

U. S. Department of Energy
Radionuclide Air Emissions Annual Report
(under Subpart H of 40 CFR Part 61)
Calendar Year 1991

Site Name: Rocky Flats Plant

Operations Office Information

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Rocky Flats Plant
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Site Information

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Section I. Facility Information

Site Description

The Rocky Flats Plant (RFP) is part of a nationwide nuclear weapons research, development, and production complex. RFP is operated by EG&G Rocky Flats, Inc., with oversight by the Rocky Flats Office of the U. S. Department of Energy. Previous to February, 1992, the primary mission of RFP was the fabrication of nuclear weapons components. RFP fabricated nuclear weapons components from plutonium (Pu), uranium (U), beryllium (Be), and stainless steel. Production activities included metal fabrication and assembly, chemical recovery and purification of process-produced transuranic radionuclides, and related quality control functions. Plutonium operations were discontinued at RFP in 1989 to address safety concerns. Recent changes in national defense policy have canceled plans for resumption of nuclear weapons component production and accelerated transition planning for future uses and scheduled remediation activities at RFP. A list of radioactive materials used or that could be potentially used at RFP is included in Appendix A.

RFP occupies an area of 6,550 acres in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver. Main production facilities are located near the center of RFP within a fenced security area of 384 acres. The remaining plant area contains limited support facilities and serves as a buffer zone to major production areas. A simplified map of RFP is shown in Figure 1.

Approximately 2 million people live within a 50-mile radius of RFP. Adjacent land use is a mixture of agriculture, open space, industry, and low-density residential housing. Surrounding communities consist of the city of Golden to the south of the plant, the cities of Arvada and Westminster to the east, and the city of Boulder to the north.

Climate at RFP is characterized by dry, cool winters and warm summers. Elevation and major topographical features significantly influence meteorological dispersion characteristics of the site. Winds, though variable, are predominantly northwesterly. Annual precipitation averages slightly greater than 15 inches with more than 80 percent occurring between April and September. Annual maximum and minimum temperatures average 76 °F and 22 °F, respectively.

RFP is situated at an elevation of about 6,000 feet on the eastern edge of a geological bench known locally as Rocky Flats. This bench, about 5 miles wide in an east-west direction, flanks the eastern edge of the Rocky Mountains. To the east, topography slopes gradually at an average downgrade of 95 feet per mile. Approximately 20 miles to the west, the Continental Divide rises to elevations exceeding 14,000 feet.

RFP is situated on the Rocky Flats Alluvium, an alluvial fan deposit, varying in thickness from 0 to 100 feet providing a gravelly cover over bedrock. Underlying bedrock formations consist primarily of claystone. Seismic activity of the area is low, as is the potential for landslides and subsidence.

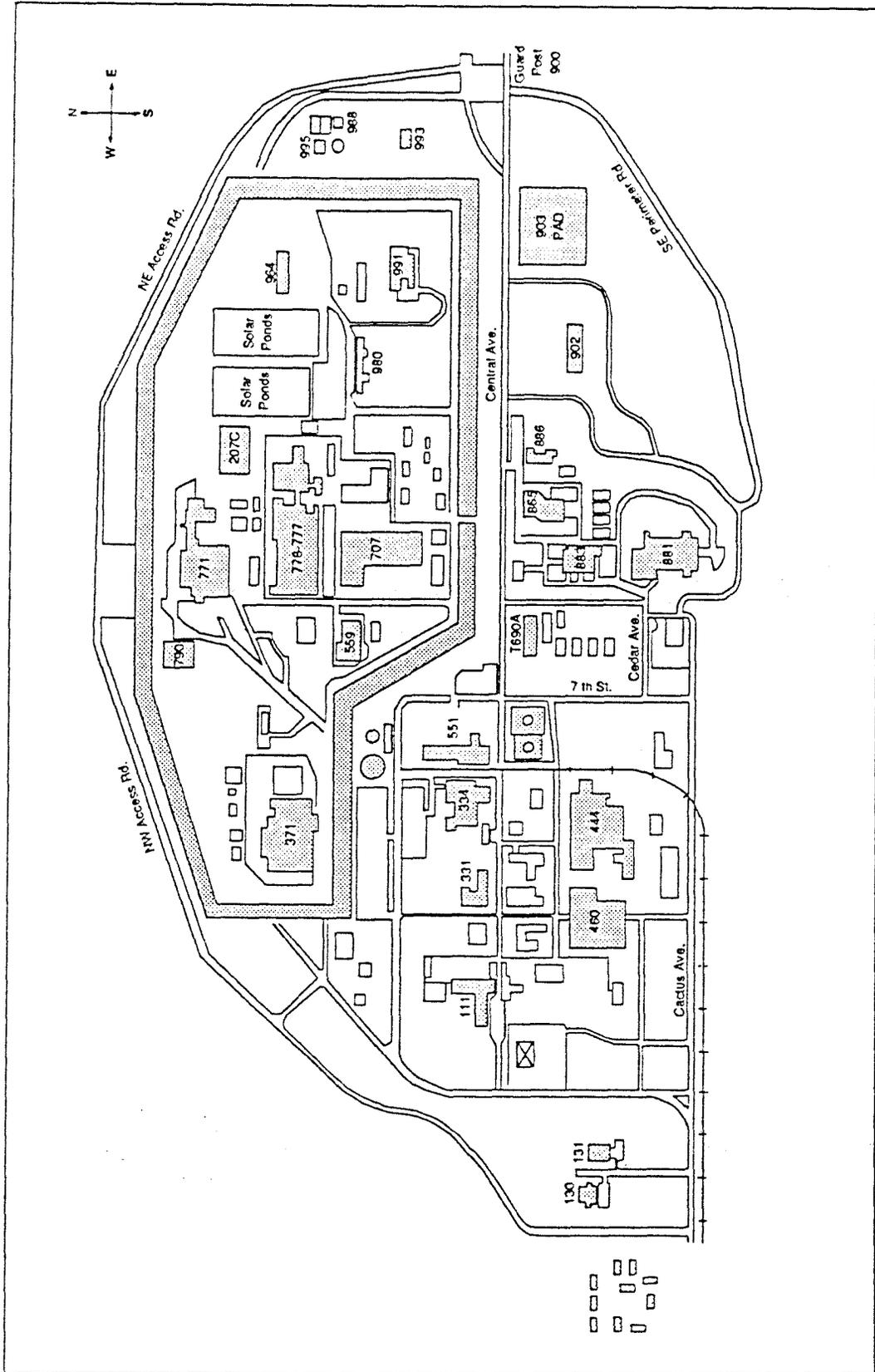


Figure 1
Rocky Flats Plant

Surface drainage generally occurs in a west to east pattern along five ephemeral streams within RFP. North Walnut Creek, South Walnut Creek, and an interceptor ditch (in the Woman Creek drainage) drain the main plant facilities area. Surface water discharges from RFP are diverted around two downstream municipal water supplies; Great Western Reservoir and Standley Lake.

Source Description

RFP can be roughly divided into halves. The Protected Area, generally located in the north half of the plant, is primarily involved with Pu processing operations. The rest of the plant generally involves U, Be, and stainless steel operations. Transuranic material processing is performed in gloveboxes. Processing operations in the gloveboxes can result in particulate matter being released and entrained in the glovebox effluent. Exhaust effluent is filtered for particulate matter through multiple stages of high efficiency particulate air (HEPA) filters. Reported radionuclide emissions are believed to be a result of primarily resuspended residual radioactive material in the ventilation systems. No routine nuclear weapons related processing will occur or has occurred since 1989. Handling of radioactive material at RFP currently involves waste processing and analytical operations.

Section II. Air Emissions Data

RFP continuously samples for radionuclides in the form of particulate matter in 63 ducts and vents downstream of the HEPA filters. RFP believes that many of the ducts and vents currently monitored continuously have associated potential source terms that are less than those for which such monitoring is required under 40 CFR 61.93(b)(4). RFP will continue to monitor the emissions from all of these locations until it is determined which locations fall under the continuous monitoring requirements of the regulation. Six ducts are sampled for tritium.

Air effluent from areas involving the processing of Pu and Am is filtered by a minimum of four stages of HEPA filters. Air effluent from areas involving the processing of primarily U is generally filtered by a minimum of two stages of HEPA filters. Filters are bench tested prior to installation to ensure that they meet a minimum filter efficiency of 99.97 percent. The filters are tested with a dioctylphthalate aerosol of a nominal 0.3 micrometer particle size. Filters are tested again for leaks following installation into a filter stage/plenum.

Depending on the source, RFP samples for Pu-238, Pu-239/240, americium (Am)-241, U-233/234, U-238, and tritium. RFP also has some quantities of beta and gamma emitting sealed sources and low activity analytical stock solutions, powders, and plated sources. Effluent sampling is not performed for these beta/gamma emitting radionuclides because of their low activity and/or non-dispersable form.

RFP main production facilities cover an area of 384 acres. The longest and shortest distance between an emission point and the nearest receptor (a residence) is 2.8 miles and 2.2 miles, respectively. The distance from the center of the plant to the nearest receptor is 2.45 miles. This distance was used as input data in the air dispersion model AIRDOS-PC, which was used to calculate the maximum effective dose equivalent (EDE) to the public. The following is a breakdown of all point sources. A study, scheduled to be completed by December, 1992, will determine which of the following sources has the uncontrolled (without HEPA filtration) potential to result in an EDE to the public of 0.1 millirem and, therefore, requires continuous effluent monitoring under 40 CFR 61.93(b)(4).

<u>Point Sources</u>	<u>Type Control</u>	<u>Minimum Efficiency per Filter¹</u>	<u>Distance to Receptor</u>
<u>Uranium Processing</u>			
444-D05	HEPA	99.97	2.6 miles
444-MAI	HEPA	99.97	2.6 miles
447-MAI	HEPA	99.97	2.6 miles
865-EEE	HEPA	99.97	2.3 miles
865-WWW	HEPA	99.97	2.3 miles
881-MA1	HEPA	99.97	2.3 miles
881-MA2	HEPA	99.97	2.3 miles

¹ Based on results of HEPA filter bench testing.

<u>Point Sources (cont.)</u>	<u>Type Control</u>	<u>Minimum Efficiency per Filter</u>	<u>Distance to Receptor</u>
881-MA3	HEPA	99.97	2.3 miles
881-MA4	HEPA	99.97	2.3 miles
883-AAA	HEPA	99.97	2.3 miles
883-BBB	HEPA	99.97	2.3 miles
883-CCC	HEPA	99.97	2.3 miles
886-875	HEPA	99.97	2.3 miles
889-MAI	HEPA	99.97	2.4 miles
<u>Plutonium Processing</u>			
371-N01	HEPA	99.97	2.8 miles
371-N02	HEPA	99.97	2.8 miles
371-SSS	HEPA	99.97	2.8 miles
374-MAI	HEPA	99.97	2.8 miles
374-SPD	HEPA	99.97	2.8 miles
559-561	HEPA	99.97	2.5 miles
707-101	HEPA	99.97	2.5 miles
707-102	HEPA	99.97	2.5 miles
707-105	HEPA	99.97	2.5 miles
707-106	HEPA	99.97	2.5 miles
707-107	HEPA	99.97	2.5 miles
707-108	HEPA	99.97	2.5 miles
707-R21A	HEPA	99.97	2.5 miles
707-R21B	HEPA	99.97	2.5 miles
707-R22A	HEPA	99.97	2.5 miles
707-R22B	HEPA	99.97	2.5 miles
707-R23A	HEPA	99.97	2.5 miles
707-R23B	HEPA	99.97	2.5 miles
707-R24A	HEPA	99.97	2.5 miles
707-R24B	HEPA	99.97	2.5 miles
707-R25A	HEPA	99.97	2.5 miles
707-R25B	HEPA	99.97	2.5 miles
707-R26A	HEPA	99.97	2.5 miles
707-R26B	HEPA	99.97	2.5 miles
707-R27A	HEPA	99.97	2.5 miles
707-R27B	HEPA	99.97	2.5 miles
707-R45A	HEPA	99.97	2.5 miles
707-R45B	HEPA	99.97	2.5 miles
707-R46A	HEPA	99.97	2.5 miles
707-R46B	HEPA	99.97	2.5 miles
771-CMA	HEPA	99.97	2.6 miles
771-CRM8	HEPA	99.97	2.6 miles
771-CRM10	HEPA	99.97	2.6 miles
771-MAI	HEPA	99.97	2.6 miles
774-202	HEPA	99.97	2.6 miles
776-201	HEPA	99.97	2.5 miles
776-202	HEPA	99.97	2.5 miles

<u>Point Sources (cont.)</u>	<u>Type Control</u>	<u>Minimum Efficiency per Filter</u>	<u>Distance to Receptor</u>
776-204	HEPA	99.97	2.5 miles
776-205	HEPA	99.97	2.5 miles
776-206	HEPA	99.97	2.5 miles
776-207	HEPA	99.97	2.5 miles
776-250	HEPA	99.97	2.5 miles
776-251	HEPA	99.97	2.5 miles
776-252	HEPA	99.97	2.5 miles
778-LDY	HEPA	99.97	2.5 miles
779-729	HEPA	99.97	2.4 miles
779-782	HEPA	99.97	2.4 miles
991-985	HEPA	99.97	2.2 miles
991-MAI	HEPA	99.97	2.2 miles

Following are the total 1991 radionuclide stack effluent emissions from RFP.

<u>Radionuclide</u>	<u>Annual Quantity (Curies)</u>
Pu-238	2.96 E-08
Pu-239/240	8.43 E-07
Am-241	1.50 E-07
U-233/234	6.29 E-07
U-238	1.00 E-06
Tritium	4.76 E-03

In addition, DOE facilities are required to include in the annual report the distance from the points of release to the nearest farm producing vegetables, meat, and milk. The shortest distance between an RFP radionuclide release point and farmland producing agricultural products is as follows:

- cropland (wheat) -- 1.25 miles;
- beef cattle -- 1.8 miles; and
- dairy cows -- 5.6 miles.

Section III. Dose Assessments

Description of Dose Model

RFP used the dose model AIRDOS-PC (Version 3.0) for calculating the EDE to the public.

Summary of Input Parameters

The nearest receptor is a residence 2.45 miles (3,942 meters) from the center of the RFP production area. This distance was used as input data for the dispersion model. The plant was divided into quadrants for simplicity. A stack height and diameter for each quadrant and the corresponding emissions for each quadrant were entered into the dispersion model. The stack height and diameter for the stack with the highest emission in a particular quadrant was entered for that quadrant. These data are available in the compliance report in Appendix B.

RFP wind rose data were entered into the model and are available in the compliance report in Appendix B. The 1991 total precipitation at RFP was 40.8 centimeters (cm) with an average annual temperature of 9.5 degrees Celsius (°C). A lid height of 1,405 meters (m) was used in the model. The buoyant factor for effluent emission was assumed to be 0.0 calories per second (cal/s), since the plant effluents tend to be near ambient temperature. AIRDOS-PC default values were used for the activity median aerodynamic diameter (AMAD) and solubility class.

The effective dose equivalent (EDE) to the nearest receptor was calculated using point source release data and does not include diffuse sources. Diffuse sources are discussed in Section IV.

Compliance Assessment

Effective Dose Equivalent: 4.38 E-05 mrem

Highest Organ Dose was to
Endosteum: 4 E-04 mrem

Location of Maximally
Exposed Individual: Southeast of RFP, corner of Indiana Street and 96th Street

Section IV. Supplemental Information

- The collective effective dose equivalent for 1991 releases was 0.005 person-rem for point sources and 0.9 person-rem for the 903 Pad area (fugitive source).
- There were no unplanned releases of radionuclides to the atmosphere from RFP during 1991.
- All effluent point sources (listed in Section II) are continuously monitored (sampled).
- In February 1992, EPA's Office of Radiation and Office of Air Quality Planning and Standards determined that "diffuse" or fugitive emission sources are subject to the requirements of 40 CFR 61, Subpart H (memorandum dated 2/11/92). The Region VIII Office subsequently requested that, if possible, RFP include fugitive emissions estimates in the calculation of EDE for 1991 and succeeding years (letter to J. O. Zane, March 26, 1992). Current waste history profiles contained in work plans for RFP operable units (OUs) indicate that six of 16 OUs have possible surface contamination with potential for release as fugitive emissions. Although the six OUs may comprise all potential fugitive radionuclide emissions sources at the facility, RFP will evaluate other data during 1992 to determine whether more fugitive sources exist at the site. The six OUs with potential fugitive emissions are:

Diffuse Sources

OU 1 - 881 Hillside

OU 2 - 903 Pad Area, East Trenches Area

OU 3 - Off-Site Areas

OU 4 - Five Solar Ponds: 207A, 207B North, 207B Center, 207B South, 207C

OU 6 - Walnut Creek Drainage

OU 11 - West Spray Fields

An emission term and resulting dose currently is available only for the 903 Pad area. The 903 asphalt pad, where radioactive waste drums were stored, involves contaminated soil resuspension near the 903 pad as a result of drum leakage. It was estimated in the 1980 RFP Environmental Impact Statement (EIS) that between 1959 and 1969, about 11 curies (Ci) of Pu leaked from the steel storage drums containing contaminated cutting oil. The 1980 RFP Environmental Impact Statement estimated a soil resuspension release of 2.2 E-02 Ci/yr of Pu-241, 4.4 E-03 Ci/yr of Pu-238/239/240, and 8.8 E-04 Ci/yr of Am-241 from an approximate area of 6.7 E+05 m^2 . A more recent published study (Appendix C) conducted at RFP indicates Pu-239/240 alpha activity resuspension releases of approximately 200 microcuries per year.

This source term was used to calculate the dose from the 903 Pad diffuse source. Resuspension of Am-241 is estimated by multiplying the amount of Pu-239/240 by a factor of 0.205 (41 microcuries/year). Resuspension of Pu-238 is estimated by multiplying the amount of Pu-239/240 by a factor of 0.0239 (4.78 microcuries/year). Resuspension of Pu-241 is estimated by multiplying the amount of Pu-239/240 by a factor of 5.207 (1000 microcuries/year). These ratios or factors are based on the typical isotopic mix of weapons-grade plutonium. (Rocky Flats Plant 1990 Site Environmental Report).

The 903 Pad is approximately 3,331 m from the nearest receptor (residence). The computer dispersion model AIRDOS-PC (Version 3.0) was used to calculate an effective dose equivalent from soil resuspension of 0.0093 mrem/yr with the highest organ dose to the Endosteum of 0.12 mrem/yr. The AIRDOS-PC calculation and other associated input data may be found in Appendix D.

- RFP handles only small quantities of Radon-226, U-232 and Thorium-232 as stock analytical solutions. This information is detailed in Appendix A.
- None of the 63 radionuclide effluent emission points at RFP meets all of the monitoring protocol requirements of 40 CFR 61.93(b). However, because of the change in mission at RFP, most of the effluent emission points may be below the emission threshold (0.1 mrem) requiring continuous effluent sampling. In that event, upgrades to current effluent sampling systems for compliance will not be necessary. A study to determine which effluent emission points require effluent sampling will be completed by December, 1992. Of those locations where continuous effluent sampling is required, system upgrades will be evaluated to achieve compliance or the existing system will be proposed to EPA for approval as an alternative monitoring technique.

RFP had pursued a Federal Facilities Compliance Agreement (FFCA) with EPA Region VIII that would allow RFP time to determine its compliance with the statute and to upgrade the systems or pursue alternative methods of monitoring as allowed under EPA 40 CFR 61.93 (b)(3). EPA Region VIII decided that an FFCA was inappropriate and issued EG&G Rocky Flats, Inc., an Administrative Compliance Order (ACO) on March 3, 1992. The ACO requires EG&G to complete four investigative projects (particle size study, isokinetic sampling study, velocity profiling study, and an "as built" duct drawings study) within 270 days (December 10, 1992) of the effective date of the order (March 15, 1992). The ACO also requires individual duct assessment packages to be submitted to EPA within 300 days (January 9, 1993) from the effective date of the order and complete all physical upgrades within 365 days (March 15, 1993) of the effective date of the order.

EG&G can complete the four investigative studies by December 10, 1992, and the sixty two (one has already been submitted to the EPA) duct assessment packages thirty days later. However, completing all required physical upgrades within 365 days is not possible. This may result in civil action by EPA Region VIII.

Preliminary cost estimates for achieving compliance with the regulation have been estimated between \$5M and \$30M. The cost will be better defined in the first half of 1993 when the scope of the noncompliance and needed corrective actions has been determined.

- Most elements of the quality assurance (QA) program described by Appendix B, Method 114, are in place. However, combining all elements into a formal quality assurance plan/program has not been completed. As the scope of the radionuclide effluent monitoring program at RFP is more defined (through the plant transition process from nuclear weapons production to environmental restoration), the quality assurance plan/program will be revised and formalized.

- The following are the 1991 radionuclide releases from RFP by building.

<u>Building</u>	<u>Radionuclide Release (Ci)</u>					
	<u>Pu-238</u>	<u>Pu-239/240</u>	<u>Am-241</u>	<u>U-233/4</u>	<u>U-238</u>	<u>H-3</u>
371	4.8E-09	1.2E-07	2.4E-08	1.2E-07	1.1E-07	0
374	2.7E-09	6.3E-08	2.6E-08	7.3E-08	9.8E-08	0
444	0	0	0	5.7E-08	6.7E-08	0
447	0	0	0	2.5E-08	3.2E-08	0
559	3.7E-10	1.2E-08	4.6E-09	1.8E-08	2.5E-08	0
707	2.5E-09	4.0E-08	4.7E-09	2.8E-08	4.9E-08	3.4E-05
771	5.8E-09	8.7E-08	1.4E-08	4.2E-08	1.1E-07	0
774	3.5E-11	3.1E-09	2.9E-10	4.0E-10	1.3E-09	0
776	7.8E-09	4.4E-07	5.0E-08	5.4E-09	8.3E-08	3.5E-03
778	6.9E-10	2.1E-08	3.3E-09	1.4E-08	6.2E-08	0
779	1.1E-09	1.4E-08	2.2E-09	9.6E-09	1.8E-08	1.2E-03
881	3.7E-09	3.0E-08	1.7E-08	7.1E-08	1.0E-07	0
883	0	0	0	1.3E-07	1.7E-07	0
865	0	0	0	3.6E-08	5.5E-08	0
886	1.5E-11	1.8E-09	2.6E-10	4.1E-09	5.1E-09	0
889	2.0E-10	2.1E-09	1.1E-09	-4.1E-09	-3.4E-09	0
991	-6.8E-11	7.5E-09	2.2E-09	9.5E-09	1.3E-08	0

Certification

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fine and imprisonment. (See 18 U. S. C. 1001.)

Terry A. Vaeth
Manager, Rocky Flats Office
Department of Energy

Signature: Terry Vaeth Date: 6/30/92

Appendix A

Radioactive Materials at Rocky Flats Plant

RADIOACTIVE MATERIALS ASSOCIATED WITH RFP

A. RADIOACTIVE MATERIALS HANDLED IN KILOGRAM QUANTITIES

1. Plutonium

ISOTOPIC COMPOSITION OF RFP PLUTONIUM

Isotope	Relative Weight (percent)	Specific Alpha Activity (Curies/gram)	Specific Beta Activity (Curies/gram)	Relative ^a Activity (Curies/gram)
Pu-238	0.01	17.01	-	0.00171
Pu-239	93.79	0.0622	-	0.05834
Pu-240	5.80	0.228	-	0.01322
Pu-241	0.36	-	103.5	0.37260
Pu-242	0.03	0.00393	-	1.18 x 10 ⁻⁶
AM-241	b	3.42	-	-

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 curies/gram
 Alpha plus beta 0.446 curies/gram

b AM-241 is a radioactive decay product of Pu-241.

2. Enriched Uranium

Common Name - Oralloy
 Normal Isotopic Composition >90% U-235

3. Depleted Uranium

Common Names - Tuballoy, D-38, U-238
 Normal Isotopic Composition <0.71%, U-235

4. Americium Am-241

5. Natural Uranium, Thorium, and Uranium-233

RFP has both the capability and potential to handle these in kilogram quantities. Some of these materials have been handled in the past.

B. RADIOACTIVE MATERIALS HANDLED IN GRAM QUANTITIES (<1Kg)

Curium-244

Neptunium-237

Uranium-233

Plutonium-238, 242

These radioisotopes can be used at RFP primarily for research and analytical activities.

C. RADIOISOTOPES USED AT RFP AS REGISTERED AND/OR ACCOUNTABLE SOURCES

1. Registered Sources - Twice Yearly Leak Test and Physical Audit:

Sealed solids >10 μ Ci

Plated >1 μ Ci

Liquids > 10⁻³ μ Ci

Americium	(Am-241)	Plutonium	(Pu-236,238,239)
Antimony	(Sb-124)	Promethium	(Pm-147)
Barium	(Ba-133)	Radium	(Ra-226)
Cadmium	(Cd-109)	Selenium	(Se-75)
Californium	(Cf-252)	Silver	(Ag-110m)
Cesium	(Cs-137)	Sodium	(Na-22)
Cobalt	(Co-57,60)	Strontium	(Sr-90)
Hydrogen (Tritium)	(H-3)	Thallium	(Tl-204)
Iridium	(Ir-192)	Uranium	(U-235)
Iron	(Fe-55)	Ytterbium	(Yb-169)
Nickel	(Ni-63)	Yttrium	(Y-88)

2. Accountable Sources - Yearly Sealed Solids < 10 μ Ci		Accountability Plated < 1 μ Ci	
Liquids < 10 ⁻³ μ Ci		Analytical stock solutions	
Aluminum	(Al-26)	Lead	(Pb-210)
Americium	(Am-241,243)	Manganese	(Mn-54)
Antimony	(Sb-125)	Mercury	(Hg-203)
Argon	(Ar-39)	Neptunium	(Np-237)
Barium	(Ba-133)	Nickel	(Ni-63)
Beryllium	(Be-7)	Plutonium	(Pu-236,238,239,240,241,242,244)
Bismuth	(Bi-207,210)	Polonium	(Po-210)
Cadmium	(Cd-109)	Promethium	(Pm-147)
Californium	(Cf-250,252)	Radium	(Ra-226)
Carbon	(C-14)	Ruthenium	(Ru-106)
Cesium	(Cs-137)	Selenium	(Se-75)
Chlorine	(Cl-36)	Silver	(Ag-110m)
Cobalt	(Co-57,60)	Sodium	(Na-22)
Curium	(Cm-244,246)	Strontium	(Sr-85,90)
Europium	(Eu-152,154,155)	Technetium	(Tc-99m)
Holmium	(Ho-166m)	Thallium	(Tl-204)
Hydrogen (Tritium)	(H-3)	Thorium	(Th-228,230,232)
Iodine	(I-129,131)	Tin	(Sn-113)
Iron	(Fe-55)	Uranium	(U-232,233,234,235,236)
Krypton	(Kr-85)	Yttrium	(Y-90)
		Zinc	(Zn-65)

Appendix B

AIRDOS-PC Compliance Report Point Sources

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

CLEAN AIR ACT COMPLIANCE REPORT
(Version 3.0 November 1989)

Facility: EG&G Rocky Flats Plant
Address: P.O. Box 464
 Golden, CO. 80402-0464
Annual Assessment for Year: 1991
Date Submitted: 5/28/92

Comments: Annual Air Emissions Report for CY 1991

Prepared By:

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Office of Radiation Programs
Washington, D.C. 20460

Facility: EG&G Rocky Flats Plant

Address: P.O. Box 464

City: Golden

State: CO

Comments: Annual Air Emissions Report for CY 1991

Year: 1991

Dose Equivalent Rates to Nearby
Individuals (mrem/year)

Effective
Dose Equivalent

4.38E-05

Highest Organ
Dose is to
ENDOSTEUM

0.0004

-----EMISSION INFORMATION-----

Radio-nuclide	Class	Amad	Stack 7xx991 (Ci/y)	Stack 3xx559 (Ci/y)	Stack 8xx (Ci/y)	Stack 4xx (Ci/y)
PU-239	Y	1.0	6.3E-07	2.0E-07	3.8E-08	0.0E-01
AM-241	W	1.0	7.7E-08	5.5E-08	1.9E-08	0.0E-01
U-234	Y	1.0	1.1E-07	2.1E-07	2.3E-07	8.1E-08
U-238	Y	1.0	3.4E-07	2.4E-07	3.3E-07	9.8E-08
H-3	*	0.0	4.8E-03	0.0E-01	0.0E-01	0.0E-01
Stack Height (m)			12.59	12.50	10.33	5.12
Stack Diameter (m)			0.91	4.57	2.44	4.57
Buoyant (cal/s)			0.0E-01	0.0E-01	0.0E-01	0.0E-01

-----SITE INFORMATION-----

Wind Data	RFONEW91.WND	Temperature (C)	10
Food Source	LOCAL	Rainfall (cm/y)	41
Distance to Individuals (m)	3942	Lid Height (m)	1405

*NOTE: The results of this computer model are dose estimates. They are only to be used for the purpose of determining compliance and reporting per 40 CFR 61.93 and 40 CFR 61.94.

ORGAN DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL

ORGAN	DOSE EQUIVALENT RATE TO THE ORGAN (mrem/y)
GONADS	4.8E-06
BREAST	8.0E-07
RED MARROW	3.0E-05
LUNGS	1.9E-04
THYROID	7.8E-07
ENDOSTEUM	3.7E-04
REMAINDER	1.8E-05
EFFECTIVE	4.4E-05

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL
BY PATHWAY FOR ALL RADIONUCLIDES

	EFFECTIVE DOSE EQUIVALENT (mrem/y)	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE ENDOSTEUM (mrem/y)
INGESTION	4.0E-06	6.4E-05
INHALATION	4.0E-05	3.1E-04
AIR IMMERSION	1.3E-13	1.7E-13
GROUND SURFACE	6.9E-09	7.1E-09
TOTAL:	4.4E-05	3.7E-04

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL
BY RADIONUCLIDE FOR ALL PATHWAYS

RADIONUCLIDE	EFFECTIVE DOSE EQUIVALENT (mrem/y)	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE ENDOSTEUM (mrem/y)
PU-239	2.3E-05	2.5E-04
AM-241	6.0E-06	1.0E-04
U-234	6.2E-06	7.2E-06
U-238	8.7E-06	1.0E-05
H-3	3.2E-07	2.3E-07
TOTAL :	4.4E-05	3.7E-04

EG&G Rocky Flats Plant

5/28/92 7:41 AM

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION
OF DISTANCE IN THE DIRECTIONS OF THE
MAXIMALLY EXPOSED INDIVIDUAL FOR
ALL RADIONUCLIDES AND ALL PATHWAYS

DIRECTION : EAST-SOUTHEAST

DISTANCE (meters)	EFFECTIVE DOSE EQUIVALENT (mrem/y)
3942	4.4E-05
10000	1.1E-05
80000	5.7E-07

EG&G Rocky Flats Plant

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION
OF ALL DISTANCES AND ALL DIRECTIONS FOR ALL
RADIONUCLIDES AND ALL PATHWAYS

DIRECTIONS:	N	NNE	NE	ENE	E	ESE	SE	SSE
DISTANCE (METERS):								
3942	2.2E-05	2.4E-05	3.1E-05	3.6E-05	3.7E-05	4.4E-05	3.4E-05	3.1E-05
10000	5.6E-06	6.2E-06	8.1E-06	9.3E-06	9.4E-06	1.1E-05	8.6E-06	7.9E-06
80000	3.0E-07	3.3E-07	4.4E-07	5.2E-07	5.0E-07	5.7E-07	4.7E-07	4.3E-07
	S	SSW	SW	WSW	W	WNW	NW	NNW
DISTANCE (METERS):								
3942	2.6E-05	2.1E-05	1.4E-05	1.1E-05	1.2E-05	1.2E-05	1.5E-05	2.2E-05
10000	6.5E-06	5.1E-06	3.4E-06	2.6E-06	2.8E-06	2.8E-06	3.6E-06	5.5E-06
80000	3.4E-07	2.3E-07	1.6E-07	1.2E-07	1.3E-07	1.3E-07	1.7E-07	2.7E-07

FREQUENCIES OF WIND DIRECTIONS AND TRUE-AVERAGE WIND SPEEDS

DIRECTION TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.050	1.82	1.67	2.57	4.26	3.50	2.54	0.00
NNW	0.056	2.31	2.37	2.57	4.36	3.30	2.41	0.00
NW	0.045	2.00	2.43	2.76	3.91	2.98	2.35	0.00
WNW	0.041	1.77	2.52	2.92	3.30	2.79	1.96	0.00
W	0.036	2.05	2.34	2.57	3.28	2.81	2.01	0.00
WSW	0.033	1.83	2.66	2.54	3.12	2.75	0.00	0.00
SW	0.042	2.08	2.40	2.82	3.52	3.01	2.52	0.00
SSW	0.060	1.84	2.39	2.73	4.23	3.16	1.78	0.00
S	0.070	1.49	2.17	2.79	4.76	3.31	2.35	0.00
SSE	0.073	1.23	2.20	2.25	4.45	3.58	2.40	0.00
SE	0.084	1.49	2.57	3.13	6.08	3.43	2.51	0.00
ESE	0.129	1.28	2.57	3.61	7.56	3.27	2.52	0.00
E	0.091	0.77	0.00	2.57	7.36	3.30	2.54	0.00
ENE	0.079	2.57	1.39	0.00	5.87	3.51	2.51	0.00
NE	0.063	1.67	1.86	2.84	4.48	3.60	2.52	0.00
NNE	0.048	2.57	0.00	1.39	4.46	3.50	2.51	0.00

FREQUENCIES OF WIND DIRECTIONS AND RECIPROCAL-AVERAGED WIND SPEEDS

DIRECTION TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.050	1.30	1.19	2.11	2.89	2.91	2.48	0.00
NNW	0.056	1.92	2.03	2.12	3.15	2.58	2.12	0.00
NW	0.045	1.48	2.17	2.52	3.07	2.46	2.00	0.00
WNW	0.041	1.26	2.42	2.72	2.62	2.17	1.43	0.00
W	0.036	1.54	1.98	2.28	2.47	2.27	1.49	0.00
WSW	0.033	1.32	2.62	2.04	2.19	2.23	0.00	0.00
SW	0.042	1.57	2.10	2.39	2.52	2.34	2.42	0.00
SSW	0.060	1.32	2.09	2.35	2.94	2.36	1.27	0.00
S	0.070	1.07	1.70	2.42	3.43	2.62	2.00	0.00
SSE	0.073	0.94	1.74	1.61	3.22	3.03	2.10	0.00
SE	0.084	1.07	2.57	1.51	3.84	2.90	2.37	0.00
ESE	0.129	0.96	2.57	2.22	5.23	2.59	2.40	0.00
E	0.091	0.77	0.00	1.73	4.66	2.70	2.48	0.00
ENE	0.079	2.57	1.01	0.00	3.44	2.87	2.38	0.00
NE	0.063	1.19	1.34	2.74	2.57	3.08	2.40	0.00
NNE	0.048	2.57	0.00	1.01	2.63	2.86	2.37	0.00

FREQUENCY OF ATMOSPHERIC STABILITY CLASSES FOR EACH DIRECTION

FOR	FRACTION OF TIME IN EACH STABILITY CLASS						
	A	B	C	D	E	F	G
N	0.0276	0.0048	0.0209	0.4019	0.4723	0.0725	0.0000
NNW	0.0147	0.0188	0.0373	0.5542	0.3475	0.0274	0.0000
NW	0.0562	0.0637	0.1480	0.5300	0.1789	0.0233	0.0000
WNW	0.1328	0.1076	0.2348	0.3776	0.1386	0.0085	0.0000
W	0.1697	0.1272	0.1922	0.3076	0.1700	0.0332	0.0000
WSW	0.1557	0.0745	0.1874	0.4051	0.1774	0.0000	0.0000
SW	0.1102	0.0854	0.1599	0.4233	0.2127	0.0086	0.0000
SSW	0.0522	0.0388	0.1123	0.5811	0.2018	0.0137	0.0000
S	0.0165	0.0148	0.0609	0.5322	0.3606	0.0151	0.0000
SSE	0.0065	0.0080	0.0176	0.3983	0.5095	0.0601	0.0000
SE	0.0069	0.0014	0.0070	0.4822	0.4326	0.0699	0.0000
ESE	0.0063	0.0009	0.0054	0.6362	0.2818	0.0693	0.0000
E	0.0051	0.0000	0.0052	0.5100	0.3736	0.1062	0.0000
ENE	0.0015	0.0044	0.0000	0.3389	0.5717	0.0834	0.0000
NE	0.0038	0.0092	0.0130	0.2686	0.5655	0.1400	0.0000
NNE	0.0025	0.0000	0.0073	0.3194	0.5448	0.1260	0.0000

METEOROLOGICAL AND PLANT INFORMATION SUPPLIED TO PROGRAM----

AVERAGE VERTICAL TEMPERATURE GRADIENT OF THE AIR (DEG K/METER)

IN STABILITY CLASS E	0.0728
IN STABILITY CLASS F	0.1090
IN STABILITY CLASS G	0.1455

PLUME DEPLETION AND DEPOSITION PARAMETERS

NUCLIDE	GRAVITATIONAL FALL VELOCITY (METERS/SEC)	DEPOSITION VELOCITY (METERS/SEC)	SCAVENGING COEFFICIENT (1/SEC)	EFFECTIVE DECAY CONSTANT IN PLUME (PER DAY)
U-239	0.000	0.00180	0.410E-05	0.000E+00
M-241	0.000	0.00180	0.410E-05	0.000E+00
P-234	0.000	0.00180	0.410E-05	0.000E+00
P-238	0.000	0.00180	0.410E-05	0.000E+00
P-3	0.000	0.00000	0.000E+00	0.000E+00

Appendix C

Resuspension of Soil Particles From Rocky Flats Containing Plutonium Particles

RESUSPENSION OF SOIL PARTICLES FROM ROCKY FLATS CONTAINING
PLUTONIUM PARTICULATES

G. Langer

Environmental Management
Air Quality & Chemical Tracking Division

EG&G Rocky Flats, Inc.
P. O. Box 464
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October 29, 1991

George H. Setlock
Reviewed for Classification/UCNI
By: George Setlock *UNK*
Date: October 29, 1991

 **EG&G ROCKY FLATS**

EG&G Rocky Flats
Internal Publication
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EXECUTIVE SUMMARY

This report presents an overview of research conducted at the Rocky Flats Plant (RFP) on the resuspension of soil particles from soil contaminated with plutonium (Pu) in the area called the "903 Field." This field is adjacent to and directly east of a former oil drum storage area which in 1969 was paved with asphalt and designated the "903 Pad." The 903 Field is a source of airborne Pu, due to wind erosion, and has been studied since 1970 for the resuspension rate of Pu particles. The following processes were considered:

- saltation (wind erosion of bare soil);
- wind resuspension of particles from grass blades;
- rain splash; and
- mechanical disturbances and grass fires.

Results indicate wind resuspension from bare soil seems to be minimal, while resuspension from grass appears to be the dominant process. Additionally, rain splash was also found to be a significant resuspension process. Over 90 percent of the resuspended Pu from the 903 Field is associated with soil and grass litter particles larger than 3 μm . The airborne radioactivity is roughly proportional to the mass of particles collected. Resuspension of respirable particles from the field is very limited; this respirable concentration at the field is about the same as that due to nuclear fallout in and around the Denver area. Maximum transport of the Pu extends to 1.5 km from the 903 Field. The release of Pu is parameterized by a resuspension factor of $5 \times 10^{-11} \text{ m}^{-1}$ and a resuspension rate of $2 \times 10^{-12} \text{ sec}^{-1}$. The total resuspension is very low, estimated at $\sim 200 \mu\text{Ci/yr}$. For a typical respirable particle concentration of 0.01 fCi/m^3 * of Pu-239 near the 903 Field, the Pu collected was equivalent to one, 1- μm particle per month, using a sampling rate of $1.1 \text{ m}^3/\text{min}$.

* $1 \text{ fCi} = 10^{-15} \text{ Ci}$

INTRODUCTION

Concern over public health in regards to the 903 Field, located adjacent to a former outdoor drum storage area for waste oil, is recognized by RFP. The plant has been monitoring this area since the first oil drum leaks were discovered 30 years ago. The waste oil in these drums contained residue particles less than $3\ \mu\text{m}$ in size of Pu from machining operations. Removal of the drums began in 1967 and the area was partially remediated and subsequently covered with an asphalt pad in 1969. During this period and continuing through the present, air at the 903 Field adjacent to the pad and in various locations around the Denver area (Figure 1) is continuously monitored for airborne Pu/soil particles by a network of surveillance air samplers. In the discussions that follow, it should be kept in mind that the Pu is attached to host soil particles that range in size from a few micrometers to millimeters. This is due to the nature of the original contamination process.

At no time since the completion in 1971 of the drum storage clean-up has Pu concentration exceeded the DOE "Derived Concentration Guide" of $20\ \text{fCi}/\text{m}^3$, either at the source area or in the surrounding community. In fact, it can be noted the concentration of respirable Pu particles at the 903 Field is near background levels found in the Front Range area of Colorado. Taking into account all significant pathways of human Pu intake, exposure to Pu at the 903 Field is well below EPA proposed guidelines (EP78, p221)*. The average total radioactivity concentration of airborne Pu at the plant boundary is $0.05\ \text{fCi}/\text{m}^3$.

The 903 Pad and Field are scheduled for further investigation and remediation in the future. The alpha radioactivity in the 903 Field soil is much less than EPA proposed guideline levels. The alpha radioactivity from RFP waste that has entered the environment amounts to a few curies, while waste tailings (uranium and thorium) from mining activity amount to a few thousand curies in an area in downtown Denver (KA84, p130). A synopsis is provided in this report of RFP research on the resuspension of Pu particles from the 903 Field. This research included:

- extent and radioactivity characterization of the source area;
- consideration of all feasible processes of resuspension; and
- investigation of the subsequent transport of the airborne particles according to their size and radioactivity category.

* The last part of the literature citation, following the "p", indicates the page number at which the information will be found.

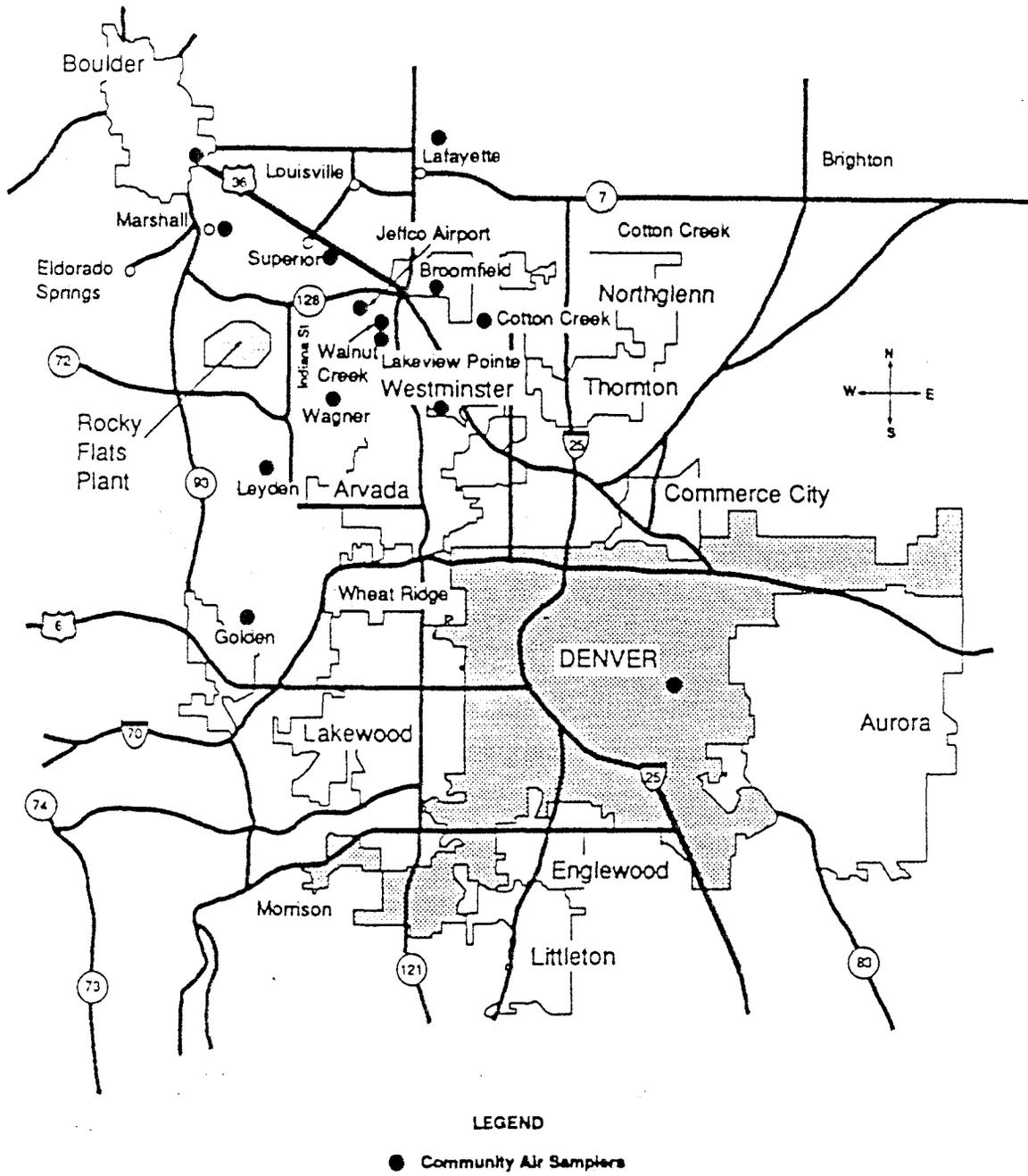


Figure 1. Area Map and Locations of RFP Community Samplers

SOURCE AREA AND SOURCE ACTIVITY

The area now known as the 903 Pad, after removal and off-site shipment of oil-covered surface rocks, was covered with gravel and then asphalt in 1969 to immobilize Pu-contaminated soil particles (Figure 2). However, during site preparation for the asphaltting, occasional high winds swept across the uncovered area. Some dust was generated and much of it settled a short distance to the east of the site towards the plant site security fence. This area near the security fence is designated the 903 Field and has been covered with off-site topsoil. Vegetation has also been re-established. During the stabilization process fugitive Pu particles in the sub-surface soil were mixed into approximately 20 cm of new topsoil. This allows the possibility that some Pu particles could be resuspended, due to water or wind erosion. Therefore, access to the area is restricted and the ambient air in this area is continuously sampled by RFP for plutonium.

It should be noted that mine tailings from radium extraction, as found in some locations within the city of Denver, and mine tailings used in Grand Junction for home construction pose greater health hazards than the Pu contamination present in the 903 Field. Mine tailings release radon gas, which is difficult to immobilize, and the radon decay products become attached to respirable dust particles. The RFP Pu particles are relatively immobile and require extensive force to become airborne, which results mostly in particles too large ($> 10\text{-}\mu\text{m}$) to be inhaled (HA80a, p216). Once the small ($<3\text{-}\mu\text{m}$) Pu particles in the waste oil were immobilized by attachment to soil particles they became very difficult to separate, due to interatomic, attractive surface forces.

Figure 2 also shows the distribution of Pu in soil at and near the plant as determined by the Atomic Energy Commission (AEC) Health and Safety Laboratory (HASL) (RF3115, p14). The amount of Pu that leaked from the drums throughout their existence in the 903 Pad area was estimated in 1971 as 6.1 Ci or 86 g (SE71, p6; EI80, p2-73) based on the amount of oil leaked and Pu content of the oil. Nearly 4.0 Ci are now immobilized under the asphalt pad. A detailed ground gamma survey (RF3689, p18) for the Am-241 associated with the Pu indicated that approximately a total of 1.2 Ci of Pu exists in the 903 Field area west of the perimeter fence and bounded to the west by the 903 Pad. This survey was made after the removal in 1978 of soil containing an estimated 0.5 Ci of Pu-239, along the hill crest on the southern edge of the 903 Field. Another 0.67 Ci of Pu exists on the east side of the security fence in a small, localized area. Figures 3 and 4 illustrate this ground Am-241

gamma survey. These regions of high Pu soil concentrations are considered the source area for chronic release of Pu from RFP and this soil will likely be removed in the future once an acceptable regulatory framework has been worked out.

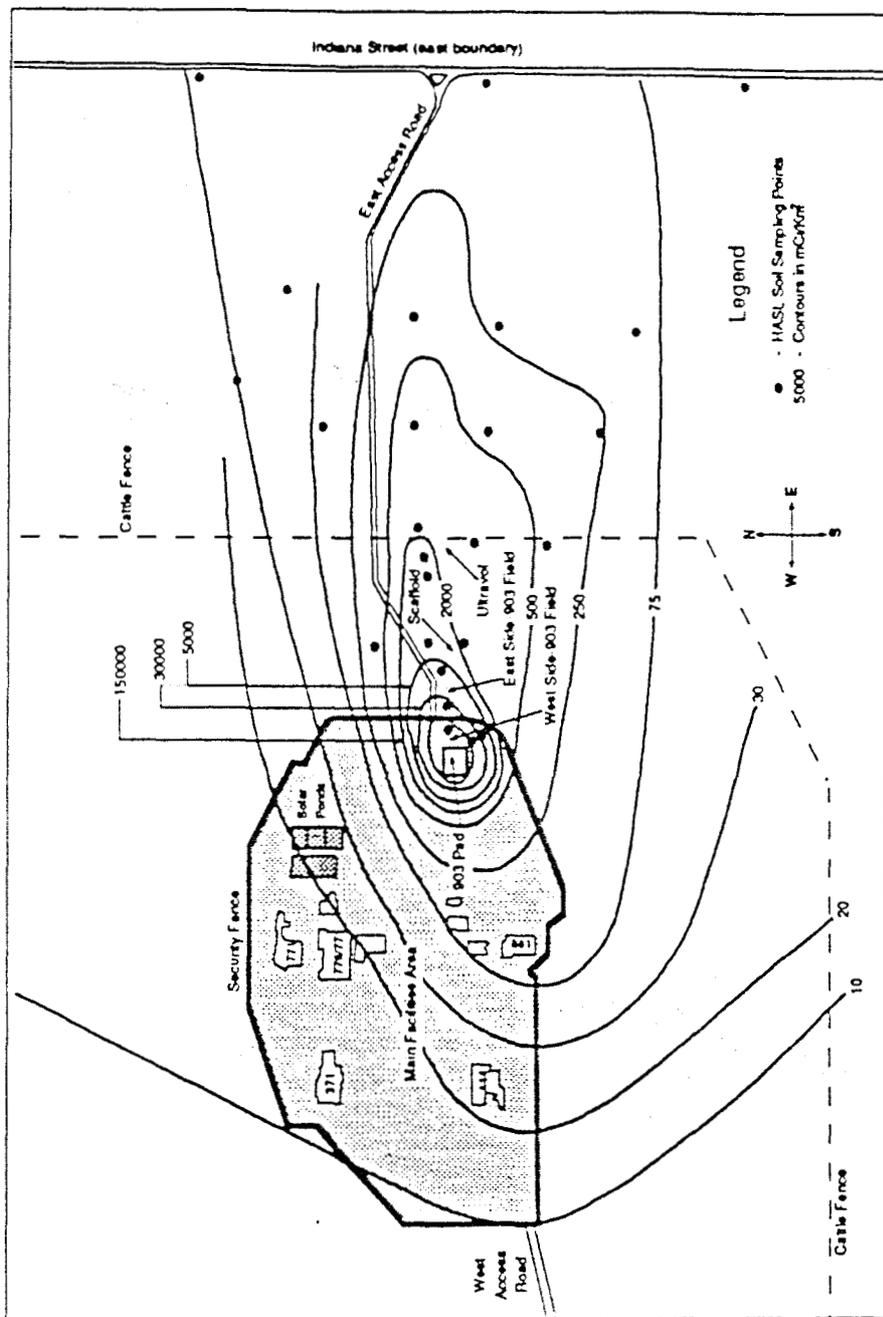


Figure 2. Plutonium-239 Deposition Contours in Millicuries Per Square Kilometer, According to HASL

Enlargement of 903 Pad Area

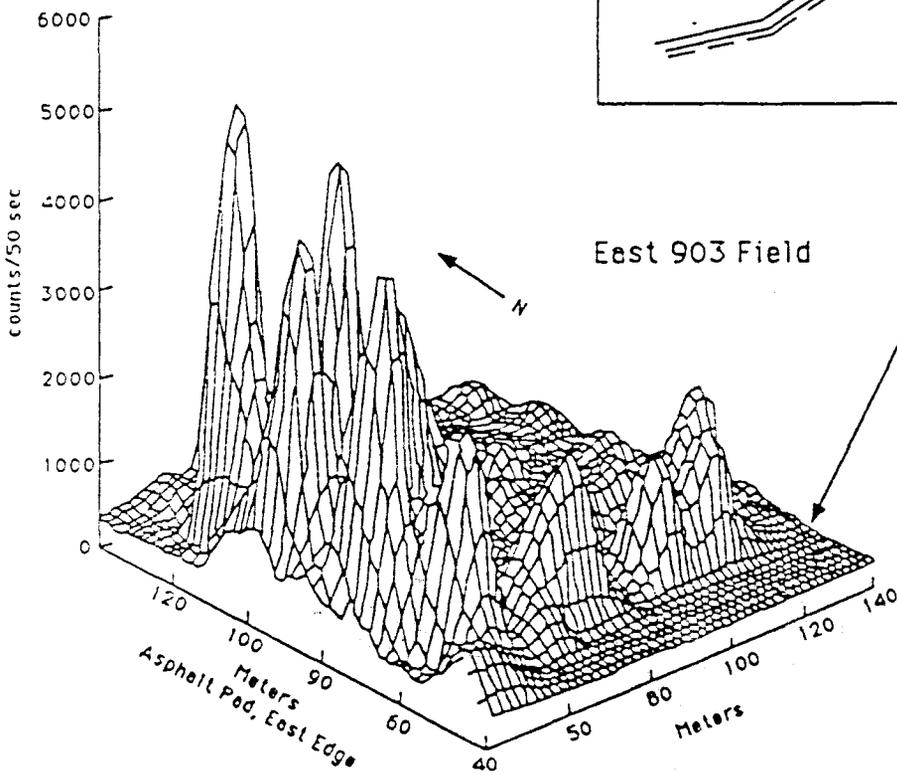
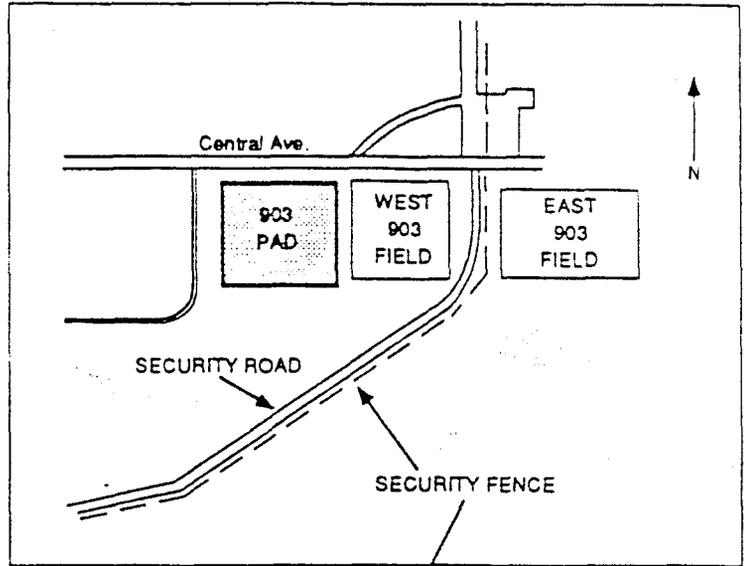


Figure 3. Three-dimentional Plot of Gamma Activity from Survey of West Side of 903 Field

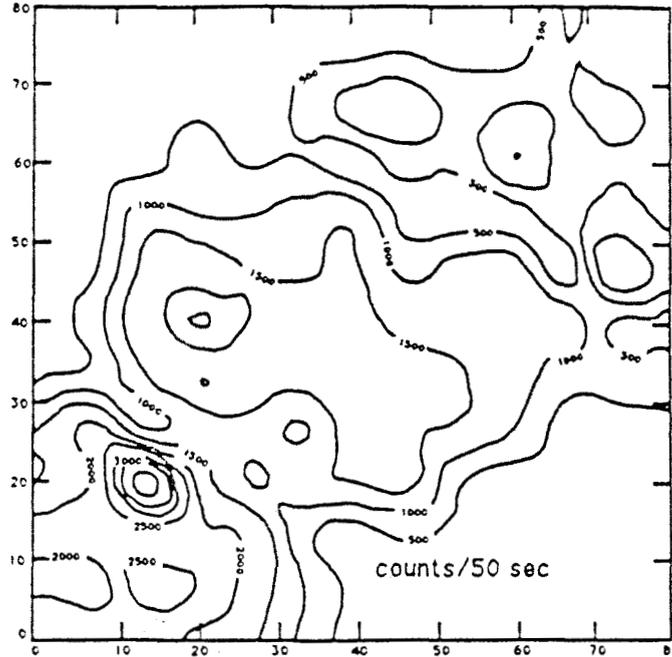


Figure 4. Contour Plot of Gamma Activity from Survey of East Side of 903 Field

P. W. Krey, in "Remote Plutonium Contamination and Total Inventories from Rocky Flats" (KR76, p214) has estimated, based on limited samples, that in addition to the Pu in the 903 Field there is another 3.4 Ci spread out over a wider region. This region, with near fallout Pu levels, extends east and southeast from the security fence. This would indicate that, based on a material balance, more than 9 Ci Pu-239 leaked from the drums instead of the 6.1 Ci estimated in 1971 and a total of about 5 Ci were resuspended from the drum storage area. Once past Indiana Street, the current eastern boundary of the plant, only a small percentage of the Pu that has been found is of RFP origin, as explained below. The rest is from residual fallout from past global atmospheric weapons testing. An isotopic ratio (Pu-240/Pu-239) analysis was used by Krey to distinguish the RFP contribution from atmospheric fallout to one-tenth of fallout levels. The RFP contribution in the region east of Indiana Street is approximately 0.1 Ci total, according to Krey.

Another possible source of RFP Pu in the environment is from safety shots, i.e., non-fission detonations, at the Nevada Test Site (NTS). Plume deposition from these shots has been tracked as far east as Grand Junction, Colorado, where it contributes 0.6 mCi/km² to the Pu in soil (BE83, p23). Global fallout away from Nevada is of this order. The dispersion of NTS Pu has not been investigated east of Grand Junction.

Also of interest are the periodic aerial gamma surveys of the plant and surrounding land by helicopter using an array of sodium iodide crystal detectors (BO82; BO90). Figure 5 presents the 1989 survey contours for Am-241 (BO90). The 1981 aerial survey data show similar results (BO82). In 1989 the sensitivity of the aerial instrumentation was improved, making it possible to detect Am-241 beyond the cattle fence which marked the plant's original boundary (e.g., to the 250-mCi/km² contour shown in Figure 2). Also, the 1989 survey extended beyond the confines of the RFP buffer zone to obtain a broader picture of background radioactivity. As far as total radioactivity is concerned, which includes natural radioactive sources, the hottest localized spot was an old mine shaft near Leyden, several miles from RFP. The major contributor to this radioactivity was Bi-214 from radon gas (BO90, p11). To detect the above background radioactivity at RFP the survey has to be specific for Am-241.

The airborne surveys showed that Pu radioactivity has not migrated significantly beyond the original source area after the 1969 asphalt stabilization of the 903 drum storage area (BO90, p25). The 1989 study also included selected ground sampling points for Am-241 measurements (Figure 6). A portable gamma spectrometer was used for this purpose, to be followed by radio-chemical analysis for Pu from soil samples from the same location.

Letter Label	Counts Per Second
A	< 50
B	50 - 120
C	120 - 240
D	240 - 600
E	600 - 2,400
F	2,400 - 9,600
G	9,600 - 38,400

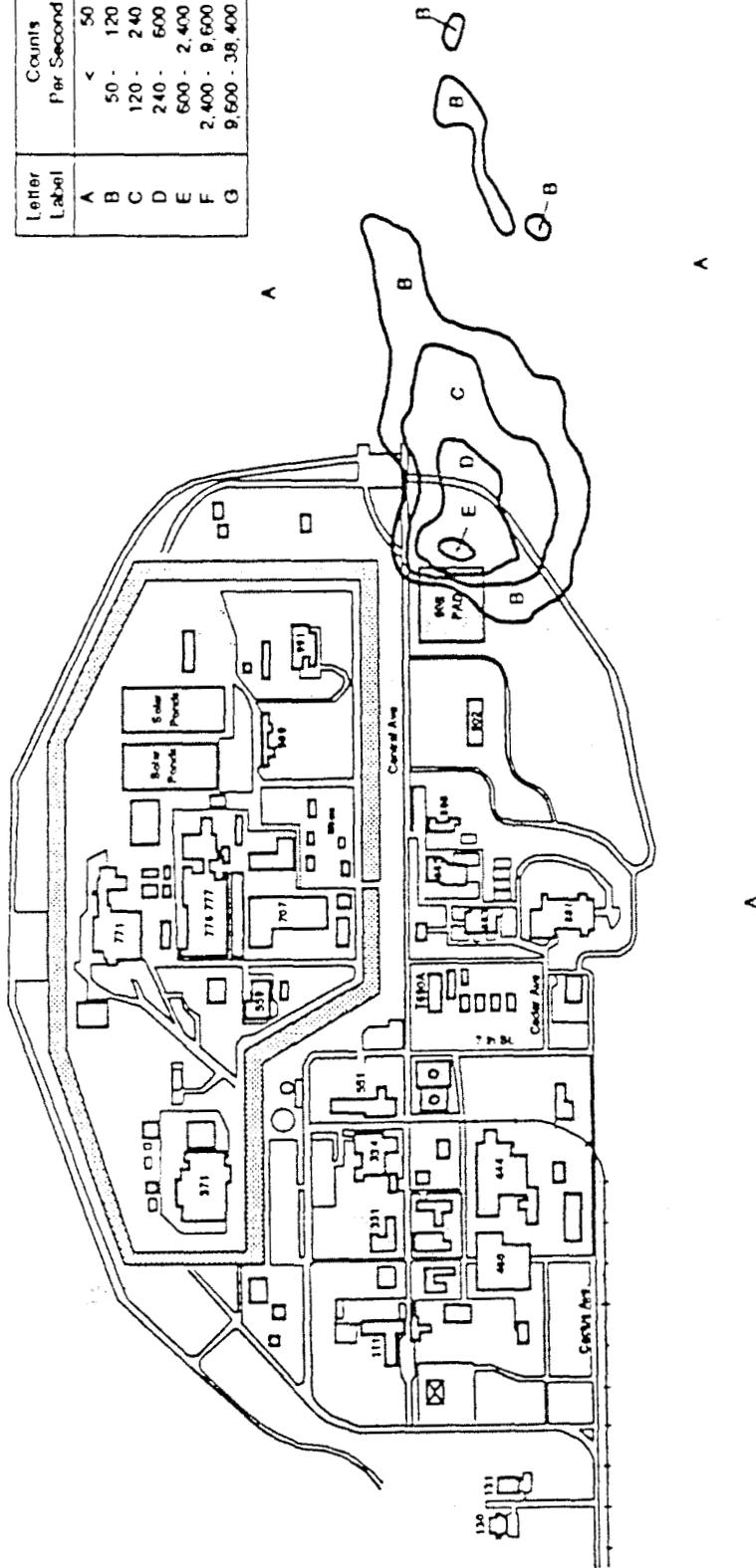


Figure 5. Aerial Gamma Survey - 1989

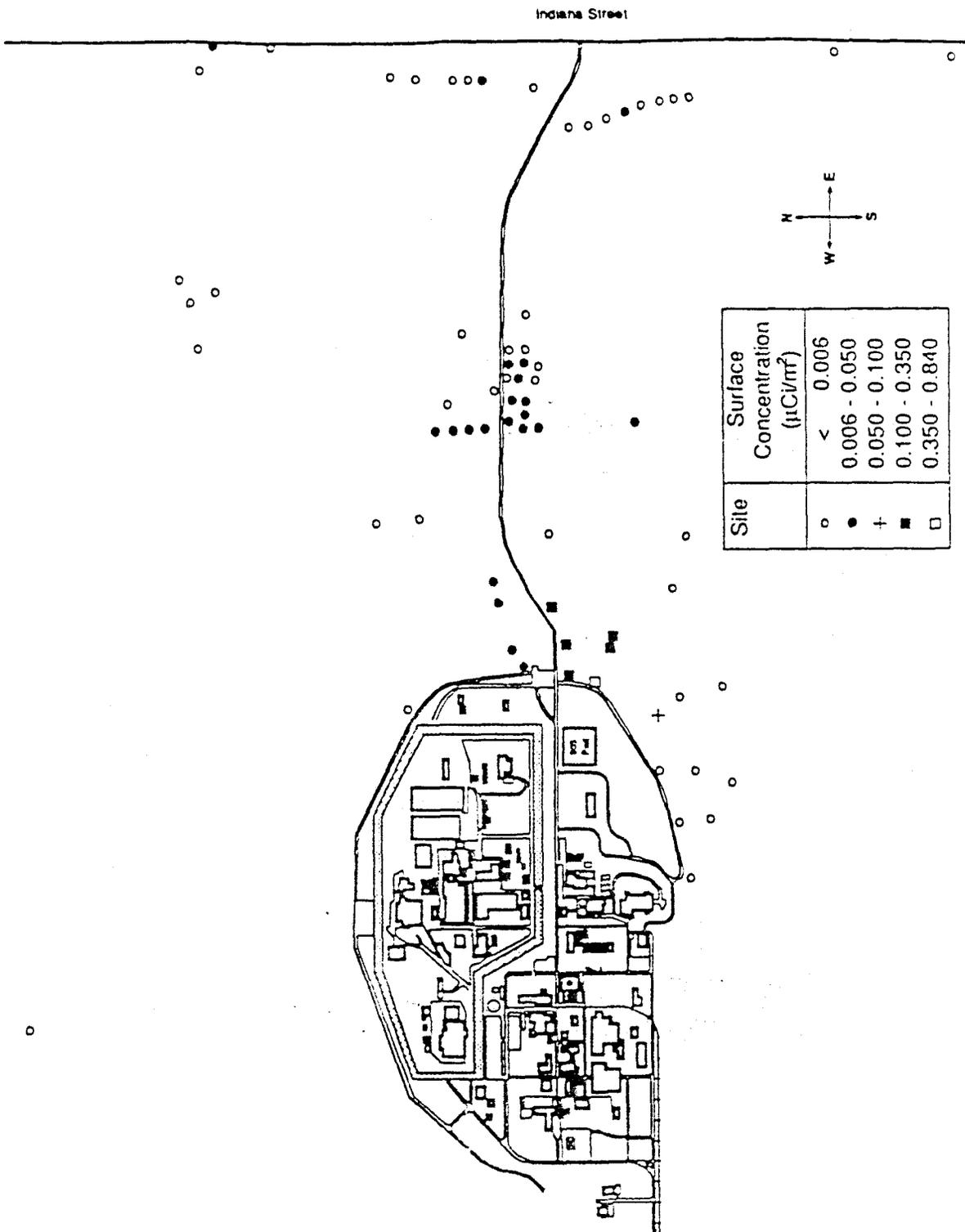


Figure 6. Gamma Ground Survey Sites for Am-241

PHYSICS OF SOIL RESUSPENSION

The potential for chronic release of airborne Pu particles from RFP is limited to soil resuspension from the 903 Field. Building releases from High Efficiency Particulate Air (HEPA) filters are small, i.e., a total of 5 $\mu\text{Ci}/\text{yr}$ in 1989 (RFENV-89, p23) vs. 200 $\mu\text{Ci}/\text{yr}$ from the 903 Field (see section on resuspension factors). We know from air monitoring that Pu particles do become airborne from soil, but the physics of the process need to be understood for dispersion modeling and remedial action purposes. Soil particles are traditionally thought to be resuspended by wind forces acting on bare soil surfaces, but studies upon which this view is based have been limited to plowed fields and desert areas. The 903 Field has only small bare soil areas between the clumps of bunch grass, but the original premise of the author and others was that the Pu particles originate from the bare soil between the clumps of grass.

Saltation

Initial resuspension studies were directed at the classical resuspension process of saltation (HA80a, p213). That is, the wind propels millimeter sized particles that protrude beyond what is called the boundary layer (the immobile or stagnant air layer approximately 1 mm in depth, adjacent to the land surface) in a series of small hops. On impact these large particles knock loose smaller particles, in a manner similar to sand blasting. The smaller particles then become entrained into the main air streams by turbulence to heights over 6 m at a distance of less than 30 m (HA80a, p222).

It remained for RFP to demonstrate if saltation could occur from small areas devoid of vegetation, because this soil surface condition has received little attention from soil scientists. Direct visual observations initially indicated that even during wind storms reaching over 100 mph, no visible quantities of dust were released (e.g., puffs of dust from bare areas). Operation of a modified Bagnold Catcher for several week-long runs, including operation during wind storms, provided no weighable dust fractions. The Bagnold Catcher (GI74) is the classical device for measuring wind erosion of soil. Nevertheless, more sensitive techniques were developed to verify if saltation processes occur on a small scale.

One technique developed by RFP was the application of a ribbon-like laser beam grazing the soil surface, to detect impacting large particles and bursts of numerous small particles

(RF3197, p8). This was done at night using time exposure photography. No particles were observed until winds exceeded 35 mph, but even then resuspension was tenuous and no clear evidence for saltation was found by this approach (RF3325, p3).

The second methodology, shown in Figure 7, involved the placement of an acoustic particle detector underground, facing a 2.5-cm opening in a soil surface area devoid of vegetation (RF3115, p11). There was no net airflow into the opening, but the objective was to detect particles over 50 μm aerodynamic equivalent diameter (AED) that were resuspended by the wind and then fell back to the ground. As the particles fell back, some dropped into the intake of the acoustic particle counter. This system could operate continuously and unattended for several days. Again, no convincing case could be made for saltation, even in high winds (RF3115, p13; RF3197, p7). Evidently, the soil is too crusty for wind erosion (HA80a, p224), except for a few small areas (RF3115, p11). Also, many of the smaller, bare areas are too deep in the grass canopy to experience the full force of the wind. Only deliberate disturbance of the ground with a stick was observed to release short bursts of particles.

The above results may seem to contradict a study by Sehmel, who developed a Pu resuspension model for the 903 Field based on the saltation process (SE72). However, this model was based on data collected by RFP from July 1970 through January 1971. In March 1970 the 903 Field was disturbed by a major ditch construction project near the west side of the perimeter fence. It took nine months for the effects of this operation to disappear, i.e., for the loose surface soil to become crusty again and for introduced grasses to grow.

Next, resuspension studies were carried out under controlled conditions using the small wind tunnel shown in Figure 8 (RF3197, p5). The objective was to observe resuspension from bare ground as well as from grassy areas. Testing of bare spots showed very little release until extreme wind velocities (e.g., equivalent to 150 mph at 10 m or about 30 mph near ground levels) were applied or the soil had previously been disturbed. But even the latter, "fresh" surface was quickly exhausted of particles (RF3689, p36). This wind tunnel, at high flow, proved to be a useful approach to soil surface sampling for Pu particles and was extensively used for this purpose (RF3689, p23).

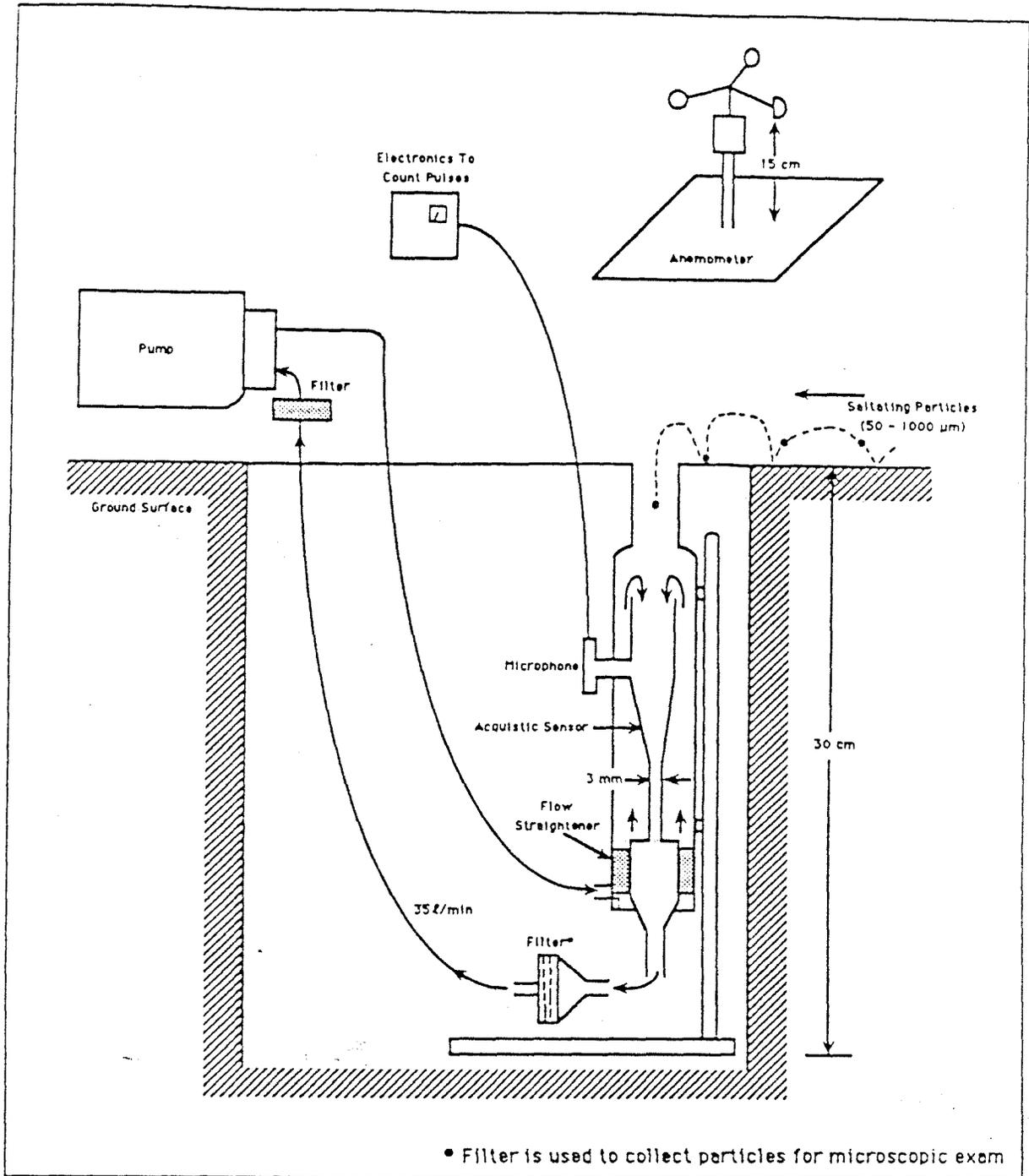


Figure 7. Acoustic Particle Counter for Saltating Particles

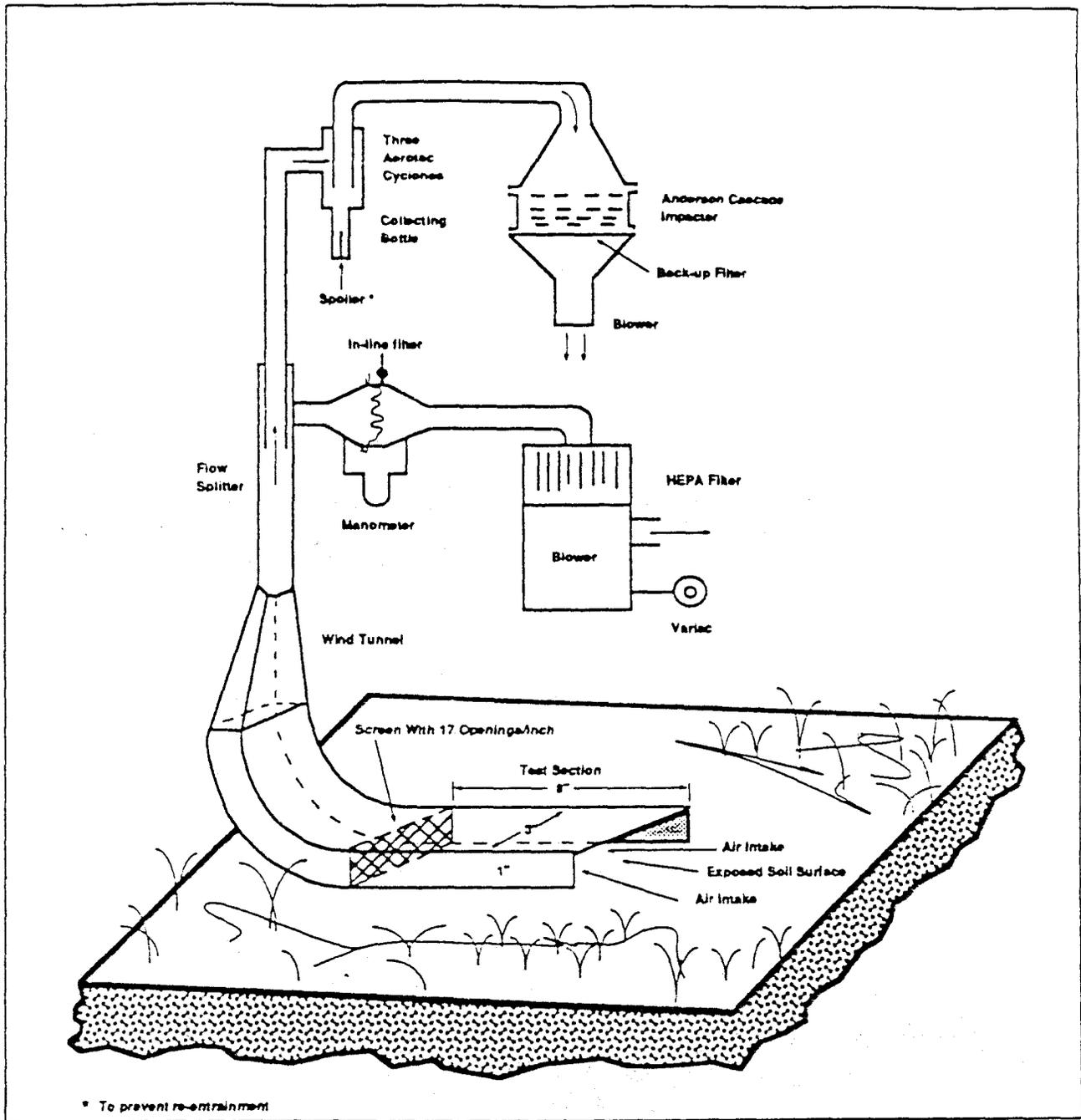


Figure 8. Portable Wind Tunnel for Resuspendable Dust

The wind tunnel was also operated on patches of grass, although it was not designed for this purpose. The height of the wind tunnel test section was less than the height of the grass. For proper testing of grass covered areas a considerably larger wind tunnel is required, such as the Gillette device (GI78). Nevertheless, even at low velocities (e.g., wind speeds equivalent to 20 mph at 10 m) the small wind tunnel detected small but significant amounts of resuspended Pu-carrying particles. This was considered important, since most of the ground in the 903 Field is grass covered. Much of the resuspended material was over 10 μm AED and was organic (i.e., grass litter) as shown by ashing the samples. The organic content was about 40 percent on the average (RF4036, p23).

Resuspension from Grass Blades

As a result of the aforementioned wind tunnel studies, attention was now focused on the details of resuspension from grass covered areas. It was not certain whether Pu resides on the grass blades and then becomes resuspended or if it originates from the grass litter on the soil surface and, as the grass decays, is then resuspended as part of decomposed grass particulates. Research was conducted to determine if both processes could be taking place.

First, it was verified quantitatively that Pu does reside on grass and grass litter (RF3914, p6). This was done by clipping the grass at successively lower levels and measuring each level for Pu distribution in relation to ground height. The Pu concentration in the underlying grass litter was also measured. Pu radioactivity was distributed fairly uniformly in relation to height for a total of 1.1×10^4 pCi for grass grown on a square meter of soil with a radioactivity of 2200 pCi Pu-239/gm of soil. The grass litter held 510 pCi Pu-239/gm of litter. Therefore, live grass must be considered a major source of Pu particles for resuspension in addition to the underlying grass litter. It should be noted that the litter is not readily accessible for resuspension because it is shielded from wind by the live grass.

The question of how the Pu becomes attached to the grass is of interest. Plant uptake of Pu is not a factor, because we are dealing with insoluble Pu particles (AR82, p33). This leaves wind driven soil particles from bare soil areas and rain splash as the source of Pu. The latter process is well documented for transferring Pu to vegetation to heights up to 30 cm (DR84, p183). Finally, the growth process of the grass as it rises through the soil surface was considered as a means of transferring Pu to the blades, but the grass blades

start from the stem of the plant after it has risen out of the ground. Therefore, no direct transfer of soil particles to the blades takes place.

Information was now required on the capacity of grass blades to hold soil particles and on potential Pu resuspension mechanisms from the grass. Therefore, the surface of grass blades was studied with a scanning electron microscope. Most grasses at RFP have blades whose surface is covered with fine fibers that act like a filter matrix which intercepts considerable amounts of dust (RF4036, p15). C. Gutfinger reports that fibrous elements extending from a surface into the viscous boundary layer enhance deposition by a factor of 10 to 1000 (GU85, p3). The microscopy showed that the blades were heavily loaded with soil particles. Conversely, dust particles should be released when the grass fibers decay and fall off and when the blades flex due to wind. Such behavior was verified with the wind tunnel tests described below.

In a small laboratory wind tunnel (RF4036, p23) samples of grass were placed in the test section and exposed to air velocities that would be found at grass level due to winds of 5 to 20 mph at a height of 10 m above ground. From a 5-cm blade of grass about 200 particles were released in the 0.2 to 12- μm range, as verified with an optical particle counter and membrane filter samples. Most pertinent were tests where the blades were mechanically flexed, which simulated wind motion. Here, the release from the blades of particles greater than ($>$)10 μm was dominant, with a median diameter of 20 μm and a maximum of 40 μm .

To verify the above results in the field, a simple test with the soil resuspension wind tunnel was made in summer with the ground soaked with water but the grass dry (RF3914, p8). The object of this test was to demonstrate how much Pu is resuspended from grass blades alone. The blades are much more exposed to the wind than the ground but may hold dust more tenaciously. The resuspension rate was about one-sixtieth of that for a similar dry area at a wind speed equivalent to 80 mph at 10 m. At 20 mph it was one-fortieth less than at 80 mph. But these resuspension rates could still account for most of the radioactivity observed by the air samplers, since 95 percent of the field is covered with grass. These data have to be interpreted with some caution, because as pointed out above, the wind tunnel was not of an optimal design for studying resuspension from grass.

This test confirmed that the release of radioactive particles from grass blades alone is important, if not dominant. Additional radioactivity exists on dead grass litter on the

ground between the standing grass, but this material is not readily available for resuspension because it is protected from the wind by the stands of grass.

Rain Splash

To determine the amount of Pu resuspension when the soil is completely saturated during long periods of rainfall, such as that encountered in spring (RF3914, p9) a series of tests were conducted. For this limited test series the airborne Pu concentration during rainfall did not differ significantly from that during dry periods. Rain splash was therefore studied as a means of releasing Pu particles into the air. First, a laboratory wind tunnel was set up to simulate single raindrops splashing on soil under controlled conditions. Provision was made to count resuspended soil particles by concentration and size with an optical particle counter. This experiment showed that soil particles do become aerosolized by rain splash, if a thin water layer exists on the soil surface (RF4036, p30).

Evidently, these airborne soil particles are the residuals that remain upon the evaporation of the hundreds of small satellite droplets that form along with big splash drops (GR73, p57). The satellite droplets are small enough to be carried by air currents.

This resuspension process was also field tested. A small plastic tent was built over a patch of Pu-contaminated bare soil at the 903 Field (Figure 9). The tent was necessary to prevent airborne Pu particles from drifting into the test area from the surrounding area. Nuclear track foils were placed on the resuspended residue particles collected from the splashes to verify the presence of Pu particles. The tests showed that soil particles containing Pu did become airborne due to drop impact (RF4036, p30). A thousand 5-mm rain drops resuspended 5 pCi into the air from soil with a surface radioactivity concentration of 2500 pCi/g. About 500 million raindrops may fall on an area of one square meter annually. To complete this analysis, the washout of resuspended soil particles by rain drops should be accounted for in a real situation (GR73, p121). The washout effect was not present in the aforementioned single drop experiment. The washout effect decreases the airborne Pu concentration as falling raindrops sweep out dust particles in the air.

Grass Fires

Another potential source of resuspended particles is the ash from grass fires. So far no fires have taken place in the 903 Field, but RFP has conducted tests to simulate such an

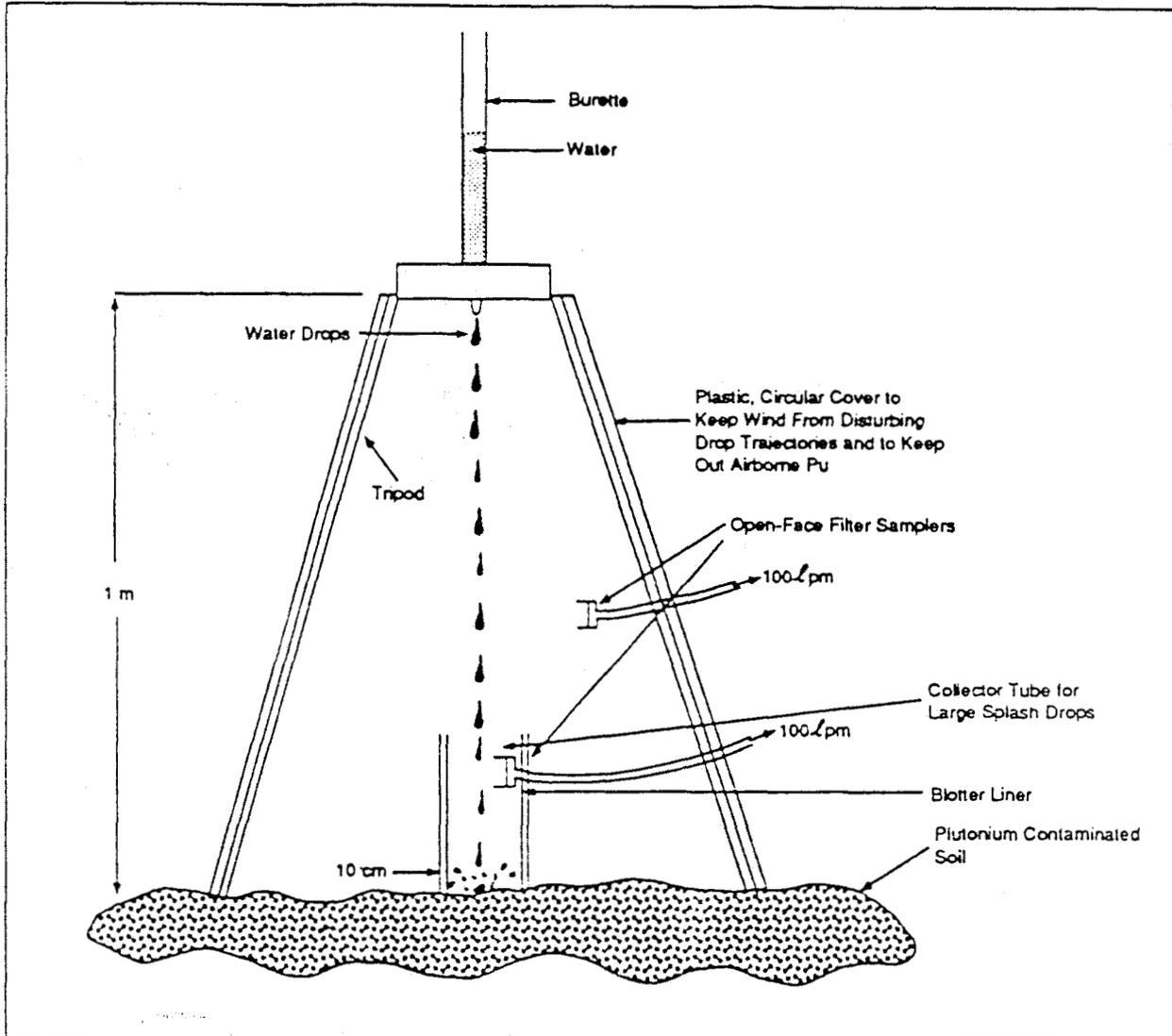


Figure 9. Simulation of the Resuspension of Plutonium-contaminated Soil Particles by Rain Splash

occurrence. Fire was set in a wind tunnel to 180 gm of grass collected from an area of soil 1 m^2 in size. The grass had a radioactivity concentration of 8.1 pCi Pu-239/g of air-dried grass. Smoke from this test fire had a total radioactivity of 34 pCi of Pu-239 or 17 pCi/g (LA86, p91). However, placed in perspective, consider that the annual limit on intake for a member of the public for Pu-239 is 170 pCi (DO90). If the whole field (0.02 km^2) were to burn, a person remaining in the plume would inhale a small fraction of this limit.

Mechanical Disturbances

Mechanical, or unnatural, disturbances were also studied as a potentially important resuspension mechanism. This includes such activities as mowing, well drilling, construction, digging, or soil removal. Mowing was considered of major interest since it takes place every year and covers the whole area. Mowing involves disturbance of both grass and soil. While research sampling took place in the 903 Field east of the plant security fence, the grass was cut during dry conditions. This was expected to maximize resuspension. At times the mowing tractor would pass right next to an air sampler. A statistically significant increase by a factor of 5 in the total Pu concentration was discerned during such a period in June 1981 (RF3464, p4). But no change was found during a similar period in 1983 at the same location (LA86, p90). Again, high variability in Pu concentrations make trends difficult to establish unless many samples are taken. In June and July of 1987, wells were drilled in the 903 Field and the nearby surveillance air samplers showed an increase by a factor of about 3 in Pu radioactivity, but such increases are often seen during the dry summer months regardless of soil disturbances. Mechanical disturbances are short-term events.

Consideration was also given to resuspension of dust containing Pu from two unpaved roads intersecting the 903 Field along the security fence. It is evident from the color and quantity of the dust collected by samplers located along the roads that much of it is resuspended by traffic. A 1973 study (MI73) showed that road dust radioactivity averaged 68 pCi/gm and remedial action was initiated (e.g., oiling, grading, etc). In 1980 another road dust evaluation was carried out. As a first step the Pu radioactivity of the road surface for one of the roads was determined by conventional soil sampling methods (RF3689, p18). The Pu radioactivity of this road surface was surprisingly low, 4.6 pCi/g of Pu-239, when compared to adjacent soils of 790 pCi/g of Pu-239 that were monitored a distance of one foot from the road. However, since 1973 the road was often graded and ballast added. It had been expected that the adjacent soil would provide a source of Pu for easy resuspension by traffic on the dirt road. However, the adjacent soil was not disturbed by traffic on the road.

Also in the 1980 evaluation a truck was driven along this road to complete the comparison with the 1973 test, and to sample a larger area than that covered by a few road soil samples. The dust generated behind a rear wheel was sampled with a high-volume air sampler (hivol) similar to that used for the dispersion studies described later. The device gives a

<3- μm and >3- μm cut. The road dust was very low in radioactivity, measuring 6.0 pCi/g of Pu-239 compared to 1000 and 2000 pCi/g of Pu-239 for two adjacent soil areas. It was concluded that the roads are no longer a significant problem, especially because of the low volume of traffic. Of considerable interest was the incidental new information that no measurable amounts of respirable (<3- μm AED) particles are generated (RF3287, p7). This was also observed during a recent dam construction project at RFP. Heavy earth moving machinery created no additional respirable dust (RF3115, p6).

Such observations indicate that considerable application of force is necessary to create <3- μm AED particles. It has been noticed that the particles <3- μm AED were mostly black combustion particles generated by vaporization-condensation (e.g., combustion) by vehicles, furnaces and other industrial activity. This is in line with the wind tunnel results, that soil resuspended from the field is very low in respirable particles, those less than 3 μm in size (RF3689, p35) and many of these particles found at RFP are a result of Denver pollution (RF3990, p31).

DISPERSION OF Pu PARTICLES FROM RFP

Combining the above processes into a coherent, predictive Pu transport model is obviously beset with problems, especially with the resuspension from the 903 Field being relatively low and of varying nature (wind, rain splash and release from grass). Procedures from previous studies can be used to derive conventional resuspension parameters which are commonly used to provide a rough estimate of the emission of soil particles containing contaminants (HA80a, p210). Such parameters are given in the section titled: "Resuspension Factors for Pu Release from the 903 Field" in this report. However, site-specific experiments were necessary for realistic estimates of Pu dispersion from RFP which would directly measure the emission and transport of Pu particles. These experiments included measurements of the vertical distribution of Pu particles in the air that passes over the 903 Field.

Two distinct steps were involved in these experiments. First, an attempt was made to measure the Pu particle flux from the 903 Field at the source. A number of research air samplers were deployed at selected points in the field to determine the total resuspension of Pu. Second, a vertical array of samplers was installed, at some distance from the 903 Field, to measure the Pu particle concentration in the air that passed over the field.

Determination of Pu Flux Characteristics for Source Area

For the first step, four research hivol (~1 m³/min) were installed toward the perimeter areas of the 903 Field and an ultrahigh-volume air sampler (ultravol - ~7m³/min) was installed near the center of the field to determine how much Pu is being released to the environment. The ultravol (Figure 10), operating at 7.4 m³/min. and providing a <10- μ m and >10- μ m fraction, was changed weekly or more often to provide high resolution Pu concentration data (RF3197, p6). This was used for special events such as wind storms, periods of snow or rain and fallout from atmospheric nuclear weapons tests (RF3464, p5). The research hivol samplers provided <3- μ m AED and >3- μ m AED fractions. These corresponded to a respirable and an inhalable-plus coarse particle size cut, respectively. The >3- μ m AED fraction was collected by combining the particles collected by a cyclone pre-separator with a nominal 5- μ m cut, followed by two impactor stages to provide a sharp 3- μ m cut. The cyclone sampler inlet was designed to turn with the wind so that the intake always pointed into the wind. The efficiency of the cyclone was evaluated and one

observation was that the inlet efficiency was not sensitive to wind speed, that is, the particle concentration and size distribution was unaffected by wind speed (RF3464, p34).

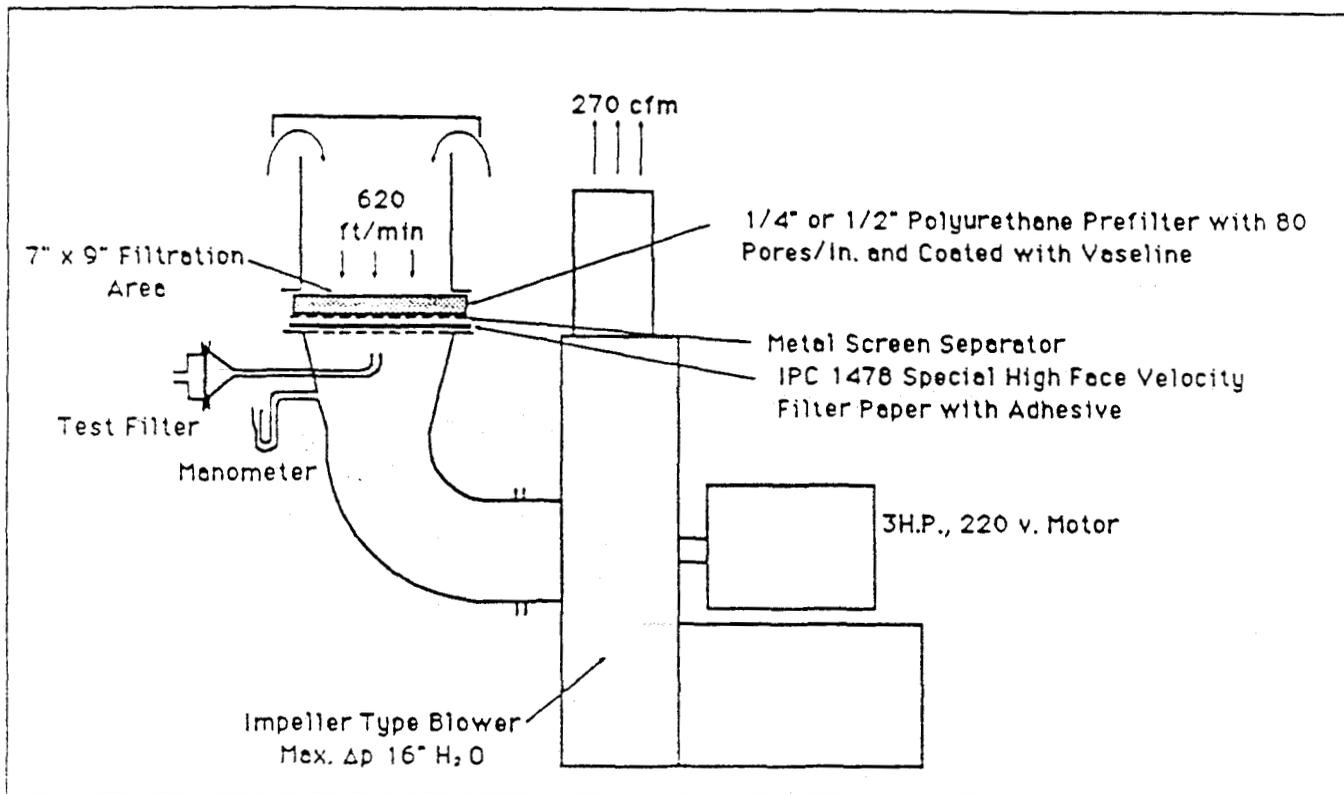


Figure 10. Ultrahigh-volume Air Sampler

The results of approximately two years of sampling (RF3464, p4; RF3650, p1) showed that monthly Pu concentrations in air that passed over the 903 Field varied by a factor of 10 to 100 at a given sampler location over a two year period. No correlation between wind speed and Pu concentration was found. Nor was there any correlation between the Pu concentrations found at the four sampler locations when plotted against time*. This observation even held for another experiment with three samplers at the same location (RF4036, p17, 23). By contrast, the corresponding dust concentrations for these tests varied by a factor of two during the same period and the concentration values at each sampling station showed identical trends with time.

* The same was true for the three RFP surveillance samplers spaced across the pad field along the security fence, i.e., the concentration data between the three samplers did not correlate in time (RF3914, p4). That is, if one sampler had a high concentration the others showed no corresponding increase, etc. The data examined were for a 9-year period.

Naturally, it is desirable know why the Pu concentrations in air at the source area varied so randomly. Especially in view of the fact that the concentration of another radioactive trace material, Be-7, correlated very well between all the samplers versus time (RF3287, p31). Be-7 is of stratospheric origin and consists of near atomic-size particles, which become attached to many dust particles in the troposphere. It is important to note that Be-7 is determined at the same time as the Am-241 values by gamma spectroscopy. The Am-241 gamma spectroscopy values fluctuated widely but correlated with the Pu values determined by alpha spectroscopy, confirming the accuracy and precision of the Pu analytical procedures (RF3650, p5-6). The next step was to examine data on Pu particle size on the presumption that the Pu particles may be relatively large and therefore few in number.

Unfortunately, data on the size of airborne Pu particles at the 903 Field are lacking. Alpha track analysis of an 8" x 10" filter proved to be quite tedious. Only a few tracks per square centimeter were present and most of these were single tracks, indicative of uranium. It was estimated from the multiple tracks that the Pu particles ranged from 0.08 to 0.3 μm (RF3115, p17), but the counting statistics were poor at a $\times 100$ microscopic magnification (i.e., alpha tracks were seldom seen). Wind tunnel resuspension of surface soil particles in the 903 Field (i.e., Pu sources area) revealed that the most common size was 0.06 to 1 μm (WA82, p23). This work was much more definitive because many alpha tracks were present in a microscope counting field.

Finally, Pu particle size data from the soil itself are of interest. Whicker (WH79) reported that most particles were 1 to 2 μm in size. Langer (RF3990, p43) reported Pu particles up to 10 μm in size. An interesting scanning electron microscopy study (ME90, p48-55) by EG&G Idaho of Pu-contaminated soil from Rocky Flats led to the identification of soil particles as large as 30 μm that contained Pu. This confirmed the idea that Pu is carried by host particles. This work also indicated that these large particles are fragile agglomerates.

From the above data it is concluded that the airborne Pu particles sampled were a few discrete, relatively large particles in a huge volume of air. This is very unlike sampling a continuum of a trace gas or atomic clusters of Be-7 attached to many dust particles. To illustrate this point, for a relatively high Pu concentration of 1.4 fCi/ m^3 in the 903 Field, 125 Pu particles 1 μm in size would account for the activity found in 40,000 cubic meters of air sampled during a typical run; or, a single 5- μm particle could account for all the activity. Such poor sampling statistics make it impossible to establish short term

concentration trends. That is, at best one can statistically compare only yearly or longer averages from each 903 Field sampling station for meaningful trends. For the community samplers, miles away from the 903 Field, it is impossible to establish Pu trends that relate to RFP activities.

The data cited also showed that most of the Pu activity is on particles $>3 \mu\text{m}$. To better define the Pu activity vs. particle size, large dust samples (gram-sized, as found during dust storms) were subjected to wet sieving of the $>3\text{-}\mu\text{m}$ AED particles into 44 and 74 μm sieve cuts. Freon was used for the suspension medium to prevent de-agglomeration (HA80a, p219). This sieving showed that the Pu distribution is roughly proportional to dust particle mass (RF4036, p22). More accurately, the specific radioactivity of the Pu in the samples was three times higher for the $>3 \mu\text{m}$ fraction than for the respirable fraction. But the specific radioactivity for the respirable fraction was small and not as accurately determined.

During normal wind conditions another test series gave the following results. The concentration of the respirable Pu fraction, 0.02 fCi/m^3 of Pu-239, was nearly at the fallout level of 0.018 fCi/m^3 of Pu-239 for June 1980 to June 1981 (RF3650, p6). The $>3\text{-}\mu\text{m}$ AED particle radioactivity was 0.71 fCi/m^3 of Pu-239. There is little emission of $<3\text{-}\mu\text{m}$ AED particles from the 903 Field (RF3464, p4). The $>3\text{-}\mu\text{m}$ AED fraction carried 97 percent of the radioactivity for the above period.

As an aside, in the spring, large amounts of pine pollen were blown from the foothills over the plant and were collected by the air samplers. Pollen is designed by nature to float long distances due to small air sacs. Scanning electron microscope photos of the coarse particle dust fractions showed the presence of pollen (RF3990, p28) which causes a yellow/green discoloration of dust collected in early summer. No unusual increase in Pu activity was seen during these periods, as suggested by Nichols (NI74).

Dispersion of Pu by Air Passing Over the 903 Field

The above studies were followed by an air sampling program using a scaffold 10 m in height and located 100 m from the eastern edge of the 903 Field (RF3914, p16). The objective was to follow the transport of Pu from the 903 Field. The scaffold had hivol samplers at a height of 1, 3 and 10 m to sample the air that passed over the 903 Field for Pu particles. The three hivol samplers had EPA-researched size selective inlets (SSI) with a

cut of 15- μm AED particle size, followed by 3 to 15- μm AED and <3- μm AED cuts. At the time the experiment was started the EPA defined the inhalable particle cut-point at 15 μm AED. This was later changed to 10 μm . The SSI was evaluated for wind speed (1-10 mph) response (intake sampling bias) by Wedding (WE82) and McFarland (MC84) in wind tunnels and by RFP researchers during 50-100 mph winds in the field (RF3914, p4). Performance was satisfactory at low speeds, but at the high wind speeds some particles were apparently blown through the circular SSI inlet and out the opposite side without being sampled. The particle flux data from this scaffold represent the sum of all resuspension processes active in the 903 Field during each two month sample period. The long sample period is necessary to accumulate sufficient Pu for analysis. These data provide basic information to estimate possible population exposure and translocation of the Pu particles from the source area.

This research program extended from November 1982 thru August 1985, collecting bimonthly samples. This two month collection period was necessary to collect sufficient Pu in each size fraction for detection. The dust concentration data showed well defined trends with sampling height (RF4036, p21). However, the respirable dust particle concentration (8.0 $\mu\text{g}/\text{m}^3$) did not change with height, as expected for particles that are slowly sedimented. The concentration for the inhalable and coarse dust particles, ranging from 10 and 25 $\mu\text{g}/\text{m}^3$ respectively, dropped off with height due to sedimentation.

The Pu concentrations (RF4036, p21) for the <3- μm or, what are termed respirable particles, was 0.0088 fCi/ m^3 of Pu-239 and for inhalable (3-15 μm) particles was 0.025 fCi/ m^3 of Pu-239. These concentrations did not correlate with height, being only 3 and 10 times greater than background concentration respectively. One must keep in mind that the Pu mass for these samples represents about 1/10th part per billion of the total sample mass. Statistically the data have to be erratic at such extremely low concentrations. For a Pu concentration of 0.010 fCi/ m^3 , typical of the respirable Pu particle concentration at the scaffold, it would require the collection of just one 1- μm Pu particle per month by a hivol operating at 1.1 m^3/min .

The concentration of 0.067 fCi/ m^3 of Pu-239 in the coarse (>15- μm) particle fraction was almost a magnitude higher than that in the respirable fraction (<3 μm). The coarse fraction exhibits a significant decrease in radioactivity with height by a factor of 3 from a height of 1 to 10 m.

No correlation was found with wind speed or direction for the Pu or dust concentration. This can be expected for the poor time resolution given by two month sample periods necessary to collect enough Pu for analysis (e.g., for the <3- μm particles).

It was obviously of interest to see how the Pu concentration changes beyond the 10 m scaffold. As a result, the ultravol sampler was operated in June 1981 at the cattle fence (Figure 2) 0.5 km due east of the scaffold. The Pu concentration in the inhalable (<10- μm) and coarse (>10- μm) ranges dropped off by a factor of 20, approaching background levels (UN81). Therefore, it did not seem worth while to continue this operation at such low levels. Evidently, most of the large Pu/soil particles that carry the bulk of the Pu radioactivity had settled out before reaching the cattle fence in the RFP buffer zone, far from any populated areas. This observation is directly supported by work of J. Hayden (HA75), who measured the size of individual Pu particles found on the soil surface from the 903 Field to Indiana Street, located 1.5 miles to the east (Figure 2). Beyond the cattle fence he considered RFP stack effluent to be the primary source of Pu particles because of the small size of these particles. The 1957 fire may have produced some small particles that settled out beyond the plant boundary. The total release was estimated at 26,000 μCi (EI80, p3-53).

Comparison of RFP Data with Previous Resuspension Studies

It is of interest to compare the above results to G. Sehmel's July 1973 Pu resuspension experiments at RFP (HA80c, p241). Although Sehmel's was a more elaborate Pu flux study than the study cited above, it only lasted for one month. Sehmel used three sampling scaffolds, one at the fence near the 903 Pad, one at the same location as the RFP 10 m scaffold and one near the cattle fence.

It is difficult to directly compare Sehmel's data to this study, because this study covered 34 months to determine statistically significant trends in the Pu concentration at three levels at one location. Sehmel's study probed the Pu particle plume at three locations with nearly 40 samplers set for specific wind speed ranges as well as continuous operation. However, to reiterate, Sehmel's research work was only of a month's duration.

There is also a problem comparing the particle fraction data. To achieve well-defined particle-size fractions, RFP took considerable precautions to coat the collection surfaces with adhesive. The object was to stop particles from bouncing through the cyclone and

cascade impactor stages onto the back-up filter (RF2866, p14; RF3115, p4). The SSI hivol inlet was also adhesive coated, long before this was an EPA requirement. Sehmel did not use adhesive on his collection surfaces. He showed that 60 to 99 percent of the Pu was in the respirable range and supposedly of RFP origin (HA80c, p262). We found that respirable Pu was mostly of fallout origin and it only represented 2 and 9 percent of the total Pu radioactivity, based on measurements at the scaffold and 903 Field respectively. Therefore, the Pu size trends are not comparable.

The drop off in Pu concentration as distance increased from the 903 Field security fence to the second scaffold varied among samplers by a factor of 10 to 1000 in Sehmel's tests (HA80c, p251). Comparable simultaneous data from our study were not available, due to access to only five hivol samplers. But taking data over the period 1980 to 1985, as RFP experiments moved eastward, the average Pu radioactivity at 1 m changed from 1.9 to 0.48, then to 0.13, and finally to 0.050 fCi/m³ measured respectively in the 903 Field, just east of the field, the scaffold, and the cattle fence. This trend represents a 40-fold reduction over a distance of 1.5 km.

Sehmel did not report a definitive relationship between wind speed and Pu radioactivity (HA80c, p244). This is similar to RFP research experience in this area.

Isotopic Ratio Determination as an Indication of Long Distance Dispersion of RFP Pu

As a final test of whether any RFP Pu particles reach the general population, the mass isotopic ratio of Pu-240/Pu-239 was determined for a series of airborne particulate samples (RF4036, p22). RFP Pu production metal has a Pu-240/Pu-239 mass ratio of 0.051, while fallout has a ratio of 0.163. Airborne dust samples collected at the scaffold showed a ratio of 0.063 and nearby soil had a ratio of 0.054. This small difference was significant, indicating that the airborne dust carried some fallout Pu, as to be expected. It is now needed to obtain the isotopic ratios for air samples taken in various parts of the Denver region to identify the RFP contribution, if any, from 903 Field resuspension or production facility emissions.

For the latter program it is also necessary to take soil samples at the air sampler sites, since most background Pu (fallout Pu) now originates from resuspension of nearby soil particles (RF4036, p29). Stratospheric influx of Pu is very low at present. Therefore, the isotopic ratio of the soil should be known at the air sample sites to adjust for any RFP Pu, if any.

already in the soil, in addition to the fallout Pu from past nuclear weapons tests. Nearly 20 years ago isotopic ratios were determined by Krey (KR76, p213) for a limited number of soil samples in the greater Denver region to identify RFP Pu. This would also be a chance to determine if any changes occurred in these ratios. Krey's data show that 1 to 2 percent of RFP Pu deposited in the environment due to releases from the 903 Pad, plant stacks, and the 1957 and 1969 fires, extends beyond Indiana Street.

Resuspension Factors for Pu Release from the 903 Field

The resuspension factor (R_f) estimates the airborne contaminant concentration directly above a contaminated area and provides a means to estimate exposure or dose. R_f equals the airborne Pu concentration measured directly above a given area divided by the soil surface Pu concentration at that location. The necessary Pu data to calculate resuspension factors for the 903 Field are available. The soil surface Pu concentration is derived from the soil density and soil radioactivity per unit mass.

Another resuspension parameter is the resuspension rate (R_r), which allows off-site dose calculations. R_r is the fraction of the total radioactivity in the soil released per second. This provides a source term for meteorological calculations to determine downwind population exposure. R_f only provides dose or exposure for a person present on the contaminated area, which is somewhat academic for real life situations, because plant personnel only spend limited time on or near the 903 Field. The RFP Pu flux data make it possible to estimate R_r , but estimates of the Pu particle plume profile have to be made.

Before proceeding to estimate R_f and R_r , the limitations for applying these factors should be understood. Resuspension factors/rates ignore the physical parameters affecting resuspension, such as wind speed, vegetative coverage, soil moisture, precipitation and contaminant/host particle size. Also, a good knowledge of the Pu surface distribution is assumed, as well as airborne concentration over the whole area in question. As Sehmel (HA80c, p269) correctly points out, realistic prediction of the relationship between surface concentration and airborne concentration is fraught with uncertainties. Such data are very site specific and depend on how the contaminant found its way into the soil/vegetation and how long the contaminant has "weathered" into the soil. For example, resuspension for the first few weeks, after a tracer was sprayed onto cut grass, was orders of magnitude higher (RE79, p27) than the RFP data given below. The preference is to use actual Pu concentration data and then draw conclusions.

Sehmel (SE72) probably made the best estimates of maximum resuspension factors at RFP for a special situation in 1969, when Pu releases were high with no vegetation on the 903 Field during the remediation project that involved earth moving machinery. Samples were taken for time periods as short as six hours in the source area. The R_f values ranged from 10^{-9} to 10^{-5} m^{-1} . However, these factors are no longer applicable, unless similar areas of fresh soil are exposed.

An R_f range of 10^{-13} to 10^{-10} m^{-1} was calculated by us, limited to areas near the 903 Field sampler (RF4036, p44). The variability in soil Pu radioactivity (see Figures 3 and 4) and ground cover raises serious questions about generalizing from these values to the entire 903 Field. The same applies to the calculations for R_r , which was estimated at $2 \times 10^{-12} \text{ sec}^{-1}$ for the entire 903 Field area. This calculation required an estimate of the average air flow over the field and the resulting fetch for resuspended particles. This parameter was used to estimate the total emission of Pu from the field to be $\sim 200 \text{ } \mu\text{Ci}$ per year.

The question of Pu transport to populated areas is better answered by downwind Pu concentration data provided earlier in this report. These long term measurements show that the Pu resuspended from the 903 Field does not contribute appreciably to off-site dose. The 903 Field influence beyond about 1.5 km could not be discerned. To further confirm this observation, future studies are suggested, involving additional air sampling along Indiana Street with improved air samplers that do a better job of efficiently collecting larger airborne particles (RF3650, p20). The Pu samples should be analyzed for the Pu-240/Pu-239 ratio as well as samples of nearby soil to identify their sources, such as fallout or Pu generated at RFP.

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Appendix D

AIRDOS-PC Compliance Report Fugitive Source

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

CLEAN AIR ACT COMPLIANCE REPORT
(Version 3.0 November 1989)

Facility: EG&G Rocky Flats Plant
Address: P.O. Box 464
 Golden , CO. 80402-0464
Annual Assessment for Year: 1991
Date Submitted: 5/28/92

Comments: 903 Pad Fugitive Emission Source

Prepared By:

Name: W. E. Osborne
Title: Rad. Effluents Engr.
Phone #: (303) 966-8609

Prepared for:
U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

Facility: EG&G Rocky Flats Plant

Address: P.O. Box 464

City: Golden

State: CO

Comments: 903 Pad Fugitive Emission Source

Year: 1991

Dose Equivalent Rates to Nearby
Individuals (mrem/year)

Effective
Dose Equivalent

0.0093

Highest Organ
Dose is to
ENDOSTEUM

0.1200

-----EMISSION INFORMATION-----

Radio-nuclide	Class	Amad	Area 903Pad (Ci/y)
PU-239	Y	1.0	2.1E-04
AM-241	W	1.0	4.1E-05
PU-241	Y	1.0	1.0E-03
Total Area (m**2)			6.7E+05

-----SITE INFORMATION-----

Wind Data	RFONEW91.WND	Temperature (C)	10
Food Source	LOCAL	Rainfall (cm/y)	41
Distance to Individuals (m)	3331	Lid Height (m)	1405

*NOTE: The results of this computer model are dose estimates.
They are only to be used for the purpose of determining
compliance and reporting per 40 CFR 61.93 and 40 CFR 61.94.

ORGAN DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL

ORGAN	DOSE EQUIVALENT RATE TO THE ORGAN (mrem/y)
GONADS	1.5E-03
BREAST	1.5E-04
RED MARROW	9.5E-03
LUNGS	2.2E-02
THYROID	1.5E-04
ENDOSTEUM	1.2E-01
REMAINDER	5.2E-03
EFFECTIVE	9.3E-03

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL
BY PATHWAY FOR ALL RADIONUCLIDES

	EFFECTIVE DOSE EQUIVALENT (mrem/y)	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE ENDOSTEUM (mrem/y)
	-----	-----
INGESTION	8.6E-04	1.5E-02
INHALATION	8.4E-03	1.0E-01
AIR IMMERSION	4.1E-11	5.7E-11
GROUND SURFACE	1.8E-06	2.2E-06
	-----	-----
TOTAL:	9.3E-03	1.2E-01

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL
BY RADIONUCLIDE FOR ALL PATHWAYS

RADIONUCLIDE	EFFECTIVE DOSE EQUIVALENT (mrem/y)	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE ENDOSTEUM (mrem/y)
PU-239	6.7E-03	7.4E-02
AM-241	2.1E-03	3.6E-02
PU-241	5.1E-04	8.0E-03
TOTAL :	9.3E-03	1.2E-01

EG&G Rocky Flats Plant

5/28/92 7:56 AM

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION
OF DISTANCE IN THE DIRECTIONS OF THE
MAXIMALLY EXPOSED INDIVIDUAL FOR
ALL RADIONUCLIDES AND ALL PATHWAYS

DIRECTION : EAST-SOUTHEAST

DISTANCE (meters)	EFFECTIVE DOSE EQUIVALENT (mrem/y)
3331	9.3E-03
10000	1.8E-03
80000	9.1E-05

EG&G Rocky Flats Plant

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION
OF ALL DISTANCES AND ALL DIRECTIONS FOR ALL
RADIONUCLIDES AND ALL PATHWAYS

DIRECTIONS:	N	NNE	NE	ENE	E	ESE	SE	SSE
DISTANCE (METERS):								
3331	4.6E-03	5.1E-03	6.6E-03	7.6E-03	7.8E-03	9.3E-03	7.2E-03	6.5E-03
10000	9.0E-04	1.0E-03	1.3E-03	1.5E-03	1.5E-03	1.8E-03	1.4E-03	1.3E-03
80000	4.8E-05	5.3E-05	7.0E-05	8.3E-05	7.9E-05	9.1E-05	7.5E-05	6.9E-05
	S	SSW	SW	WSW	W	WNW	NW	NNW
DISTANCE (METERS):								
3331	5.5E-03	4.5E-03	3.0E-03	2.3E-03	2.4E-03	2.5E-03	3.1E-03	4.6E-03
10000	1.1E-03	8.3E-04	5.5E-04	4.3E-04	4.5E-04	4.6E-04	5.8E-04	8.9E-04
80000	5.4E-05	3.7E-05	2.7E-05	2.0E-05	2.1E-05	2.2E-05	2.7E-05	4.4E-05

FREQUENCIES OF WIND DIRECTIONS AND TRUE-AVERAGE WIND SPEEDS

DIRECTION TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.050	1.82	1.67	2.57	4.26	3.50	2.54	0.00
NNW	0.056	2.31	2.37	2.57	4.36	3.30	2.41	0.00
NW	0.045	2.00	2.43	2.76	3.91	2.98	2.35	0.00
WNW	0.041	1.77	2.52	2.92	3.30	2.79	1.96	0.00
W	0.036	2.05	2.34	2.57	3.28	2.81	2.01	0.00
WSW	0.033	1.83	2.66	2.54	3.12	2.75	0.00	0.00
SW	0.042	2.08	2.40	2.82	3.52	3.01	2.52	0.00
SSW	0.060	1.84	2.39	2.73	4.23	3.16	1.78	0.00
S	0.070	1.49	2.17	2.79	4.76	3.31	2.35	0.00
SSE	0.073	1.23	2.20	2.25	4.45	3.58	2.40	0.00
SE	0.084	1.49	2.57	3.13	6.08	3.43	2.51	0.00
ESE	0.129	1.28	2.57	3.61	7.56	3.27	2.52	0.00
E	0.091	0.77	0.00	2.57	7.36	3.30	2.54	0.00
ENE	0.079	2.57	1.39	0.00	5.87	3.51	2.51	0.00
NE	0.063	1.67	1.86	2.84	4.48	3.60	2.52	0.00
NNE	0.048	2.57	0.00	1.39	4.46	3.50	2.51	0.00

FREQUENCIES OF WIND DIRECTIONS AND RECIPROCAL-AVERAGED WIND SPEEDS

D TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.050	1.30	1.19	2.11	2.89	2.91	2.48	0.00
NNW	0.056	1.92	2.03	2.12	3.15	2.58	2.12	0.00
NW	0.045	1.48	2.17	2.52	3.07	2.46	2.00	0.00
WNW	0.041	1.26	2.42	2.72	2.62	2.17	1.43	0.00
W	0.036	1.54	1.98	2.28	2.47	2.27	1.49	0.00
WSW	0.033	1.32	2.62	2.04	2.19	2.23	0.00	0.00
SW	0.042	1.57	2.10	2.39	2.52	2.34	2.42	0.00
SSW	0.060	1.32	2.09	2.35	2.94	2.36	1.27	0.00
S	0.070	1.07	1.70	2.42	3.43	2.62	2.00	0.00
SSE	0.073	0.94	1.74	1.61	3.22	3.03	2.10	0.00
SE	0.084	1.07	2.57	1.51	3.84	2.90	2.37	0.00
ESE	0.129	0.96	2.57	2.22	5.23	2.59	2.40	0.00
E	0.091	0.77	0.00	1.73	4.66	2.70	2.48	0.00
ENE	0.079	2.57	1.01	0.00	3.44	2.87	2.38	0.00
NE	0.063	1.19	1.34	2.74	2.57	3.08	2.40	0.00
NNE	0.048	2.57	0.00	1.01	2.63	2.86	2.37	0.00

FREQUENCY OF ATMOSPHERIC STABILITY CLASSES FOR EACH DIRECTION

FOR FRACTION OF TIME IN EACH STABILITY CLASS

	A	B	C	D	E	F	G
N	0.0276	0.0048	0.0209	0.4019	0.4723	0.0725	0.0000
NNW	0.0147	0.0188	0.0373	0.5542	0.3475	0.0274	0.0000
NW	0.0562	0.0637	0.1480	0.5300	0.1789	0.0233	0.0000
WNW	0.1328	0.1076	0.2348	0.3776	0.1386	0.0085	0.0000
W	0.1697	0.1272	0.1922	0.3076	0.1700	0.0332	0.0000
WSW	0.1557	0.0745	0.1874	0.4051	0.1774	0.0000	0.0000
SW	0.1102	0.0854	0.1599	0.4233	0.2127	0.0086	0.0000
SSW	0.0522	0.0388	0.1123	0.5811	0.2018	0.0137	0.0000
S	0.0165	0.0148	0.0609	0.5322	0.3606	0.0151	0.0000
SSE	0.0065	0.0080	0.0176	0.3983	0.5095	0.0601	0.0000
SE	0.0069	0.0014	0.0070	0.4822	0.4326	0.0699	0.0000
ESE	0.0063	0.0009	0.0054	0.6362	0.2818	0.0693	0.0000
E	0.0051	0.0000	0.0052	0.5100	0.3736	0.1062	0.0000
ENE	0.0015	0.0044	0.0000	0.3389	0.5717	0.0834	0.0000
NE	0.0038	0.0092	0.0130	0.2686	0.5655	0.1400	0.0000
NNE	0.0025	0.0000	0.0073	0.3194	0.5448	0.1260	0.0000

METEOROLOGICAL AND PLANT INFORMATION SUPPLIED TO PROGRAM----

AVERAGE VERTICAL TEMPERATURE GRADIENT OF THE AIR (DEG K/METER)

IN STABILITY CLASS E	0.0728
IN STABILITY CLASS F	0.1090
IN STABILITY CLASS G	0.1455

PLUME DEPLETION AND DEPOSITION PARAMETERS

NUCLIDE	GRAVITATIONAL FALL VELOCITY (METERS/SEC)	DEPOSITION VELOCITY (METERS/SEC)	SCAVENGING COEFFICIENT (1/SEC)	EFFECTIVE DECAY CONSTANT IN PLUME (PER DAY)
PU-239	0.000	0.00180	0.410E-05	0.000E+00
AM-241	0.000	0.00180	0.410E-05	0.000E+00
PU-241	0.000	0.00180	0.410E-05	0.000E+00