLING LOCATIONS (estimated location for SS100383)
SCALE 1 300'
0
150
300
N
French Drain
AREA DISTURBED DURING FRENCH DRAIN CONSTRUCTION
South Interceptor Ditch
Pond C 1
Woman Creek
SS100383
SS100183
SS100283
881 18/19
881-16/15
119.2
119.1
130
104
103
102
107
145
74312 pi 071394/300

have been developed to varying degrees within a few miles of the buffer zone, particularly to the east and southeast Additionally, several ranches are located within 10 miles of RFETS These ranches are associated with equestrian activities and produce crops, beef cattle and milk Two small cattle herds of approximately 10 to 20 cattle each are located southeast and east of RFETS The predominant uses immediately southeast of OU1 appear to be open space single family detached dwellings and horse boarding operations In all 70 parcels in Jefferson County surrounding RFETS to the east south and west have been identified and designated The land use data are summarized in Table 2 1 Land to the north is in Boulder County and has not been identified

Table 2-1

Jefferson County Land Use Surrounding RFETS

Number of Parcels	Land Use Type	Generalized Zoning
11	Single Family Detached	Agricultural Planned Development Residential
30	Industrial	Industrial Planned Development Mining-Conservation
4	Office/Retail	Restricted Commercial Planned Development
1	Mining	Mining Conservation
1	Farm/Ranching	Agricultural
5	Water/Utilities	Agricultural Industrial Mining-Conservation
18	Vacant or not designated	Agricultural Industrial

Adapted from DOE 1994 App F Tabl F4-1 Original Source Jefferson County Land Use Inventory

2 3 PHYSICAL ENVIRONMENT AND ECOLOGY

There are no floodplains, natural wetlands or historical/archeological features at OU1 OU1 is not intended for development of any unique natural resource There is a constructed wetland located in the vicinity of OU1 which was built because of damage to wetlands during construction of the french drain an Interim Measure/Interim Remedial Action (IM/IRA) implemented at OU1 Wetlands occur along Woman Creek and Pond C 2 which are south of OU1 The wetlands will not be affected by this removal action

Preliminary studies conducted to date have not indicated the presence of unique ecosystems at the Rocky Flats Environmental Technology Site The bald eagle (endangered) black footed ferret (endangered), peregrine falcon (threatened), and whooping crane (endangered) were

identified by the U S Fish and Wildlife Service as potentially present RFETS (Peregrine falcons nest on high cliff sides and river gorges, which are absent at RFETS Peregrine falcon nesting sites have been recorded 4 to 5 miles west of the site) However the U S Fish and Wildlife Service found no adverse affect on endangered species resulting from current activities at OU1

2 4 RELEASE OR THREATENED RELEASE INTO THE ENVIRONMENT OF A HAZARDOUS SUBSTANCE, POLLUTANT OR CONTAMINANT

2 4 1 Hot Spot Investigation

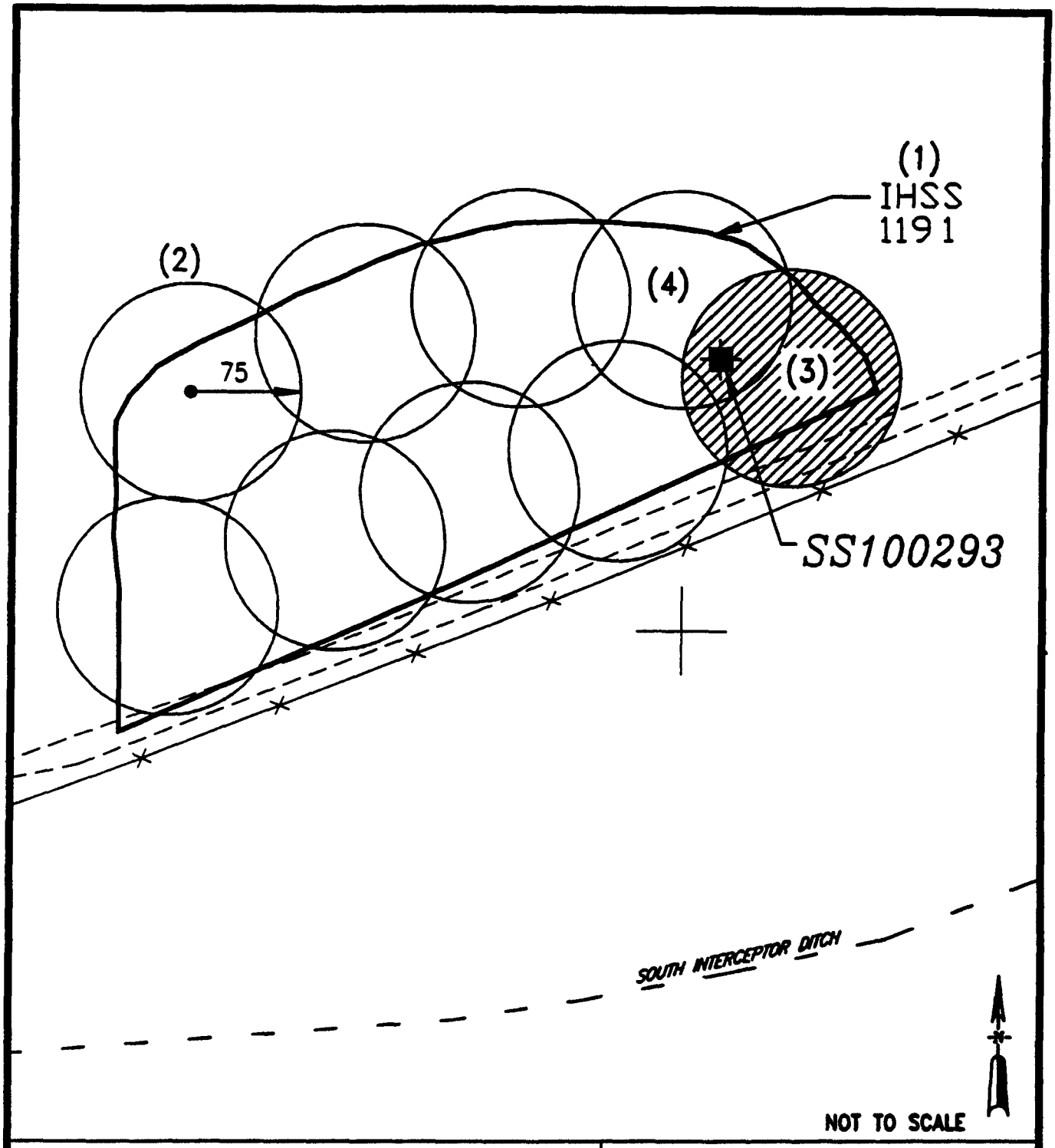
A hot spot was discovered unexpectedly during a pre job survey for the maintenance of the IM/IRA extraction well within IHSS 119 1 The hot spot dimensions were preliminarily determined to be roughly 10 inches in diameter by 12 inches deep with activities ranging from 10 nanoCuries per gram (nCi/g) (surface) to 50 picoCuries per gram (pCi/g) (at 1 foot) The area was posted and staked off in August of 1992 to control access

EG&G prepared a Supplemental Surficial Radiological Characterization Action Plan to evaluate whether other hot spots exist at OU1 The action plan presented a two-part field characterization approach as follows

- Part I Characterizing the areal extent of the identified anomaly using a Field Gamma Spectroscopy System (FGSS) consisting of a truck mounted High Purity Germanium (HPGe) Detector and characterizing the vertical extent through subsurface sampling and analysis

- Part II Conducting a quantitative and qualitative radiological survey (QQRS) to identify other hot spots using multiple field measurement techniques These techniques included FGSS followed by walk-over Field Instrument for the Detection of Low Energy Radiation (FIDLER) surveys followed by portable gamma spectroscopy system (PGSS) surveys of identified areas of elevated activity

This approach as well as the details of the plan was reviewed and approved by EPA and CDH Figure 2 2 exhibits the conceptual design of the characterization plan Table 2 2 summarizes the actual events of the hot spot sample activities



EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS)

CHARACTERIZATION APPROACH:

1) Identify IHSS with Potential Surface Radionuclide Contamination
2) Use HPGe FGSS to get 100% Coverage of IHSS and Identify Potential Hot Spots
3) Conduct Walk-over Survey with FIDLER to Locate Hot Spot
4) Sample Hot Spot Locations Identified in Step 3.

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Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
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Conceptual Depiction of the OU1 Surficial Radiological Characterization Action Plan

Figure 2-2

JULY 1994

R74267 PJCWPJ-071394/100

Table 2-2

Hot Spot History

Event	Date
Original hot spot identified	August 1992
HPGe Survey (identifies 9 areas in 119 1 119 2 and 130)	December 1992 to January 1993
Sampling of original hot spot	January 1993
FIDLER Survey (identifies 4 hot spots)	March to April 1993
Hot spot sampling	April 1993
Receipt of validated data	September 1993
Draft Report	February 1994
Final Report	June 1994

EG&G conducted preliminary characterization and comprehensive sampling of the originally identified hot spot on January 14 and 15 1993 The original location is identified on Figure 2 1 as location SS100493 A PGSS was used to count each sample for radioactivity during the sampling activities Using a shovel and trowel, soil was sampled at approximately 1/2 inch intervals Samples for chemical analyses were collected at 0 75 inches 4 to 5 inches and 9 to 10 inches below ground surface The sample hole was terminated at approximately 10 inches below ground surface due to the samplers encountering a large rock The samples were temporarily stored on site pending determination of an appropriate laboratory to conduct the analyses

The Supplemental and Surficial Radiological Characterization Action Plan Part I and II FGSS surveys were conducted in December 1992 and January 1993 Based on waste history, IHSSs 119 1 119 2 and 130 were investigated Each survey measurement covered a 75 foot radius (150-foot diameter) providing approximately 90% to 100% detection coverage Each FGSS survey location with an integrated point source activity greater that 20 microcuries of americium 241 was surveyed using the FIDLER The FGSS survey identified nine anomalous areas and a FIDLER survey was conducted to isolate and delineate potential anomalies identified by the FGSS survey

The FIDLER survey was subsequently conducted in March and April 1993 to characterize the nine anomalous areas Based on the survey four hot spot locations were identified for soil

sampling (Figure 2 1) The soil sampling was performed on April 29 1993 by EG&G personnel with subcontractor support Surface soil samples were collected using the CDH protocol that specifies the collection of surface scrapes to a depth of 1/4-inch below ground surface Samples were then collected using a hand auger at depth until auger refusal Each sample was screened using a PGSS A summary of the samples collected, sample depth and the analyses requested is provided in Table 2 3 It has been noted that the samples originally collected from SS100493 were not submitted for organic analyses due to the time lapse between collection and laboratory selection, however, the location was resampled in April 1993 to collect samples for organic analysis

The radiological surveys described above failed to detect the presence of two uranium hot spots previously identified in a surface soil radiological characterization study conducted in 1987 The sample identification numbers for these hot spots were 881 16/17 and 881 18/19 During July and August 1994 an additional soil radiological survey was performed using the FIDLER and FGSS to verify the existence of these hot spots They were located, staked, and surveyed Their locations are shown on Figure 2 1

2 4 2 Hot Spot Soil Sampling Results

2 4 2 1 Radionuclides

Hot spots were generally found to be markedly contaminated with either plutonium/americium or uranium

Uranium was below background levels at SS100393, slightly above background at SS100493 and significantly above background at SS100193, SS100293, 881 16/17, and 881 17/18 (Table 2-4) The uranium contamination at SS100193 and SS100293 is not at the immediate surface, as the deeper composites have the higher activities Although there is insufficient data to determine the depth of uranium contamination at SS100193 the significantly lower uranium activity in the 0- to 3 7 foot composite sample versus the 0- to 2 foot composite at SS100293 suggest the uranium contamination is largely in the upper 2 feet Only surface samples were collected from 881 16/17 and 881 18/19 therefore the depth of the uranium contamination is unknown However the data from the other hot spots suggest the uranium contamination is also near the surface The maximum total uranium activities at SS100193 SS100293, 881 16/17 and 881 18/19 are 566 pCi/g 248 pCi/g, 1 350 pCi/g, and 3,060 pCi/g respectively

Plutonium at activities greater than 10,000 pCi/g, which is three to four orders of magnitude higher than the activity of any other soil sample at OU1 was found in soil samples from hot spot SS100493 located in IHSS 119 1 (Table 2-4) This is the original location that prompted the hot spot investigation The plutonium activity is 6,670 pCi/g at the lowest depth sampled (9 to 10 inches below ground surface) which suggests the potential presence of significant plutonium contamination at depths greater than 10 inches The distribution of americium

Table 2-3

Soil Samples Collected During the Hot Spot Investigation

Sample Location	Sample Number	Depth Collected	Analyses Requested				
			Metals	Radionuclides	VOCs	SVOCs	Pesticides/ PCBs
SS100193 (IHSS 119 1)	SS10002ST	0-0 25	X	X	X	X	X
	SS10003ST	0-1 4	X	X	NS	X	X
		1 4-1 7	NS	NS	X	NS	NS
SS100293 (IHSS 119 1)	SS10004ST	0-0 25	X	X	X	X	X
	SS10005ST	0-2 0	X	X	NS	X	X
		2 0 2 3	NS	NS	X	NS	NS
	SS10006ST	2 0-3 7	X	X	NS	X	X
		3 7-4 0	NS	NS	X	NS	NS
SS100393 (IHSS 119 2)	SS10007ST	0-0 25	X	X	X	X	X
	SS10008ST	0-1 0	X	X	NS	X	X
		1 0-1 3	NS	NS	X	NS	NS
SS100493 (IHSS 119 1)	SS10009ST	0-0 25	NS	NS	X	NS	NS
	SS10010ST	2 0-2 3	NS	NS	X	NS	NS
	SS10011ST	3 3 3 6	NS	NS	X	NS	NS
SS100493 (IHSS 119 1)	SS10001EG*	0 75	X	X	NA	NS	NS
	SS10002EG*	4 5	X	X	NA	NS	NS
	SS10003EG*	9 10	X	X	NA	NS	NS

* Original hot spot location (same location as SS100493) sampled by EG&G 14 and 15 January 1993

NA = Not analyzed resampled at SS100493
NS = Not sampled

Refer to Figure 2 1 for sample locations

Table 2 4

Radionuclides Detected in OU1 Hot Spot Samples[a]

Sample Location	Depth	Americium 241		Plutonium 239 240		Uranium 233 234		Uranium 235		Uranium 238	
		Activity (pCi/g)	+/	Activity (pCi/g)	+/	Activity (pCi/g)	+/	Activity (pCi/g)	+/	Activity (pCi/g)	+/
SS100193	0 0 to 0 25	0 0294	0 0208	0 0735	0 0527	6 09	1 3	0 176	0 066	3 38	0 74
SS100193	0 0 to 1 4	0 0493	0 0505	0 133	0 106	429	101	14 6	4 1	122	29
SS100293	0 0 to 0 25	0 153	0 099	0 429	0 0202	25 4	5 6	0 843	0 358	1 39	0 46
SS100293	0 0 to 2 0	0 192	0 298	0 878	0 598	240	51	6 23	2	1 51	0 75
SS100293	0 0 to 3 7	0 0372	0 0437	0 0539	0 0634	8 27	1 93	0 301	0 179	0 779	0 295
22100393	0 0 to 0 25	4 15	1 27	22 7	5 6	1 49	0 66	0 107	0 214	0 892	0 5
SS100393	0 0 to 1 0	1 9	0 53	14 7	3 4	0 64	0 259	0 0557	0 0812	0 75	0 283
SS100493	0 75	2650	570	11100	2700	9 68	6 32	0	0	4 69	3 96
SS100493	4 0 to 5 0	4260	930	17400	4400	7 46	5 56	0 92	1 85	8 22	5 81
SS100493	9 0 to 10 0	2010	450	6670	1540	0 91	2 33	2 07	3 45	1 22	2 25
881 16[b]	0 0 to 0 25	NA	NA	0 3	0 06	50	190	0	13	1 300	100
881 17[b] (duplicate of 881 16)	0 0 to 0 25	NA	NA	0 78	0 19	19	74	9	6	590	70
881 18[b]	0 0 to 0 25	NA	NA	0 42	0 08	60	230	12	16	3 000	300
881 19[b] (duplicate of 881 18)	0 0 to 0 25	NA	NA	0 09	0 06	10	740	6	6	550	60

Adapted from DOE 1994

[b] Data from Richard Lawton personel communication 1989

NA = Not analyzed

parallels that of plutonium The highest activities (2 000 to 4 260 pCi/g) were also detected in samples from SS100493 (Table 2-4) Considering the extremely low vertical migration potential of plutonium and americium in soils at the RFETS (DOE 1993), and considering the uranium (a more mobile radionuclide) contamination at SS100293 appears confined to the upper 2 feet, it can be reasonably assumed the plutonium/americium contamination at SS100493 is also confined to the upper 2 feet

Plutonium was below background levels at SS100193 and SS100293, but was 22 7 pCi/g at SS100393 (0 to 0 25 inches) located just east of 119 2 This activity is consistent with OU2 surface soil data indicating the 903 Pad as a plutonium source However, the 0- to 1 foot composite sample had an activity of 14 7 pCi/g which is somewhat inconsistent with the near surface contamination hypothesis

2 4 2 2 Organic Contaminants

Polychlorinated Biphenyls (PCBs)

As mentioned PCBs were analyzed in each sample collected from SS100193 SS100293 and SS100393 (Table 2 3) No sample from SS100493 was submitted for PCB analysis Of the seven samples analyzed PCBs (Aroclor 1254) were detected in three of the samples the 0- to 1 4-foot composite at SS100193 (260 micrograms per kilogram [μg/kg]) the 0- to 0 25 inch surface scrape at SS100393 (780 μg/kg) and the 0 to 1 0-foot composite at SS100393 (460 μg/kg) (Table 2 5) The PCB concentrations are similar to those found in samples from nearby surface soil sampling stations (range 132 5 to 1,200 μg/kg) (DOE 1994) The nearby surface soils do not contain hot spot levels of radionuclides therefore it does not appear that fluids associated with released radionuclides contained PCBs, although this cannot be entirely ruled out

Polynuclear Aromatic Hydrocarbons (PAHs)

Eleven PAHs were detected in the hot spot samples collected in OU1 The total PAH concentrations are shown on Table 2 5 Concentrations are similar to the results of the OU1 wide surface soil sampling results PAHs are ubiquitous in surface soils in urban areas and the elevated concentrations do not appear to be associated with waste-related activities at the IHSSs

Volatile Organic Compounds

Toluene was present in samples collected from each of the four hot spot locations and tetrachloroethene (PCE) was present in the sample collected from location SS100493 located in IHSS 119 1 The reported concentrations are summarized in Table 2 5 The toluene results indicate a trend of increasing concentrations with depth The surface samples at each location generally show the lowest concentration, and the highest concentration was generally reported

Table 2-5

Organic Compounds Detected in Hot Spot Samples

Sample Location	Sample Depth	Concentrations (µg/kg)			
		Toluene	PCE	Total PAHs	PCB
SS100193	0-0 25	ND	ND	3219	ND
	0-1 4	NA	NA	ND	260*
	1 4-1 7	100	NA	NA	NA
SS100293	0-0 25	23	ND	2907	ND
	0-2 0	NA	NA	NA	ND
	2 0-2 3	54	ND	NA	NA
	2 0-3 7	NA	NA	ND	ND
	3 7-4 0	69	ND	NA	NA
SS100393	0-0 25	13	ND	4602	780*
	0-1 0	NA	NA	3179	460*
	1 0-1 3	85	ND	NA	NA
SS100493	0-0 25	ND	6	NA	NA
	2 0-2 3	120	170	NA	NA
	3 3-3 6	28	15	NA	NA

Refer to F gure 2 1 for sample locations
Aroclor 1254
NA = Not analyzed
ND = Not detected
µg/kg = micrograms per kilogram

Note Only radiological data exist for hot spots 881 16/17 and 881 18/19

in the deepest interval This is true for each hot spot with the exception of location SS100493 where the highest concentration (120 μg/kg) was found in the middle interval (2 0 to 2 3 feet below ground surface) The deeper interval (3 3 to 3 6 feet) showed a marked decrease in the toluene concentration (28 μg/kg)

PCE was only detected in the samples collected from location SS100493 The lowest concentration was reported in the surface scrape sample (0 to 0 25 inch), and the middle zone (2 0 to 2 3 feet) exhibited the highest concentration of 170 μg/kg The deeper interval, collected at 3 3 to 3 6 feet showed a marked decrease in the PCE concentration (15 μg/kg) which is consistent with the toluene trend

2 4 3 Potential for Radionuclide Migration

At this time radionuclide contamination at the hot spots is confined to small areas However, the radionuclides in the surface soils could be mobilized by wind action (sustained winds over 50 miles per hour are not unusual at RFETS) This mobilization could result in transport of radionuclides to distant downwind locations Winds prevail from the west/northwest Air flow and dispersion characteristics indicate winds come from the mountains to the west turn and move north and northeast along the South Platte River valley and pass west and north of Brighton Colorado The hot spot soils may also be eroded and transported in overland runoff into the Woman Creek drainage Surface water migration is most likely to occur during periods of intense rainfall, such as that associated with the summer thunderstorms common to the RFETS vicinity It appears that the radionuclides are in a chemical form with limited water solubility Limited solubility reduces the potential for radionuclides to leach into deep vadose soils or groundwater The RFI/RI report indicates that radionuclides are not contaminants of OU1 groundwater

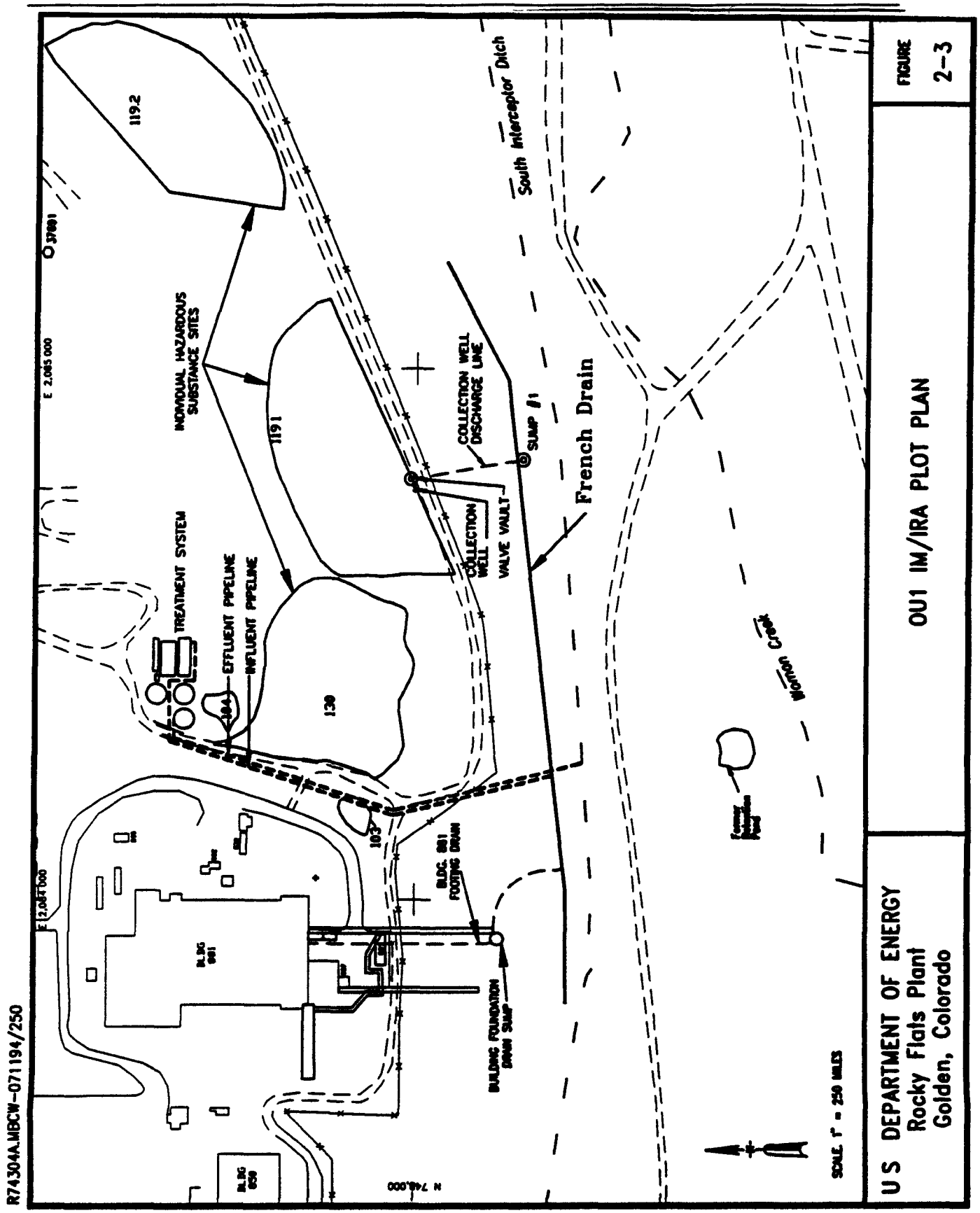
2 5 NATIONAL PRIORITIES LIST (NPL) STATUS

RFETS was proposed for inclusion on the NPL on October 15 1984 pursuant to Section 105 of CERCLA 42 U S C § 9605 and became final on September 21 1989 Accelerated Response Actions are being planned pursuant to the language to modify the current IAG, and 40 CFR 300 415

2 6 OTHER ACTIONS TO DATE

2 6 1 Previous Actions

Previous actions at OU1 include implementation of an IM/IRA to collect and treat contaminated groundwater which began operation in April 1992 (Figure 2 3)


1192
1191
130
103
INDIVIDUAL HAZARDOUS SUBSTANCE SITES
TREATMENT SYSTEM
EFFLUENT PIPELINE
INFLUENT PIPELINE
COLLECTION WELL DISCHARGE LINE
COLLECTION WELL VALVE VAULT
SUMP #1
South Interceptor Ditch
French Drain
Woman Creek
BLDG. 881 FOOTING DRAIN
BUILDING FOUNDATION DRAIN SUMP
BLDG 881
BLDG 850
E 2,085,000
E 2,084,000
N 744,000
SCALE 1" = 250 FEET
R74304A.MBCW-071194/250
U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado
OU1 IM/IRA PLOT PLAN
FIGURE 2-3

Groundwater is collected by a downgradient french drain as well as from a building footing drain (Building 881) and an extraction well and is treated by a system consisting of ultraviolet (UV)/peroxide oxidation for removal of organics and ion exchange for removal of trace metals and salts Treated groundwater is discharged to surface water after it has been treated to meet the Applicable and Relevant and Appropriate Requirements (ARARs) established for OU1 The treatment system capacity is 30 gallons per minute (gpm)

2 6 2 Current Actions

Actions being conducted at OU1 are limited and include normal operation of the French Drain and treatment facility Collected waters are also sampled for subsequent chemical analysis

2 7 STATE AND LOCAL AUTHORITIES' ROLE

2 7 1 State and Local Actions to Date

Through its authority pursuant to the IAG CDH has provided oversight during the RFI/RI process To date neither CDH nor local authorities have taken specific actions to address removal of the hot spots

2 7 2 Potential for Continued State and Local Response

CDH will continue regulatory oversight through the IAG It will not be necessary for local authorities to undertake response actions as the responsibility lies completely with DOE By way of this PAM DOE is aggressively pursuing the removal action

3 0 POTENTIAL THREATS TO PUBLIC HEALTH AND ENVIRONMENT

This Accelerated Response Action is being undertaken because the site conditions specified in 40 CFR 300 415(b)(2) have been observed and the response action can be conducted in less than 6 months per the draft revised IAG Based upon the review of the potential for exposure to and migration of chemicals present in the surface and shallow subsurface soils at the hot spots locations the conditions specified at 40 CFR 300 415(b)(2)(i iv, and v) have been met i e actual or potential exposure to human populations high levels of hazardous substances largely at or near the surface and weather conditions that may cause hazardous substances to migrate

3 1 THREATS TO PUBLIC HEALTH

There are current health risks to workers and future health risks to the public posed by the radionuclides (plutonium and americium) in the hot spot soils (DOE, 1994) The dominant pathways for exposure to the radionuclides are incidental ingestion of soils and inhalation of

dust As shown in Table 3 1, the estimated carcinogenic risk for a current on site worker (security specialist) is 1 1 x 10^{-4} This risk just exceeds EPA s 10^{-6} to 10^{-4} range for acceptable exposure [40 CFR 300 430(e)(2)(i)(A)(2)] The risk to an on site future resident is 2 7 x 10^{-2} if the hot spots are present, and only 9 8 x 10^{-6} if the hot spots are removed (DOE 1994) Although the risk estimation is conservative because the hot spot radionuclide activities were averaged with the other surface soil data without consideration for area weighting, it is clear that the presence of the hot spots have the potential to pose unacceptable health risks

Furthermore the hot spot soils proposed for removal are currently subject to erosion and subsequent migration of radioactive contaminants into the Woman Creek drainage area The potential for migration and spreading of contamination through runoff is increased by permitting the contaminants to remain in place

Table 3-1

Estimated Carcinogenic Risk from Exposure to Plutonium and Americium in OU1 Soils*

Exposure Scenario	Exposure Pathway	Carcinogenic Risk		
		Pu 239 240	Am 241	Total
Current On Site Worker (w/hot spots present)	Ingestion of soil	3 6 x 10^{-6}	1 1 x 10^{-6}	4 7 x 10^{-6}
	Inhalation of dust	8 5 x 10^{-5}	2 x 10^{-5}	1 05 x 10^{-4}
			Total Risk	1 1 x 10^{-4}
Future On Site Resident (w/hot spots present)	Ingestion of soil	1 8 x 10^{-3}	4 5 x 10^{-4}	2 2 x 10^{-3}
	Inhalation of dust	2 1 x 10^{2}	4 3 x 10^{-3}	2 5 x 10^{-2}
			Total Risk	2 7 x 10^{2}
Future On Site Resident (w/hot spots removed)	Ingestion of soil	6 6 x 10^{-7}	1 2 x 10^{7}	7 8 x 10^{7}
	Inhalation of dust	7 9 x 10^{-6}	1 1 x 10^{-6}	9 0 x 10^{-6}
			Total Risk	9 8 x 10^{-6}

*Adapted from DOE 1994

3 2 THREATS TO THE ENVIRONMENT

The RFI/RI concluded that while some contaminants in OU1 soils occur at potentially toxic levels the contaminated areas are not large enough to result in a significant threat to the populations of plants or animals at and in the vicinity of OU1 (DOE 1994) PCBs and PAHs but not radionuclides are at concentrations in surface soils potentially toxic to ecological

receptors The concentrations of PCBs and PAHs in the hot spots are typical of those found sporadically in surface soils at OU1 However the restricted distribution of these contaminants limits the duration and frequency of contact with the receptors, and therefore limits exposure With respect to the radionuclides the activities at the hot spots were lower than the calculated soil activities that are estimated to result in a critical dose of 0 1 rad/day in animal tissues [The International Atomic Energy Agency states that dose rates below 0 1 rad/day do not result in adverse effects in plants or animals (IAEA 1992)] The soil activities that could result in the critical dose are 600 000 pCi/g 560,000 pCi/g and 1 800,000 pCi/g for plutonium americium and uranium respectively The maximum activities in the hot spots for these radionuclides are 17,400 pCi/g, 4,260 pCi/g, and 3,060 pCi/g respectively

4 0 ENDANGERMENT DETERMINATION

Actual or threatened releases of radionuclides from this site if not addressed by implementing the response action selected in this action memorandum may present an imminent and substantial endangerment to the public health

5 0 PROPOSED ACTIONS AND ESTIMATED COSTS

5 1 PROPOSED ACTIONS

5 1 1 Proposed Action Description

The proposed ARA will consist of simple excavation of contaminated surface and shallow subsurface soil The removal will be conducted in accordance with a site specific Health and Safety Plan (HSP) and Sampling and Analysis Plan (SAP) by trained Rocky Flats Environmental Technology Site staff The HSP addresses the physical and chemical hazards associated with the work and the SAP includes the details of the field and laboratory analyses that will be employed to guide the excavation and provide confirmation data that the soils were removed

Prior to excavation of the soils the FIDLER and FGSS will be used to establish baseline radionuclide specific activities at the hot spots The soils will then be excavated using hand tools or a backhoe The hot spots appear to be approximately 3 feet in diameter and approximately 2 feet in depth This equates to a volume of approximately 0 5 cubic yards (yd^3) per hot spot Provision has been made for containerization and storage of up to 1 5 yd^3 of soil per hot spot, if required Hot spot soils will be placed into lined, steel drums as they are excavated Excavation will proceed in 6-inch depth increments and continue until the remaining soil exhibits local background levels of radioactivity as measured with a FIDLER The hot spots have surface activities as measured by a FIDLER that are typically 2 to 100 times local background Therefore 10 FIDLER readings on the local soils surrounding each hot spot will be taken to

establish a mean and standard deviation for local background radiation The mean reading plus 2 standard deviations (the 95th percentile of the local background activity measurements) will be used to define the local background activity at each hot spot

After soils have been excavated to achieve local background levels an additional 6 inches of soil will be excavated to ensure the hot spot has been removed The FGSS will again be used to establish post removal radionuclide specific total activities in the excavation and in the surrounding soil Confirmatory samples will be collected and shipped for off site laboratory analysis (Pu 239 240 Am 241 U 233 234 U 235, and U 238) to document the hot spot was removed and local background levels of radionuclides remain If it is determined local background levels have not been achieved, additional excavation of hot spot(s) will continue until the objective has been met

The HSP identifies the occupational air monitoring and dust control measures that will be utilized during the excavation In preparing the HSP, the Final Plan for Prevention of Contaminant Dispersion (PPCD) (February 1992) was used for specific guidance as to the appropriate actions to take during excavation activities in order to prevent resuspension of contaminated material and limit potential exposure to the workers public and the environment

The maximum measured soil contamination levels of the hot spots have been compared to the Soil Threshold Levels for Zone B in Appendix 5, Attachment A 5 1 of the PPCD Contamination levels in soil were found to be less than the threshold levels Therefore, the excavation is considered a Stage 1 activity For Stage 1 activities occupational air monitoring and dust suppression are nevertheless required

The hot spot removal action is considered a minor excavation, similar to trenching This type of excavation results in minimal soil disturbance with the preferred dust suppression method being spraying the area with clean water Section A 6 3 2 of the PPCD states the method is easily implemented highly effective Manual misting, as defined in the HSP will be conducted as the excavation proceeds Saturation of the soils will not be required, in that a soil moisture content of 10 to 15% is adequate to limit suspension of soils (Section 7, PPCD) Occupational air monitoring conducted during the excavation will include lapel sampling for airborne radioactivity according to *Procedure 4-16300-RO1 04 06 Lapel Air Sampling* with an action level of 1/10 of the Derived Airborne Concentration (DAC)

The excavated material placed in the lined steel drums will be managed in accordance with RCRA/Colorado Hazardous Waste Act (CHWA) and DOE requirements (see Section 5 1 5) Drums of contaminated soil will be placed into storage on the day of generation in accordance with DOE Order 5820 2A It is estimated that the volume of contaminated soil should fill a total of approximately 12 to 36 55 gallon drums for all 6 hot spots It is anticipated that this material will be stored at RFETS RCRA Site 18 04 Although not part of this ARA, the soil will likely be sent to Envirocare in Utah for disposal DOE currently has a contract with Envirocare for

the disposal of low level and low level mixed wastes generated at the Rocky Flats Environmental Technology Site

The proposed ARA will achieve a high degree of performance reliability implementability and safety In terms of performance it will permanently reduce potential public health risks and migration of radionuclides that are posed by the present disposition of the hot spots

Excavation is a reliable technology for removal of contamination and long term operation and maintenance is not required Excavation can also be implemented easily and readily Special permits will not be required and mixed waste storage capacity is available at RFETS for the excavated soils In terms of safety, the hot spots are relatively small and their excavation will not present a risk to the public or result in adverse affects to the environment As mentioned appropriate health and safety precautions will be taken to ensure safety of both workers and the public

5 1 2 Contribution to Remedial Performance

This ARA reduces the potential risk to on site workers associated with exposure to contaminated soil through direct contact or inhalation of suspended particulates and prevents radionuclide migration into the Woman Creek drainage through erosion or surface water transport in overland runoff This is achieved by removing field-detectable radionuclide contamination from the areas thus eliminating the potential for human exposure or radionuclide migration Although the long term cleanup plan for OU1 has not been formulated, the objectives of permanently reducing health risks and contaminant migration potential at OU1 should be consistent with future long term cleanup plans It is noted that this action is not intended to remove all radionuclide contamination or to be a final action for the specific IHSSs Any remaining contamination will be addressed in the OU1 Corrective Measures Study/Feasibility Study The response action will be performed in less than 6 months

5 1 3 Description of Alternative Technologies

A discussion of alternative technologies to land disposal is not required as this ARA does not include treatment and/or disposal of the drummed soils

5 1 4 Engineering Evaluation/Cost Analysis

An Engineering Evaluation/Cost Analysis (EE/CA) is not required for ARAs per the proposed language to modify the current IAG

5 1 5 Applicable or Relevant and Appropriate Requirements

Response actions at Superfund sites must meet two fundamental cleanup requirements First, they must attain a level of cleanup which at minimum, ensures protection of human health and the environment [CERCLA Section 121(d)(1)] Second response actions must attain or exceed the requirements of all applicable or relevant and appropriate federal and state environmental and health standards (ARARs) [CERCLA Section 121(d)(2)] Because this response action will occur on site only the substantive ARARs will apply, administrative requirements (such as permits) need not be met

The hot spot removal action for Operable Unit 1 will meet all federal and state ARARs CERCLA ARARs are divided into three types chemical specific action specific and location specific Chemical specific ARARs are those that set health based or risk based concentration limits for soil, groundwater or surface water for specific pollutants Soil cleanup standards for toluene and tetrachloroethene do not yet exist These standards will be established in the federal rule that is pending, that will revise the hazardous waste identification process (RCRA) There are no chemical specific ARARs for radionuclides in soils However, there are residual soil standards for radionuclides as a class (DOE Order 5400 5) Location specific ARARs are regulations that set restrictions on activities or contaminant levels based on unique characteristics of the site Examples of these are standards under the Wilderness Protection Act the National Register of Historical Places and the National Flood Insurance Program There are no promulgated federal or state chemical specific or location specific ARARs for the removal action The appropriate action specific ARARs are listed specifically in Table 5 1

Federal action specific ARARs for this response action include RCRA standards for generators of hazardous waste and for container storage (42 U S C Section 6901 et seq , and 40 CFR Parts 262 and 264) OSHA standards for worker protection during hazardous waste site remediations (29 U S C Section 651 et seq and 29 CFR Part 1910), Atomic Energy Act (AEA) standards for protecting workers in the handling of radioactive material and standards for storage of radioactive material (42 U S C Section 2201 and 10 CFR Parts 820 and 830 and all applicable DOE Orders pursuant to the AEA)

State action specific ARARs for the removal include CHWA standards for hazardous waste generators and container storage (CRS Section 25 15 101 to 25 15 313 and 6 CCR Section 1007) (These appropriate standards are identical to the federal RCRA standards for large-quantity generators and for container storage and therefore are not repeated) and Colorado Air Pollution Prevention and Control Act standards for air emissions (CRS Section 25 7 101 to 25 7 609 and 5 CCR Section 1001

Table 5-1
Action-Specific ARARs for Hot Spot Removal
Operable Unit 1

Action	Requirement	Prerequisite	Citation	ARAR	Comments
Container Storage (On-Site)	If wastes are stored beyond 90 days generator must comply with storage requirements in Part 264 (detailed below)	Storage of hazardous waste beyond 90 days for large quantity generators	40 CFR 262 34(b)	A	
	Containers of hazardous waste must be • Maintained in good condition • Compatible with hazardous waste to be stored and • Closed during storage (except to add or remove waste)	RCRA hazardous waste (listed or characteristic) held for a temporary period before treatment, disposal or storage elsewhere in a container (i e any portable device in which a material is stored transported disposed of or handled) (40 CFR 264 10)	40 CFR 264 171 40 CFR 264 172 40 CFR 264 173	A	RCRA container storage requirements are applicable
	• Inspect container storage areas weekly for deterioration		40 CFR 264 174		
	• Place containers on a sloped crack free base that is impervious to spills and protect container from contact with any accumulated liquid No containment system necessary for solid materials Remove spilled or leaked waste in a timely manner		40 CFR 264 175		
	• Keep incompatible materials separate Separate incompatible materials stored near each other by a dike or other barrier		40 CFR 264 177		
	• At closure remove all hazardous waste and residues from the storage area and decontaminate or remove all containers		40 CFR 264 178		
	• RCRA hazardous waste generators must put the date storage begins and the words Hazardous Waste on the containers		40 CFR 262 34(a)	R&A	Since storage is long term date on container may not be applicable

Table 5 1
Action-Specific ARARs for Hot Spot Removal
Operable Unit 1

Action	Requirement	Prerequisite	Citation	ARAR	Comments
Hazardous Waste Operation (Excavation and Containing of Soils)	As mandated by SARA OSHA has promulgated regulations that require employers to develop and implement a written safety/health program designed to regulate employee safety and health during hazardous waste operations The safety and health program must include Site-Specific Health & Safety Plan A site health and safety plan must be prepared for each phase of operation	Regulations apply to hazardous substance operations under CERCLA corrective action under RCRA hazardous waste operations that have been designated for cleanup by state or local authorities most operations involving the treatment, storage or disposal of hazardous wastes regulated under RCRA and emergency response operations for releases or threats of releases of hazardous substances	29 CFR 1910 120	A	
	Site Control Implement site control zones to minimize employee exposure to hazardous substances		29 CFR 1910 120(d)	A	Site control zones will be defined in site-specific health and safety plans
	• Training Initial training and refresher training required before employee is permitted to engage in site activities		29 CFR 1910 120(e)	A	Personnel engaged in remedial actions at OU1 are required to meet minimum training requirements as specified in the OSHA standards
	Medical Surveillance Employers must implement medical surveillance for employees potentially exposed to hazardous substances		29 CFR 1910 120(f)	A	
	• Engineering Controls, Work Practices, and Personal Protective Equipment One or all of these shall be used to minimize exposure of employees to hazardous substances and health hazards		29 CFR 1910 120(g)	A	

Table 5-1
Action-Specific ARARs for Hot Spot Removal
Operable Unit 1

Action	Requirement	Prerequisite	Citation	ARAR	Comments
Hazardous Waste Operation (Excavation and Containing of Soils) (Continued)	Monitoring Monitoring of exposures of employees to hazardous substances is required to determine the efficacy of protective equipment and engineering controls		29 CFR 1910 120(h)	A	
	Information Programs Employees, contractors and subcontractors shall be informed of the degree and nature of hazards associated with site activities		29 CFR 1910 120(i)	A	All personnel involved in site activities will be required to read and comply with the site safety plan The safety plan will outline the anticipated physical and chemical hazards
	• Material Handling Hazardous substances contaminated soils liquids or other residues shall be handled transported, and labeled according to subsection (j) of the OSHA standard		29 CFR 1910 120(j)	A	DOT specification containers will be used to handle store or transport.
	• Decontamination Decontamination procedures outlined in subsection (k) of the standard must be complied with during on-site remedial action		29 CFR 1910 120(k)	A	
	• Site Excavation Site excavations must be shored or sloped to prevent collapse		29 CFR 1910 120/1926	A	
	• Contractors and Subcontractors Employers must inform contractors or subcontractors of potential hazards associated with site activities		29 CFR 1910 120	A	
Container Storage (PCB)	PCBs at concentrations of 50 ppm or greater and PCB items with a concentration of 50 ppm or greater are subject to storage requirements under 40 CFR 761 65	Waste oils fluids or other waste material containing PCBs above 50 ppm must be handled according to TSCA regulations	40 CFR 761 65	Not an ARAR	Not Subject to this requirement PCB content in soils < 50 ppm

Table 5-1
Action Specific ARARs for Hot Spot Removal
Operable Unit 1

Action	Requirement	Prerequisite	Citation	ARAR	Comments
Soil Cleanup (PCB)	Existing spills are excluded from the spill cleanup policy	The hot spot removal also is exempted because it is an apparent existing spill	40 CFR 761 120		This apparent historical spill of PCB is exempt from CFR 40 Part 761 Subpart G
Storage	Ensure protection of public health and safety External exposure to waste and concentrations of radioactive material which may be released into surface water groundwater soil, plants and animals can only result in an effective dose equivalent not exceeding 25 mrem/yr to any member of the public Ensure that committed effective dose equivalents received by individuals who inadvertently intrude into facility after 100 years will not exceed 100 mrem/yr for continuous exposure or 500 mrem for a single acute exposure • Protect groundwater resources	DOE facilities must comply with DOE Orders pertaining to health and safety and protection of workers from radiation	DOE Order 5820 2A Chapter III	A	
	Storage facility must be monitored for migration of radionuclides Monitor surface soil and air Maintain records for all low level waste that enters and leaves the storage facility Purpose of storage may be to allow nuclides to decay or to store wastes until disposal method becomes available		DOE Order 5820 2A Chapter III	A	
Excavation and Storage	Comply with all applicable environmental protection safety and health standards	DOE facilities must comply with DOE Orders and promulgated DOE regulations in 10 CFR concerning environmental health and safety	DOE Order 5480 4	A	

Table 5 1
Action Specific ARARs for Hot Spot Removal
Operable Unit 1

Action	Requirement	Prerequisite	Citation	ARAR	Comments
	Comply with dose limits for protection of public and limits for residual radioactive material in environment		DOE Order 5400 5	A	
	Comply with generally applicable nuclear safety standards in this rule		10 CFR 830[b] (59 FR 15843 Final Rule)	A	
	Develop and implement quality assurance program		10 CFR 830 120[b] (59 FR 15843 Final Rule)	A	
	• Occupational exposure to workers must be maintained within acceptable limits and as far below the limits as is reasonably achievable Comply with Limiting Values for radiation exposure		10 CFR 835[c] (59 FR 65458 Final Rule)	A	
Excavation	Personnel conducting storage and handling operations from which fugitive particulate emissions will be emitted must use all available practical methods to minimize the emissions Personnel may use enclosures cover compacting watering limitation of fines and other methods There may be no off-property emissions		Regulation 1 CO Air Quality Control Commission III D 1 III D 2 c		
	Residual concentrations of Radionuclides (general) in soil should be derived from the basic dose limits (100 mrem effective dose equivalent in one year) by an environmental pathway analysis (See DOE/CH-8901)		DOE Order 5400 5 Chapter IV	A	

[a] Colorado regulations pursuant to the Colorado Hazardous Waste Act for hazardous waste generators and container storage are identical to federal RCRA standards Therefore they are not repeated (6 CCR 1007 3)

[b] This order (5700 6c) has been codified (10 CFR 830 120) in the April 15 1994 Federal Register (59 FR 15843)
This order (5480 11) has been codified (10 CFR) in the December 14 1993 Federal Register (58 FR 65458)

NOTE DOE Order 5400 3 Hazardous Waste and Radioactive Mixed Waste Program was cancelled as of August 1994

Colorado s Radiation Control Act applies to parties licensed or registered under the state program Because DOE has its own licensing program it is not licensed by the State of Colorado Therefore the Colorado Radiation Control Act is not applicable to this action or to the Rocky Flats Environmental Technology Site

5 1 6 Project Schedule

Assuming the ARA begins September 20 1994, as originally scheduled, 5 working days are allowed for mobilization followed by 10 working days for the hot spot removal, sampling, and waste transfer to permitted storage and a final 2 working days are allowed for demobilization/decontamination The ARA is thus expected to be completed by October 12 1994

5 2 COST

As shown in Table 5 2 the total estimated cost for removal of the six hot spots is $229,000 The scope estimate considers the cost of planning, soil removal packaging, and storing and reporting There is no operation and maintenance cost associated with excavation and storage of the soil The estimate does not include any costs for analysis, treatment or disposal of the soils

Table 5-2

OU1 Hot Spot Removal Costs

Capital	Cost ($)
Project Management	75 600
Field Mobilization	13 100
Soil Removal	72 300
Waste Transfer	7 100
Demobilization (Decontamination)	9 600
Reporting	31 000
Contingency	20,300
Subtotal Capital Cost	229 000
Operation and Maintenance	0
Subtotal O&M Cost	0
TOTAL COST	229 000

6 0 EXPECTED CHANGE IN THE SITUATION SHOULD ACTION BE DELAYED OR NOT TAKEN

Any delay in the proposed removal action will result in additional potential unacceptable exposure of on site workers to radionuclides through direct contact and particulate inhalation and further environmental migration through wind action and surface water runoff from summer showers Therefore removal of the hot spots prior to the final remedial action at OU1 is necessary

7 0 RECOMMENDATION

DOE intends to initiate the proposed removal action by September 20, 1994

8 0 REFERENCES

DOE (U S Department of Energy) 1993 *Preliminary Draft Phase II RFI/RI Report 903 Pad Mound and East Trenches Areas (Operable Unit No 2)* Department of Energy, Rocky Flats Plant Golden Colorado December 1993

DOE (U S Department of Energy) 1994 *Final Phase RFI/RI Report 881 Hillside Area (Operable Unit No 1)* Department of Energy Rocky Flats Plant, Golden, Colorado, June 1994

IAEA (International Atomic Energy Agency) 1992 *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards* Technical Reports Services 332 IAEA Vienna