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FINAL
PAST REMEDY REPORT

Operable Unit No. 3 - IHSS 199

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

MAY, 1991

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Date 8-19-91

ENVIRONMENTAL RESTORATION PROGRAM

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EXECUTIVE SUMMARY

This Past Remedy Report for Individual Hazardous Substance Site (IHSS) 199 was prepared in response to requirements in the Interagency Agreement (IAG) The IAG identifies the following primary objectives for the Past Remedy Report

1 Detail the history of the IHSS 199 remedy ordered by the U S District Court,

2 Detail the activities conducted to date to implement the remedy,

3 Detail the effectiveness of the remedy, and

4 Provide a health assessment which identifies the public health risk associated with potential exposure of the public prior to completing any site remediation, during implementation of the remedy, and after completion of the remedy

The existing data for IHSS 199 were collected for the purpose of site characterization rather than to support a rigorous quantitative health risk assessment. After evaluating the existing data against U S Environmental Protection Agency (EPA) guidance for data useability in risk assessments, it became apparent that the data do not meet current quality control standards necessary to support a quantitative risk assessment. As a result, this Past Remedy Report includes a qualitative human health risk assessment which evaluates release mechanisms, transport mechanisms, and exposure routes associated with IHSS 199 In addition, a "generic" risk assessment calculation is included which shows the steps and the many assumptions underlying a quantitative risk assessment, and which generates risk values based upon hypothetical plutonium concentrations in soil under various exposure scenarios This calculation is useful in helping to determine whether known contamination at IHSS 199 poses an imminent health risk to the public The generic recreational lifetime excess cancer calculations of $7x10^{7}$ to $7x10^{8}$ is below the EPA target range of 10^{-4} to 10^{6} The following discussions provide a brief summary of the information provided in this report in support of the objectives listed above

IHSS 199 is one of four IHSSs in Rocky Flats Plant (RFP) Operable Unit No 3 (OU 3) OU 3 differs from other RFP OUs in that it targets possible contamination outside the RFP boundary IHSS 199, Contamination of the Land's Surface, specifically targets off-site soil contamination as a result of RFP releases Numerous studies have attempted to define the presence and extent

of such contamination, and to identify prospective on-site source(s) of contaminants These studies have focused almost exclusively on airborne emissions of plutonium from the RFP, and particularly upon three possible RFP sources 1) a September, 1957 fire in Building 771, 2) a May, 1969 fire in Building 776, and, 3) plutonium-contaminated soils at and around the 903 Pad, a former drum storage area east of the RFP main production area These studies have concluded that the great majority of off-site soil plutonium contamination originated as windborne particulates from the 903 Pad. The 903 Pad was capped with asphalt in November 1969, effectively eliminating it as a direct source of contamination to IHSS 199 It is possible that on-site soils contaminated by the 903 Pad could in turn generate windborne particulates which might affect IHSS 199, as could any future non-routine emission from the RFP, including those generated by soil remediation and similar activities at on-site RFP OUs Available data from off-site air monitoring stations suggest that IHSS 199 has not been measurably impacted by plutonium emissions from the RFP since the off-site air monitoring system was established in 1975 The air monitoring data are corroborated by on-site and off-site soil monitoring data.

Included within IHSS 199 are approximately 350 acres (142 hectares) of land which were the subject of a 1975 lawsuit filed by landowners against the United States and other defendants A Settlement Agreement finalized in July, 1985 required the RFP to undertake remedial actions (remedy) on those portions of the land containing plutonium at concentrations exceeding a Colorado Department of Health (CDH) special construction requirements plutonium in soil standard (0 9 picocuries per gram [pCi/g]) adopted by the court. The remedy involves tilling the contaminated areas to reduce plutonium concentrations, and revegetating these areas to control wind and water erosion of the soil To date, approximately 110 acres (45 hectares) have been tilled and partially revegetated. While plutonium concentrations in these areas have been reduced by tilling to below the CDH standard, the success of the revegetation to date has been limited by the following factors

- insufficient amounts and poor seasonal distribution of precipitation
- extremely rocky surfaces or clayey soils
- intense competition from weeds, which provide insufficient soil stabilization
- an expanding prairie dog population
- the effects of slope and aspect on soil water

Specific actions to increase revegetation success have been identified, and include actions to change the seed mixture and control prairie dog and weed populations

Because past studies and data collection activities at IHSS 199 have focused almost exclusively on plutonium contamination, little is known about other possible contaminants there As a result, the qualitative risk assessment focuses on plutonium as the contaminant of concern at IHSS 199 Air samples collected immediately downwind of the remedy acreage during remedy activities and at air monitoring stations in population centers downwind of the IHSS 199 remedy acreage have recorded no increases in airborne plutonium during or after the remedy actions taken to date, suggesting that there has been no measurable impact to human receptors downwind of the site as a result of the remedy Without acceptable data, however, it is not possible to fully differentiate between the potential risk to human health prior to remedy implementation, during implementation, or after implementation It is also uncertain without a quantitative assessment whether the remedy implementation activities will in fact reduce the potential risk

The information presented in this report points to the following conclusions about IHSS 199

- There does not appear to be any imminent human health hazard posed by IHSS 199 This conclusion is preliminary because of data quality limitations

- Plutonium concentrations measured in some IHSS 199 soils during past studies and data collection activities exceed the CDH plutonium standard used by the U S District Court as the lawsuit acreage remedy action level The data that support this conclusion, however, cannot be validated and may not be of comparable quality, and are therefore considered inconclusive

- Remedial actions implemented to date on 120 acres of Jefferson County remedy acreage have successfully reduced plutonium concentrations in soil to below the 0 9 pCi/g (0 03 Bq/g) action level mandated by the lawsuit Settlement Agreement Attempts to restabilize the remediated acreage through revegetation have been only 50% successful due to insufficient precipitation, extremely rocky surfaces and/or clayey soils, intense competition from weeds, an expanding prairie dog population, and the effects of slope on soil moisture Specific actions to improve the revegetation effort include weed control, prairie dog suppression, and changes to the revegetation seed mixture specified in the Settlement Agreement

- Multiple plutonium exposure pathways from IHSS 199 were analyzed The pathway analysis suggests that the airborne dust inhalation pathway is the most significant in terms of human health risk under current site conditions Under a future residential

use scenario, the soil ingestion pathway may also be significant Although other exposure pathways are not considered significant under this analysis, all pathways will be addressed under scheduled RCRA Facility Investigation/Remedial Investigation (RFI/RI) activities at IHSS 199

- Although the actual receptor exposures could be expected to vary, the completed exposure pathways are the same for pre-remedy, remedy implementation, and post-remedy conditions at IHSS 199 If the remedy is successfully implemented, however, the concentration of plutonium available for transport as airborne dust will be reduced through tilling, and the probability of occurrence for the airborne dust pathway will be reduced through revegetation

- The control measures used to reduce off-site impacts during remedy implementation at IHSS 199 appear to have been effective Available data from air samplers set up immediately downwind of the remedy acreage during remedy implementation and air monitoring stations in populated areas downwind of the acreage show no increases in airborne plutonium during or after remedial actions taken to date

Additional data collection activities will be conducted during scheduled RFI/RI activities Risk assessment and site characterization needs will be integrated to ensure that all potential site contaminants and exposure pathways are identified and characterized to the extent necessary to perform a quantitative human health risk assessment

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LIST OF ACRONYMS AND ABBREVIATIONS

µm	Micrometer (10^{-6} meters)
ANL	Argonne National Laboratory
ARARs	Applicable or Relevant and Appropriate Requirements
Bq	Becquerels
CCEI	Colorado Committee for Environmental Information
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
CHWA	Colorado Hazardous Waste Act
Ci	Curies
cm	Centimeter (10^{-2} meters)
CSF	Cancer Slope Factors
CSU	Colorado State University
DNA	Deoxyribonucleic acid
DOE	U S Department of Energy
dpm	Disintegrations per minute
DRCOG	Denver Regional Council of Governments
DWR	Colorado Division of Water Resources
EG&G	EG&G Rocky Flats
EPA	U S Environmental Protection Agency
F_1	Gastrointestinal Absorption Factor
FS	Feasibility Study
ft	Feet
g	Gram
gal	Gallons
GI	Gastrointestinal
He	Helium
hr	Hour
IAG	Interagency Agreement

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

ICRP	International Commission on Radiation Protection
IHSS	Individual Hazardous Substance Site
in	Inches
K_d	Distribution coefficient (ratio of concentration in soils to concentration in water for plutonium)
km	Kilometers (10^3 meters)
l	Liter
lbs	Pounds
LET	Linear Energy Transfer
m	Meter
m^{1}	Per meter
mCi	Millicuries (10^{-3} curies)
MeV	Million Electron Volts
mm	Millimeter (10^{-3} meter)
mph	Miles per hour
NAS-BEIR	National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiations
NCP	National Oil and Hazardous Substances Contingency Plan
NCRP	National Council on Radiation Protection
OU	Operable Unit
pCi	Picocuries (10^{-12} Curies)
PuO_2	Plutonium dioxide
QA/QC	Quality Assurance/Quality Control
RAG	Risk Assessment Guide
RCRA	Resource Conservation and Recovery Act
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
SCS	U S Department of Agriculture Soil Conservation Service
sec	Second
TGLD	Task Group on Lung Dynamics

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
US	United States
USGS	United States Geological Survey, U S Department of the Interior
Yr	Year

LIST OF DEFINITIONS

Completed Exposure Pathway[1] The route a chemical or radionuclide takes from a source to an exposed organism A completed exposure pathway describes a unique mechanism by which an individual or population is exposed to a chemical or radionuclide originating from the site Each completed exposure pathway includes a source, a transport media, a mode of uptake, and a receptor

Curie A curie (Ci) is a unit of radioactivity equal to $2\ 22 \times 10^{12}$ radioactive disintegrations per minute

Detection Limit[1] The lowest value that can be reliably detected above the background noise of a given analytical instrument or method.

Health Assessment The assessment of chemical or radiological releases from a site and the analysis of public health threats resulting from those releases

Picocurie A unit of radioactivity A picocurie (pCi) is one one-billionth of a Ci, or 10^{12} Ci, and is equal to 2 22 radioactive disintegrations per minute

Qualitative Risk Assessment An estimate of the likelihood of an adverse health effect by analyzing both exposure and dose response data in a non-numerical manner

Quantitative Risk Assessment Based on completed exposure pathways, probabilities that an individual will develop cancer over a lifetime of exposure are estimated from projected intakes and chemical/radionuclide-specific dose response information

Risk A unitless probability of an individual being affected by an event.

Risk Coefficient For the purposes of this document, a unitless probability of an individual developing cancer from a chronic daily intake of plutonium averaged over seventy years

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[1] Definitions from the EPA Risk Assessment Guidance for Superfund (EPA, 1986b)

1.0 INTRODUCTION

This Past Remedy Report presents a summary of the history of the IHSS 199 remedy ordered by the U S District Court, an evaluation of the effectiveness of the remedy actions implemented to date, and a preliminary human health risk assessment for IHSS 199, Contamination of the Land's Surface, of RFP OU 3 (Off-Site Releases) The RFP is owned by the U S Department of Energy (DOE) and contractor-operated by EG&G Rocky Flats, Inc (EG&G) as a nuclear weapons research, development, and production complex The RFP is situated on 6,550 acres (2,653 hectares) of federal property 16 miles (25 7 kilometers [km]) northwest of downtown Denver, Colorado (Figure 1-1) OU 3 is unique among RFP operable units in that it is located outside the RFP boundaries

As presently defined, IHSS 199 includes all soils outside of the RFP boundary which are contaminated by releases from the RFP Past attempts to define the presence and extent of off-site soil contamination have focused almost exclusively on airborne plutonium emissions from the RFP This topic is addressed in detail in Section 2 1 2 Included within IHSS 199 are approximately 350 acres (142 hectares) of land which were the subject of a 1975 lawsuit filed in U S District Court (Civil Action No 75-M-1162) by the land owners against the United States and other defendants (hereafter referred to as the lawsuit), alleging contamination of the land surface by releases from the RFP during its operating history Several technical investigations and studies of the lawsuit acreage were conducted by the various parties to the lawsuit to provide supporting evidence in the case A Settlement Agreement finalized in July, 1985 (the Settlement Agreement) (U S District Court, 1985a) required that the RFP undertake remedial action on those portions of the land (hereafter referred to as the remedy acreage) containing plutonium at concentrations exceeding an action level adopted by the court from a CDH special construction standard for plutonium in soil Two contiguous tracts of land, which currently are owned by the City of Broomfield and Jefferson County, were targeted for remediation based upon the CDH standard.

OU 3 also includes three nearby reservoirs, designated IHSSs 200, 201, and 202, which are the subject of a separate report (DOE, 1990)

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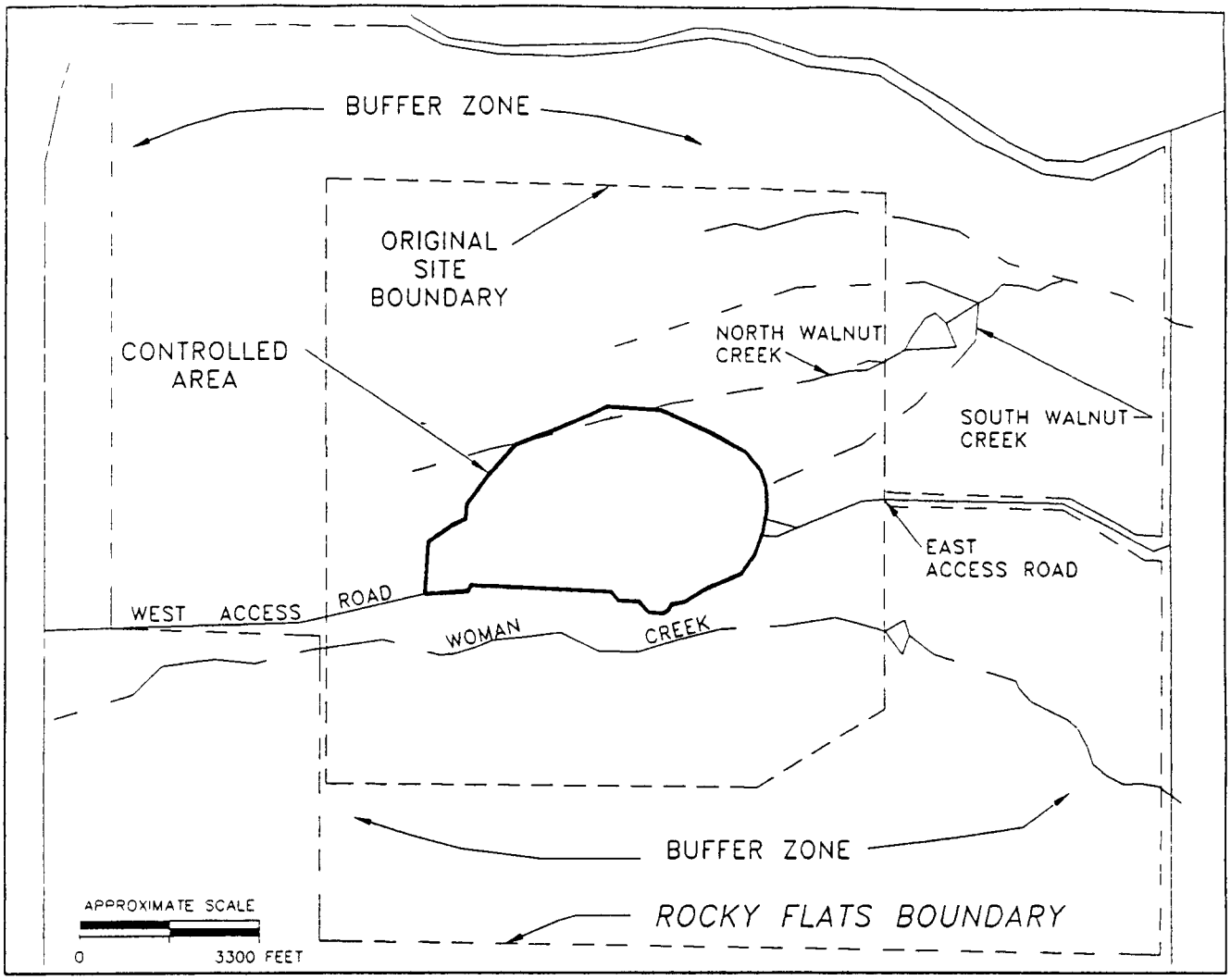


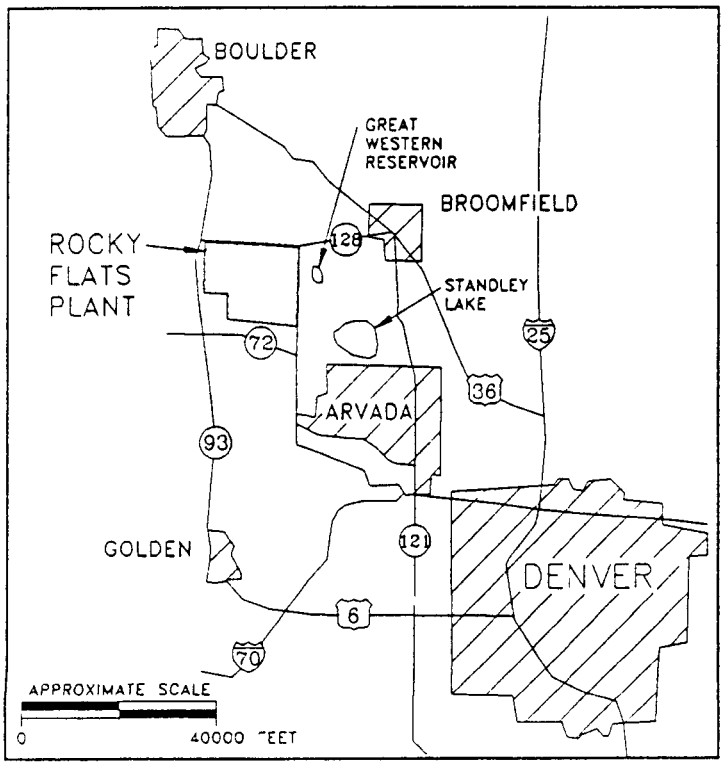


FIGURE 1-1

ROCKY FLATS LOCATION MAP

ADAPTED FROM FIG 1-1 E G & G DRAFT GEOLOGIC CHARACTERIZATION REPORT JAN 5 1990

1 1 PURPOSE AND OBJECTIVES

The purpose and objectives of this report are derived primarily from the IAG between the CDH, the EPA, and the DOE (EPA et al , 1991) The IAG requirements for the Past Remedy Report are as follows

> " Submit a report detailing the history of the remedy ordered by the U S District Court pursuant to the land owner's suit settled on July 10, 1985, the implementation of the remedy, and the effectiveness of the remedy Within this report include a health assessment identifying the public health risk associated with potential exposure to the public prior to completing any site remediation, during implementation of the remedy, and after completion of the Settlement Agreement imposed remedy This report must detail the effectiveness of the remedy and the risks associated with a no-action alternative as well as detailing the risks associated with plausible exposure during implementation of the remedy and after completion of the remedy "

Section VII D of the IAG Statement of Work details the components of the health risk assessment required in the above passage These components are the basis of a rigorous, quantitative assessment of the human health risks associated with contamination at a site, and it is the intent of the IAG that they be applied to IHSS 199 to assess public health risk prior to remedy implementation, during remedy implementation, and after completion of the remedy Critical to the performance of such a risk assessment are the quality and specificity of the data used to support the assessment The EPA "Guidance for Data Useability in Risk Assessment" document (EPA, 1990a) establishes guidelines for the minimum level of data quality control required to perform a defensible, quantitative risk assessment. Virtually all of the available data for IHSS 199 have been collected for the purpose of site characterization rather than risk assessment While these data are well suited for site characterization, a detailed evaluation against EPA useability criteria (Appendix A) indicates that existing IHSS 199 data do not meet current quality control standards to support a quantitative risk assessment This report therefore provides a qualitative risk assessment in which human health risk is defined in relative terms rather than calculated risk values Also included is a "generic" risk assessment calculation which shows the steps and the many assumptions underlying a quantitative risk assessment, and which generates risk values based upon hypothetical plutonium concentrations in soil under various exposure scenarios (Appendix C) This calculation is useful in helping to determine whether known contamination at IHSS 199 poses an imminent health risk to the public Additional data needed

to support a quantitative risk assessment for IHSS 199 are identified in Section 4 14, these data will be collected under scheduled RFI/RI activities at the site

The following specific objectives for this report are based upon the IAG requirements for the Past Remedy Report and the preceding discussion on data useability

- Describe IHSS 199 site physical characteristics
- Provide a historical summary of litigation, environmental investigations, and remedial activities at the IHSS 199 lawsuit acreage
- Evaluate the efficacy of remedial action conducted to date in accomplishing the intended goals of the remedy
- Formulate a conceptual model for contaminant fate and transport from IHSS 199
- Provide a preliminary health risk assessment for the IHSS 199 remedy acreage which considers three scenarios
  - No action
  - Implementation of the remedy
  - Post remedy
- Identify additional data needed to support a quantitative risk assessment for IHSS 199

1 2 REGULATORY BACKGROUND

The IAG groups the IHSSs at the RFP into 16 Operable Units (OUs), one of which is OU 3 The OU numbering system reflects the relative order of priority for the OUs OU 3 formerly was designated Operable Unit No 10 The present RFP OU system has emerged from IAG negotiation and public comment, which have increased the number of OUs from ten to sixteen and changed their relative order of priority

The primary source for the scope of work for investigation and remediation of RFP OUs is the IAG, which specifies a phased approach tailored to the particular requirements of the RFP As stated in Paragraph 256 of the IAG, all response activities by the DOE under the IAG are to be performed " in accordance with the requirements of all applicable federal and state laws and regulations " These include the applicable requirements of the Comprehensive Environmental

Response, Compensation, and Liability Act (CERCLA), the National Contingency Plan (NCP), the Resource Conservation and Recovery Act (RCRA), the Colorado Hazardous Waste Act (CHWA), and pertinent EPA guidance documents Investigation of the RFP OUs is scoped in the IAG per EPA RCRA and CERCLA guidance, which specify collection of data under an RFI/RI to support a site characterization, a health risk assessment, and an environmental evaluation In the Past Remedy Report, however, the IAG specifies the use of existing site data to perform a health risk assessment and does not require an environmental evaluation Preparation of the Past Remedy Report is an additional IAG requirement that falls outside the scope of RCRA and CERCLA guidance

Under the terms of the 1985 Settlement Agreement with landowners, a 250-acre (101 hectare) tract of land was transferred to Jefferson County for use in its Open Space program, and 100 adjoining acres (41 hectares) were allotted to the City of Broomfield for future expansion of Great Western Reservoir These lands were deeded with the understanding that the RFP would implement remedial activities on these 350 acres (142 hectares) as specified in the Settlement Agreement, at the request of the owners The action level for the remedy was based upon the CDH special construction requirements standard for plutonium in soil of 0 9 pCi/g, or 0 03 becquerels per gram (Bq/g) (CDH,1976) This standard is somewhat more stringent than the EPA screening level guidance of $2x10^5$ pCi ($6\ 67x10^3$ Bq) of transuranic radionuclides per square meter of soil surface area, which translates to a calculated total transuranic concentration in soil in the range of 8 to 20 pCi/g (EPA, 1990b) It is stated in the Settlement Agreement that adoption of the CDH standard is not meant to imply concurrence between the lawsuit parties on the reasonableness, appropriateness, or applicability of the standard as an action level for the remedy (U S District Court, 1985a) Jefferson County requested in 1986 that remediation commence on the portions of their acreage targeted for remediation To date, the remedy has been implemented on 110 of the 250 acres of Jefferson County land. Rather than allow immediate use of the acreage as Open Space, the county has chosen to not allow public access to this land until the remediation is completed To date, Broomfield has not requested that the RFP begin remediation on their affected acreage, and has not proceeded with plans to expand Great Western Reservoir Broomfield does not allow public access to this land

1 3 REPORT ORGANIZATION

The remainder of this report is organized into the following sections

- Section 2 0 provides a discussion of site characteristics, site history, a description of the remedial actions performed to date, and a discussion on the effectiveness of the remedy
- Section 3 0 provides a description of the site conceptual model used in the preliminary human health risk assessment
- Section 4 0 provides a preliminary human health risk assessment, including identification of data needed to conduct a quantitative human health risk assessment
- Section 5 0 provides conclusions and recommendations
- Section 6 0 provides references
- Appendix A provides an evaluation of existing IHSS 199 data useability for risk assessment against EPA criteria
- Appendix B provides general guidelines for development of a risk assessment
- Appendix C provides a "generic" risk assessment calculation for IHSS 199
- Appendix D provides selected IHSS 199 data source documents

2.0 SITE BACKGROUND AND DESCRIPTION

The RFP fabricates metal components for nuclear weapons from plutonium, uranium, beryllium and stainless steel Additional production activities include chemical recovery and purification of recyclable transuranic radionuclides, metal fabrication and assembly, and related control functions Support activities include research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry and physics These operations generate nonhazardous, hazardous, radioactive and mixed radioactive waste streams (DOE, 1987) The 385 acre (156 hectare) main production area of the RFP, within the controlled area, is surrounded by a 6,150 acre (2,491 hectare) buffer zone which delineates the RFP boundary (Figure 1-1)

2 1 LOCATION AND PHYSICAL DESCRIPTION

The RFP is located in the northwest portion of Township 2 South, Range 70 West, Jefferson County, Colorado (Figure 2-1) IHSS 199 encompasses all lands outside the RFP boundary which are contaminated by releases from the RFP, including the remedy acreage The IHSS 199 boundary, therefore, is delineated by the extent of off-site contamination, which has not been conclusively defined Previous work which has attempted to determine this extent is detailed in Section 2 1 2

The IHSS 199 remedy acreage is located on two contiguous tracts of land totalling 350 acres (142 hectares) in the southern half of Section 7 and the western half of Section 18, Township 2 South, Range 69 West (T2S, R69W) Both areas are just outside the eastern boundary of the RFP, approximately 1 5 miles (2 4 km) east of the main production area of the plant (Figure 2-1) Both are generally downwind and downgradient of the RFP

2 1 1 RFP Contamination Sources

Krey and Hardy (Appendix D, Document D-1) sought, among other goals, to identify on-site sources of the plutonium found in off-site soils These investigators focused on four sources which might conceivably have resulted in off-site contamination 1) a September 11, 1957 fire

in Building 771 (Dow, 1973), 2) a May 11, 1969 fire in Building 776 (USAEC, 1969, CCEI, 1970), 3) leaking drums of plutonium-contaminated lathe coolant at the 903 Pad, a drum storage area in the southeastern part of the RFP main production area, and, 4) chronic low-level stack effluent Based on the particle size of the contaminated soil fraction, meteorological data, and RFP monitoring records, the Krey and Hardy investigation concluded that the great majority of the plutonium at IHSS 199 originated as windborne particulates from the 903 Pad, and largely dismissed the contributions of the 1957 and 1969 fires and chronic stack emissions Contamination at the 903 Pad resulted from 55-gallon drums of plutonium-contaminated lathe coolant which corroded and leaked over a 10-year period starting in 1958 The 903 Pad was capped with asphalt in November, 1969, effectively eliminating it as a direct source of contamination to IHSS 199 Numerous other investigations focusing on plutonium in off-site soils since the Krey and Hardy study have reinforced the conclusion that the 903 Pad was the primary source of off-site soil plutonium contamination from the RFP (Appendix D, Documents D-2, D-3, D-4, D-5, and D-7)

It is possible that on-site soils contaminated by the 903 Pad could in turn generate windborne particulates which might impact IHSS 199, as could any abnormal emission from the RFP, including those generated by soil remediation and similar activities at on-site RFP OUs Results from off-site air monitoring stations (Appendix D, Document D-17) suggest that IHSS 199 has not been measurably impacted by airborne emissions from the RFP since the off-site air monitoring system was established in 1975 It is expected that any future RFP emission potentially impacting IHSS 199 will also impact on-site soils and ambient air, and that the contamination will be detected through routine on-site air and soil monitoring (Section 2 1 3)

2 1 2 IHSS 199 Contamination

In an attempt to delineate off-site plutonium contamination around the RFP, Krey and Hardy (Appendix D, Document D-1) established contours, in millicuries per square kilometer (mCi/km^2), for plutonium in soil around the RFP, based upon analytical results from 33 soil samples collected from locations up to 40 miles (64 km) from the plant (Figure 2-2) Dow (Appendix D, Document D-2) based similar contours (Figure 2-3) on results from 135 soil samples Dow's 1972 Rocky Flats Annual Environmental Monitoring Report included soil plutonium contours,

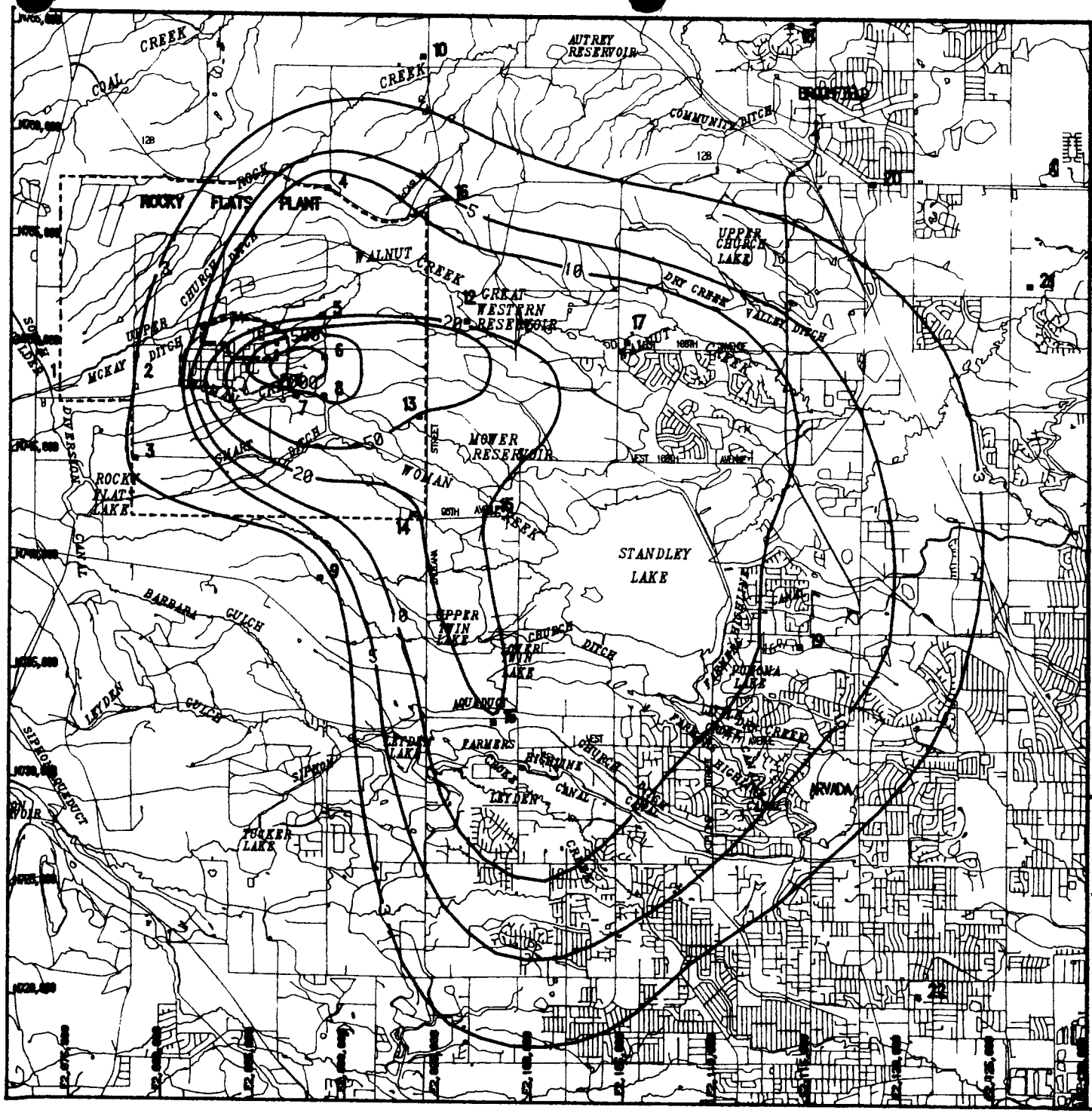
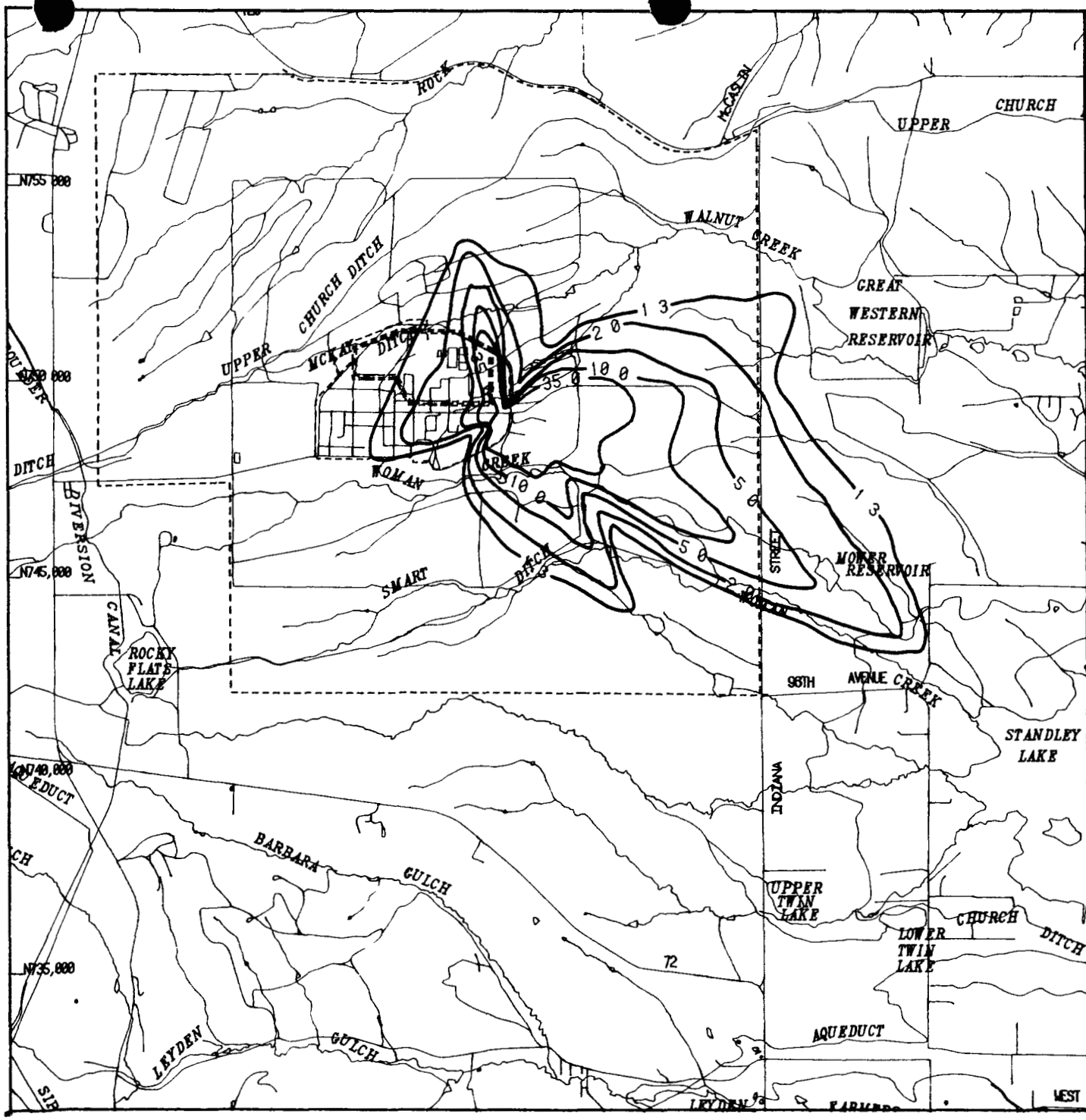


FIGURE 2-2

PLUTONIUM-239 CONTOURS IN THE VICINITY OF THE ROCKY FLATS PLANT KREY AND HARDY (1970)



MAP LEGEND

- - - - - RFP BOUNDARY AND PSZ

——— CONTOUR VALUES IN pCi/g

SOURCE ADAPTED FROM DOW, 1971 (APPENDIX D, DOCUMENT D-2)

N

0 feet 2000 4000

PLUTONIUM-239 CONTOURS IN THE VICINITY OF THE ROCKY FLATS PLANT

(INTERIOR CONTOURS REMOVED FOR FIGURE CLARITY)

Figure 2-3

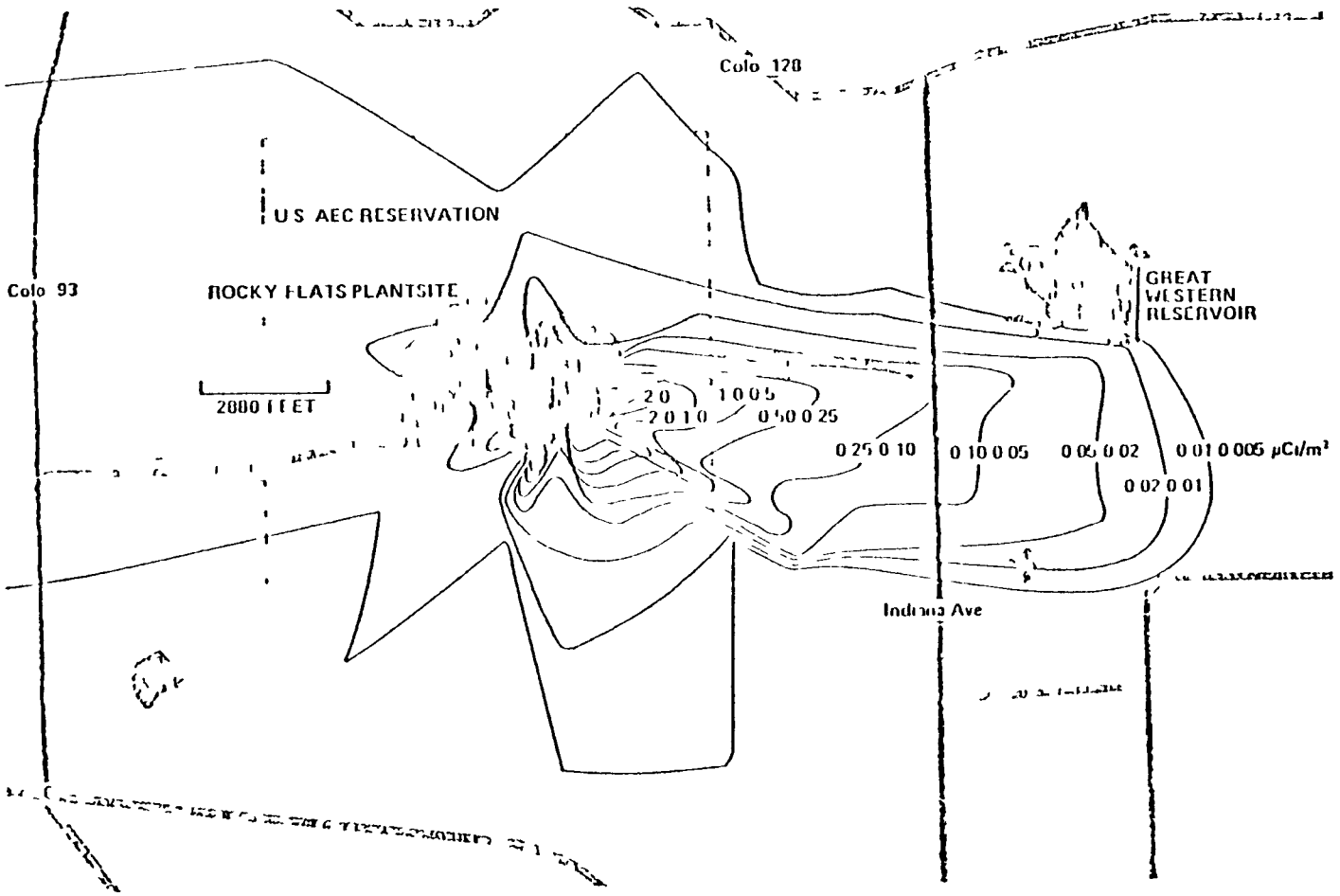


FIGURE 2-4

PLUTONIUM CONTOURS
AROUND
ROCKY FLATS PLANT
DOW (1972)

SOURCE DOW CHEMICAL COMAPANY ANNUAL ENVIRONMENTAL REPORT
ROCKY FLATS PLANT JANUARY-DECEMBER 1972

DRAWN BY KRONER 3-1-91
CHECKED BY BCR 3-11-91
APPROVED BY TDK 3-22-91
DRAWING NUMBER 304923-A19

in microcuries per square meter (uCi/m^2), based on over 300 soil samples (Figure 2-4) The differences in the results of these studies help to illustrate the inherent difficulty in drawing conclusions about IHSS 199 contamination based upon existing data. Results, and hence conclusions, vary widely depending upon sampling methods, analytical methods and uncertainty, definition of "background" concentrations, units of measurement, and numerous other factors Most of the data collected since 1972 have focused specifically on characterizing the lawsuit acreage rather than defining IHSS 199 as a whole (see Appendix D, Documents D-4, D-7, D-8, D-9, D-10, and D-11)

In short, the extent of off-site soil contamination as a result of RFP releases, which will delineate the boundaries of IHSS 199, has not been conclusively defined Studies conducted to date, however, do point to the following delimitations

- IHSS 199 is most likely limited to areas downwind of the RFP, namely to the northeast, east, and southeast of the plant

- The 350 acres of lawsuit acreage targeted for remediation were shown to have the highest concentrations of plutonium in soil of all lawsuit acreage, which adjoined most of the eastern and southern boundaries of the RFP (Appendix D, Document D-7) "Hot spots" may occur which were not detected through lawsuit acreage sampling, however, because other IHSS 199 lands downwind of the RFP are further from the plant than the remedy acreage, it is expected that these lands contain lower concentrations of plutonium than the remedy acreage

- 99 percent of the total ecosystem plutonium inventory was contained in the top 8 3 inches (in), or 21 centimeters (cm), of plutonium-contaminated soils, one-half of the total plutonium was in the top 1 2 in (3 0 cm) (Appendix D, Document D-1)

- The most likely pathways of plutonium migration from IHSS 199 are wind and water erosion of surface soil (SCS, 1985)

Very limited data exist for contaminants other than plutonium which could affect off-site soils as a result of RFP releases In 1976 and 1977, the RFP tested lawsuit acreage soils for isotopes of americium, cesium, thorium, neptunium, cerium, radium, and potassium in addition to plutonium The sampling program also included five sites remote from the RFP in order to determine representative background concentrations (Appendix D, Documents D-4 and D-7) The

Rockwell International Disclosure to the City of Broomfield following the lawsuit (Appendix D, Document D-8) based the following conclusion on the results of the 1976-1977 sampling

> " Analysis of 25 soil samples from plaintiffs' lands and samples from each of the five background locations used in the testing program show that with respect to radionuclides other than plutonium and americium, the levels of these radionuclides on plaintiffs' lands are consistent with background levels "

As indicated in this passage, americium-241, a daughter product of plutonium-241 decay, was detected in IHSS 199 soils above the background concentrations recorded at the five remote sampling locations However, neither Document D-8 nor Document D-7, which also refers to americium data from the 1976-1977 sampling program, provide the analytical results for americium Poet and Martell (1972) measured americium-241 and strontium-90 concentrations in soil samples collected in 1969 from several locations around the RFP This study calculated that americium contributed 3-15 percent as much alpha activity as did plutonium in the areas sampled, and estimated that the americium contribution to alpha activity would eventually approach that of plutonium as decay of plutonium-241 into americium-241 progressed The RFP soil sampling program conducted by CDH (see Section 2 1 3 3 and Appendix D, Documents D-5 and D-18) has periodically included analyses for cesium-137 and uranium 1989 samples were not analyzed for americium-241, as indicated in Document D-18 (CDH, 1991) These limited efforts represent the only known characterizations of radionuclides other than plutonium at IHSS 199 Possible contaminants other than radionuclides present in IHSS 199 soils as a result of RFP releases have not been characterized, with the exception of beryllium measurements in 1971 under the CDH soil monitoring program CDH concluded that beryllium concentrations in the soil were consistent with expected background levels (CDH, 1991)

Ongoing studies of RFP OU 2 will provide more detailed characterizations of soil contamination between the 903 Pad and the RFP eastern boundary Studies are also underway to define background concentrations in soil of potential RFP contaminants, including "background" plutonium and americium resulting from atmospheric testing of nuclear weapons The relevance of these background concentrations to IHSS 199 will be addressed in future RFI/RI activities Cumulative depositions of plutonium due to nuclear testing on ground surfaces in the United

States range from 0 001 to 0 003 uCi/m^2 (EPA, 1990b) Data on RFP climatology also are available (Section 2 1 4 4) It is believed that geostatistical methods incorporating these various data can be utilized during future RFI/RI activities at IHSS 199 to help focus efforts to define the site boundary by selecting appropriate sample locations and sampling density

2 1 3 RFP Environmental Monitoring

The RFP conducts routine radiological and non-radiological environmental monitoring of effluent air, ambient air, surface water, ground water, tap water, stream sediments, and soil at locations on and in the vicinity of the RFP Results from these monitoring programs are published monthly and/or annually in RFP environmental monitoring reports (Dow et al , 1971-1989) The ambient air, effluent air, and soil monitoring programs are of primary importance to the detection of RFP emissions which may impact off-site soils Ambient air and soil are also monitored by CDH in locations around the RFP The following information about these programs is taken primarily from the monthly and annual environmental reports

2 1 3 1 Ambient Air Monitoring

The RFP maintains a network of continuously operating ambient air samplers on and in the vicinity of the plant site These samplers trap influent particulates on a filter element Specific information regarding sampler types and locations, analytical protocols, and analytical results have been summarized since 1971 in the RFP annual environmental monitoring reports (Dow et al , 1971-1989) There currently are 51 samplers in the ambient air sampling network, of which 23 are located on the RFP site (Figure 2-5), 14 are located along the RFP boundary (Figure 2-5), and 14 are located within nearby communities (Figure 2-6) The RFP has conducted on-site ambient air monitoring since the plant opened in 1951 The original network of low-volume (approximately two cubic feet per minute [cfm]) air samplers was upgraded in 1974-1975 to the high-volume (approximately 25 cfm) samplers currently in use Off-site (community) samplers were added to the network at this time

Sampling and analytical protocols have varied throughout the history of the ambient air monitoring program Plutonium analysis of selected ambient air samples began in 1975, prior to this, on-site ambient air samples were analyzed for total long-lived alpha radiation only

Under the current protocol, on-site samples are collected biweekly and analyzed for total long-lived alpha activity If the results of this analysis exceed the RFP guideline of 0 11 pCi/m^3 (0 0037 Bq/m^3), plutonium analysis is performed As of December, 1990, the biweekly on-site samples are composited into a single monthly sample Samples from the RFP perimeter and from nearby communities are collected biweekly and composited into a single monthly sample, which is analyzed for plutonium. The CDH also maintains off-site air samplers for measuring plutonium concentration in ambient air in the vicinity of the RFP (CDH, 1970-date)

Starting in the early 1980s, the RFP conducted on-site monitoring for EPA criteria pollutants (total suspended particulates, ozone, sulfur dioxide, carbon monoxide, nitrogen dioxide, and lead) utilizing a mobile ambient air monitoring unit This mobile unit was replaced in mid-1986 with a permanent monitoring station located just inside the RFP east gate Starting in 1989, this program was scaled back to include total suspended particulates and respirable particle fraction (those particles smaller than or equal to 10 microns in size) only

In 1976, nine ambient air monitoring stations were installed by the RFP at and near the IHSS 199 lawsuit acreage These stations were operated from November, 1976 through July, 1978 specifically to collect monthly airborne plutonium concentration data for the lawsuit It was determined in 1978 that data collected from the lawsuit-specific stations did not significantly differ from nearby ambient air monitoring program sampler data, and the lawsuit-specific stations were therefore removed (Appendix D, Document D-6)

Airborne plutonium concentrations were monitored by the RFP immediately downwind of the remedy acreage during court-ordered tilling to supplement data obtained from permanent stations downwind of the acreage A tabulation of the 1987 remedy-specific monitoring data is included in Appendix D, Document D-12 A summary of average annual ambient air plutonium concentrations from selected monitoring stations near the remedy acreage during the period of remedial activity (1985-1988) is provided in Appendix D, Document D-17 The results of this monitoring in terms of human health risk are discussed in Section 4 0

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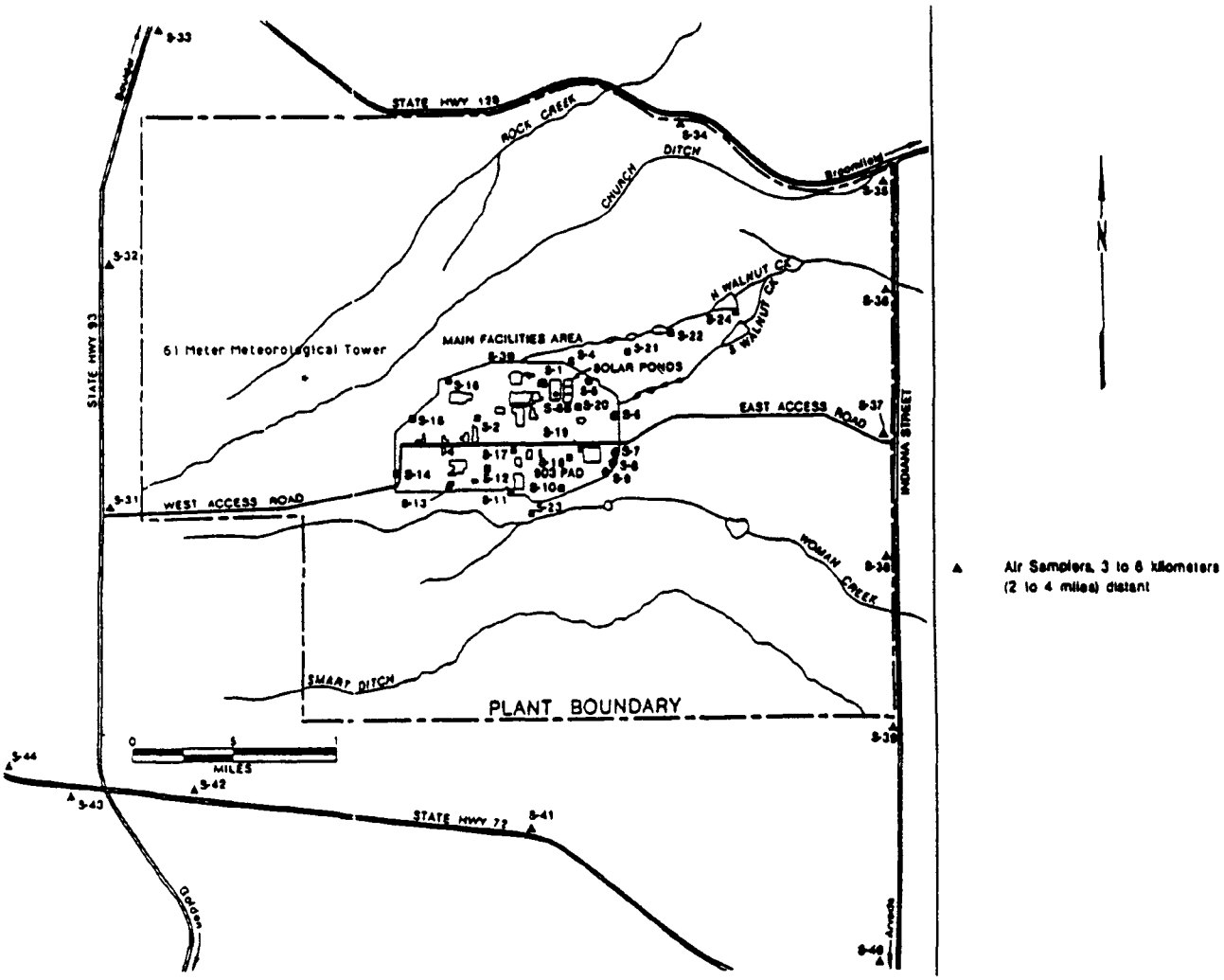

NOTE PORTIONS OF FIGURE ARE NOT TO SCALE

FIGURE 2-5

LOCATION OF ONSITE AND PLANT PERIMETER AMBIENT AIR SAMPLERS

SOURCE EG&G ROCKY FLATS ROCKY FLATS PLANT MONTHLY ENVIRONMENTAL MONITORING REPORT

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	3-4-91	APPROVED BY	TPR		

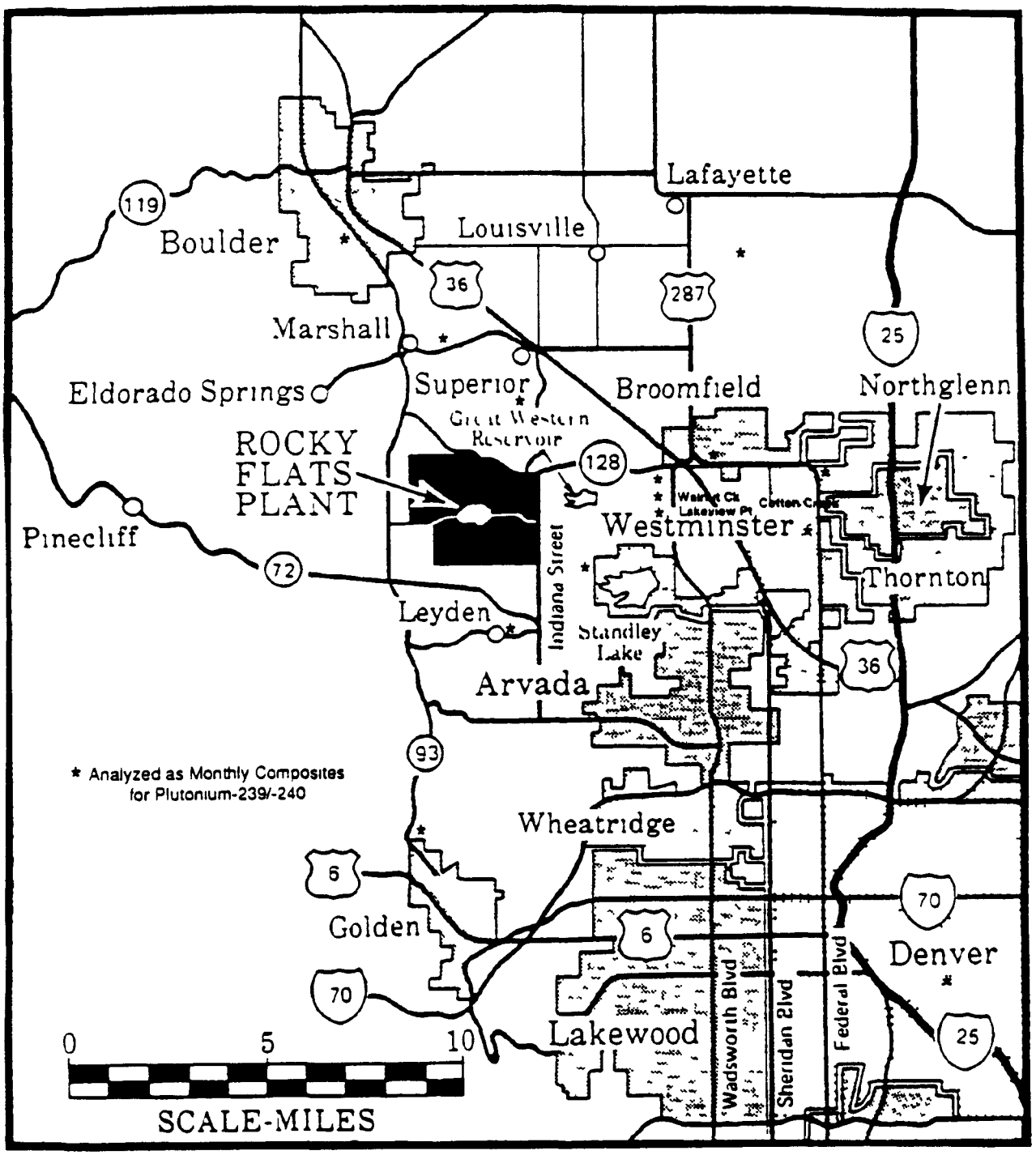


FIGURE 2-6

LOCATION OF COMMUNITY AMBIENT AIR SAMPLERS

SOURCE EG&G ROCKY FLATS ROCKY FLATS PLANT MONTHLY ENVIRONMENTAL MONITORING REPORT

2 1 3 2 Effluent Air Monitoring

RFP effluent air has been monitored since the RFP opened in 1951 Effluent air monitoring is addressed in detail in RFP monthly and annual environmental monitoring reports (Dow et al , 1971-1989) and in the RFP Environmental Impact Statement (DOE, 1980) Continuous effluent air samplers are located in the ventilation exhaust systems of each production and research building at the RFP As is the case with the ambient air monitoring program, the sampling and analytical protocols for effluent air monitoring have varied throughout the history of the RFP Plutonium analysis of selected effluent air samples began in 1975, prior to this, airborne effluents were analyzed for total long-lived alpha radiation only Under current protocol, effluent air samples are analyzed at regular intervals for total long-lived alpha activity Individual samples from each exhaust system are composited monthly into area-specific samples, which are analyzed for plutonium, americium, uranium, and beryllium Exhaust streams known to potentially contain tritium are also analyzed for tritium concentration three times each week

2 1 3 3 Soil Monitoring

Beginning in 1984, soil samples have been collected annually by the RFP to evaluate changes in soil plutonium concentrations The soil monitoring program is addressed in detail in the RFP annual environmental monitoring reports (Dow et al , 1971-1989) Under current protocol, soils samples are collected once per year from 40 sites located on concentric circles one and two miles (1 6 and 3 2 km) from the center of the RFP and are analyzed for plutonium A similar soil sampling program was conducted in 1977, with the addition of 17 samples collected from locations on a circle five miles (eight km) from the RFP center

The CDH also monitors soil plutonium concentrations in areas near the RFP (Appendix D, Document D-18) Under this program, five subsamples are collected within each of 13 predefined sectors near the RFP and composited into a single sample, which provides an average soil plutonium concentration within the sector Soil samples also are collected from eight Colorado locations remote from the RFP in order to assess soil plutonium concentrations due to world-wide atmospheric fallout. The CDH soil sampling program was conducted annually between 1970-1978, and in 1980, 1981, 1986, and 1989 Results are published in RFP environmental surveillance reports prepared monthly by CDH, (CDH, 1970-date) A summary

table of results between 1970-1986 is included in Appendix D, Document D-18 Several of the past sampling programs, including the 1989 program, have included analysis of selected radionuclides other than plutonium and of beryllium (CDH, 1991)

2 1 4 Site Conditions

The following sections address the soils, hydrology, climatology, and biota of IHSS 199 as each pertain to potential contaminant fate and transport and to court-ordered remedial activities at the site Because IHSS 199 boundaries have not been conclusively defined, and because site conditions at the IHSS 199 remedy acreage adjoining the RFP have been studied in detail, the following descriptions focus primarily upon the remedy acreage

2 1 4 1 Soils

A general description of the soils in the IHSS 199 areas east and south of the RFP is provided in the U S Department of Agriculture Soil Conservation Service (SCS) Soil Survey of the Golden Area, Colorado (SCS, 1980) According to this survey, soils in the area are characteristically well drained, clayey and loamy soils on high terraces, hill slopes, and fans The primary soil type in this area is mapped by the SCS as Nunn-Denver complex, comprised of approximately 45 percent Nunn, 25 percent Denver, and 30 percent other soil types and Urban land Nunn and Denver soils are deep and well drained, and form from clayey material derived predominantly from mudstone and shale The surface layer is a clay loam The Nunn subsoil is a clay loam to a depth of 60 in (152 cm), while the Denver subsoil is clay to the same depth The SCS also notes that Primen and Leyden soil units occur within the area on gravelly and cobbly hill slopes

Soil characteristics in the IHSS 199 remedy acreage were considered by the SCS in providing erosion control and revegetation recommendations for the remedy (SCS, 1985) The soils were characterized as Denver-Kutch-Midway clay loams, estimated at 50 percent Denver, 30 percent Kutch, and 20 percent Midway, with Denver and Kutch soils on hill slopes and Midway soils on ridge crests Establishment and maintenance of grasses and other vegetation in the Denver-Kutch-Midway soil complex are restricted by the slope, the clay loam surface layer and clayey subsoil, and, on the Midway soil, shallow depth to bedrock The complex is described as generally unsuitable for cultivation due to the high risk of erosion When attempting to vegetate

the soil, supplemental irrigation at planting time and during dry periods is recommended (SCS, 1980)

The SCS estimated annual soil loss rates due to water and wind erosion for northeast-facing slopes at the remedy acreage under worst-case conditions (i e bare soil) and under remedial activity conditions (i e tilled, with a cover crop) Total annual loss through water and wind erosion may range from 93 to 143 tons per acre (209 to 321 metric tons per hectare) under worst-case conditions This loss would be reduced to 13 to 22 tons per acre (29 to 49 metric tons per hectare) under remediation without using protective mulch between plowing and establishment of a cover crop If such a mulch was used, the loss due to erosion is predicted to be 1 to 3 tons per acre per year (2 2 to 6 7 metric tons per hectare per year), due almost exclusively to water erosion Gullying, which might increase the total loss in the worst-case scenario, was identified as a likely problem if the land was not adequately protected during remedial activities (SCS, 1985)

Revegetation of IHSS 199 remedy acreage has been hampered by abundant cobbles in the soil, which were brought to the surface by tilling Surface accumulations of cobbles are estimated to cover some 30 percent of the 110 tilled acres, and in some areas cover nearly 90 percent of the surface (Appendix D, Documents D-15 and D-16) An inactive gravel pit is located in the northeastern corner of the Section 7 remedial acreage It can be inferred from these observations that the rock fragment content of some portions of the remedy acreage soil is appreciable, perhaps 15 - 20% or more by volume

2 1 4 2 Surface Water

Surface water features in the vicinity of the RFP include drainages, diversions, and impoundments (Figure 2-1) The City of Broomfield remedy acreage in Section 7 abuts Great Western Reservoir to the north The Jefferson County remedy acreage in Section 18 surrounds Mower Reservoir (IHSS 202) Mower Reservoir is fed by a diversion from Woman Creek, which flows from the southern part of the RFP Outflow from Mower Reservoir discharges to the east, eventually entering Church Ditch Woman Creek itself traverses the southern end of the Jefferson County remedy acreage before discharging into Standley Lake (IHSS 201)

Existing slopes at and near the remedy acreage are 2 to 15 percent, generally to the east Slopes to the west also are present (SCS, 1985) Topographic maps of the site indicate that most of the remedy acreage drains into two ephemeral channels which flow southeast from the acreage into Standley Lake (USGS, 1980) Portions of the northernmost City of Broomfield remedy acreage in Section 7 drain north into Great Western Reservoir (IHSS 200) The southernmost Section 18 remedy acreage drains directly into Woman Creek

The frequency and amount of surface runoff depend upon several factors, including soil infiltration capacity, surface vegetation, and slope The clay loam soils at IHSS 199 are assumed to have relatively low infiltration capacity due to clay content, except where fractures may have significantly increased vertical permeability Vegetation cover, addressed in more detail in Section 2 1 4 5, is somewhat sparse, consisting mostly of native grasses and weeds Parts of the 110 acres of remedy acreage tilled during 1986-1987 contain adequate to marginal ground cover of perennial grasses and weeds Some surfaces of the remedy acreage are poorly vegetated due to prairie dog colonies and cobbles brought to the surface by tilling Application of mulch on this surface (see Section 2 2 3 2) would reduce the likelihood of surface runoff Although revegetation of the remedy acreage has been limited by these and other factors (see Section 2 2 3 2), the area is not highly erodible due to ground cover of perennial grasses, weeds, and surface rocks A site-wide study of the hydrology of the RFP determined that runoff in the Woman Creek basin averages only 1 4 percent of rainfall, indicating either a high infiltration rate for the soil or a high surface retention capacity This figure was based on records for long-duration, low-intensity storms, runoff may be much higher for a short-duration, high-intensity event (USGS, 1976)

2 1 4 3 Ground Water

Currently, there are no dedicated ground water monitoring wells outside of the RFP eastern boundary Numerous privately-owned water wells, however, have been drilled just east of the RFP Limited information was obtained from drilling and filing records held by the Colorado Division of Water Resources These records suggest that the thickness of surficial deposits ranges from 15 to 50 ft (4 6 to 15 m) and averages approximately 25 ft (7 6 m) near the remedy acreage Surficial deposits typically are described in the well records as clay, sandy clay, or clay

with gravel and boulders, locally capped by five or six feet of topsoil The underlying bedrock is described in the well records as alternating layers of shale and sandstone, which is assumed to be a very generalized description of the Arapahoe Formation Most of the wells studied were completed in sandstones at depths ranging from 35 to 275 ft (10 7 to 84 m) Static water levels averaged 10 to 50 ft (3 0 to 15 m) higher than the screened interval, indicating moderate pressure head in the sandstones The static water level was 20 ft (6 1 m) in one well completed in the shallow aquifer in the southwest corner of Section 6, just north of the IHSS 199 remedy acreage (DWR, 1990)

Although little site-specific information is available for ground water at IHSS 199, plant-wide hydrogeologic studies provide an indication of ground water conditions in the vicinity of the RFP Two hydraulically-connected ground water systems occur at the RFP An unconfined system which is present in saturated surficial deposits (the upper hydrostratigraphic unit) in many areas of the RFP, and a confined system in sandstones and claystones of the underlying Arapahoe Formation (the lower hydrostratigraphic unit), which is assumed to also underlie IHSS 199 surficial deposits (USGS, 1976) The shallow unconfined system is recharged by infiltration from incident precipitation and from surface and baseflow water (e g , drainages and reservoirs) Ground water flow is generally to the east and towards drainages Ground water locally discharges as seeps or springs in drainages, especially where the surficial deposit/bedrock contact is exposed. Large water table fluctuations may occur in the shallow system in response to seasonal variations in recharge and discharge, with the highest water levels generally occurring during the months of May and June and the lowest water levels generally occurring in January and February As a result of these fluctuations the lateral and vertical extent of saturated surficial deposits varies seasonally Several past studies have measured hydraulic conductivity in the upper and lower hydrostratigraphic units using drawdown-recovery tests, pump tests, packer testing and slug testing on selected wells (USGS, 1976, Hydro-Search, 1985, Rockwell, 1988a)

Confined ground water in the lower hydrostratigraphic unit occurs primarily in lenticular sandstone bodies within claystone Ground water flow in the upper hydrologic unit occurs in the unconsolidated Quaternary surficial deposits and the shallow sandstone within the bedrock Recharge to this unit occurs from infiltration from streams and precipitation The lower

hydrologic unit is found in the deeper bedrock sandstones which exhibit confined conditions Recharge to this unit occur primarily from baseflow and leakage from the overlying claystone Ground water in the lower hydrologic unit flows east towards a regional discharge area along the South Platte River, some 20 miles (32 km) east of the RFP Local seeps occur along the sides of drainages where the bedrock crops out Calculated horizontal linear flow velocities for the system average 0 1 ft/day (0 03 m/day) in the sandstones and approximately $9x10^{-4}$ ft/day ($2\ 7x10^{-4}$ m/day) in the claystone A relatively steep downward gradient is also observed in areas of the formation The effects on ground water movement by faulting in the lower hydrologic unit are not known (USGS, 1976, Hydro-Search, 1985)

2 1 4 4 Climatology

Water and wind erosion are the primary contaminant transport mechanisms for contaminated soils at IHSS 199 These mechanisms are discussed in greater detail in Sections 3 0 and 4 0

Water erosion of soil occurs as a result of surface runoff Surface runoff at IHSS 199 is the result of precipitation, primarily from rainfall and to a lesser extent from snowmelt The volume of runoff is controlled by the intensity and duration of precipitation, antecedent soil moisture, and the surface and soil characteristics discussed in Section 2 1 4 2 Rainfall intensity and duration vary widely During a three-year hydrological study of the RFP between 1972 and 1975, rainfall intensities varied from <0 1 in/hr (<0 25 cm/hr) to approximately 0 5 in/hr (1 25 cm/hr) (USGS, 1976) Frontal storms with long, low-intensity rainfall durations occur in the fall and early spring, while short, intense cloudbursts are frequent in the late spring and summer months The cloudbursts produce much greater surface runoff than the frontal storms, despite their typically short durations Spring snowmelt can also generate high runoff Average total precipitation for the RFP area is approximately 15 inches per year (in/yr) (38 cm/yr), with 40 percent of this falling during the spring (DOE, 1980)

Winds in the area are variable in direction but are predominantly from the west (westerly) Stronger winds occur during the winter months (DOE, 1980) Wind data for 1989, which meet EG&G Rocky Flats Environmental Restoration Program quality assurance standards, are discussed in Section 4 0

2 1 4 5 Biota

An environmental evaluation of IHSS 199, which will characterize and evaluate the impact of contamination on the site ecosystem, will be conducted in accordance with EPA guidance during future RFI/RI activities at the site Because environmental evaluation falls outside of the scope of the Past Remedy Report, biota at IHSS 199 are addressed only as they pertain to potential contaminant fate and transport and to court-ordered remedial activities at the site

The vegetation in the IHSS 199 area consists of native grasses and weeds, with various shrubs and small trees along drainages Native grasses common to the area include western wheatgrass, green needlegrass, blue grama, and sideoats grama (SCS, 1980) Portions of the area are used for pasture, grazing, and crops (Section 2 2 1)

Lands which have been tilled and seeded as part of remediation have been dominated in the early stages of regrowth by weeds, including Canadian, Russian and musk thistles, mustards, bindweed, and cheatgrass (Appendix D, Document D-14) Although these weeds compete with the grasses planted at the remedy acreage, they provide fair but unreliable stabilization of soils As of late 1990, planted grasses have become established on approximately 50 percent of the northern (Section 7) remedy acreage and provide excellent soil stabilization Planted grasses were characterized as marginally established on 15-20 percent of the northern acreage and unestablished on 30-35 percent of the acreage, owing primarily to surface cobbles and competition from weeds (Appendix D, Document D-16) The seed mix mandated by the Settlement Agreement includes western wheatgrass, sideoats grama, pubescent wheatgrass, and smooth brome (SCS, 1985) Winter wheat and sorghum also have been planted on these lands as winter cover to help prevent soil erosion during remediation

Prairie dogs have been identified as a potential threat to revegetation of the remedy acreage As of late 1989, the prairie dog population impacted approximately 60 percent of the northern (Section 7) land and 30 percent of the southern (Section 18) land. Prairie dogs contribute to soil destabilization through burrowing, consumption of new seedlings, and stripping of vegetation around burrows for visual defense against predators While burrowing may locally dilute

plutonium concentrations, it may also provide a pathway for deeper infiltration of plutonium into the soil and subsoil at IHSS 199

2 2 HISTORY OF SITE

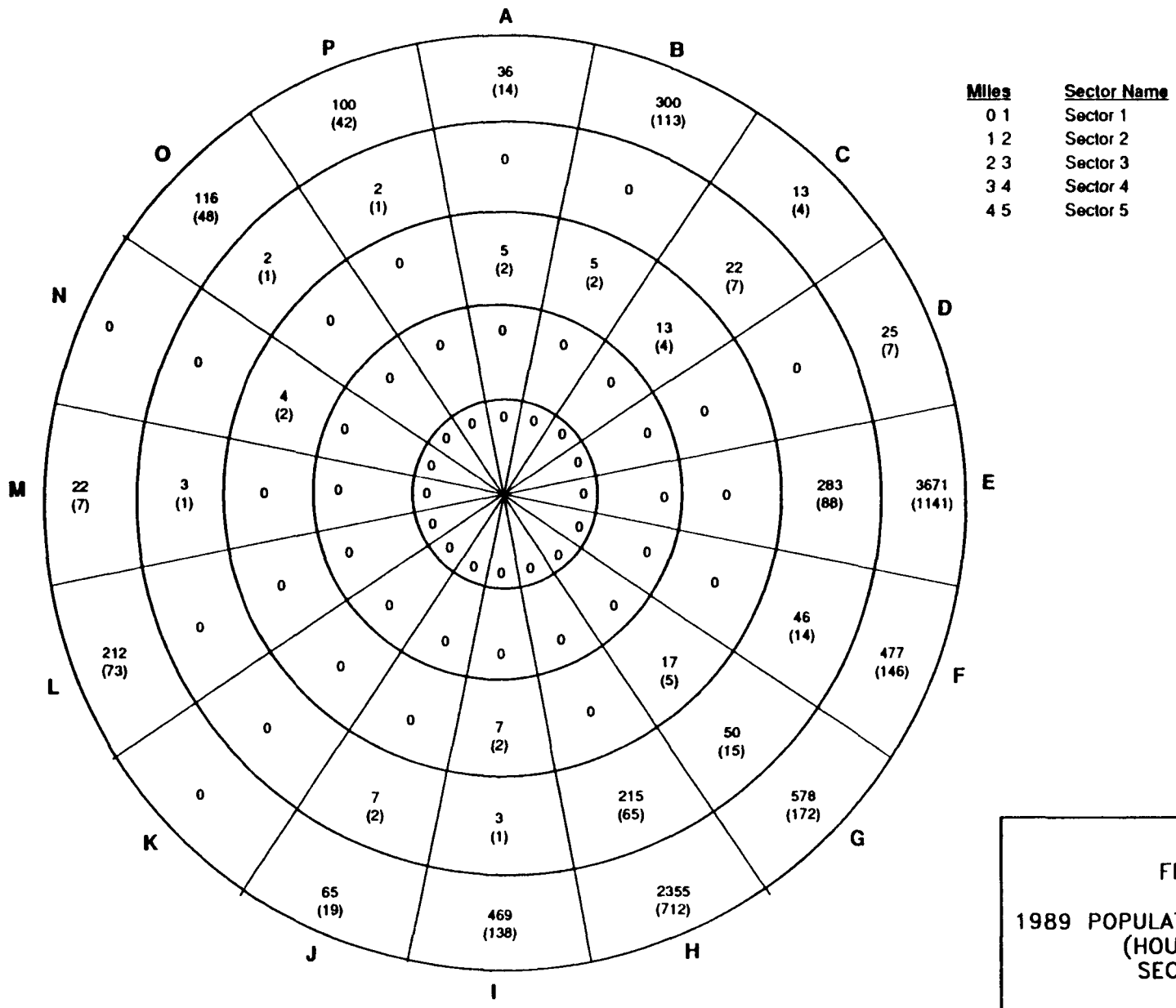
The following sections address past and present land usage and future land use scenarios at IHSS 199, summarize the legal history of the site, and describe the remedial actions undertaken to date at the site as a result of the Settlement Agreement.

2 2 1 Land Usage

The population, economics, and land use of the areas surrounding the RFP are described in a 1989 Rocky Flats vicinity demographics report by DOE (DOE, in press) This report divides general use of areas within zero to 10 miles (zero to 16 km) of the RFP into residential, commercial, industrial, parks and open spaces, agricultural and vacant, and institutional classifications, and considers current and future land use near the plant

2 2 1 1 Current Usage

The majority of residential use within five miles (eight km) of the RFP is located immediately north and southwest of Standley Lake (Figure 2-1) Single (unincorporated) residents are located closer to the RFP boundary to the east and south Figure 2-7 shows the 1989 population distribution within areas up to five miles from the RFP Commercial development is concentrated near the residential developments north and southwest of Standley Lake, and around the Jefferson County Airport several miles northeast of the RFP Industrial land use within five miles (eight km) of the plant is limited to quarrying and mining operations Open Space lands are located northeast of the RFP, near the city of Broomfield, and in small parcels adjoining major drainages and small neighborhood parks in the cities of Westminster and Arvada Standley Lake Park, which surrounds Standley Lake, is approximately five miles (eight km) southeast of the RFP Irrigated and nonirrigated cropland, producing primarily wheat and barley, are located northeast of the RFP near the cities of Broomfield, Lafayette, and Louisville, north of the RFP near Louisville and Boulder, and in scattered parcels directly east of the RFP The area south of the RFP contains several horse operations and many small hay fields The demographics report characterizes much of the vacant land adjacent to the RFP as rangeland (DOE, in press)



Miles	Sector Name
0 1	Sector 1
1 2	Sector 2
2 3	Sector 3
3 4	Sector 4
4 5	Sector 5

FIGURE 2-7

1989 POPULATIONS AND (HOUSEHOLDS), SECTORS 1-5

SOURCE DOE 1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT (IN PRESS)

DRAWN BY KRONER 3-21-91 CHECKED BY CJR 3-22-91 APPROVED BY TDK 3-22-91 DRAWING NUMBER 304923-A27

The remedy acreage originally was privately owned by the lawsuit plaintiffs and utilized as pasture for grazing livestock. Portions of the land were cultivated with winter wheat, these areas had been tilled for 25 years or more prior to their abandonment in 1980 (Appendix D, Document D-11) An inactive gravel pit also is located in the northeast corner of the Broomfield remedy acreage The operational history of this pit is not known

As a condition of the Settlement Agreement, IHSS 199 land totalling 350 acres (142 hectares) was transferred from the plaintiffs to the City of Broomfield and Jefferson County The 100 acres (40 hectares) in Section 7 deeded to Broomfield were to be used for expanding Great Western Reservoir To date this reservoir expansion has not occurred The land has remained in its original state and public access is not permitted The 250 acres (101 hectares) of Jefferson County land in Sections 7 and 18 were dedicated to that county's Open Space program Rather than allow immediate use of the acreage as Open Space, the county has chosen to prevent public access to this land until remedy activities are completed.

2 2 1 2 Future Use

Future land use at IHSS 199 most likely involves continued suburban expansion in areas north, east, and south of the RFP, increasing the density of residential, commercial, and perhaps industrial land use in these areas Future land use may also include construction of W-470, the western portion of a beltway encircling the Denver metropolitan area Two corridors currently are under consideration for W-470 1) west of the RFP, along or just west of the existing Colorado Highway 93, and, 2) east of the RFP The east route would pass approximately one quarter mile (0 4 km) east of Great Western Reservoir At this time, it appears very likely that the west route will be selected. Construction of W-470 probably will not commence before the mid-1990s

The expected trend in population growth in the vicinity of the RFP is addressed in the DOE demographics study (DOE, in press) This report considers expected variations in population density by comparing the current (1989) setting to population projections for the years 2000 and 2010 A 21-year profile of projected population growth in the vicinity of the RFP can thus be

examined. The DOE projections are based primarily upon long-term population projections developed by the Denver Regional Council of Governments (DRCOG)

Expected population density and distribution around the RFP for the years 2000 and 2010 are shown in Figures 2-8 and 2-9, respectively Table 2 1 summarized the population data presented in Figures 2-7, 2-8, and 2-9 Sectors 3, 4, and 5 depicted in these figures are relevant to the risk assessment presented in Section 4 0, while sectors 1 and 2 represent property within the RFP boundary In addition, only radial Sectors B through H are considered relevant to IHSS 199 Review of Table 2 1 and Figures 2-7, 2-8, and 2-9 suggests the following relative to potentially exposed future populations

- Sector 3, the two- to three-mile band from the center of the RFP, contains the remedy acreage There is no projected population growth in this sector over the next 20 years

- Population growth in Sectors 4 and 5 is expected to be substantial through the year 2010 However, most of this projected increase is anticipated in northern and southern areas more distal from the areas of known contamination in IHSS 199

- In the year 2010, approximately 90 percent of the projected 23,239 residents in the area of interest to IHSS 199 will reside in Sector 5, which is 2 to 3 miles from the RFP boundary

These observations suggest that, while the population in the vicinity of the RFP is expected to grow in the next 20 years, the dynamics of this growth do not constitute an imminent concern for residential exposure to known IHSS 199 contamination This topic is addressed in detail in Section 4 0

Use of the remedy acreage after completion of the remedy has not yet been determined by the owners It is likely that, at least for the short term, the Jefferson County remedy acreage will be used under the county's Open Space program, which allows public access for hiking, bicycling, and horseback riding The EPA Risk Assessment Guidance for Superfund (EPA, 1989) recommends, for purposes of risk assessment, that a residential use scenario be assumed if it appears possible based on existing information Future residential use of IHSS 199 is considered in the generic risk assessment (Appendix C)

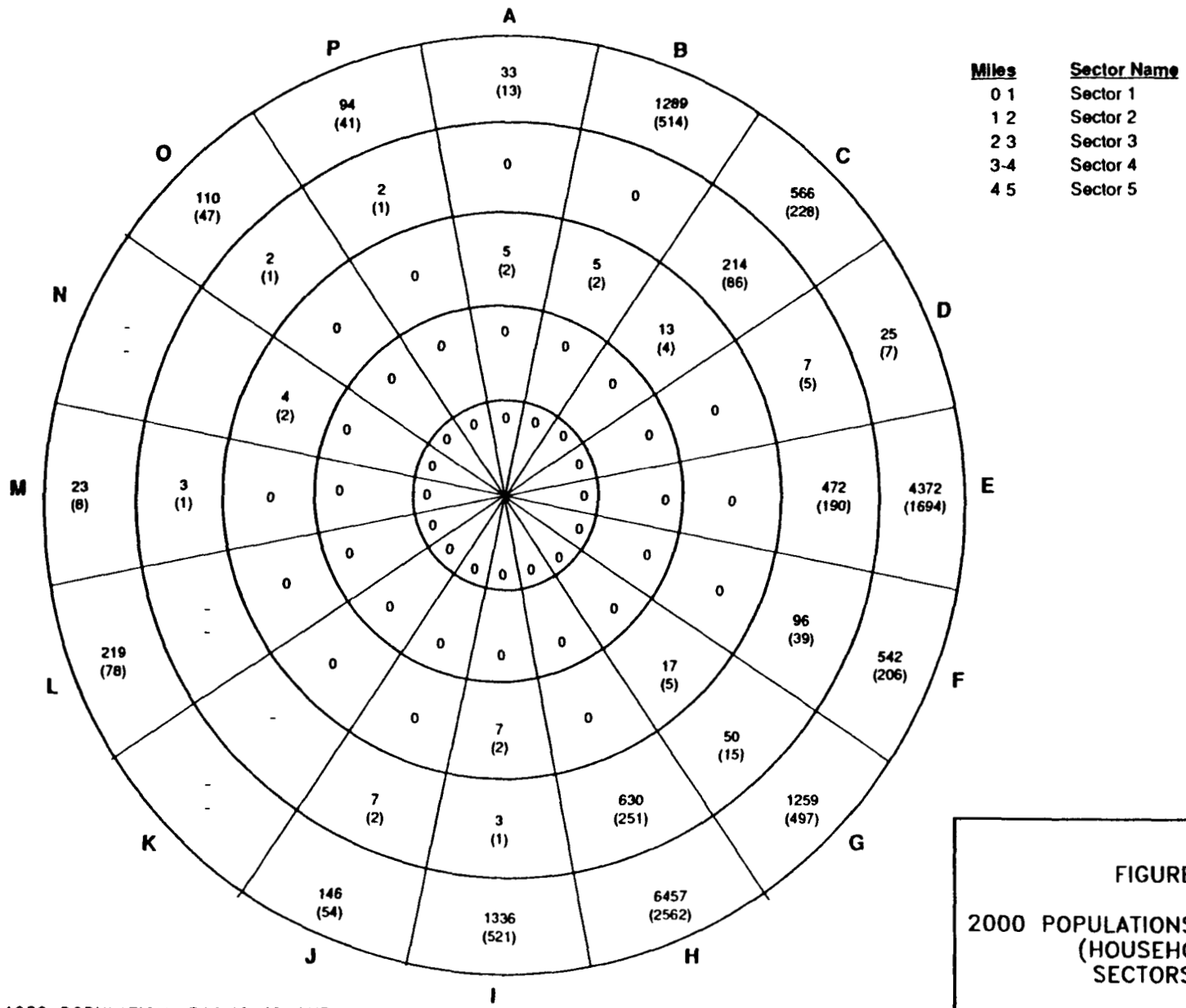


FIGURE 2-8

2000 POPULATIONS AND (HOUSEHOLDS), SECTORS 1-5

SOURCE DOE 1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT (IN PRESS)

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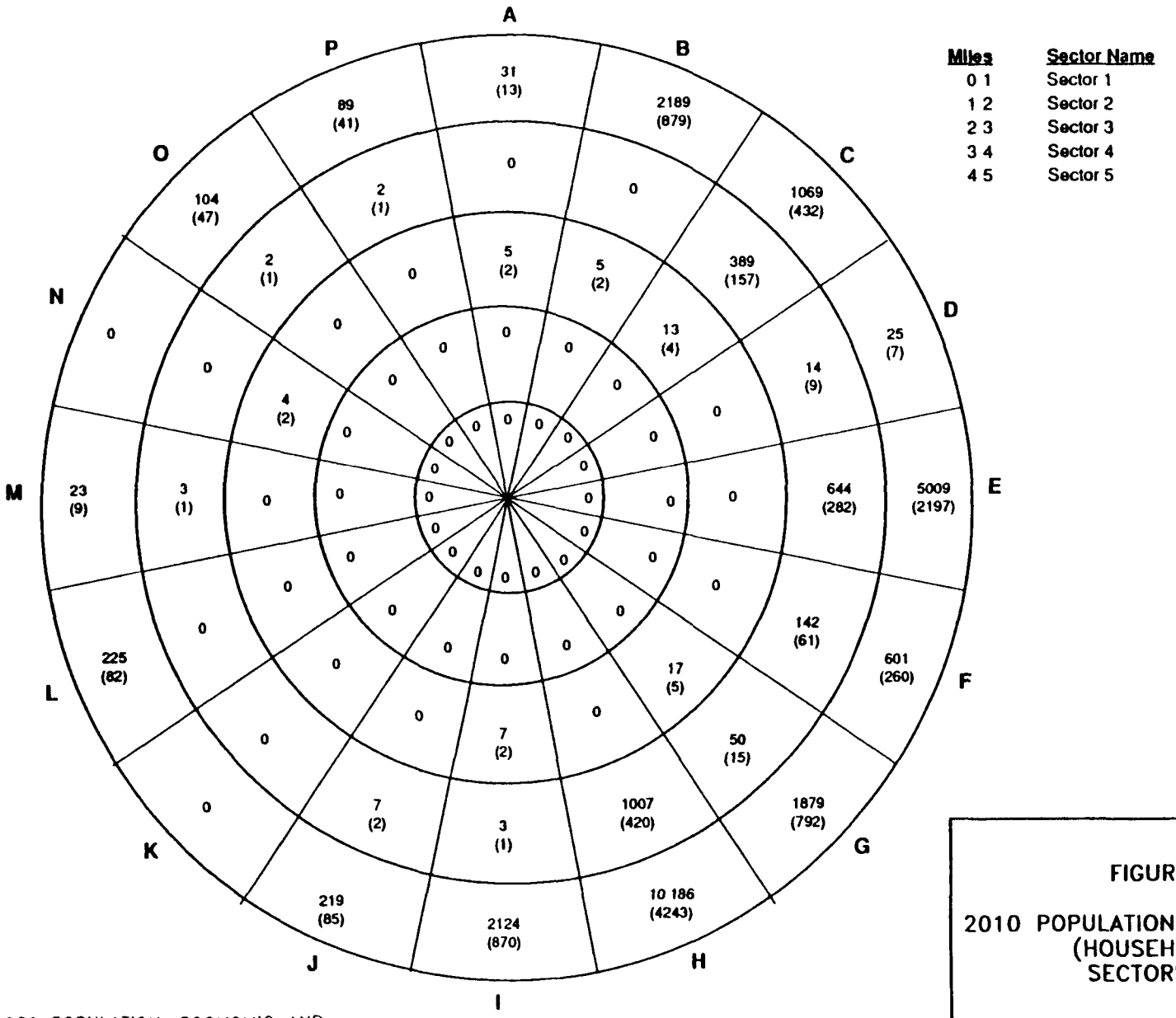

Miles	Sector Name
0 1	Sector 1
1 2	Sector 2
2 3	Sector 3
3 4	Sector 4
4 5	Sector 5

FIGURE 2-9

2010 POPULATIONS AND (HOUSEHOLDS), SECTORS 1-5

SOURCE DOE 1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT (IN PRESS)

DRAWN BY KRONER 3-21-91 | CHECKED BY CJR 3-28-91 | APPROVED BY TDK 3-28-91 | DRAWING NUMBER 304923-A29

TABLE 2.1

CURRENT AND PROJECTED POPULATION IN THE VICINITY OF THE ROCKY FLATS PLANT

Sector	Segment							Sum
	B	C	D	E	F	G	H	
Year: 1989								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	5	13	0	0	0	17	0	35
4	0	22	0	283	46	50	215	616
5	300	13	25	3,671	477	578	2,355	7,419
SUM	305	48	25	3,954	523	645	2,570	8,070
Year: 2000								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	5	13	0	0	0	17	0	35
4	0	214	7	472	96	50	630	1,469
5	1,289	566	25	4,372	542	1,259	6,457	14,510
SUM	1,294	793	32	4,844	638	1,326	7,087	16,014
Year: 2010								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	5	13	0	0	0	17	0	35
4	0	389	14	644	142	50	1,007	2,246
5	2,189	1,069	25	5,009	601	1,879	10,186	20,958
SUM	2,194	1,471	39	5,653	743	1,946	11,193	23,239

Source DOE (in press)

2 2 2 History of Litigation

In May, 1975, a lawsuit was filed against Rockwell International Corporation, Dow Chemical Company, and the United States of America by the Church (McKay) plaintiffs and Great Western Venture partnership (U S District Court, 1985b) The plaintiffs' holdings consisted of approximately 2,000 acres (810 hectares) to the west, south and east of the RFP The plaintiffs alleged that their lands were damaged by releases of plutonium and other radioactive materials from the RFP The plaintiffs claimed that these materials had rendered their land unfit for human habitation and had diminished the market value of their properties for commercial, residential or other non-agricultural uses The plaintiffs further claimed that the mere presence of the RFP next to their property further diminished the value of their properties The defendants acknowledged that releases of radioactive materials occurred at various times from the 1950s through the late 1960s, but contended that the releases had not violated applicable regulations established for the protection of the public (U S District Court, 1985b)

On the basis of scientific exhibits presented early in the proceedings and objections raised during the hearings, the parties agreed to conduct a field investigation on the plaintiffs' lands that would include collection and analysis of soil samples for plutonium and americium Prior to commencement of the field investigation, the parties agreed to specific methodologies for collecting, preparing, and analyzing the soil samples (Appendix D, Document D-4) The field investigation program commenced in 1977 and continued through 1979 Results of the program indicated plutonium concentrations on the plaintiffs' properties ranging from <0 01 to 3 4 pCi/g ($3\ 7 \times 10^{-4}$ to 0 13 Bq/g) (Appendix D, Documents D-4, D-5, and D-7) After additional testing, the parties agreed to accept some of the data as evidence for the trial (U S District Court, 1985b)

In March, 1978 the Ackard-Butler interests intervened in the legal proceeding and were added to the lawsuit as plaintiffs Church and Ackard-Butler added, by amended complaint, the State of Colorado and Jefferson County, Colorado as defendants in 1982, claiming that if the government defendants prevailed in this litigation, then the State and County had acted unlawfully in precluding development of plaintiffs' lands In 1982 the Court dismissed the plaintiffs' claims for lack of jurisdiction, ruling that the issues were not determinable under

Rule 56 In 1983, the Tenth Circuit Court of Appeals reversed this ruling, stating that the plaintiffs were entitled to a trial or trials on some of their claims

In December, 1984 a settlement was reached between the defendants and plaintiffs (U S District Court, 1985a) The Settlement Agreement, as amended on July 2, 1985, called for ripping, plowing and discing (referred to generically in this report as "tilling") of affected soils to reduce plutonium concentrations to less than the CDH special construction requirements standard of 0 9 pCi/g (0 03 Bq/g) Historical incidents (e g , Palomares, Spain, circa 1960) established a precedent for tilling plutonium contaminated lands, which reduces the concentration of plutonium by dispersing it throughout the soil (Lawton, 1990) Results of soil sampling during 1977 indicated that plutonium levels in several tilled wheat fields on the plaintiffs' property were consistently lower than levels on adjacent undisturbed ground The agreement required the RFP to conduct additional soil sampling to verify that plutonium concentrations were reduced, and to revegetate the tilled soils to provide stabilizing vegetation Specific standards for evaluating the success of revegetation were not included in the agreement. The option of remediating the land through "other processes" was left open in the agreement The selected remedial actions were jointly agreed upon by Rockwell International, DOE, and CDH One of the conditions of the agreement was the preparation and dissemination by the RFP of an annual status report on remediation progress The RFP currently provides semi-annual status reports Status reports prepared to date are provided in Appendix D The Settlement Agreement also made provisions in the event there are any future release(s) from the RFP If a release occurs, the RFP must demonstrate that contaminants on affected properties do not exceed applicable standards

Court-supervised soil sampling was conducted in 1985 on the affected lands according to CDH sample collection protocol (Appendix D, Documents D-8 and D-9) Approximately 350 acres (142 hectares) of land with concentrations of plutonium greater than 0 9 pCi/g (0 03 Bq/g) were delineated by the sampling program These areas, which were subsequently transferred to Jefferson County and the City of Broomfield, are the only land to which the Court-ordered remedial action applies Another 490 acres (198 hectares) pertinent to the settlement did not exceed the soil plutonium concentration limit and therefore were not targeted for remedial action

The 1985 sampling data corroborated earlier observations that areas originally cultivated with wheat contained substantially lower concentrations of near-surface plutonium It was also noted that average plutonium concentrations in the surficial soil appeared to have decreased significantly between 1977 and 1985 This apparent decrease may have been due to plutonium migration (see discussion in Section 3 0) The lower values may also have resulted from (1) the use of different laboratories utilizing differing analytical techniques, or, (2) the significantly larger area represented by the 1985 samples (10 acres [4 hectares] per sample) as compared to the 1977 samples (0 2 acres [0 08 hectares] per sample) (Appendix D, Document D-10)

On May 28, 1986, Jefferson County requested that the remedial actions be undertaken on their lands (Rockwell, 1988b) To date, the City of Broomfield has not requested that their lands be remediated.

2 2 3 Remediation of Jefferson County Lands

Soil remediation currently is underway on approximately 250 acres (101 hectares) of Jefferson County lands The following sections address the scope of the remedial activities and the history and present status of the remediation

2 2 3 1 Scope of Soil Remediation

The July, 1985 amended Settlement Agreement outlines a specific course of remedial action for plutonium contaminated lands The nature and scope of remedial actions were developed and agreed upon by Rockwell International, DOE, and CDH Recommendations concerning erosion control and revegetation were provided by the SCS on behalf of Rockwell It should be noted that, due to concerns over soil stabilization, the SCS concluded that it would be best to leave the affected lands undisturbed rather than to attempt remediation (SCS, 1985)

The Settlement Agreement specifies the following remedial actions (U S District Court, 1985b)

- Spring ground preparation (plowing and discing ["tilling"] to reduce plutonium concentrations through mixing and dilution) plus a summer (June) cover crop
- Drilling grass seed into cover crop stubble in the fall
- Supplemental mulch

- Timely irrigation during the establishment period
- Weed control to ensure successful establishment of grasses

More specifically, the Settlement Agreement requires that the remediation shall consist of the following remedial actions, any of which may be modified by agreement between the owner of the land and the RFP

- Erosion Control -- Small areas of land may be worked on all at once, but larger areas will require a phased approach Land shall be broken out in alternating strips perpendicular to the prevailing winds or, on long slopes, on the contour Strip widths shall be determined by a number of site-specific variables, including soil characteristics, slope length and gradient, vegetative cover, and field width Work on the other set of strips shall not begin until the first set is successfully reestablished in grass Properly done, this will minimize erosion in "normal" weather There shall be some standby provisions for emergency erosion control such as extra mulching and sediment-trapping diversions, in the event of unusual weather

- Soil Preparation -- May is the logical time for the plowing, discing, chiseling, and harrowing operations necessary to satisfy the soil mixing objective of the remedial action plan and to prepare a seedbed for the cover crop The frequency of tillage required depends on successful reduction of soil plutonium concentrations to the remedy action level Additions of nitrogen and phosphorous shall be made as necessary

- Cover Crop -- The revegetation scheme utilizes a cover crop (forage sorghum) which will be planted in June when the soil has warmed to 60°F (16°C)

- Grass Seeding -- Grass shall be drilled into the ground after November 1

- Mulch -- The cover crop should leave adequate residue for soil protection If it is insufficient in some areas, mulch will be needed.

- Supplemental Irrigation -- Timely irrigation through establishment of the grass seed mix shall be used to improve the chances for a successful planting Supplemental irrigation may also be required during establishment of the cover crop

- Special Conditions -- In order to prevent possible resuspension of plutonium on the soil surface, the mixing operation will be conducted only when the soil moisture content is greater than 15 percent and the wind velocity is less than 15 mph (24 km per hour) Portable air samplers will be operated downwind from the soil mixing operations during all phases of the program The samples will be analyzed for plutonium and all activities will be shut down if the plutonium

concentration in the air exceeds a control level of 0 02 pCi/cubic meter (7 4 x 10^{-4} Bq per cubic meter)

- Maintenance -- Areas that do not develop satisfactory ground cover in a reasonable length of time (two growing seasons) would be reseeded after an evaluation of the circumstances by representatives of Rockwell (now EG&G) and the land owners involved.

2 2 3 2 Effectiveness of the Remedy Implementation

Court-ordered remedial actions taken to date on the Jefferson County remedy acreage are summarized in Table 2 2 These actions are addressed in much greater detail in the remedy status reports prepared by the RFP under the terms of the Settlement Agreement Remedy status reports prepared to date are contained in Appendix D (Documents D-10, D-11, D-13, D-14, D-15, and D-16) To date, the City of Broomfield has not requested that remedial activities commence on their 100 acres (41 hectares) of remedy acreage

As indicated in Table 2 2, remedy actions have been implemented on two plots of Jefferson County remedy acreage, a 20-acre (8 hectare) plot in Section 18, T2S, R69W (the southern area) and a 100-acre (41 hectare) plot in Section 7, T2S, R69W (the northern area) The southern and northern areas have been tilled in strips as an erosion control measure, as shown in Figures 2-10 and 2-11, respectively Alternate strips were plowed in 1986 with the remaining strips to follow upon successful revegetation The plutonium concentrations shown in these figures represent post-tilling conditions Tilling of these 120 acres appears to have successfully reduced soil plutonium concentrations to below the 0 9 pCi/g (0 03 Bq/g) CDH standard adopted by the court as a remedy action level Attempts to stabilize the tilled soils through revegetation have met with mixed success to date The outcome of the revegetation effort appears to result from the following factors (Appendix D, Documents D-15 and D-16)

- insufficient amounts and/or seasonal distribution of precipitation
- extremely rocky surfaces or clayey soils
- intense competition from weeds
- an expanding prairie dog population
- the effects of slope on soil moisture

TABLE 2.2

IHSS 199 REMEDY ACTIONS

Dates	Activity	Result
June 1986	Soil tilling and subsequent seed bed preparation of the northern area (approximately 100 acres) in Section 7	Partial success, approximately 80 acres were successfully remediated and approximately 20 acres exceeded the plutonium concentration standard
July 1986	Initiated application of sorghum seed on the approximately 80 acres successfully remediated in Section 7	First sprouts appeared 08/04/86
July 1986	Second tilling operation of the approximately 20 acres in Section 7 where the initial effort was unsuccessful This operation consisted of tilling the area three more times	Unsuccessful, plutonium concentration exceeded the standard
July 1986	Third tilling operation of the approximately 20 acres in Section 7 This operation consisted of deep plowing an additional three times and one application of a Vibrashank ripper	Successfully remediated
August 1986	Planted the additional 20 acres in Section 7 with sorghum seed	Sorghum stopped growing in October and wilted after the first frost
October - November 1986	Applied wild grass seed to the approximately 20 acres in Section 7	Failure
June 1987	Reripped the approximately 100 acres in Section 7 and replanted sorghum seed	Successful, sorghum came up well
June - July 1987	Plowed and ripped the southern area (approximately 20 acres) in Section 18	Partial success, approximately 15 acres were successfully remediated and the remaining approximately 5 acres exceeded the plutonium concentration standard
July 1987	Replowed and reripped approximately 5 of the 20 acres in Section 18 which exceeded the plutonium concentration standard	Successfully remediated
November 1987	Conducted weed control on the approximately 100 acres in the North Area in Section 7 that were remediated The area was sprayed with Roundup herbicide The primary target was cheatgrass	Very successful
November 1987	Conducted weed control by discing the approximately 20 acres of remediated land in the South Area in Section 18	Unknown
November - December 1987	Performed erosion control measures consisting of planting winter wheat and the placement of mulch on the surface of the 20 acres of remediated land in Section 18	Successful, subsequent inspections revealed little erosion was occurring
April 1988	Reseeded grasses on the approximately 120 acres of remediated land in Sections 7 and 18	Poor to marginal success, native grasses successfully established on only about 10 percent of the area.*
January 1991	Collected soil samples from both tilled and untilled areas in the Jefferson County acreage This was performed because soil samples collected in 1986 and 1987 do not meet current quality assurance protocols	Analytical results pending

* The January 1991 remedy report (Appendix D, Document D-16) indicates that a successful 1990 growing season significantly reduced the amount of area requiring reseeding

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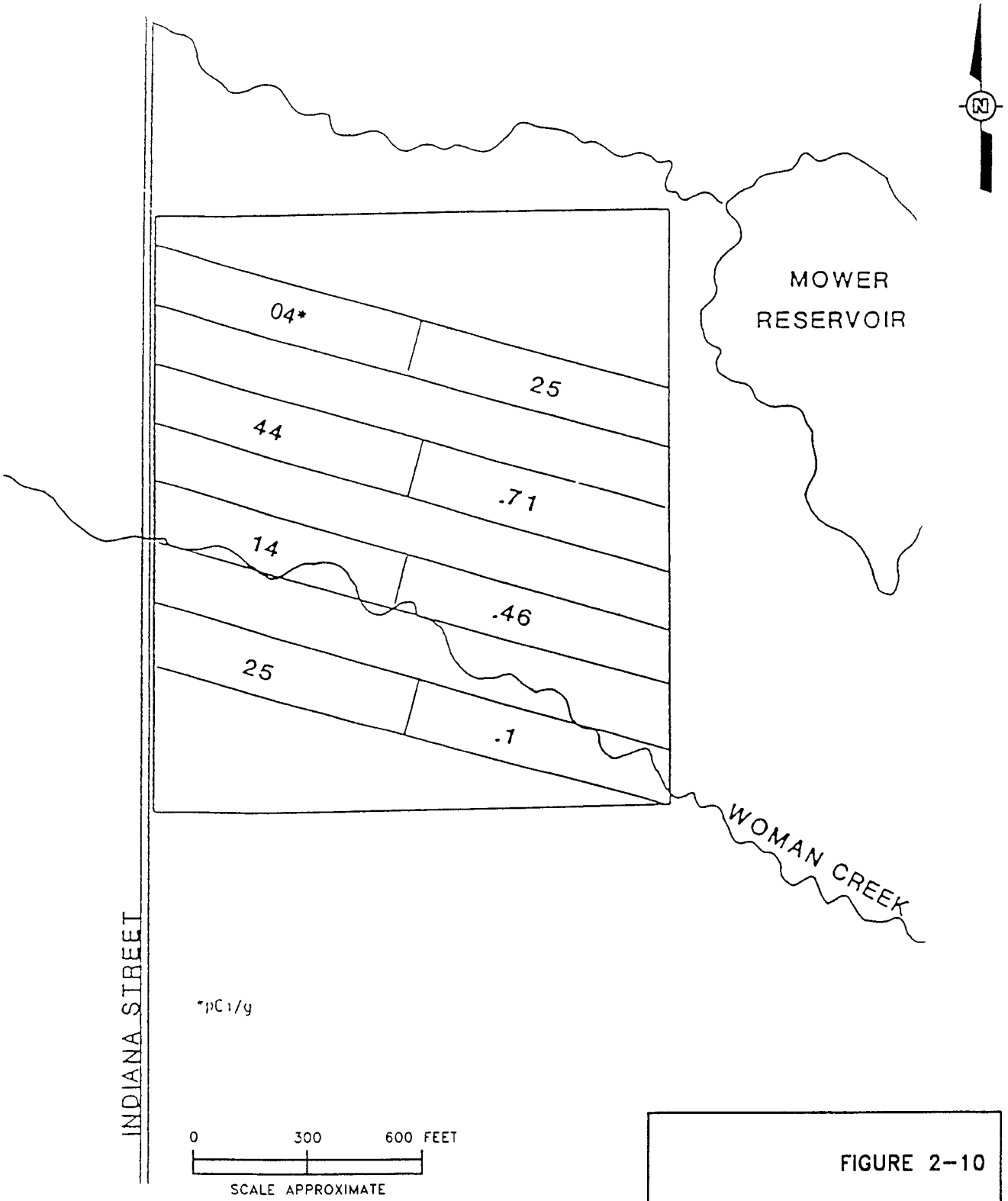
	3-20-91	APPROVED BY	TDK		
			3-22-91		

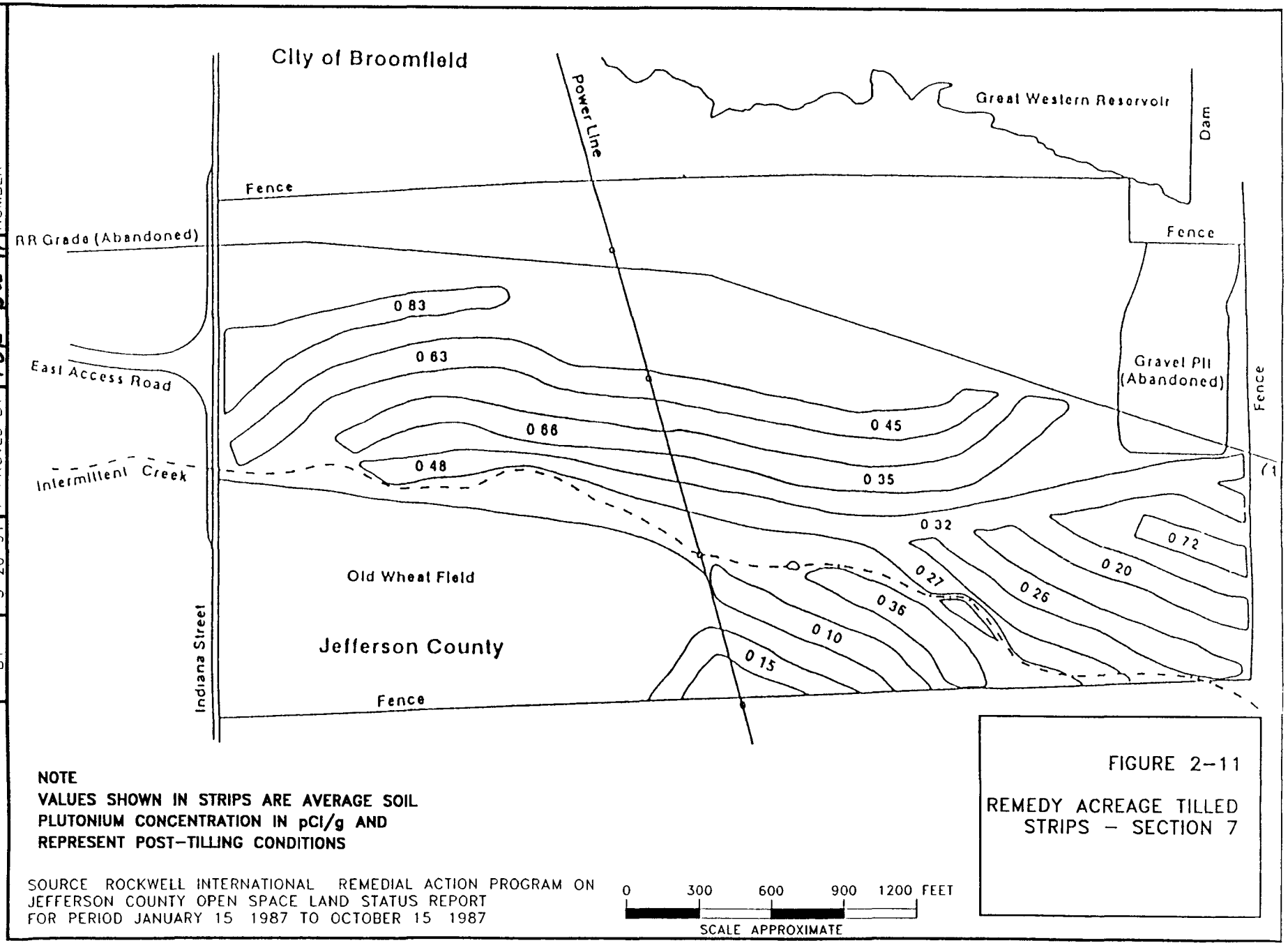


NOTE
VALUES SHOWN IN STRIPS ARE AVERAGE SOIL PLUTONIUM CONCENTRATION IN pCi/g AND REPRESENT POST-TILLING CONDITIONS

SOURCE ROCKWELL INTERNATIONAL REMEDIAL ACTION PROGRAM ON JEFFERSON COUNTY OPEN SPACE LAND STATUS REPORT FOR PERIOD JANUARY 15 1987 TO OCTOBER 15 1987

FIGURE 2-10

REMEDY ACREAGE TILLED STRIPS – SECTION 18



NOTE
VALUES SHOWN IN STRIPS ARE AVERAGE SOIL PLUTONIUM CONCENTRATION IN pCi/g AND REPRESENT POST-TILLING CONDITIONS

SOURCE ROCKWELL INTERNATIONAL REMEDIAL ACTION PROGRAM ON JEFFERSON COUNTY OPEN SPACE LAND STATUS REPORT FOR PERIOD JANUARY 15 1987 TO OCTOBER 15 1987

0 300 600 900 1200 FEET
SCALE APPROXIMATE

FIGURE 2-11

REMEDY ACREAGE TILLED STRIPS – SECTION 7

The 1990 remedy status report (Appendix D, Document D-15) proposed specific actions to improve the revegetation effort, which at the time was estimated to be only ten percent successful Between 1988 and 1990, the RFP operating contractor changed from Rockwell International to EG&G, and several key personnel changes occurred within the EG&G group responsible for implementation of the remedy As a result, the remedy actions proposed in the 1990 report were not implemented.

The January 1991 remedy status report (Appendix D, Document D-16) provides the latest available assessment of the revegetation effort This report indicates that, after a successful 1990 growing season, planted grasses have become established on approximately 50 percent of the northern (Section 7) acreage, significantly reducing the amount of land requiring reseeding The January 1991 report proposes the following actions to facilitate revegetation of the remaining acreage

- weed control
- prairie dog suppression
- change of seed mixture

Irrigation of the revegetated areas, which was proposed in the 1990 Remedy Status Report (Appendix D, Document D-15), is not being considered due to water quality issues in using RFP water for irrigation and concerns over surface runoff transport of contaminants from the remedy acreage

Because soil samples collected from the remedy acreage in 1986 and 1987 (Table 2 2) do not meet current quality assurance protocols, soil samples were collected again in January 1991 from both tilled and untilled Jefferson County acreage to confirm the soil plutonium concentrations on these lands These samples will be analyzed for plutonium and americium, and the results reported as soon as they are available (Appendix D, Document D-16)

3 0 CONCEPTUAL MODEL OF CONTAMINANT FATE AND MOBILITY

Contamination of off-site surface soils near the RFP has been attributed primarily to wind dispersal and deposition of plutonium-contaminated soil from the 903 Pad (Appendix D, Document D-1) Utilizing the information obtained in past studies (Section 2 1), a description of the potential contamination transport mechanisms at IHSS 199 is presented here for use in the evaluation of the potential risks of IHSS 199 soil contamination to human health (Figure 3-1 and Table 3 1)

For an exposure pathway to be considered complete it must contain the following components

- Contaminant Source For purposes of the conceptual model, the primary current source area is the plutonium-contaminated soils of IHSS 199 Plutonium from IHSS 199 could be released to air, ground water, surface water or biota Each of these media can subsequently become a secondary source for further releases

- Contaminant Release Mechanism The potential release mechanisms for plutonium from the soil to each media are presented The main mechanisms are resuspension into air, surface water runoff, dissolution into water, and colloid formation in water A distinction is made between primary release mechanisms (those mechanisms which release contaminants directly from the source area) and secondary release mechanisms (those mechanisms which release contaminants from secondary media contaminated by the source area)

- Transport Media Once plutonium is released it can be transported within transport media to exposure points The transport media can be air, ground water, surface water, or biota. Behavior and fate of plutonium in these media are important relative to exposure routes and receptors The conceptual model identifies both primary transport media (the media in which contaminants exist at the source area) and secondary transport media (those media in which contaminants are transported away from the source area)

- Exposure Route Any point of potential contact with a contaminated medium is an exposure point. Exposure routes are determined according to the media contaminated and the anticipated activities at the exposure points Exposure route can be by ingestion, inhalation, or dermal contact

- Receptor The receptors are the populations exposed to contaminants at the exposure points

TABLE 3.1

CONCEPTUAL MODEL FOR IHSS 199 CONTAMINATED SOILS

Primary Release Mechanism	Secondary Media	Secondary Release Mechanism	Exposure Route	Potential Receptors
Fugitive dust	Air	Airborne Settled dust-plant Settled dust-soil Settled dust-water	Inhalation Ingestion	Residents Visitors Biota
Surface runoff	Surface water	Biotic Uptake Deposition Irrigation Infiltration Fugitive Dust	Ingestion Inhalation	Visitors Biota
Infiltration/ Percolation	Groundwater	Seepage Pumpage Transfer to Surface Water	Ingestion	Off-site, downgradient residents dependent on ground water
Biotic uptake	Biota	Biodegradation/ Percolation	Ingestion	Vegetation Terrestrials
Biotic movement	Tracking by Organisms	Physical Transfer	None	None

The conceptual model provides a contaminant source characterization and an overview of all the potential migration pathways that may result from releases from and/or into each transport media Some of these pathways have a higher potential for occurrence than others Significant migration pathways are identified by evaluating the fate and mobility of the contaminant in each potential media that is included in the conceptual model Exposure routes and receptors, which are also components of a completed exposure pathway, are addressed in Section 4 0

The transformation, transport, and fate of contaminants in each potential transport media are important in evaluating completed exposure pathways Contaminant fate and mobility are assessed by defining the mechanisms and magnitude of potential intermedia transfers and releases, and by analyzing the chemical and physical forms, stability, and reactivity of the contaminants The magnitude of intermedia releases depends on the physical and chemical properties of the media and the contaminants

3 1 SOURCE AREA CHARACTERIZATION

Although the RFP has been identified as the historic source of plutonium contamination at IHSS 199, the IHSS 199 soils are considered to be the current contaminant source for purposes of risk assessment The following discussions focus on soil, contaminant, and climatological characteristics which affect contaminant transport

3 1 1 Soil Characteristics

A discussion of IHSS 199 soils is presented in Section 2 1 4 1 The organic matter content of the surface soils varies between 2 to 4 percent and the pH values range from 6 6 to 8 4 (neutral to slightly alkaline) The vertical permeability of these soils is 0 06 to 0 6 in/hr (0 15 to 1 5 cm/hr) Runoff is generally rapid and water erosion potential is high The predominant minerals of the fine soil fraction are montmorillonitic clays with calcareous materials (SCS, 1980) These conditions may have changed on the remedy acreage as a result of court-ordered remediation In particular, the following changes may have occurred as a result of tilling

- Increased erosion potential due to vegetation loss
- Mixing of soil horizons and redistribution of rock fragments
- Loss of plant nutrients, particularly nitrogen, through leaching

- Loss of organic matter through increased oxidation
- Loss of soil structure.

It should be noted that water erosion does not appear to be a common or significant problem on undisturbed soil surfaces in and around the remedy acreage It is believed, therefore, that successful revegetation of the remedy acreage will greatly reduce the contribution of surface runoff and erosion to plutonium transport at IHSS 199

3 1 2 Contaminant Characteristics

As discussed in Section 2 1 2, plutonium and its decay product, americium, are the only contaminants which have been shown to exist in IHSS 199 soils above background concentrations (as recorded at sampling locations remote from the RFP) as a result of RFP releases. Plutonium concentrations in lawsuit acreage soils have been characterized by numerous sampling programs (Appendix D, Documents D-4, D-7, D-8, D-9, D-10, and D-11) Concentrations of a number of radionuclides other than plutonium, including americium, were measured in 1976-1977 in the lawsuit acreage soils (Appendix D, Documents D-4, D-5, D-7, and D-8) Although americium concentrations apparently were found to exceed expected background levels (Appendix D, Document D-8), sufficient americium data to perform even a qualitative risk assessment for IHSS 199 are lacking The only nonradioactive contaminant known to have been measured in IHSS 199 soils is beryllium, which was measured in 1971 by CDH (CDH, 1991) None of the available data for contaminants other than plutonium meet the criteria established by EPA for performing a human health risk assessment (EPA, 1990a, see Appendix A) For these reasons, plutonium is the only contaminant considered for purposes of this conceptual model and the qualitative risk assessment (Section 4 0) Data for other potential IHSS 199 contaminants will be developed during scheduled RFI/RI activities at the site

There are 15 known isotopes of plutonium that decay into other elements at different rates (half-lives range from hours to 387,000 years) If water containing dissolved plutonium evaporates, the plutonium undergoes a series of hydrolysis reactions, eventually passing from the dissolved state to the thermodynamically stable solid form of plutonium, plutonium dioxide (PuO_2) (Ames and Rai, 1978)

At the typical temperature, pH, and Eh conditions of environmental concern, plutonium will exist either as PuO_2 or as a solid hydroxide (Brookins, 1984) If oxygen is excluded from the soil, there is a possibility that plutonium may ionize and hence become more soluble, however, vadose-zone soils (those above the water table) are almost exclusively oxidizing The stable form of plutonium in the surface soils at IHSS 199, therefore, is almost certainly PuO_2 When particles containing PuO_2 are deposited on soil surfaces, they typically attach themselves by chemical and physical bonding to soil particles, especially to clays, metal dioxides, and organic matter (CSU, 1974, Brookins, 1984) Subsequent mobility of plutonium from these soils is determined by

- The strength of this bonding, which is determined largely by the clay, metal dioxides, and organic matter content of soils and the type and form of plutonium
- The physical and chemical conditions present at the site, such as precipitation, soil moisture content, wind speed, frequency, and turbulence, vegetation cover, pH, Eh, and temperature

These factors ultimately determine the processes that may be responsible for mobilization of plutonium to other media or exposure points The processes could be either one or a combination of the following

- resuspension
- dissolution/precipitation
- hydrolysis
- oxidation/reduction
- ion exchange
- desorption
- colloid formation
- complexation

3 1 3 Climatological Characteristics

Of particular importance to the fate and mobility of plutonium at IHSS 199 are wind and precipitation The climate in the IHSS 199 area is typified by strong, often gusty winds The stronger winds blow from the west and northwest, and occur more often during the winter months The average annual precipitation for the area is 15 in (38 cm), of which 40 percent falls during the spring Rainfall intensity varies from long, low-intensity frontal storms in the fall and early spring to short, intense cloudbursts in the late spring and summer months Snowmelt can

also generate high runoff in the area Snowfall at the RFP averages 85 in/yr (216 cm/yr) (DOE, 1980) IHSS 199 climatology is discussed in more detail in Section 2 1 4 4

3 2 RELEASE MECHANISMS AND TRANSPORT MEDIA

The following sections present detailed discussions of the processes described in Section 3 1 and how they affect the fate and mobility of plutonium in air, ground water, and surface water

3 2 1 Plutonium Fate and Mobility in Air

Atmospheric resuspension of soil particles contaminated with plutonium is the principal intermedia transfer process affecting plutonium soil contamination Resuspension occurs as a result of wind action, and is often amplified by soil disturbance The resuspension factor is defined as the ratio of the air concentration to soil concentration and is expressed as per meter (m^{1})

Resuspension factors for each known contaminated section of T2S, R69W are presented in Rockwell International's disclosure to the City of Broomfield regarding the remedy acreage (Appendix D, Document D-8) These resuspension factors are

- Section 6 -- $1\ 5 \times 10^{-9}\ m^{1}$
- Section 7 -- $1\ 0 \times 10^{-9}\ m^{1}$
- Section 18 -- $1\ 8 \times 10^{-9}\ m^{1}$

The methodology behind the development of these values is given in SCS remedy recommendations (SCS, 1985) CDH developed similar values in the 1970s for quiescent, vegetated lands in the vicinity of the RFP A further finding was that vehicular disturbance would change the average values to approximately $1 \times 10^{8}\ m^{1}$ (CDH, 1976)

Once resuspended in the air, the particles can move long distances depending on wind velocity and turbulence Smaller diameter particles will be carried longer distances, therefore, the size of PuO_2-contaminated soil particles is critical Previous studies have shown that the distribution of plutonium by soil particle sizes at the RFP was variable, indicating the association of PuO_2 with soil mineral phases of various sizes (McDowell and Whicker, 1978) The respirable percentage of suspended plutonium-contaminated soil particles in air (those with diameters less

than 10 micrometers [µm]) has been estimated to be approximately 20 to 40 percent (Whicker et al , 1974) Because of the small settling velocities associated with such particles, they can be transported long distances by winds before settling Particle size characterization will be conducted as part of scheduled IHSS 199 RFI/RI activities

3 2 2 Plutonium Fate and Mobility in Ground Water

There are five oxidation states of plutonium (Pu) in aqueous solutions Pu(III), Pu(IV), Pu(V), Pu(VI), and Pu(VII) However, under the oxidizing and near-neutral conditions typical of surface water, the Pu(IV) oxidation state is the most stable Pu(IV) is practically insoluble under these conditions because it readily hydrolizes to form $Pu(OH_4)$, and, upon loss of water, to produce the thermodynamically stable PuO_2 (DOE, 1991)

PuO_2 is extremely insoluble in water, but can undergo limited dissolution in the pH range of environmental interest. The solid phase of PuO_2 is a colloidal polymer of neutral or positive charge Pu(V) and PU(VI) can coexist as ions with the PuO_2 polymer (DOE, 1991) Such colloids can contain from 10^6 - 10^{10} atoms of plutonium (Andelman and Rozzell, 1970) Increasing pH tends to reduce the charge density of the polymer, and at pH>9, it is expected that the colloids become negatively charged, decreasing the affinity of PuO_2 for soils and thus increasing its mobility in surface water The solubility of plutonium can also be increased through complexation with humic acid (DOE, 1991) However, Krey and Hardy (Appendix D, Document D-1) found that 99 percent of the total ecosystem plutonium in the environs of the RFP, derived primarily from the 903 Pad, occurred in the top 8 3 inches (21 cm) of soil This finding indicates that plutonium migrated a very limited distance through the soil in the twelve years between the first contamination from the 903 Pad (1958) and the 1970 study This lack of transport probably results from a combination of factors, including atmospheric transport to the soil, limited precipitation, and the strong tendency of plutonium to adsorb to clay in the soil (Shade et al , 1984, Baes and Sharp, 1983)

The migration of plutonium ions in ground water is retarded due to continuous distribution of plutonium between soil and water phases The distribution coefficient (K_d), which quantifies the tendency to be adsorbed onto a solid particle relative to remaining dissolved, for plutonium is

10^3-10^5 (Allard and Rydberg, 1983) The EPA (1990b) gives a distribution coefficient of $2x10^3$ for plutonium Plutonium would not be expected to migrate readily in ground water with such high K_d values Furthermore, plutonium will tend to remain adsorbed to solid particles at pH values between three and nine (Roxburgh, 1987) However, it has been shown that plutonium bound to colloidal particles in ground water may be unaffected by the forces that act to retard plutonium ion movement through ground water systems and migrate distances far beyond those expected from K_d values alone (Penrose et al 1990) The Penrose et al study describes dissolved plutonium (and americium) from a treated aqueous effluent migrating through a shallow alluvial aquifer derived from volcanic tuff The mineralogy of this aquifer is not described, but fine-grained material described as silty clay may, in fact, be zeolites The plutonium source, mode of transport, depositional mechanism, and aquifer environment are potentially very different than the surface soil environment at IHSS 199 Indeed, the Penrose et al study cautions against extrapolating the results to dissimilar environments and conditions without careful site-specific study The vertical distribution of plutonium in IHSS 199 soils and, if appropriate, the IHSS 199 ground water environment will be studied during scheduled RFI/RI activities at the site

3 2 3 Plutonium Fate and Mobility in Surface Water

The fate, transport, and human health risk associated with plutonium in drainage and reservoir sediments in the vicinity of the RFP have been evaluated and discussed (DOE, 1990) This document provides an evaluation of the potential transport and exposure pathways associated with the potential surface water runoff and soil erosion mechanisms discussed below

Soil erosion by water may transport contaminated soils to surface waters (creeks, rivers, reservoirs) Combined surface water and wind erosion of soils at IHSS 199 is estimated by the SCS at 93 to 143 tons per acre per year (209-321 metric tons per hectare per year) for bare unvegetated soils and 1 to 3 tons per acre per year (2 2-6 7 metric tons per hectare per year) for vegetated areas (SCS, 1985) These figures indicate that revegetation will significantly decrease surface water erosion Because plutonium adsorbs to particulate matter, its mobility in surface water depends upon the amount of suspended solids in the water However, dissolved organics, carbonates, or other complexing agents in the water can form complexes with plutonium and increase its solubility As a result, plutonium may stay in the dissolved phase in surface waters

When moving water becomes stagnant, plutonium attached to particles settles out as bottom sediments It has been shown that clay-rich sediments, such as those in impoundments near the RFP, have an extremely high affinity for plutonium in an aquatic system (CSU, 1974) As a result, the bottom sediments will immobilize plutonium considerably However, high dissolved organic carbon, carbonate, fluoride, chloride, or nitrate concentrations along with a high percolation rate may leach some of the plutonium in bottom sediments downward toward the water table There is no evidence, however, that this process is occurring in reservoirs near the RFP The concentrations of plutonium instead decrease to background levels at a depth of 8 to 12 in (20 to 30 cm) in the reservoir sediment columns (Rockwell, 1984, Rockwell, 1985a)

It has been demonstrated that density stratification of lake waters in summer months results in a reducing environment in deeper water The distribution coefficient of plutonium in reducing waters is threefold to tenfold lower than in oxidizing conditions As a result, the mobility of plutonium will increase somewhat. However, the K_d values for these waters are still very high (ANL, 1986)

Resuspension of plutonium from bottom sediments is also possible by organisms that disturb the sediments The resuspended plutonium will eventually settle back out and again become part of the sediment.

3 3 PLUTONIUM MIGRATION PATHWAY SUMMARY

Plutonium at IHSS 199 most likely exists in the thermodynamically stable solid state, PuO_2 (Section 3 1 2) Consideration of potential surface water and ground water migration pathways must take into account existing post-depositional characterization of the contamination The 1970 Krey and Hardy investigation (Appendix D, Document D-1) determined that after twelve years of potential transport, 99 percent of the total amount of plutonium in the soils was contained in the top 8 3 in (21 cm) of soils around the RFP, and, furthermore, that half of the total plutonium remained in the top 1 2 in (3 cm)

These factors have important implications regarding the potential surface water and ground water migration pathways at IHSS 199 If surface water was an effective plutonium transport

mechanism, half of the plutonium would not be expected to remain within the top 1 2 in (3 cm) of soil over a period of twelve years Plutonium would have been effectively removed from the land surface through erosion or would have infiltrated deeper into the soils

Infiltration toward the ground water system also does not appear to be a plausible migration pathway for plutonium at IHSS 199 If infiltrating ground water was an effective plutonium transport mechanism, the plutonium would be expected either to have a more uniform depth distribution within the unsaturated surface materials, or to be present in higher concentrations at depth than at the surface

The observed distribution of plutonium in IHSS 199 soils strongly suggests that neither surface water nor ground water are likely pathways for plutonium migration at the site Research and investigations into plutonium mobility at other locations have demonstrated that lack of plutonium transport through unsaturated porous media is the rule rather than the exception (Andelman and Rozzell, 1970, Brookins, 1984, Kim et al , 1984, Shade et al , 1984, Silva et al , 1979, Staley et al , 1979) The reasons for this lack of mobility appear to be the extremely low solubility of plutonium and the strength with which plutonium is adsorbed to fine-grained particles in the unsaturated porous media

4.0 PRELIMINARY HUMAN HEALTH RISK ASSESSMENT

Section 300 430(d) of the NCP (Federal Register March 8, 1990, pg 8709) states that as part of the remedial investigation, a baseline risk assessment (BRA) is to be conducted to determine whether the contaminants of concern identified at the site pose a current or potential risk to human health and the environment in the absence of remedial action Table 5 of the IAG Statement of Work modifies this objective for the OU 3 preliminary reports by limiting the risk assessment to human health concerns based on a no further action alternative A complete quantitative risk assessment will be performed under the scheduled OU 3 RFI/RI The following discusses the general aspects of a BRA, and the specific differences of this preliminary assessment.

4 1 BASIS AND PURPOSE OF THE BRA AND THE PRELIMINARY HUMAN HEALTH RISK ASSESSMENT

The major objective of a BRA is to identify and define (quantify) potential human health risks and environmental impacts associated with exposure to the constituents present in the various environmental site media. The assessment is not intended to estimate the true risks to which human or environmental populations will be subject, rather it presents upper bound estimates of these risks to be used in the remedial decision-making process The true risks are likely to be much lower than their upper bound values It is used as input into the feasibility study (FS) to focus on the most appropriate remedies (if any), which reduce identified risks (if any) to acceptable levels The BRA essentially establishes the site baseline conditions from which a selection of the most appropriate type and extent of corrective actions (if any are needed) can be made

4 1 1 BRA Objectives

In general, the major objective of the BRA is attained by identifying and characterizing the following

- Toxicity and quantity of hazardous substances present in each media of concern
- Environmental fate and transport mechanisms within specific environmental media, such as physical, chemical, and biological degradation processes

- Hydrogeological, airborne, surface water, and biota evaluation and assessment
- Potential exposure pathways and extent of actual or expected exposure
- Population at risk
- Extent of expected harm and the likelihood of such harm occurring
- Acceptable levels of exposure based on regulatory and toxicological information
- Comparison of concentrations present with Applicable or Relevant and Appropriate Requirements (ARARs)
- Development of a site-specific model that will provide a calculation of risk, given site-specific parameters

At most facilities the principle data source document for conducting the BRA is the RFI report or the RI report These include general site characterization information, chemical analytical information, and a detailed description of the hydrogeological regime and predictions of groundwater flow and contaminant transport mechanisms The characterization of site-specific parameters such as airborne contaminant concentrations, types and distribution of biota, occurrence of surface water, and soil contaminant concentrations are also performed during this RFI/RI The BRA presents the data collected during these investigations in the context of potential human and environmental exposure and focuses on the most toxic of the site contaminants The human health aspects of the BRA uses the data and the characterization of the site and contaminant distribution patterns for all environmental media by reinterpreting them in the context of potentially complete exposure pathways leading to human receptors, with one added dimension, namely focusing on the toxic constituents The following discussions focus on the human health aspects of a risk assessment

Once all potential exposure pathways have been evaluated the carcinogenic risks from each are summed to produce a total risk posed to humans from the contaminants located on-site This value is then compared to the EPA target carcinogenic risk range of 10^{-4} to 10^{-6} The EPA does not require the complete elimination of risk or of all known or anticipated adverse effects, rather it does require protection of human health and the environment Appendices B and C of this report provide additional information concerning the concepts of risk

In 40 CFR Section 300 430(3)(2)(i)(A)(2) the EPA states that "For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}, using information on the relationship between dose and response." Furthermore, the EPA has stated in this section that the 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure, however, this 10^{-6} cumulative risk level is to be used only as a starting point, and does not reflect a presumption that the final decision on remedial action should attain such a risk level It is possible that given site-specific parameters, a calculation that results in a cumulative total risk level of 10^{-4} to the public could still be protective of human health, thus eliminating the need for remedial action

4 1 2 Qualitative Risk Assessment Objectives

Unfortunately, a quantitative BRA cannot be performed using existing IHSS 199 data Appendix A of this document presents the data useability review for the purposes of a quantitative risk assessment of existing documents and concludes that the available data are not adequate to perform a defensible quantitative risk assessment A quantitative risk assessment will, however, be performed based on EPA guidance (EPA, 1989) as part of the remedial investigation report

Since a quantitative human health risk assessment cannot be performed with existing data, a qualitative human health risk assessment for IHSS 199 is presented in this section The objectives of this qualitative assessment are to identify all potential exposure pathways which will be evaluated in the IHSS 199 RFI/RI, to discuss the relative significance of each pathway using existing information to make qualitative judgments, and to identify additional information needed to perform a quantitative assessment. The qualitative assessment uses the existing information to make judgments concerning the potential exposure pathways and to identify the plausible exposure pathways and qualitative risks which are applicable to the following scenarios

- No further action for current land use scenario
- Implementation of the remedy (workers and the public) for current land use scenario
- Post remedy for current and future land use scenarios

These judgments are not used, however, to eliminate potential exposure pathways from evaluation under the RFI/RI

The qualitative risk evaluation for the no further action alternative and the remedy implementation alternative are based on the current land use (recreation is assumed) condition In order to provide some estimate of whether there is any imminent threat to human health, a hypothetical risk assessment has been provided that uses generic exposure pathway assumptions based on a future residential land use This hypothetical risk assessment does have limitations in that only plutonium is assessed. This assessment is provided in Appendix C, and includes discussions of the relative difference in risk based on plutonium concentrations in soil of 1 pCi/g, 10 pCi/g, and 100 pCi/g The reader may compare the calculations for each pathway to assess if there is agreement between the qualitative description of risk from each pathway with the risk calculated for that pathway in Appendix C

Due to the inherent uncertainty of a qualitative risk assessment, it is not possible in this assessment to accurately compare the relative risks of the no action, remedy implementation, and post remedy scenarios Only the relative differences in the significance of various pathways can be discussed. The media specific pathways, routes of uptake, and potential human receptors are the same for all three scenarios, however, the concentration of plutonium (source term) will decrease for the implementation and post remedy condition

Data reviewed (see Section 6 0 for a list of references) indicate that plutonium is the only contaminant at IHSS 199 that has been characterized and which can be attributed to RFP historical releases Only very limited data are available for other radionuclides potentially present at IHSS 199 as a result of RFP releases, such as americium-241 If americium does occur at IHSS 199, it would likely exist in small quantities compared to plutonium This statement is based on the plutonium/americium ratio in the weapons grade materials handled at RFP Table 4 1 lists the isotopic composition of RFP plutonium The initial historic plutonium/americium ratio was 15 1 As a result of the radioactive decay of plutonium-241 and subsequent in growth of americium-241, it is likely that the current ratio is closer to 5 1 (DOE, 1988) Since americium produces almost twice the internal dose as plutonium (ICRP, 1979),

TABLE 4.1

ISOTOPIC COMPOSITION OF ROCKY FLATS 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 1	—	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	—	$1\ 18 \times 10^{-6}$
Am-241	—[b]	3 42	—	—

Source Rockwell, 1985b

[a] Relative activity is obtained by multiplying the percent by weight by the specific activity

Total activity for the plutonium isotopes is

Alpha 0 0732 curies/gram
Alpha plus Beta 0 446 curies/gram

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

determination of its magnitude and extent must be accomplished in order to conduct a quantitative risk assessment. Because very few americium measurements are available for IHSS 199, its contribution to this qualitative assessment cannot be addressed. An examination of the possible risk that americium presents relative to the risk of plutonium has been performed. Since the current land use scenario indicates that the inhalation pathway is the most significant, the following statements can be made

- The cancer slope factor for inhalation of plutonium-239 and americium-241 is similar (4.1×10^{8} vs 4.0×10^{8})
- Based on conservative assumptions americium-241 can be present at an upper bound activity of 20 percent of the current activity of plutonium-239

Therefore the inclusion of americium-241 would only add an additional 20 percent risk to the current use scenario. Since the exposure pathways for the potential contaminants of concern are similar and significantly more data would be needed to quantitatively assess the risks associated with these contaminants, only plutonium will be addressed specifically in this qualitative risk assessment and in the generic risk assessment (Appendix C). Since a future use scenario could include residential exposure, it is important to characterize potential pathways that may transport americium-241 to human receptors. A more comprehensive determination of all contaminants of concern will be performed during the scheduled RFI/RI activities.

4.2 QUALITATIVE ASSESSMENT CONCEPTUAL APPROACH

Since the primary historic source of plutonium contamination to IHSS 199 has been mitigated by paving of the 903 Pad, this assessment is based on the assumption that the plutonium present at IHSS 199 represents the highest possible concentration that will be available for human receptor impact. Concentrations in the soil will be reduced over time by either natural processes (soil erosion, vertical downward migration, fugitive dust), or remedial action (tilling and revegetation) for the remedy implementation and post-remedy scenarios.

This qualitative risk assessment uses hazard rankings (Sections 4.5.3 and 4.7.1) instead of plutonium concentration values, transport equations and receptor dose calculations to make judgments concerning relative magnitude of specific media occurrence, release probabilities,

potential routes of uptake and the ultimate impact on a human receptor Since the potential pathways are the same for pre-remedy implementation, and post-remedy, the qualitative risk characterization is developed only for the no-action current use (Open Space) condition, but is applicable to all three As discussed, a generic quantitative risk assessment is also included in Appendix C, so that the relative magnitude of the qualitative hazard ranking can be compared with the numerical magnitude of the exposure pathway analysis provided in Appendix C The relative difference in risk between these three conditions will be determined when the quantitative risk assessment is conducted.

The EPA Risk Assessment Guidance (RAG) document identifies the following four elements for a completed exposure pathway (EPA, 1989)

- A source and mechanism of chemical release to the environment
- An environmental transport medium for the released chemical (air, ground water, etc)
- A point of potential human or biota contact with the contaminated medium (exposure point)
- A mode of uptake at the exposure point (ingestion, inhalation, or dermal contact)

If any of these elements are absent, there is no resultant human exposure and consequently no risk For the purposes of this assessment, the terms exposure pathway and completed exposure pathway will be used only when all four of these elements are present

The qualitative risk assessment will be developed as follows

Toxicity Assessment (Section 4 3)

The human health risks associated with radiation exposure are briefly described, with emphasis on exposure to plutonium A more rigorous toxicity assessment will be performed as part of scheduled RFI/RI activities once adequate site-specific data have been collected

Source Term (Section 4 4)

The source term describes the amount and distribution of contaminant (plutonium) found in the environment For IHSS 199, the source term corresponds to plutonium concentrations in soil The concentration and depth profile of plutonium in the soil affect the magnitude of any release into other media

Exposure Pathways (Section 4 5)

Potential exposure pathways for IHSS 199 are identified based on existing data The relative importance of any individual potential exposure pathway is then assessed by estimating the magnitude of potential exposure, the frequency and duration of these exposures, and the media-specific pathways by which humans are potentially exposed The magnitudes of potential exposures are based upon the soil contamination being a contamination source for other media Media-specific pathways for both the current and future land use conditions (see Section 2 2 1) are qualitatively assessed in this section for their relative importance to exposure routes leading to human uptake

Exposure Routes (Mode of Uptake) (Section 4 6)

The various routes of plutonium uptake by humans and other organisms important to human exposure are identified and ranked by relative importance to the risk assessment The risks associated with potential points of human contact are qualitatively assessed based on all identified exposure pathways A description of the behavior of plutonium in biological systems is included in this section Exposure routes for both the current and future land use condition are qualitatively assessed in this section for their relative importance to the risk characterization

Risk Characterization (Section 4 7)

The elements developed in preceding sections are combined into a site-specific risk characterization, which evaluates the concentration of plutonium in each media, its likelihood for transport to other media, and its likelihood to impact a human receptor based on current land use conditions All potential exposure pathways are systematically examined, and those which do not meet the criteria of a completed pathway based on

current and future land use conditions are eliminated from the risk assessment In addition, a risk characterization is presented that qualitatively assesses the potential hazard to workers and the public during remedial action, as well as the risk posed by post-remedy concentrations of plutonium-239

4 3 TOXICITY ASSESSMENT

The purpose of a toxicity assessment is to weigh available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects A toxicity assessment is rather straightforward for radionuclides, since the type of effects and the likelihood of occurrence of any one of the number of possible adverse effects from radiation exposure depends on the radiation dose The following provides a brief summary of human and experimental animal data that establishes the basic hazards of radiation exposure A more rigorous toxicity assessment will be performed during the quantitative risk assessment, when additional site characterization data are available

4 3 1 Hazard Identification

The foundation of any risk assessment is that two conditions must be met for a risk to be present 1) a hazard (presence of a toxic substance at a concentration where exposure can result in a toxicologically significant dose) must be present, and, 2) exposure (of a receptor) to that hazard must occur If either factor is absent, the hazard or the exposure, there is no risk In simple mathematical terms, the risk is equal to the potency (a measure of the hazard) times the effective dose (a measure of the exposure)

Hazards associated with chemicals are described toxicologically in terms of exposure mode and duration Modes of environmental exposure are characterized as inhalation, ingestion, and direct contact (dermal absorption)

In addition to these exposure categories, health effects are divided into two main categories health consequences that may occur at any exposure level greater than zero (carcinogenicity), and

health effects which will not be elicited unless the constituent concentration is above some threshold level (non-carcinogens) For this site it is assumed that the concentrations present will pose a potential of only a carcinogenic hazard to the public, and may be used as the sole basis for assessing the radiation related to human health risk at this site (EPA, 1989)

Because carcinogenic effects are believed to be initiated at the molecular level, current regulatory policy is based on the concept that there is no finite dose or threshold below which carcinogens do not exert a potential effect. In the case of chemicals exhibiting non-carcinogenic effects, it is believed that organisms have protective mechanisms that must be overcome before the toxic endpoint is manifested

In determining health risks associated with chronic exposure to toxic materials, two categories based on the nature of the health consequences exist For all health effects associated with chronic exposure to non-carcinogenic toxic materials there is some threshold concentration below which the impact will not occur; however, there is no threshold concentration for carcinogenic toxic constituents Materials that are carcinogenic may also induce other health effects which occur at a lower concentration

In order to evaluate the potential risks posed by plutonium, it is important to understand the toxicity hazards of radiation for different exposure routes Radiation is defined as the transfer of energy from one place to another Heat, sound, and light are radiation but do not carry enough energy to break the atomic bonds of molecules, however, ionizing radiation, when interacting with matter, has sufficient energy to break the atomic bonds of molecules, and produce (emit) an ejected electron and a positively charged ion Ionizing radiation may be in the form of particles or electromagnetic waves

The principal adverse biological effects associated with ionizing radiation exposures from radioactive substances in the environment are carcinogenicity, mutagenicity, and teratogenicity Carcinogenicity is the ability to produce cancer Mutagenicity is the property of being able to induce genetic mutation, which may be in the nucleus of either somatic (body) or germ (reproductive) cells Mutations in germ cells lead to genetic or inherited defects Teratogenicity

refers to the ability of an agent to induce or increase the incidence of congenital malformations as a result of permanent structural or functional deviations produced during the growth and development of an embryo (more commonly referred to as birth defects) Radiation may induce other deleterious effects at acute doses above about 100 rem, but doses of this magnitude are not normally associated with radioactive contamination in the environment.

Ionizing radiation causes injury by breaking molecules into electrically charged fragments (i e , free radicals), thereby producing chemical rearrangements that may lead to permanent cellular damage The degree of biological damage caused by various types of radiation varies according to how spatially close together the ionizations occur Ionizing radiations from plutonium (e g , alpha particles) produces high density regions of ionization For this reason, they are called high-LET (linear energy transfer) particles Other types of radiation (e g , x-rays, gamma rays, and beta particles) are called low-LET radiations because of the low density pattern of ionization they produce In equal doses, the carcinogenicity and mutagenicity of high-LET radiations may be an order of magnitude or more greater than those of low-LET radiations, depending on the endpoint being evaluated The variability in biological effectiveness is accounted for by the quality factor used to calculate the dose equivalent This variability has been accounted for in the generic risk assessment developed in Appendix C

4 3 2 Carcinogenesis

An extensive body of literature exists on radiation carcinogenesis in man and animals This literature has been reviewed most recently by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiations (NAS-BEIR Committee) (UNSCEAR, 1977, 1982, 1988, NAS, 1972, 1980, 1988) Estimates of the average risk of fatal cancer from low-LET radiation from these studies range from approximately 0 007 to 0 07 fatal cancers per 100 rem

An increase in cancer incidence or mortality with increasing radiation dose has been demonstrated for many types of cancer in both human populations and laboratory animals (UNSCEAR, 1982, 1988, NAS, 1980, 1988) Studies of humans exposed to internal or external

sources of ionizing radiation have shown that the incidence of cancer increases with increased radiation exposure This increased incidence, however, is usually associated with appreciably greater doses and exposure frequencies than those encountered in the environment Therefore, risk estimates from small doses obtained over long periods of time are determined by extrapolating the effects observed at high, acute doses Malignant tumors in various organs most often appear long after the radiation exposure, usually 10 to 35 years later (NAS, 1980, 1988, UNSCEAR, 1982, 1988) Radionuclide metabolism can result in the selective deposition of certain radionuclides in specific organs or tissues, which, in turn, can result in larger radiation doses and higher-than-normal cancer risk in these organs

Ionizing radiation can be considered pancarcinogenic, i e , it acts as a complete carcinogen in that it serves as both initiator and promoter, and it can induce cancers in nearly any tissue or organ Radiation-induced cancers in humans have been reported in the thyroid, female breast, lung, bone marrow (leukemia), stomach, liver, large intestine, brain, salivary glands, bone, esophagus, small intestine, urinary bladder, pancreas, rectum, lymphatic tissues, skin, pharynx, uterus, ovary, mucosa of cranial sinuses, and kidney (UNSCEAR, 1977, 1982, 1988, NAS, 1972, 1980, 1988) These data are taken primarily from studies of human populations exposed to high levels of radiation, including atomic bomb survivors, underground miners, radium dial painters, patients injected with thorostat or radium, and patients who received high x-ray doses during various treatment programs Extrapolation of these data to the much lower doses that the public would be exposed to at IHSS 199 is the major source of uncertainty in determining low-level radiation risks (EPA, 1989) It is assumed that no lower threshold exists for radiation carcinogenesis

On average, approximately 50 percent of all of the cancers induced by radiation are lethal The fraction of fatal cancers is different for each type of cancer, ranging from about 10 percent in the case of thyroid cancer to 100 percent in the case of liver cancer (NAS, 1980, 1988) Females have approximately two times as many total cancers as fatal cancers following radiation exposure, and males have approximately 1 5 times as many (NAS, 1980)

Cancer slope factors (CSF) for the ingestion and inhalation of radionuclides are presented in Table B 1 of Appendix B CSFs are estimated with mathematical extrapolation models, which

extrapolate the effects (cancer induction) seen at high doses to potential effects at low doses The CSFs for radionuclides are considered "best estimates" while slope factors for chemicals are computed at the 95% confidence level This method for determining risk will be used for any significant exposure to a radionuclide The acceptable cancer risk range is $1x10^{-4}$ to $1x10^{-6}$ as specified in 40 CFR 300 Subpart E

4 3 3 Mutagenesis

Very few quantitative data are available on radiogenic mutations in humans, particularly from low-dose exposures Some mutations are so mild they are not noticeable, while other mutagenic effects that do occur are similar to nonmutagenic effects and are therefore not necessarily recorded as mutations The bulk of data supporting the mutagenic character of ionizing radiation comes from extensive studies of experimental animals (UNSCEAR, 1977, 1982, 1988, NAS, 1972, 1980, 1988) These studies have demonstrated all forms of radiation mutagenesis, including lethal mutations, translocations, inversions, nondisjunction, and point mutations Mutation rates calculated from these studies are extrapolated to humans and form the basis for estimating the genetic impact of ionizing radiation on humans (NAS, 1980, 1988, UNSCEAR, 1982, 1988) The vast majority of the demonstrated mutations in human germ cells contribute to both increased mortality and illness (NAS, 1980, UNSCEAR, 1982) Moreover, the radiation protection community is generally in agreement that the probability of inducing genetic changes increases linearly with dose and that no "threshold" dose is required to initiate heritable damage to germ cells

The incidence of serious genetic disease due to mutations and chromosome aberrations induced by radiation is referred to as genetic detriment Serious genetic disease includes inherited ill health, handicaps, or disabilities Genetic disease may be manifest at birth or may not become evident until some time in adulthood. Radiation-induced genetic detriment includes impairment of life, shortened life span, and increased hospitalization The frequency of radiation-induced genetic impairment is relatively small in comparison with the magnitude of detriment associated with spontaneously arising genetic diseases (UNSCEAR, 1982, 1988)

4 3 4 Teratogenesis

Radiation is a well-known teratogenic agent The developing fetus is much more sensitive to radiation than the mother The age of the fetus at the time of exposure is the most important factor in determining the extent and type of damage from radiation The malformations produced in the embryo depend on which cells, tissues, or organs in the fetus are most actively differentiating at the time of radiation exposure Embryos are relatively resistant to radiation-induced teratogenic effects during the later stages of their development and are most sensitive from just after implantation until the end of organogenesis (about two weeks to eight weeks after conception) (UNSCEAR, 1986, Brent, 1980) The brain appears to be most sensitive during development of the neuroblast (these cells eventually become the nerve cells) The greatest risk of brain damage for the human fetus occurs at 8 to 15 weeks, which is the time the nervous system is undergoing the most rapid differentiation

4 3 5 Summary

In general, there are two distinct human hazards presented by radiation, those of external and internal radiation exposure External radiation exposure is due mainly to gamma ray emissions from radioactive decay Although plutonium and americium do produce x- and gamma rays, they are very weak and only comprise a small percentage of the total energy emitted Therefore, this risk assessment does not consider external radiation exposure as a hazard from IHSS 199 Plutonium does, however, present an internal radiation hazard, primarily from inhalation The inhalation of plutonium or americium can lead to the deposition and retention of radioactivity in the lung, and produce continual, localized internal irradiation of lung and other body tissues for extended periods of time

The following summarizes the important properties of plutonium

Physical half-life 2 44x10^4 years
Sources used in nuclear weapons
Principal modes and energies of decay, in million electron volts (MeV) alpha 5 06 (11%) 5 13 (17%) 5 15 (73%)

Special chemical characteristics member of the actinide series of rare-earth elements Forms insoluble fluoride, hydroxides, and oxides Oxidizes rapidly on exposure to air to form plutonium dioxide (PuO_2)

Critical Organs bone (soluble), liver

Atomic number 94
Physical form silvery-white metal
Melting point 680°C

Plutonium is primarily an alpha particle emitter An alpha particle is essentially a helium nucleus without orbital electrons It is composed of two protons and two neutrons with a charge of plus two Since these alpha particles have a relatively large mass and +2 charge, they react strongly with matter, and create a large amount of ionization in a very short distance However, even alpha particles with the high kinetic energies of plutonium travel only about 1 6 inches (4 cm) in air, and can be stopped by a piece of paper, or the outermost layer of dead skin Alpha particles therefore do not present an external exposure hazard. These same properties do however produce much more cellular damage than an equivalent amount of gamma energy, if both alpha and gamma are internally deposited. The range of penetration of a plutonium alpha particle in tissue is approximately 100 um ($3\ 9 \times 10^{-3}$ in), indicating that an alpha particle retained in the body will deposit 100 percent of its ionizing radiation to localized tissue The concepts developed in this section describe the various ways plutonium can enter the body (exposure routes), and the relative risk of each mode of uptake For the purposes of this qualitative risk assessment it is assumed that the insoluble form of plutonium, plutonium dioxide (PuO_2), will be the predominant radionuclide available for biological uptake This assumption is based on a variety of studies (Eisenbud, 1987, Bair, 1973, McClellan, 1972, Romney, 1972) that indicate plutonium will oxidize in an environmental setting and thus form insoluble compounds The calculations performed in Appendix C, however, use the conservative EPA HEAST values that correspond to a more soluble form of plutonium (plutonium nitrate) Characterization of the actual solubility form of plutonium will be accomplished during the RI

4 4 SOURCE TERM

The initial step of this assessment involves data evaluation of the source term at the remedial acreage at IHSS 199 For purposes of this risk assessment, the potential source term is taken as the plutonium-contaminated surface soils of the remedy acreage Historical radiological site data relevant to a human health evaluation were collected from DOE and CDH sources (Appendix D) These data were evaluated for the concentration of plutonium present in all media The accuracy

with which the source term is characterized is the primary determinant of the ultimate validity of a risk assessment

An examination of the available data for IHSS 199 has been performed and is presented in Appendix A The examination indicates that soil sampling has not occurred throughout IHSS 199 and that, in some cases, the quantitation limits and detection limits for analyses which have been performed were not included in the referenced documents It is believed that most of the published data have not been through a rigid Quality Assurance/Quality Control (QA/QC) analysis It is also evident that sampling procedures for all media have differed between various sampling agencies In addition, there is some uncertainty as to the extent of the plutonium contamination Both the extent and the magnitude of the source term will be characterized during the RFI/RI activities Because of these uncertainties, a numerical value cannot be assigned to the source term at IHSS 199 with any certainty Analysis of existing data indicate that the plutonium concentrations average less than 5 pCi/g representing the highest average concentration from the seed report, which may include some on-site sample points Table 4 2 summarizes data from sources provided in Appendix D The reader may compare the values found in Table 4 2 to the calculated risk from exposure to 1, 10, and 100 pCi/g, found in Appendix C and also compare these values to the existing background level of plutonium found throughout the United States of 0 2 pCi/g (EPA, 1990b) Section 4 14 discusses additional data needed for a reliable determination of IHSS 199 source term to support a quantitative risk assessment

4 5 POTENTIAL EXPOSURE PATHWAYS

The identification and assessment of exposure pathways is accomplished by characterizing all potential contaminant release mechanisms which may contribute to a completed exposure pathway to human and environmental receptors The release mechanism analysis evaluates the possible migration of the chemicals of concern, taking into account their physical and chemical properties that affect environmental fate in the various site media. Certain site characteristics such as hydrogeology, meteorology, soil organic carbon, climate, and vegetative cover, etc may also have a significant influence on the migration potential Current and future use of the site (residential use, farming, grazing, use as open space) may also determine the current and future exposure scenarios

TABLE 4.2

SUMMARY OF IHSS 199 HISTORICAL PLUTONIUM IN SOIL DATA

Data Source	Range (pCi/g unless otherwise noted)	Average (pCi/g unless otherwise noted)	No of Data Points	Comments
"Plutonium in Soil Around the Rocky Flats Plant," by P W Krey and E P Hardy, 1 August 1970 (Appendix D, Document D-1)	0 0007-0 963	0 085	27	1, 2, 3
"Committee Evaluation of Plutonium Levels in Soil Within and Surrounding USAEC Installation at Rocky Flats, Colorado " by J R Seed et al , 9 July 1971 (Appendix D, Document D-2)	0 045-139 7	5 0	123	1, 2, 4
"Soil Sampling East of Indiana Avenue," by R W Loser and R L Tibbals, 29 November 1972 (Appendix D, Document D-3)	2 7-594 mCi/km^2	99.3 mCi/km^2	14	1, 5
"Results of Special Soil Samples Collected Adjacent to the Rocky Flats Plant Site," by C T Illsley, 7 September 1977 (revised 30 November 1979) (Appendix D, Document D-4)	0 01-1 48	0 207	20	1, 2
"Radioactive Soil Contamination (Cesium-137 and Plutonium) in the Environment Near the Rocky Flats Nuclear Weapons Plant," by CDH, September 1977 (Appendix D, Document D-5)	Data contained in this report are included in the 1970-1989 CDH report (Document D-18 below)			
"Plutonium Concentrations in Soil on Lands Adjacent to the Rocky Flats Plant," by C T Illsley and M W Hume, 16 March 1979 (Appendix D, Document D-7)	0 009-3 42	0 19	160	1, 2
"Disclosure to the City of Broomfield," by Rockwell International, 22 January 1985 (Appendix D, Document D-8)	0 06-7 7	N/A	N/A	1, 2, 6
"Soil Sample Collection and Analysis for Plutonium on Lands Adjacent to Great Western, Reservoir for the City of Broomfield," by C T Illsley, 15 January 1987 (Appendix D, Document D-9)	0 04-3 8	1 2	15	1, 2
"Remedial Action Program on Jefferson County Open Space Land in Section 7, T2S, R69W, South of Great Western Reservoir," by C T Illsley, 15 October 1987 (Appendix D, Document D-11)	1977 0 06-7 7	1.55	22	1, 7
	1985 0 03-5 6	1 70	24	
"Rocky Flats Surface Soil Survey, 1970-1989," by CDH, February 1990 (Appendix D, Document D-18)	1970 0 01-11 0	1 2	13	1, 2, 4
	1971 0 03-30 1	2 6	13	1, 2, 4
	1972 0 02-25 1	2 1	13	1, 2, 4
	1973 0 03-0.38	0 12	5	1, 2
	1974 0 02-12 7	1.2	13	1, 2, 4
	1975 0 01-4.30	1 1	10	1, 2
	1976 0 02-3.50	0 4	13	1, 2
	1977 0 03-4.20	0 5	13	1, 2
	1978 0 03-0.25	0 09	6	1, 2
	1980 0 01-3 1	0.3	13	1, 2
	1981 0 18-2 2	0.3	12	1, 2
	1986 0 01-1.5	0 2	13	1, 2

TABLE 4.2

SUMMARY OF IHSS 199 HISTORICAL PLUTONIUM IN SOIL DATA
(continued)

COMMENTS

1 Data do not meet EPA useability criteria for risk assessment (see Appendix A)
2 Values originally expressed in dpm/g, converted to pCi/g using 0 45 multiplier
3 Included multiple analyses by various laboratories, some data points have multiple values
4 Some data points are within the present RFP boundary, sample locations are not defined clearly enough to separate these from data points outside the RFP boundary
5 Document lacks adequate description of sampling and analytical methodology and contains inconsistent definition of sample locations Because conversion of mCi/km^2 to pCi/g requires detailed knowledge of methodology and properties of the medium sampled, this conversion could not reliably be performed, however, reported values appear to be much higher than those recorded in other sampling programs in this area Very low confidence in these values
6 Document presents high, low, and average values from Broomfield remedy acreage sampling between 1977-1985
7 1977 data do not include Broomfield remedy acreage

A preliminary description of the exposure pathway should answer the following questions

- Where, when and how will the release of the toxicant occur?
- What is in the immediate vicinity of the release?
- What is the quantity, physical state, and chemical identity of the released material?

Again, an examination of the data presented in Appendix A concludes that the information necessary to perform a rigorous exposure pathway characterization was not contained in any of the existing reports Although answers to the above questions cannot be obtained from the existing information, it is possible to identify likely site-specific release mechanisms and transport media based on the generic risk assessment presented in Appendix C Characterization of all potential exposure pathways will be performed during the RFI/RI activities

4 5 1 Identification of Potential Release Mechanisms

Potential primary and secondary release mechanisms of plutonium from soil at IHSS 199 are identified in the conceptual model as shown in Table 3 1 and Figure 3-1 The potential primary release mechanisms include

- Fugitive dust from wind erosion and recreational use
- Surface water runoff
- Water infiltration/percolation
- Biotic uptake
- Tracking by insects, birds and animals

The potential secondary release mechanisms include

- Resuspension of settled dust
- Direct fugitive dust
- Settled dust -- plants
- Settled dust -- soil (leading to possible airborne dust)
- Settled dust -- water
- Biotic uptake of surface water
- Surface water deposition
- Surface water irrigation
- Surface water infiltration
- Surface water evaporation leading to possible airborne dust
- Ground water seepage
- Ground water pumpage
- Biomagnification

4 5 2 Identification of Transport Media

A physical examination of IHSS 199 and a review of available historical data for the current use of the site indicate that potential transport media for plutonium to leave the IHSS 199 areas are air, surface water, groundwater, and biota (Figure 3-1) The primary transport media would also be the same for a future use scenario of remedial action or post remedy remedial action Numerous possible primary release mechanisms are listed above, but it is the release of fugitive dust from surface soils that can cause the greatest impact on the secondary transport media of air The following discussion provides a more detailed description of the generation of fugitive dust and some description of the surface water runoff, ground water, and biotic uptake transport mechanisms at IHSS 199

4 5 2 1 Soil

The general principles of atmospheric fate and mobility of plutonium are described in Section 3 2 1 However, a further explanation of atmospheric transport parameters is offered in this section because inhalation and ingestion of plutonium particles from the remedy acreage is considered to be the most probable means of human exposure adjacent to the site The principal mode of transport of plutonium particles is direct airborne movement from the IHSS 199 source area, either by uplift or particle impact, or by resuspension of previously deposited small particles by wind action or other disturbances (EPA, 1990b) It is important to understand the mechanisms of contaminant transport before considering the corrective actions needed to reduce or eliminate transport To quantitatively assess the environmental impact and human health risk resulting from the contamination under pre-remedy, remedy implementation and post remedy conditions, additional soil and meteorological data specific to the site will need to be collected as part of the RFI/RI activities (Section 4 14)

Direct action of air moving past a particle may exert enough force to accelerate the particle, causing it to roll along the surface or to be lifted up and moved in the air stream A second mechanism of initiating particle movement can also be initiated through the impact of airborne particles with particles on the ground. Particles on a solid surface which have chemical and physical properties different from the base material have cohesive attraction to the substrate For resuspension to occur with this scenario, the force on the particle must be equal to or greater than

the force holding the particle to the surface Several factors are known to influence particle cohesion

- particle material
- size
- shape
- surface roughness
- relative humidity of the ambient air
- presence of electrostatic charge
- nature and physical characteristics of the substrate

The primary meteorological factors which influence the suspension of material from ground deposits are wind and ground surface moisture The amount of material that can be carried in the air currents is dependent on the density, velocity, and viscosity of the air

Particles that are dislodged from the ground surface can then move in three ways suspension, saltation, and surface creep Suspension occurs when upward wind eddies counteract free fall, allowing transport of the particle at the average forward speed of the wind. These particles are generally less than 0 05 millimeter (mm) in diameter and are redeposited via rainout or by gravity after the wind subsides Particles between 0 05 mm and 1 0 mm in diameter move by a series of short bounces called saltation Larger particles greater than 1 0 mm in diameter can roll and/or slide along the surface in what is called surface creep (EPA, 1990b) Particle movement predominantly occurs by saltation Successful revegetation of the contaminated acreage can reduce all three methods of particle transport

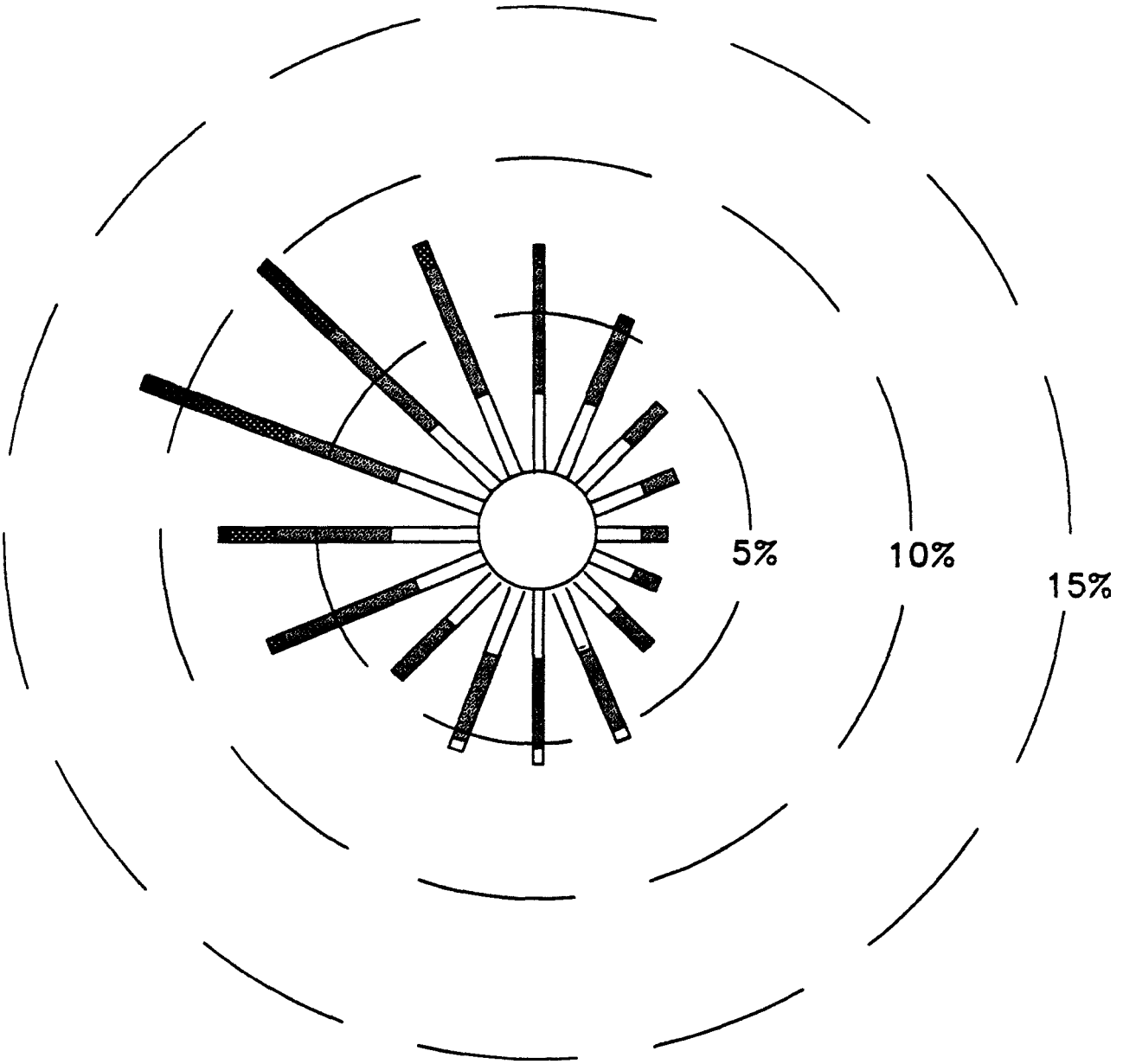
Due to the elapsed time since the last known releases to IHSS 199 from RFP (1970), it can be assumed that any free plutonium, (i e , that available for air transport in the soil environment) has been subject to weathering and aging Krey and Hardy (Appendix D, Document D-1), Whicker et al (1974) and general textbooks (Wick, 1967) support this statement concerning the behavior of plutonium in the environment. Thus, the deposited plutonium is assumed to have become an integral part of the surface soil, and that it behaves according to the concepts developed for soil erosion Additional studies are needed to verify this assumption Among the parameters which most influence the movement of soil by wind are the space and time variation of the soil particle size distribution However, since plutonium is generally found in an agglomeration with soil, it

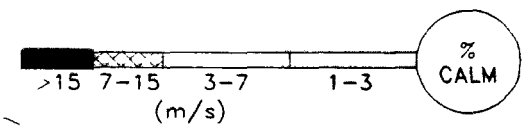
is much less likely to be available for deposition in the lung (Langer, 1986) Nevertheless, the conservative assumption of both this qualitative risk assessment and the generic risk assessment (Appendix C) is that all airborne plutonium is of a respirable particle size

It is very likely that fixation of the plutonium has occurred at IHSS 199 through all of the above-described processes, and that the fixed material is dispersed in a surface layer several centimeters deep As such, since environmental conditions produce continuous changes in surface layer characteristics, a simple relationship between wind speed and the resuspended material has little validity However, data are available that indicate a resuspension factor of 10^{-10} to 10^{-8} per meter (m^{-1}) for a fine powder from prairie terrain at measured wind speeds of approximately 2 2 to 45 mph (1 to 20 m/sec) Resuspension factors approximate 10^{-10} per meter at 2 2 mph (1 m/sec), and increase rapidly to 10^{-8} per meter at 11 2 mph (5 m/sec) where they appear to reach a plateau (Rockwell, 1985b)

An average wind speed of 9 mph (4 m/sec) is stated for RFP (DOE, 1980) The Rocky Flats Risk Assessment Guide (Rockwell, 1985b) uses a resuspension factor of 10^{-10} m^{-1} for reentrained soil This value is an order of magnitude lower compared to values discussed in Section 3 0 for IHSS 199, which is indicative of the different type of vegetative cover present at IHSS 199 Even though ten times more surface soil may be reentrained at IHSS 199 than for a similar sized plot of undeveloped land at RFP, the potential impact on human receptors appears low, based on measurements by air sampling devices downwind of IHSS 199 The EG&G Operational Health Physics Group performed air sampling at selected locations on and around IHSS 199 Results were obtained for the period of June 22, 1987 through December 4, 1987, during which time tilling, discing, and seeding were conducted on the remedy acreage (Appendix D, Document D-13) The airborne plutonium concentrations ranged from zero to 0 009778 pCi/m^3 with an average value of 0 000014 pCi/m^3 The average airborne concentration is far below the CDH limit of 0 02 pCi/m^3 for public exposure to plutonium Even the maximum concentration measured is below the standard by 50 percent

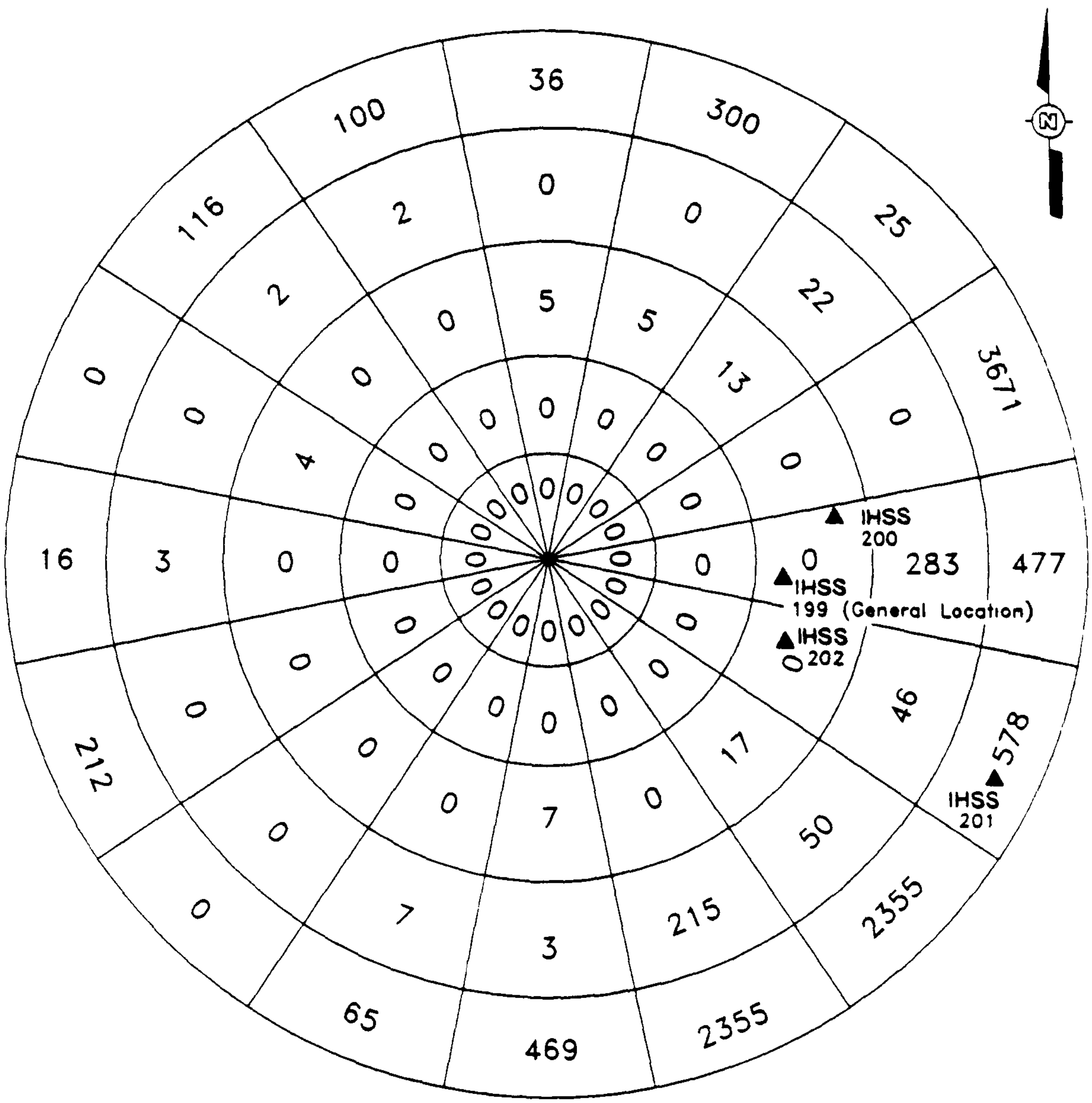
Figures 4-1 and 4-2 represent 1989 population distribution in 0-5 mile and 10-50 mile sectors, respectively, from the RFP Overlain on these figures is a wind rose showing variations in wind





5% Frequency of Occurrence

OVERLAY FIG 4-2



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	8/24/90	APPROVED BY		10-16-90	304923-A4

Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5

65 Number of persons living in sector

FIGURE 4-1

WIND ROSE AND 1989 POPULATION 0-5 MILE SECTORS ROCKY FLATS PLANT

REFERENCE FIGURE 2-1 DOE 1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT

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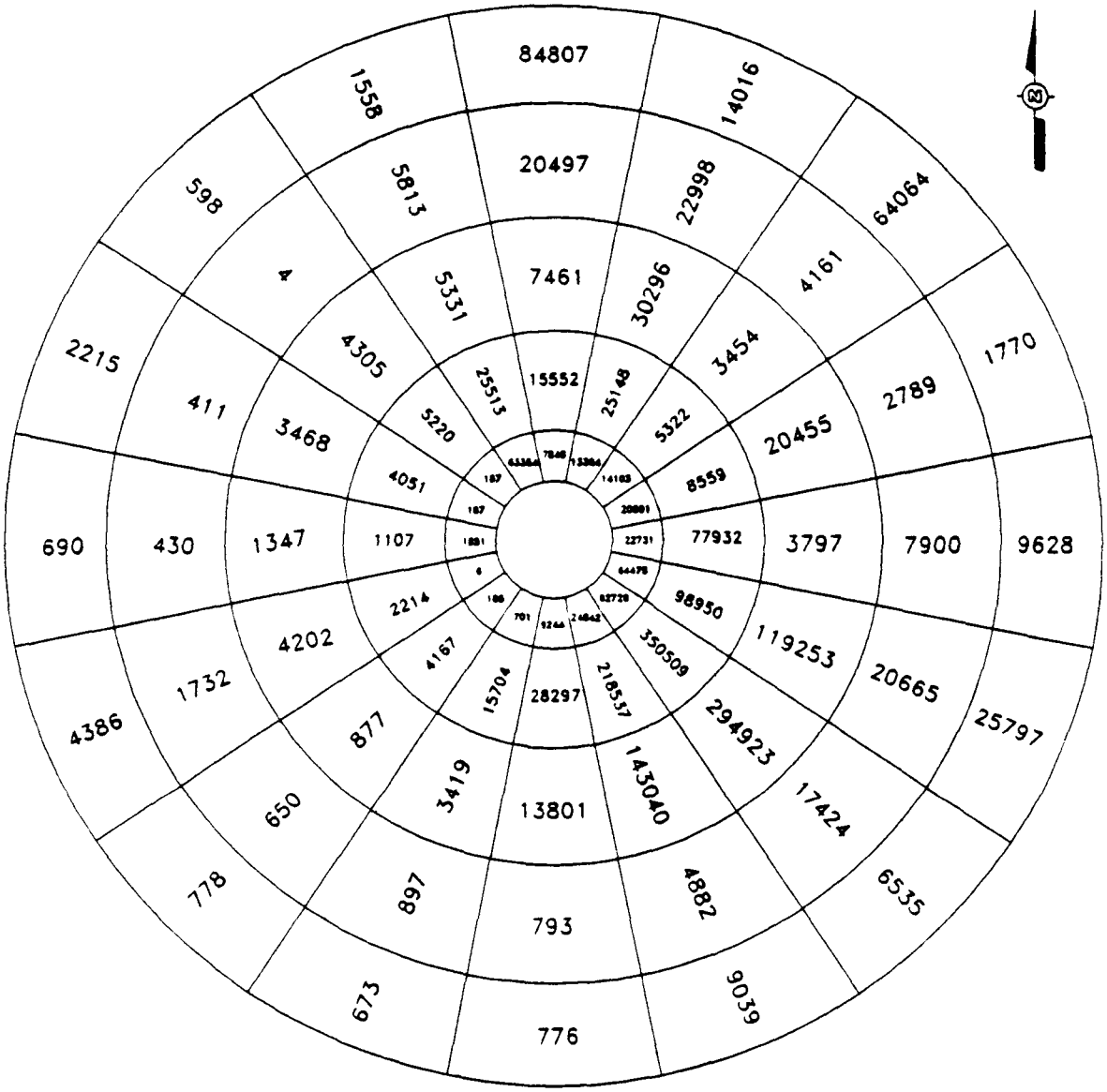
		APPROVED BY	TDK 10-16-90		



Miles	Sector Name
5–10	Sector 10
10–20	Sector 20
20–30	Sector 30
30–40	Sector 40
40–50	Sector 50

65

Number of persons living in sector

FIGURE 4-2

WIND ROSE AND 1989 POPULATION 10-50 MILE SECTORS ROCKY FLATS PLANT

REFERENCE FIGURE 2-4 DOE 1989 POPULATION ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT

speed and velocity around the RFP based upon 1989 meterological data. These figures help to show populations around the RFP potentially at risk of exposure from windborne dust from IHSS 199 Detailed characterization of populations at risk of exposure will be conducted under scheduled RFI/RI activities

In addition, a number of fixed environmental monitoring air samplers are located in the general downwind direction some distance from the remedy acreage Table 4 3 provides the yearly results of airborne levels of plutonium and Figure 2-6 places these sample locations relative to the RFP and IHSS 199 The results indicate that neither the current condition nor previous remedial action has caused an increase in airborne plutonium concentrations measured at these sample locations These results are below many reported values of ambient airborne concentrations of plutonium taken throughout the United States (Eisenbud, 1987, EPA, 1990b) For comparison purposes, it is noted that the average radon concentration in the United States is 110 pCi/m^3 (NCRP, 1987)

4 5 2 2 Plutonium Uptake in the Food Chain

As described in Section 3 0, plutonium forms relatively insoluble compounds in the environment and is therefore not generally considered ecologically mobile (Eisenbud, 1987) Since plutonium has no known biological function, it can only be passively incorporated into organisms, mainly by physical processes such as surface contact, inhalation, and ingestion of plutonium adsorbed to the surfaces of plants and zooplankton The generic risk assessment in Appendix C does take into account food chain transfer and foliar deposition of plutonium leading to human uptake It is not likely, however, that current land use conditions (open space) could produce off-site food chain transfer

As a general rule, radioisotopes present in soil sediments can pass into the root system of plants in the same manner as nonradioactive isotopes of the same element. The element may or may not be required for normal metabolism, and some elements (e g , iodine, cobalt, uranium, and radium) are known to be present in plants although they serve no metabolic function However, literature reviewed indicates that even when plutonium has been applied in a water-soluble form

TABLE 4.3

PLUTONIUM AMBIENT AIR MONITORING DATA
YEARLY AVERAGE (pCi/m^3)

YEAR	CONDITION	LOCATION		
		S-52 Jeffco Airport	S-57 Walnut Creek	S-58 Wagner
1985	Before Tilling	0 000002	0 000004	0 000002
1986	Deep Plowing	0 000003	0 000003	0 000002
1987	Revegetation	0 000003	0 000002	0 000003
1988	Revegetation	0 000003	0 000001	0 000004

Source Appendix D, Document D-17

and mixed into surface soil, plutonium is strongly excluded from uptake in the first crop plants grown on that plot The relative concentration factor expressed as parts per million in dry plant material/part per million in dry soil has been measured at less than 0 01% for plutonium (Menzel, 1965) This value has been replicated in a study of sheep grazing in a marsh estuary near Sellfield, England (Ham, 1989)

Radioactive substances can pass directly to the food chain by foliar deposition The radionuclides may then pass directly to grazing animals or man as superficial contamination, or they may be absorbed metabolically by the plant from its foliar surface The significance of plant surface contamination varies with the growing season, since the potential risk due to direct contamination of crops is obviously greater just before a harvest or during active grazing by stock animals Conversely, the potential risk may be lowest in winter months when there are no standing crops, although it is possible that even during these months direct fallout on the basal structure of grasses in permanent pastures may be stored until the following spring Retention of this type will be greatest for plants that develop a mat of basal parts, old stems, and surface roots

The significance of foliar contamination of plants will also depend on the structure of the plants and the role of the various parts of the plant in relation to the dieting habits of man Wheat plants have a shape that tends to maximize entrapment of settled fugitive dust Other cereal grains and grasses also have relatively high foliar retention Foliar contamination also can be removed by rain, other weathering effects, and by drying and dropping of plant parts (field loss) Chamberlain (1970) has examined data from a number of investigators and found the field loss during the growing season to be about 0 05 percent per day Potential foliar contamination at IHSS 199 will be addressed under scheduled RFI/RI activities

4 5 2 3 Surface Water

This transport media for plutonium depends almost totally on the amount of soil erosion by rain at IHSS 199 since the solubility of plutonium is so low The most stable form of plutonium in the pH range generally encountered in natural waters is $Pu(OH)_4$ (Andelman and Rozzell, 1970) This hydroxide has been reported to have a solubility product constant of $7x10^{-56}$ which is indicative of a high degree of insolubility (Taube, 1964) Once plutonium contaminated soil is

picked up by surface waters, plutonium could migrate along slopes and drainage on-site There are no perennial surface waters located at IHSS 199 It is also possible that heavy rains could cause particulate matter containing plutonium to move some distance, be redeposited on the soil, and create availability for fugitive dust wind erosion Numerous studies have documented that surface runoff can cause plutonium to migrate, albeit a very short distance This probability of occurrence is low to moderate, since all 350 acres (142 hectares) do have some form of vegetative cover The likelihood that this transport media would produce an impact on a human receptor is negligible at IHSS 199 because of the lack of potential human contact with runoff sediment However, some migration of plutonium from IHSS 199 to the adjacent reservoirs may be occurring as a result of erosion processes This potential pathway will be characterized during the RFI/RI stage

4 5 2 4 Ground Water

Ground water monitoring wells have been installed and sampled downgradient of the RFP, but not downgradient of IHSS 199 Plutonium has been detected (inconclusively) one time at the RFP (in Well 4-86) This is almost exclusively due to the fact that plutonium is not very soluble in water, and instead is highly adsorbed to clays and other soil particulates The probability of plutonium transport in ground water through infiltration/percolation is therefore believed to be negligible Site-specific ground water characterization data will be required to conduct the quantitative risk assessment

4 5 3 Potential Exposure Pathways at IHSS 199

Potential exposure pathways are discussed in this section Figure 3-1 identifies all of the various potential transport media which exist at IHSS 199, along with their associated primary and secondary release mechanisms Section 3 0 also describes plutonium fate and mobility in the environment, and concludes that for conditions at IHSS 199, plutonium is highly insoluble in ground water and surface water, and bonds strongly to soil surfaces As stated previously, a completed exposure pathway must exist for a hazard to be conveyed to the receptor Many of the potential transport media and release mechanisms identified thus far do not form a completed pathway, and therefore do not pose a risk to human health The only credible completed exposure pathway based on current land use for IHSS 199 is shown in Figure 4-3 If future

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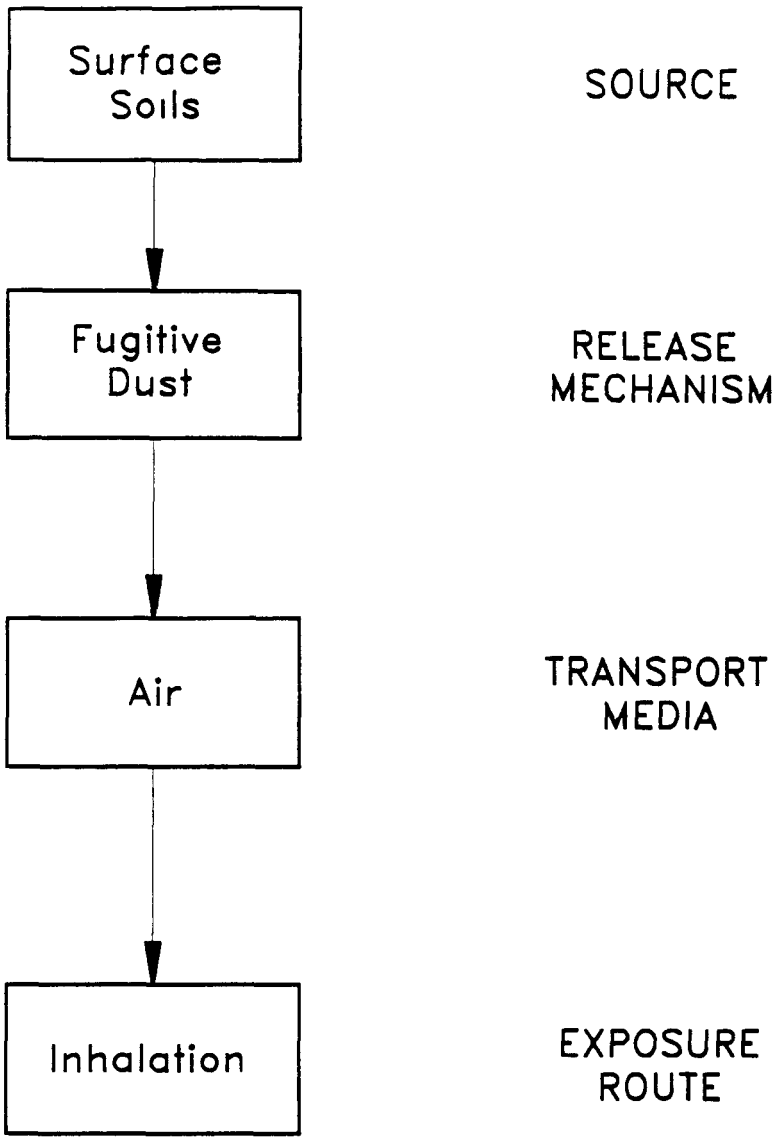


FIGURE 4-3

CURRENT OPEN SPACE LAND USE COMPLETED EXPOSURE PATHWAYS, IHSS 199 QUALITATIVE RISK ASSESSMENT

residential home construction occurs at IHSS 199, the additional pathway of ingestion of soil and foodstuffs would be added to the exposure pathway as illustrated in Figure 4-4 Although other pathways are addressed in this report for the sake of completeness, they are not considered in the determination of qualitative risk However, all potential pathways will be characterized during the RFI/RI stage.

Primary and secondary release mechanisms for the current land use scenario are grouped with transport media (Table 4 4) to determine their probability of transporting plutonium in the environment based on the following probability ranking

1 High -- historic records or physical characteristics of IHSS 199 indicate that plutonium has a high probability of being released by this mechanism or transported by this media

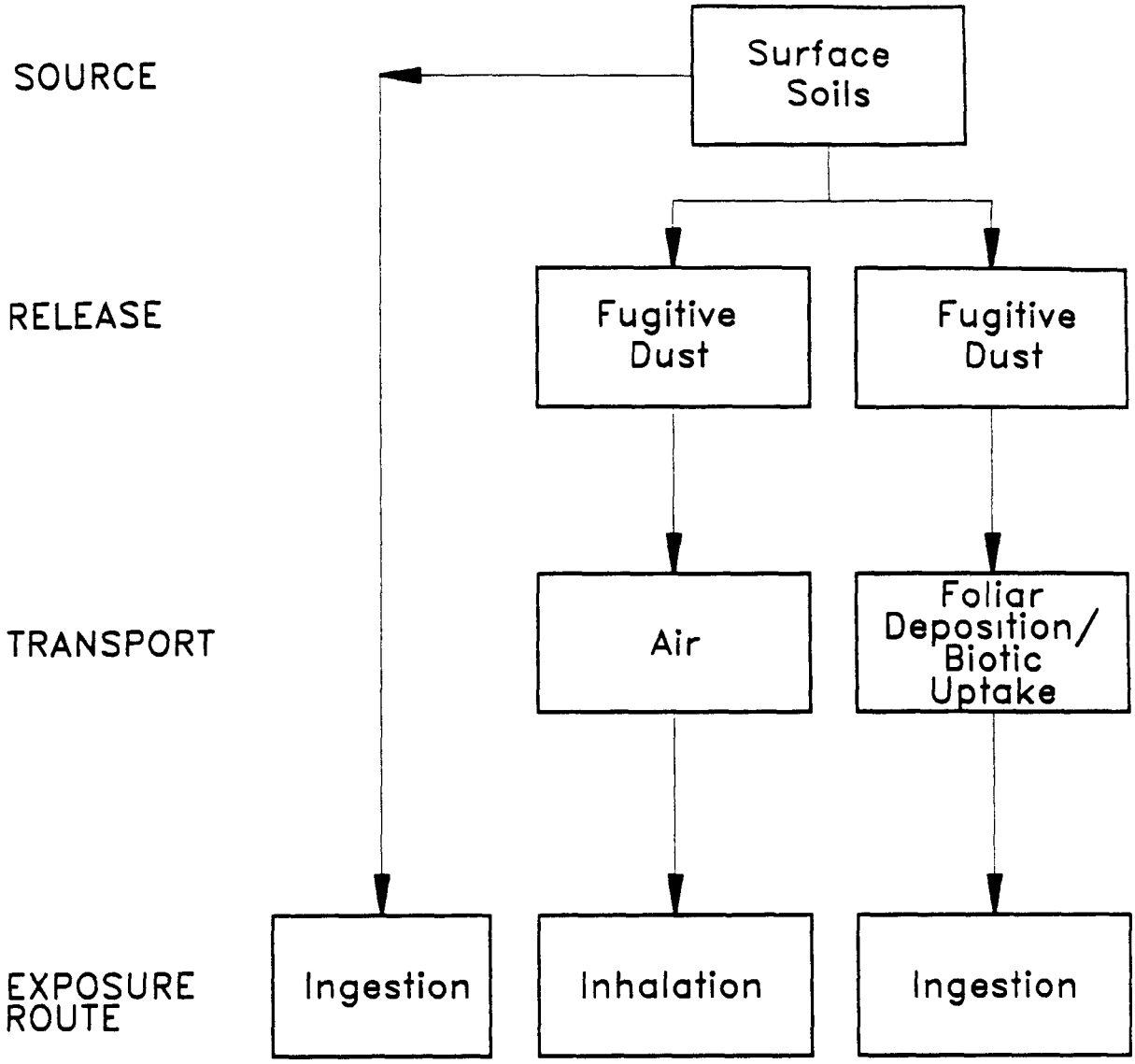
2 Moderate -- a possibility exists that plutonium may be released by this mechanism or transported by this media (airborne, fugitive dust, surface runoff)

3 Low -- the likelihood is that this release mechanism or transport media does not provide any significant possibility of release or transport in the environment (fugitive dust)

4 Negligible -- all historic data and physical characteristics of plutonium indicate that this is not a credible release mechanism or transport pathway for plutonium (ground water, surface water, biotic uptake)

4 5 3 1 Soil

Much of the soil data reviewed indicate that natural processes such as biological activity, weathering and percolation will cause plutonium to move vertically downward in the top few centimeters of the soil column, but that soil characteristics and plutonium properties will limit the depth of migration Section 3 0 of this document describes some of the factors most important to plutonium transport in soil One of the most important factors is the distribution coefficient (K_d) This term reflects the ability of ions and molecules to adhere to solid surfaces The fine particles of soil and sediment have enormous surface areas relative to their volumes, and carry electric charges Ions and molecules can bond to these surfaces by forces that range from those due to weak residual electric charges to strong chemical bonds Typical K_d values (unitless) for plutonium are 10^3 to 10^5 indicating its high potential for immobilization by soil



DRAWN BY	KRONER 2-26-91	CHECKED BY	CJA 3-22-91	DRAWING NUMBER	304923-A14
		APPROVED BY	TDK 3-22-91		

FIGURE 4-4

FUTURE RESIDENTIAL LAND USE COMPLETED EXPOSURE PATHWAYS, IHSS 199 QUALITATIVE RISK ASSESSMENT

TABLE 4.4

SUMMARY OF TRANSPORT AND RELEASE MECHANISMS FOR CURRENT LAND USE AT IHSS 199 ROCKY FLATS PLANT

Primary Transport Media	Primary Release Mechanism	Probability of Occurrence of Contaminant in Media	Secondary Transportation Media	Secondary Release Mechanism	Probability of Occurrence of Contaminant in Media
Soil	Fugitive Dust	moderate-high	Air	Airborne Settled dust-plant Settled dust-soil Settled dust-water	moderate-high moderate-high moderate-high negligible
Soil	Fugitive Dust	moderate-high	Soil	Direct ingestion	moderate-high
Soil	Surface Runoff	low-moderate	Surface Water	Biotic Uptake Deposition Irrigation Infiltration Fugitive Dust	negligible negligible negligible negligible low-moderate
Soil	Infiltration/ Percolation	negligible	Ground Water	Seepage Pumpage Transfer to Surface Water	negligible negligible negligible
Soil	Biotic Uptake	low	Biota	Biodegradation/ Percolation	low
Soil	Biotic Movement	negligible	Tracking by Organisms	Physical Transfer	negligible

(Allard and Rydberg, 1983) This has an important bearing on assessment of the fate and transport of plutonium in the environment

Although plutonium is relatively immobile in the soil environment, it can be physical transported with dust particles The concepts of soil reentrainment in air for IHSS 199 were discussed in Sections 3 0 and 4 5 2 1 One significant factor is that reentrainment for the RFP is estimated to be 10^{-10} m^{1}, while reentrainment for IHSS 199 is calculated to be 1 0 - 1 8x10^{-9} m^{1}, almost an order of magnitude higher (Appendix D, Document D-8) This may be attributed to the reduced vegetative cover of the area.

As stated previously, the existing data are limited in areal and vertical coverage, and probably would not withstand QA/QC validation However, these data do provide an indication of the plutonium concentration present in the soils Soil sampling at IHSS 199 was performed during 1977 and 1985 (Appendix D, Document D-10) The results indicated a decrease in plutonium concentration in 1985 versus 1977 for all samples in the survey The decrease was attributed to the weathering of the soil and vertical migration of plutonium in the soil However, these results appear inconclusive because (1) the 1985 survey took one sample per 10 acres (4 hectares) compared to one sample per 0 2 acre (0 08 hectares) in 1977, which averages to 50 samples per 10 acres, and (2) different analytical laboratories utilizing different radiochemical procedures for plutonium extraction and counting were used.

The concepts developed in this document indicate that the soil pathway for IHSS 199 soils can produce fugitive dust from wind erosion, leading to an inhalation exposure route for a human receptor The direct air pathway, as well as dust resuspension after redeposition on the soil, will be retained in this qualitative risk assessment.

The following soil pathway will be eliminated for the current land use scenario since ingestion is not a credible pathway for plutonium exposure at this IHSS

Surface Soil → Direct Ingestion
Surface Soils → Fugitive Dust → Air → Settled Dust (to Soil)
Surface Soils → Fugitive Dust → Air → Settled Dust (to Water)

Current land use conditions on the remedy acreage preclude the direct soil ingestion pathway due to restrictions on land use The generic risk assessment developed in Appendix C indicates that for a recreational use scenario the inhalation pathway produces almost all of the dose to individuals recreating at this IHSS, while the ingestion pathway produces a negligible component of the total risk Figure 4-3 indicates that the inhalation exposure pathway is retained for current land use conditions

There is a possibility that residential home construction could occur at IHSS 199 at some future date In this case, additional completed exposure pathways are possible All potential pathways will be characterized during the RI

As shown in Figure 4-4, a future residential land use scenario would retain the inhalation pathway, the direct soil ingestion pathway, and the foliar deposition/foodstuff pathway

4 5 3 2 Surface Runoff

The only credible release mechanism involving surface runoff would be surface runoff carrying suspended plutonium particles that subsequently deposits these soils in a dry area Only in this manner could fugitive dust be generated by wind erosion This pathway is not likely to produce any measurable amounts of airborne plutonium due to the low activity present in the soil and the characteristic immobility of plutonium in the environment. Ingestion of contaminated water, and biotic uptake of contaminated sediments from surface runoff is possible, but its contribution to the overall risk is negligible Therefore, it will not contribute to a completed exposure pathway and will not be retained in this risk assessment The following surface runoff pathways will therefore be eliminated for IHSS 199

Surface Soils → Surface Runoff → Surface Water → Biotic Uptake
Surface Soils → Surface Runoff → Surface Water → Deposition
Surface Soils → Surface Runoff → Surface Water → Irrigation
Surface Soils → Surface Runoff → Surface Water → Infiltration

However, areas of obvious surface water drainage will be characterized during the RFI/RI to validate or refute this conclusion

4 5 3 3 Ground Water

An extensive system of ground water monitoring wells has been installed on the RFP The well locations were selected to monitor ground water in background areas, in areas where potential contamination might be expected, and downgradient of potential contaminant sources Well locations include areas near holding ponds, evaporation ponds, and creek beds Monitoring wells in the buffer zone along the eastern boundary of the RFP have been sampled, and only one instance of plutonium levels above background was detected in any of the wells This suggests that the soil/sediment column is a good medium for binding plutonium and preventing it from reaching ground water Although no direct sampling data are available concerning plutonium transport from the land areas of IHSS 199 to ground water, it can be inferred from the RFP on-site data that this pathway will likely not contribute to a completed exposure pathway Therefore, consideration of the following pathway will be eliminated from the qualitative risk assessment

Surface Soils → Infiltration/Percolation → Ground Water → Seepage and Pumpage

Site-specific data will, however, be collected for IHSS 199 during the RFI/RI to confirm that this is not a viable pathway

4 5 3 4 Biotic Uptake

Due to the insoluble nature of plutonium, its uptake in the biota by transport through the food chain is not likely Indicator plants and animals located on the RFP have been identified, sampled, and found to contain normal background ranges of plutonium (CSU, 1974) However, no sampling site specific data concerning biotic uptake at IHSS 199 is available Insects are also a potential source of bioaccumulation, but no sampling data are available that provide the results of potential bioconcentration Prairie dogs heavily populate IHSS 199, and their burrowing activities produce a vertical redistribution of the plutonium in soil This activity enhances "tilling action" and effectively dilutes the plutonium concentration in soil (Winsor, 1980) However, this prairie dog activity negatively impacts the success of the revegetation effort. No sampling data are available that describe plutonium uptake and bioaccumulation by these prairie dogs In summary, there is no significant evidence of bioaccumulation through succeeding trophic levels since metabolic discrimination usually acts against the biouptake of plutonium (EPA, 1990b)

The literature reviewed for this document (Section 6 0) indicates that biotic uptake for plutonium leading to a human receptor is highly unlikely at IHSS 199 based on current land use conditions Therefore, the following pathway will be eliminated from the qualitative risk assessment

Surface Soils → Biotic Uptake → Biota

A future use scenario of residential home construction would retain this pathway and has been included in the generic risk assessment in Appendix C Foliar deposition on grazing lands and home gardens could potentially provide a completed exposure pathway and contribute a significant percentage of the total risk posed by the site, as developed in the generic risk assessment.

4 5 3 5 Tracking

Tracking (transport and redeposition) of plutonium by organisms living on or migrating through IHSS 199 is considered insignificant for the transport of plutonium when compared to movement by wind The following pathway will therefore be eliminated from further consideration

Surface Soil → Tracking

4 5 3 6 Recreational Use

Jefferson County has dedicated its 250 acres (101 hectares) of IHSS 199 to the Jefferson County Open Space program County regulations allow public access to Open Space lands for hiking, mountain bike riding and horseback riding At the present time, however, there is no public access to the IHSS 199 acreage owned by Jefferson County, and recreational usage is not allowed If the land is opened to recreational usage in the future, it is believed that the permitted activities would generate negligible amounts of reentrained surface soil (dust), and therefore present a negligible risk from airborne plutonium to recreational users A generic recreational risk scenario for exposure to 1, 10, and 100 pCi/g of plutonium is presented in Appendix C

At the time of the Settlement Agreement (1985), the City of Broomfield intended to use its 100 acres (41 hectares) of IHSS 199 for future expansion of Great Western Reservoir To date, the reservoir has not been expanded. The land has remained in its original state, and acts as part

of a buffer zone around the reservoir Public access is not allowed. The City of Broomfield has no definite plans for future use of their IHSS 199 acreage (Broomfield, 1990) So for current use conditions, the following pathway will be eliminated from further consideration

Surface Soil → Fugitive Dust (Recreation) → Air → Inhalation

Risk from recreational use has been calculated in the generic risk assessment for use of IHSS 199 The inhalation and direct soil ingestion pathway has been retained for this potential future use scenario

4 5 4 Summary of Transport and Release Mechanisms for Current and Future Land Use

The only credible transport and release mechanism for IHSS 199 which leads to a completed pathway, based on existing information, is wind erosion of the surface soil which produces fugitive dust. This dust may then be transported to human receptors in a form available for uptake as follows

Surface Soil → Fugitive Dust → Air → Inhalation

Table 4 4 Summarizes the transport and release mechanisms for current land use conditions

Future land use scenarios include both residential home construction and recreational use of IHSS 199 The following transport and release mechanisms could impact human receptors for this scenario

Surface Soil → Direct Ingestion
Surface Soil → Fugitive Dust → Air → Inhalation
Surface Soil → Fugitive Dust → Foliar Deposition → Ingestion

Table 4 5 summarizes the transport mechanisms for future land use conditions

4 6 EXPOSURE ROUTES FOR CURRENT LAND USE CONDITIONS

The three exposure routes (routes of entry) which can lead to internal radiation exposure are inhalation, ingestion, and dermal contact. The two primary exposure routes of plutonium uptake

TABLE 4.5

SUMMARY OF TRANSPORT AND RELEASE MECHANISMS FOR FUTURE LAND USE AT IHSS 199 ROCKY FLATS PLANT

Primary Transport Media	Primary Release Mechanism	Probability of Occurrence of Contaminant in Media	Secondary Transportation Media	Secondary Release Mechanism	Probability of Occurrence of Contaminant in Media
Soil	Fugitive Dust	moderate-high	Air	Airborne Settled dust-plant Settled dust-soil Settled dust-water	moderate-high moderate-high moderate-high negligible
Soil	Fugitive Dust	moderate-high	Soil	Direct ingestion	moderate-high
Soil	Surface Runoff	low-moderate	Surface Water	Biotic Uptake Deposition Irrigation Infiltration Fugitive Dust	negligible negligible negligible negligible low-moderate
Soil	Infiltration/ Percolation	negligible	Ground Water	Seepage Pumpage Transfer to Surface Water	negligible negligible negligible
Soil	Biotic Uptake	low	Biota	Biodegradation/ Percolation	low
Soil	Biotic Movement	negligible	Tracking by Organisms	Physical Transfer	negligible

that could most likely lead to internal radiation exposure are the inhalation and ingestion of radioactive materials Dermal contact is not considered a significant exposure route (Section 4 3) The estimation of organ burden and exposure, as well as of the resulting dose rates and doses, due to uptake by these pathways is based on the use of mathematical models which depend on many parameters Publications ICRP 30 (ICRP, 1979), ICRP 31 (ICRP, 1980), ICRP 48 (ICRP, 1988a) and ICRP 30 (revised) (ICRP, 1988b) provide the criteria necessary to calculate the committed effective dose equivalent for both occupational workers and the general public This section will show that the magnitude of the dermal contact/ingestion pathway is insignificant when compared to inhalation

4 6 1 Inhalation

The inhalation of an aerosol carrying radionuclides is a potential mechanism for damage to the respiratory tract as well as a possible pathway for the translocation of inhaled radioactive material to other reference organs The complexity of the biological phenomena which govern transmission and elimination of such material complicates the assessment of potential health effects due to inhalation of radioactive material Factors which must be included are

1 The fractional deposition of inhaled material in the respiratory tract depends on properties of the aerosol size and mass distribution, chemical form, and charge, as well as on the breathing rate and such physiological characteristics of the lung as its surface properties and configuration For the purposes of this qualitative risk assessment, it is assumed that 100 percent of the plutonium in dust is available for uptake

2 The duration and extent of the exposure depends on the biological and physical mechanisms which transport the deposited material and its decay products within the body These include the various clearance paths, the nuclide half-lives, the chemical form, the solubility, and the degree of retention in each organ of interest

3 The dose depends on the duration, of the activity of both parent and daughter radionuclides in the organ, the organ mass, the emitted energy of each nuclide, and the fraction of that energy absorbed by the organ tissues

The inhalation mode of exposure has long been recognized as being of major importance for radioactive materials The model used in Appendix C to calculate a generic plutonium risk assessment for current use indicates that for conservative assumptions, the contribution of the

inhalation pathway comprises 97 percent of the total risk This route provides a direct pathway for alpha particles to enter the sensitive organ which is the lung The lung is the organ of primary concern when assessing the risks from plutonium in soil (EPA, 1990b)

When inhaled, plutonium is retained in the lung with an effective half-life that varies from hundreds of days for plutonium oxides (Y class) to tens of days for more soluble forms (W class) A significant portion of the insoluble plutonium oxide that leaves the lung is translocated to the tracheobronchial lymph nodes Inhaled soluble plutonium is translocated to the liver and skeleton where it is very strongly retained (Bair, 1973) This is in contrast to the ingestion pathway, where the gut wall acts as a barrier to plutonium absorbed by blood.

Inhalation is the most common pathway by which plutonium can cross the barriers of the body and penetrate into and across living cells The aerodynamic particle size of the aerosol, which accounts for not only the sizes of the particles but also their density and shape, determines the fractional deposition and sites of deposition in the respiratory tract The bioavailability of plutonium adsorbed to particles often depends on this aerodynamic particle size Particles with a diameter greater than 5 microns usually become imbedded in the mucous of the pharynx, trachea, or bronchi The mucous is swept up the respiratory tract and swallowed Therefore, the residence time of inhaled plutonium in the nasopharyngea and tracheo-bronchial regions is short The absorption efficiency of these large particles depends on the gastrointestinal absorption efficiency, which is extremely low for plutonium (Section 4 6 2) Consequently, inhaled particles that are subsequently ingested reduce the magnitude of the inhalation pathway The subsequent rates and routes of clearance, the translocation to, deposition in, and rate of clearance from other tissues, and the excretion in urine and feces of plutonium depend on particle size, solubility, density, shape and other physicochemical characteristics of the plutonium aerosol The radiation dose delivered from an inhaled radionuclide is a function of the transportability of the particular chemical form from the lung to other organs of the body Chemical forms of radionuclides are classified as Class D, W, or Y from most transportable to least transportable, respectively The biological half lives in the lung are defined for these three solubility classes as Days (0 5 days),

Weeks (50 days) and Years (500 days) The ICRP has determined the solubility class for various plutonium compounds (ICRP, 1988b) These are

- Class D (days) - no plutonium compounds
- Class W (weeks) - all plutonium compounds except oxides
- Class Y (years) - plutonium oxides

Environmental sources and airborne releases of plutonium are likely to be in the oxide from (EPA, 1990b)

Class Y plutonium refers to the solubility and body retention of the radionuclide This class is insoluble in the body and, if breathed in, tends to be retained in the lungs for months to years However, if ingested, Class Y plutonium tends to pass through the body with no biological uptake As stated previously, PuO_2 is considered to be insoluble in the body, and thus is classified as Class Y plutonium.

4 6 2 Ingestion

The ingestion of radioactive material (soil, water) represents another pathway by which radioactivity may be transferred internally to blood and, subsequently, to other organs While a description of this pathway is simpler than for inhalation, due to the direct deposition of the ingested material into the gastrointestinal (GI) tract, evaluation of the balance of the biological-physical processes involved is affected by the same uncertainties of biological parameters as were discussed for the inhalation model In the ingestion model the critical transfer mechanism is the absorption of radioactive material into the systemic blood from the small intestine, however, the gastrointestinal tract provides a substantial barrier to the uptake of plutonium ingested with food or water In adult animals less than 0 01 percent of ingested plutonium is absorbed from the intestines (ICRP, 1988a) Inhaled plutonium will also be cleared from the lungs to the gastrointestinal tract, so gastrointestinal absorption is a consideration, although inhalation followed by ingestion is considered a negligible pathway with regard to risk Values for the fraction, f_1 (GI absorption factor), of ingested radioactivity transferred to blood have been studied in animals and to a limited extent, are still subject to large uncertainties which strongly affect projected doses to the reference internal organ The ICRP lists an f_1 value of 1 0E-05 for oxides

of plutonium, an f_1 value of 1 0E-04 for nitrates plutonium and an f_1 value of 1 0E-03 for all other forms of plutonium (ICRP, 1988b), while the HEAST lists an f_1 value of 1 0E-04 for the oxide form of plutonium These low f_1 values indicate that the ingested plutonium will not easily transfer to other body compartments The HEAST lists an f_1 value of 1 0E-03 for americium Since americium does exhibit greater solubility in the environment than plutonium, characterization of potential americium pathways will also be accomplished during the RI

For future land use scenarios, the ingestion pathway may become more significant, and in fact may contribute the greatest percentage of risk This is due to potential foliar deposition of plutonium/americium on home gardens directly at IHSS 199, with subsequent human ingestion

4 6 3 Dermal Contact

Plutonium-239 and plutonium-240 are alpha emitters and hence only present a biological hazard if they are transferred into a biological system, however, dermal absorption is not a major route of exposure (EPA, 1990b) The dermal contact human transfer pathway for plutonium would involve skin contamination and subsequent transfer into the body through an open wound or by ingestion Unbroken skin has been shown to be an effective barrier to the penetration of plutonium, and dermal absorption coefficients cited in the literature are on the order of 5×10^{5} (NRC, 1988) It is highly unlikely that soluble plutonium is present at IHSS 199 in a concentration that would lead to transfer through an open wound by skin contamination Since the GI absorption factor is $1\ 0 \times 10^{5}$ for oxides of plutonium, human bio-uptake of plutonium soils by the dermal contact pathway and subsequent GI absorption is not plausible

These risk values are restated here to reinforce that for the current use scenario The inhalation pathway produces by far the principal hazard from IHSS 199 Because of plutonium's low soil mobility and water insolubility, the additive risk associated with plutonium soil/water ingestion are insignificant when compared to the health risk associated with plutonium inhalation

4 7 RISK CHARACTERIZATION

This qualitative risk assessment is a systematic identification of potential hazards of events that could result in undesirable consequences, and is inherently basically subjective The main

disadvantage of this qualitative approach is that it is difficult to make specific numerical comparisons among the risks of different events or scenarios However, as shown in Tables 4 6 and 4 7, hazards can still be grouped by relative importance into risk categories (i e , critical, marginal) and linked with frequency categories (i e , high, moderate, low, negligible) Pathways and release mechanisms that are classified as having critical importance to the risk assessment would have a high probability of impacting a human receptor Those that have a marginal importance have a very low probability of impacting a human receptor These groupings, coupled with the risk evaluation presented in Appendix C, also can be used to indicate that there is not any imminent threat to human health from IHSS 199

4 7 1 Risk Characterization Process

The risk characterization presented here evaluates the magnitude of the relative occurrence of plutonium in each media, its likelihood for transport to other media, and its likelihood to impact a human receptor The concepts developed in preceding sections are utilized to determine the magnitude of risk (using existing information) based on the following ranking

1 High -- A significant potential hazard to human health exists based on historical data, physical characteristics and/or present conditions.

2 Moderate -- maximum credible assumptions of release mechanisms and exposure pathways, it is possible that plutonium will be measured at the receptor point

3 Low -- It is highly unlikely that a hazard to human health exists, using maximum credible assumptions of release mechanisms and exposure pathways combined with historical data, the physical characteristics of plutonium transport and present conditions

4 Negligible -- The release mechanisms and completed exposure pathways do not exist, therefore there is no risk to human health

4 7 2 Physical Model

Providing a reasonable estimate of internal radiation doses due to inhalation and ingestion requires that a consistent model for both the respiratory and gastrointestinal tracts be employed While a large amount of theoretical and experimental work on such models has been done, the most widely accepted models that provide reasonable estimates of internal radiation doses have been those developed by members of the respective ICRP working groups

TABLE 4.6

PROBABILITY OF OCCURRENCE AND QUALITATIVE RISK, FOR CURRENT LAND USE IHSS 199, ROCKY FLATS PLANT

Primary Release Mechanism	Probability of Occurrence of Contaminant in Media	Secondary Source	Secondary Release Mechanism	Probability of Occurrence of Contaminant in Media	Importance to Risk Assessment	Magnitude of Qualitative Risk
Fugitive Dust	moderate-high	Air	Airborne Settled dust-plant Settled dust-soil Settled dust-water	moderate-high negligible moderate-high negligible	critical marginal marginal marginal	low-negligible negligible negligible negligible
Surface Runoff	low-moderate	Surface Water	Biotic Uptake Deposition Irrigation Infiltration Fugitive Dust	negligible negligible negligible negligible low-moderate	marginal marginal marginal marginal marginal	negligible negligible negligible negligible negligible
Infiltration/ Percolation	negligible	Ground Water	Seepage Pumpage Transfer to Surface Water	negligible negligible negligible	marginal marginal marginal	negligible negligible negligible
Biotic Uptake	negligible	Biota	Biodegradation/ Percolation	negligible	marginal	negligible
Biotic Movement	negligible	Tracking by Organisms	Physical Transfer	negligible	marginal	negligible

TABLE 4.7
PROBABILITY OF OCCURRENCE AND QUALITATIVE RISK, FOR FUTURE LAND USE
IHSS 199, ROCKY FLATS PLANT

Primary Release Mechanism	Probability of Occurrence of Contaminant in Media	Secondary Source	Secondary Release Mechanism	Probability of Occurrence of Contaminant in Media	Importance to Risk Assessment	Magnitude of Qualitative Risk
Fugitive Dust	moderate-high	Air	Airborne Settled dust-plant Settled dust-soil Settled dust-water	moderate-high moderate-high moderate-high negligible	critical critical critical marginal	low-negligible low-negligible low-negligible negligible
Fugitive Dust	moderate-high	Soil	Direct ingestion	moderate-high	critical	low-negligible
Surface Runoff	low-moderate	Surface Water	Biotic Uptake Deposition Irrigation Infiltration Fugitive Dust	negligible negligible negligible negligible low-moderate	marginal marginal marginal marginal marginal	negligible negligible negligible negligible negligible
Infiltration/Percolation	negligible	Ground Water	Seepage Pumpage Transfer to Surface Water	negligible negligible negligible	marginal marginal marginal	negligible negligible negligible
Biotic Uptake	low	Biota	Biodegradation/ Percolation	low	marginal	low-negligible
Biotic Movement	negligible	Tracking by Organisms	Physical Transfer	negligible	marginal	negligible

The proposed ICRP Task Group on Lung Dynamics (TGLD) model for the respiratory tract has been well documented. Parameters suggested for use in the model have been extensively reviewed and, to some extent, improved in ICRP publications (ICRP, 1979, ICRP, 1980, ICRP, 1988b) The ICRP TGLD proposed model comprises three major respiratory compartments the nasopharyngeal, the tracheobronchial, and the pulmonary Each of these major compartments is divided into subcompartments corresponding to various transfer mechanisms, which are treated as essentially independent processes In addition, the associated lymph nodes are appended to the pulmonary compartment in one of the transfer chains Direct deposition through inhalation occurs to the three major compartments, with the fractional deposition in each being a function of the aerosol properties Subsequent transfer and/or clearance is governed by parameters specified for each subcompartment.

For the calculation of soil/water ingestion, the ICRP gastrointestinal tract model can also be used to determine internal exposure The model comprises a four-compartment tract consisting of the stomach, small intestine, and lower and upper large intestine

4 7 3 Risk From All Modes of Exposure

The chemical forms of plutonium found in the off-site soils at RFP are highly insoluble both in the environment and in the human body Based on a review of exposure pathways and routes, it appears that for the current use scenario, the potential for human uptake is negligible and poses a very low potential risk in the qualitative model Developing these concepts in tabular form, biological uptake mechanisms from all release pathways can be ranked from the most likely to the least likely for the current land use scenario

Exposure Route

- Inhalation
- Direct ingestion of soils
- Inhalation then ingestion
- Bioaccumulation
- Dermal contact
- Ingestion of drinking water

The last four routes are considered negligible from a risk standpoint For a future land use scenario, biological uptake from the following completed exposure pathways may occur and are ranked from most likely to the least likely

Exposure Route

- Ingestion of home garden foodstuffs
- Inhalation
- Direct ingestion of soil
- Ingestion of contaminated biota
- Dermal contact
- Ingestion of drinking water

For the future use scenario, the last three routes are considered negligible from a risk standpoint

A qualitative comparison of pathway specific risk is provided by the EPA (EPA, 1990a) The EPA has developed the following media-specific concentration-based unit risk factors for age-averaged lifetime excess total cancer per unit daily intake (exposure for 70 years) of Class Y plutonium-239

Risk per Unit Concentration[1]		
Air 1 pCi/m^3	Drinking Water 1 pCi/l	Soil Ingestion 1 pCi/g
2 6 E-2	1 6 E-6	8 4 E-8

[1] The media-specific risks are based on standard man (155 lbs [70 Kg]) intake rates of

- 706 ft^3/day (20 m^3/day) inhaled air
- 0 6 gal/day (2 2 l/day) ingested liquid
- 2 2 x 10^{-4} lbs/day (0 1 g/day) ingested soil

These values assume that all daily media exposure is derived from contaminated airborne fugitive dust (706 ft^3), surface water/surface runoff (0 6 gal water), and soil (2 2 x 10^{-4} lbs) and that exposure occurs continuously for a 70-year lifetime In other words, per unit concentration in each media, the unit risk is far greater from inhalation of dust in air than the other two exposures, however, it should be kept in mind that unit concentrations in these media are not comparable in terms of likelihood of occurrence In fact, the generic risk assessment developed in Appendix C indicates that for the future use residential scenario, the ingestion pathway would

contribute the significant percentage of total risk Inhalation has been calculated to be the primary risk for the no further action current use, the worker and public scenario during remedial action, and any recreational future use scenarios

These unit risk factors use the same basic approach as other models (DOE, ICRP), however, the EPA uses the model to derive risk from each type of media. These risk factors reinforce the premise that inhalation of plutonium (pCi/m^3) has a much greater risk factor than from ingestion of water (pCi/l) or soil (pCi/g) Under current land use (i e , no public access) the air pathway from IHSS 199 produces a negligible risk to the public, therefore, it can be inferred that other pathways must also produce a negligible risk

This conclusion will be validated or routed by calculation of a true site-specific quantitative risk assessment during the RFI/RI

4 8 ASSESSMENT OF QUALITATIVE RISK FROM NO FURTHER ACTION ALTERNATIVE

An analysis of the relative magnitude of the source term release mechanisms, transport media, receptor points and modes of uptake at IHSS 199 has been presented in this qualitative risk assessment. A summary of these analyses for the current and future land use conditions are provided in Table 4 6 and Table 4 7

The concentration of plutonium (source term) in the soil at IHSS 199 appears to be low, although above background While the concentrations are above background, in most areas they are below the CDH standard of 0 9 pCi/g (0 03 Bq/g) Release mechanisms, transport media, known receptors and modes of uptake have been evaluated, and the only completed exposure pathway for the current use scenario is the airborne dust pathway due to wind erosion of soil

Completed exposure pathways for the future use scenario include inhalation from airborne dust, direct soil, ingestion, and foliar deposition followed by human ingestion of these contaminated foodstuffs Court-ordered soil tilling and revegetation have been conducted on portions of IHSS 199 in an attempt to reduce the average plutonium concentration in soils that exceeded the 0 9 pCi/g (0 03 Bq/g) level and to stabilize the soils (Section 2 2 3) The tilling has succeeded

in lowering plutonium concentrations to below CDH guidelines Revegetation of tilled areas has been only partially successful, however, areas in which planted grasses have not been successful have developed a natural cover of opportunistic grass and weed species While this vegetative cover is not considered adequate from a remediation standpoint, it does nonetheless provide some soil stabilization and reduce the likelihood of airborne dust generation Therefore, based on the physical parameters of IHSS 199, the nature of plutonium transport in the environment, the plutonium concentration present at IHSS 199 and the single completed exposure pathway, the magnitude of risk from a no further action alternative is judged to be low to negligible

As calculated in Appendix C, future residential use of IHSS 199 would result in a similar low to negligible risk

4 9 RISK DUE TO DELAY OF IMPLEMENTING REMEDIAL ACTION

As stated in this document, plutonium movement due to precipitation and surface water runoff tends to be low due to its high affinity for the soil by adsorption In addition, vegetative cover does exist on most contaminated lands at IHSS 199, and field sampling data indicate a gradual reduction overtime in the plutonium concentration in the upper 0 8 in (2 cm) of soil (Appendix D, Document D-18) It is possible that this reduction is due to the plutonium becoming reentrained and blowing east, east-southeast, or south-southeast from IHSS 199 However, samplers located in these general wind directions (Table 4 3) are not detecting increased airborne plutonium activity Therefore, this gradual decrease in soil concentration could be from the vertical downward migration of plutonium in a soil column over time Qualitatively, human health risk to the public due to the delay in implementing remedial action (see Section 2 2 3 2) is judged to be negligible

4 10 ASSESSMENT OF RISK DURING REMEDY IMPLEMENTATION

Plowing and tilling will not remove the plutonium from the soils, but would dilute the concentration below the CDH plutonium-in-soil standard of 0 9 pCi/g (0 03 Bq/g) Successful revegetation will also reduce the likelihood of subsequent transport of plutonium from IHSS 199 Certain precautions in performing this remedial action are mandated in the Settlement Agreement

Since generation of airborne dust containing plutonium is of the greatest concern, remedial action can only be performed when the following conditions are present

- Wind velocities are no greater than 15 mph (33 km/hr)
- Soil moisture must be greater than 15%
- Airborne plutonium contaminant levels cannot exceed 0 02 pCi/m^3 (7 4 x 10^{-4} Bq/m^3)
- A fugitive dust control permit has been obtained from CDH

Inherent in the compliance with the above conditions is the necessity for water trucks to be on-site and actively wetting down the soil as remedial action proceeds at IHSS 199 A number of other methods are available for prevention of plutonium exposure to site workers Adherence to standard operating procedures, reducing fugitive dust emissions, and airborne radionuclides monitoring are established methods for reducing worker radiation exposure Respirators can be used if engineering controls are not sufficient to provide protection for workers

Given the fact that the required controls are expected to prevent airborne migration of plutonium during remedial action, it is determined that the incremental risk to IHSS 199 workers and the public would be negligible during implementation of soil plowing and tilling, and any subsequent revegetation

The generic risk assessment in Appendix C addresses potential risks to both site workers and the public

4 11 ASSESSMENT OF POST-REMEDY RISK

It has been demonstrated that soil mixing by plowing and tilling would reduce the concentration of plutonium currently on the surface of IHSS 199 Therefore, implementation of the court-mandated remedial action would reduce plutonium concentrations in soil and reduce the risk associated with the contamination

Since the plutonium in the soil standard has been set at 0 9 pCi/g, the generic risk assessment for 1 pCi/g plutonium-239 provided in Appendix C can be applied to determine the potential risk to the public from post remedy concentrations of plutonium in soil

4 12 SUMMARY OF QUALITATIVE RISK

Table 4 8 summarizes the hypothetical qualitative risk characterization derived from the generic risk assessment. The generic risk assessment is based on a hypothetical multipathway exposure scenario All exposure pathways utilize plutonium-239 in soil as the source media The following two scenarios and component pathways are considered

Residential	Recreational
Incidental Soil Ingestion	Incidental Soil Ingestion
Inhalation of Dust	Inhalation of Dust
Ingestion of Leafy Vegetables	
Ingestion of Tuber Vegetables	
Ingestion of Beef Tissue	
Ingestion of Beef Liver	
Ingestion of Cow's Milk	

Details of the hypothetical-generic risk assessment are presented in Appendix C

As indicated in Table 4 8, risk incurred from exposure to plutonium-239 in a recreational exposure scenario at IHSS 199 before, during, and after remedial activities would be below EPA's target range of acceptable risk (i e , below $1x10^{-6}$) Similarly, risk incurred from exposure to plutonium-239 in a future-us residential exposure scenario at IHSS 199 after remedial activities would also be below EPA's target range of acceptable risk (i e , below $1x10^{-6}$) Residential use exposure cannot occur at IHSS 199 before or during the remedy activities

4 13 UNCERTAINTIES IN THE RISK EVALUATION

The methods used to assess potential human health and environmental risks in this and most such evaluations are subject to a wide variety of uncertainties In general, the five main sources of uncertainty in risk assessment are the following

- Inadequate sample population
- Sampling and analytical methods
- Fate and transport modeling
- Exposure estimation
- Toxicological data and dose response extrapolation

TABLE 4.8

HYPOTHETICAL QUALITATIVE RISK CHARACTERIZATION DERIVED FROM THE GENERIC RISK ASSESSMENT[a]

Exposure Scenario	Before Remedy	During Remedy	After Remedy
Recreational Use	Below EPA's Range of Acceptable Risk	Below EPA's Range of Acceptable Risk	Below EPA's Range of Acceptable Risk
Residential Use	NA	NA	Below EPA's Range of Acceptable Risk

[a] The risk estimates presented in this table are hypothetical They are based on the generic curve presented in Figure C-1 of Appendix C in conjunction with estimates of soil concentration that have been judged to be unacceptable for performing a Baseline Risk Assessment See Appendix A for a discussion on the limitations on all data presented in this report.

NA - based on conditions at the site, these exposure conditions did not exist during the remedy phase specified

Errors associated with sampling and analysis include inherent errors in laboratory analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix Although QA/QC programs serve to reduce these errors, they cannot eliminate all errors associated with sampling and analysis

4 13 1 Toxicological Uncertainties

Toxicological data errors are also a source of uncertainty The EPA noted this in its guidelines for carcinogenic risk assessment.

> "There are major uncertainties in extrapolating both from animals to humans and from high to low doses There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in large site susceptibility Human populations are variable with respect to geographic constitution, diet, occupational and home environment, activity patterns and other cultural factors (EPA, 1986) "

The estimation of exposure requires numerous assumptions to describe the potential exposure situations There are a number of uncertainties regarding the fate and transport of plutonium, the likelihood of exposure, the frequency of contact with contaminated media, the concentration of constituents at exposure points, and the time period of exposure These assumptions tend to oversimplify actual site conditions There are inherent uncertainties in determining the intake value when combined with toxicological information, to assess risk In this qualitative assessment, specific assumptions with standardized values were used The major assumptions used in this assessment are as follows

- Constituent concentrations remain constant over the exposure period
- Exposure remains constant over time
- Average concentrations of constituents detected are reasonable estimates of exposure at the exposure point
- Exposed populations remain constant over the exposure period
- No dilution factor for the contaminants is offered, and they are available for 100 percent bio-uptake
- Risks are additive

Table 4 9 qualitatively describes the general assumptions used in the risk assessment, and their effect on the risk assessment.

4 13 2 Carcinogenic Risk Uncertainties

Numerous references provide numerical estimates of the risk of fatal cancer induction from ionizing radiation These estimates may be a function of dose to an individual organ, whole body dose, duration of exposure, or quantity of radioactive material ingested or inhaled

A single slope factor (EPA, 1990a) was chosen to estimate lifetime risk of fatal cancer as a function of the receptor's lifetime intake of the individual radionuclide Based on a review of current risk estimates, it is assumed that the use of the single risk factor will generate an overestimation or underestimation of one order of magnitude compared to the use of a situation-specific factor

Because of the low probability of cancer induction at the levels of human exposure to radioactive material normally encountered in the environment, additional uncertainties arise from extrapolating risk estimates from much higher levels, where deleterious effects may be observed, to the low levels that are actually encountered. Also, uncertainty results from assuming a linear relationship at low levels of human exposure

Because of gaps in current scientific understanding of radiocarcinogenesis, radiological cancer risk assessment requires the use of a series of judgmental decisions on numerous unresolved scientific issues These judgmental decisions lead to uncertainties in cancer risk assessment because major assumptions are necessary for data extrapolation The four main data extrapolations are discussed in the following

- The extrapolation of experimental results across species from laboratory animals to humans
- The extrapolation of data from high-dose region of exposure of human or laboratory animals to the low-dose region of exposure of the general population
- The extrapolation of data across exposure durations from acute to chronic cases

TABLE 4.9

ASSUMPTIONS AND THEIR EFFECTS ON RISK ESTIMATION, IHSS 199, ROCKY FLATS PLANT

Assumption	Effect on Risk		
	May Over-Estimate Risk	May Under-Estimate Risk	May Over/Under-Estimate Risk
Environmental Sampling and Analysis			
Sufficient samples may not have been taken to characterize the matrices being evaluated			Moderate
Systematic or random errors in the radiochemical analysis may yield erroneous data			Low
Plutonium concentrations reported as "below method detection limit" are considered to be a non-detect data point.		Low	
The qualitative public health evaluation is based on the chemical of concern (Plutonium) only This may represent a subset of the chemicals possible at the site		Moderate	
Exposure Parameter Estimation			
The standard assumptions regarding body weight, period exposed, life expectancy, population characteristics, and lifestyle may not be representative for any actual exposure situation			Moderate
The amount of media intake is assumed to be constant and representative of the exposed population.	Moderate		
Exposure to contaminants remains constant over exposure period	Moderate		
Concentration of contaminants remains constant over exposure period	High		
All plutonium is available for inhalation in respirable-size particles	High		

TABLE 4.9

ASSUMPTIONS AND THEIR EFFECTS ON RISK ESTIMATION, SWMU 199, ROCKY FLATS PLANT
(continued)

Assumption	Effect on Risk		
	May Over-Estimate Risk	May Under-Estimate Risk	May Over/Under-Estimate Risk
For most contaminants all intake is assumed to come from the medium being evaluated This does not take into account other contaminant sources such as diet, exposures occurring at locations other than the exposure point being evaluated, or other environmental media which may contribute to the intake of the chemical (i e , relative source contribution is not accounted for)		Moderate	
Environmental Parameter Measurement			
Food does not contribute to plutonium uptake		Moderate	
Dermal absorption of plutonium from soil is negligible		Low	
Toxicological Data			
Risks are assumed to be additive Risks may not be additive because of synergistic or antagonistic actions or other chemicals			Moderate
Assumes absorption is equivalent across species This is implicit in the derivation of the acceptable intakes or cancer slope factors in this assessment.			Low
Extrapolation of toxicity data from high dose to low dose, and across species and ages			Moderate

- The extrapolation of data across age groups from adults to children or across ethnic populations from Japan to the United States

The uncertainties associated with these four basic data extrapolations are inherent in EPA slope factors for radionuclides and risk coefficients used in conventional radiological risk assessment methodology These uncertainties in risk estimation are discussed in the following paragraphs

4 13 2 1 Internal Exposure

Uncertainties in internal dose calculations based on ICRP models arise primarily from five sources (1) the uncertainty in reference man data (age- and sex-specific differences and biological and ethnic variability in anatomical and physiological parameters), (2) the uncertainty in the lung and GI tract models describing the translocation and absorption of inhaled or ingested radionuclides into the blood (e g , the uncertainty in the anatomical model of the lung and GI tracts and age-specific physiological and morphological properties of the models), (3) the uncertainty associated with the formulation of the ICRP (1979) biokinetic models describing the distribution and retention of radioactivity among the various organs in the body (e g , the biokinetic models are mainly based on animal data and often estimate excretion inaccurately, the growth of radioactive daughters is usually handled unrealistically), (4) the uncertainty in the dose models used to calculate the absorbed dose to organs from radionuclides retained in the body (nonuniform distribution of the activity is normally found in human organs), and (5) the uncertainty in the model parameters (e g , absorption fraction [f_1], which contribute the largest uncertainty in the GI tract model, intake rate, and effective half-life)

Uncertainties in risk estimation from internal exposure arise from the following sources (1) the assumption of the dose response model for estimating radiation-induced cancer risks at low doses and low dose rates based on data at high doses and high dose rates, (2) the choice of the risk models, latency period, and expression period for various types of radiation-induced cancers beyond the years of observation, (3) the age-specific parameters (risk coefficients) used for both absolute and relative risk models are obtained from the Japanese atomic bomb survivor data, which are based on relative high doses and Japanese populations, (4) the use of age-specific mortality rates based on data collected in the United States in 1970, and (5) the use of mortality-to-incidence risk ratios for various types of cancers (Cancer incidence statistics are incomplete,

and there is a possibility of differences in the relative frequency of cancer types between radiogenic cancers and those caused by other factors)

4 13 2 2 External Exposure

Uncertainties in external dose calculations based on the EPA model arise primarily from four sources First, the use of a hypothetical plane source with zero-depth distribution of radioactivity in the slope factor method fails to account for shielding by the soil in which the radioactivity is deposited If the radioactivity is uniformly distributed in a 10 cm layer of soil, shielding by the soil layer can reduce the air dose rate by about a factor of 8 for 0 1 MeV photons, a factor of 4 or 0 5 MeV photons, and a factor of 3 for photon energies between 1 to 10 MeV Even if the uniformly mixed radioactivity extends to an infinitely thick soil layer, the air dose rate can be reduced by a factor of 7 for 0 1 MeV photons, a factor of 3 for 0 5 MeV photons, a factor of 2 for 1 MeV photons, and a factor of 1 5 for 10 MeV photons

Second, the slope factor method does not account for shielding provided by roughness of the ground surface, irregularities in terrain, or the shielding provided by buildings Each of these factors reduces external dose rates

Third, the assumption of uniform distribution of radioactivity in soil in the slope factor method may not always be valid. It has been shown that the sources would have to be approximately uniform over distances up to a few hundred meters from the individual for the air dose rate to be accurate for ground surface exposure

Fourth, the slope factor method employs the factors relation organ dose to air dose from immersion in an airborne plume of photon sources to calculate dose from contaminated soil sources The assumption that the radiation field for the ground surface source is isotropic and has the same energy distribution as for the airborne immersion source is not valid

Uncertainties in risk estimation from external exposure arise from similar considerations from internal exposure

4 14 DATA NEEDS

It is evident that sufficient field data are lacking to perform an adequate quantitative risk assessment of IHSS 199 The following quantitative information would greatly increase the accuracy of any future risk assessment. Many of the parameters listed below have been quantified for the RFP as a whole, however, the applicability of the existing data to IHSS 199 has not been rigorously evaluated, and much of the existing data have not been validated An early step in the data acquisition process, therefore, should be to evaluate the applicability of existing environmental data from the RFP to IHSS 199 While the following sections describe some of the additional information which will be required to conduct a quantitative risk assessment, the IHSS 199 RFI/RI work plan will address these data needs in greater detail

4 14 1 Physical Parameters of the Site

Soil parameters such as soil particle size, determination of soil particle size fraction with which plutonium is associated, organic content, and bulk density should be determined Meteorological parameters such as the frequency distribution of windspeed, direction and annual stability class should be collected Worst case soil and meteorological conditions (i e , those conditions at the site most conducive to plutonium transport) should be identified

4 14 2 Determination of Fugitive Dust Impact from Remedial Action

More exact information of the potential for wind erosion from bare soil, and the contribution of tilling and remedial action should be collected and evaluated.

4 14 3 Hydrology

The surface and ground water characteristics at IHSS 199 need to be adequately characterized as they relate to contaminant transport Site specific data will be collected as part of the RFI/RI activity

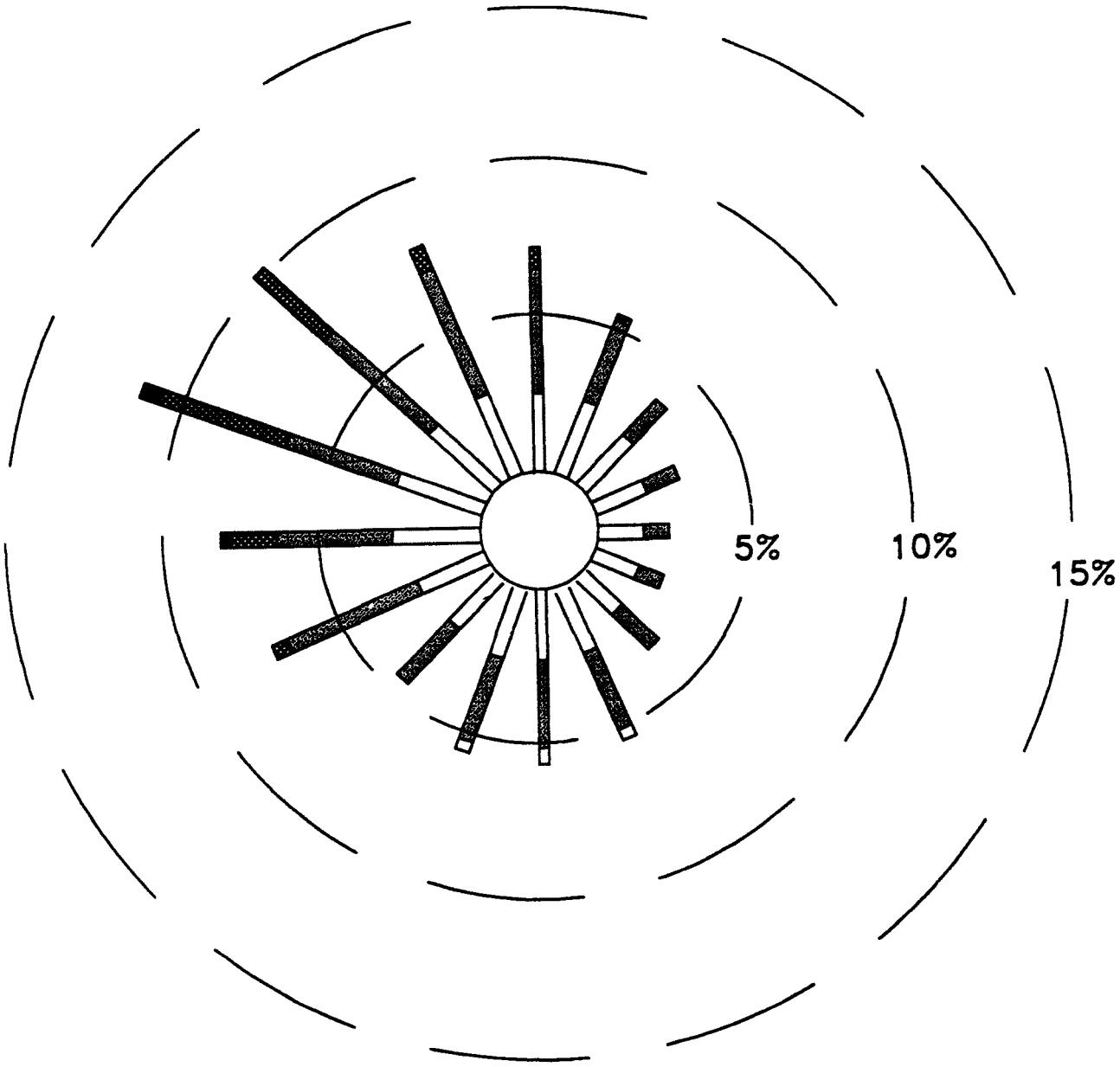
4 14 4 Radiological Characterization

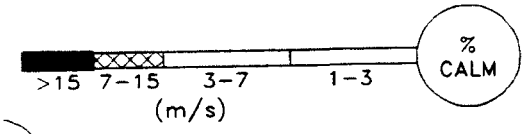
The lateral and vertical extent and magnitude of plutonium and americium (and any other radiological parameters) in soil should be determined. Additional soil cores should be collected to determine the vertical migration of plutonium in the soil column Transport of plutonium in

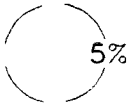
surface runoff should be assessed. Data are available that describe plutonium-soil mixing by prairie dogs, however, the radioecology of the site has not been adequately characterized Biotic samples should be collected to characterize the extent of contamination in the environment Studies should be conducted to determine if a pathway to humans through the food chain exists for radionuclides present.

4 14 5 Other Contaminants

Additional characterization of the site for potential inorganic and organic contaminants needs to be conducted. The media of greatest concern are soil, surface water (primarily runoff), and ground water







Frequency of Occurrence

OVERLAY FIG 4-1

5.0 CONCLUSIONS AND RECOMMENDATIONS

The review of historical information, the evaluation of the remedy effectiveness, and the preliminary risk assessment developed in this document indicate the following

- There does not appear to be any imminent human health hazard posed by IHSS 199 This conclusion is preliminary because of data quality limitations

- Plutonium concentrations measured in some IHSS 199 soils during past studies and data collection activities exceed the CDH plutonium standard used by the U S District Court as the lawsuit acreage remedy action level The data that support this conclusion, however, cannot be validated and may not be of comparable quality, and are therefore considered inconclusive

- Remedial actions implemented to date on 120 acres of Jefferson County remedy acreage have successfully reduced plutonium concentrations in soil to below the 0 9 pCi/g (0 03 Bq/g) action level mandated by the lawsuit Settlement Agreement. Attempts to restabilize the remediated acreage through revegetation have been only 50% successful due to insufficient precipitation, extremely rocky surfaces and/or clayey soils, intense competition from weeds, an expanding prairie dog population, and the effects of slope on soil moisture Specific actions to improve the revegetation effort include weed control, prairie dog suppression, and changes to the revegetation seed mixture specified in the Settlement Agreement

- Multiple plutonium exposure pathways from IHSS 199 were analyzed The pathway analysis suggests that the airborne dust inhalation pathway is the most significant in terms of human health risk under current site conditions Under a future residential use scenario, the soil ingestion pathway may also be significant Although other exposure pathways are not considered significant under this analysis, all pathways will be addressed under scheduled RFI/RI activities at IHSS 199

- Although the actual receptor exposures could be expected to vary, the completed exposure pathways are the same for pre-remedy, remedy implementation, and post-remedy conditions at IHSS 199. If the remedy is successfully implemented, however, the concentration of plutonium available for transport as airborne dust will be reduced through tilling, and the probability of occurrence for the airborne dust pathway will be reduced through revegetation

- The control measures used to reduce off-site impacts during remedy implementation at IHSS 199 appear to have been effective Available data from air samplers set up immediately downwind of the remedy acreage during remedy implementation and air monitoring stations in populated areas downwind of the acreage show no increases in airborne plutonium during or after remedial actions taken to date

To confirm the above conclusions, it is recommended that additional site data, including meteorological parameters, surface and ground water characterization, biological uptake, and concentrations of plutonium and other radionuclides in all media be obtained Further soil sampling should be performed to confirm or negate conclusions concerning plutonium and americium concentrations in soil at IHSS 199 A quantitative risk assessment can then be performed to quantify the differences in potential risk to human health between the pre-remedy, remedy implementation, and post-remedy situations These data collection activities will be integrated into the RFI/RI

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APPENDIX A1 DATA SOURCES AND DATA USEABILITY WORKSHEETS FOR IHSS 199

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1.0 INTRODUCTION

A baseline human health risk assessment has five basic components, these are

- Data collection and evaluation
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty Analysis

Each of these facets of a risk assessment need to be performed in an appropriate manner so that a quantitative risk assessment is performed.

This section examines the "Data Collection and Evaluation" that has been performed on IHSS 199 with respect to EPA's Guidance for Data Useability in Risk Assessment (EPA 540/G-90/008), dated October 1990 The following criteria were used to evaluate and compare historical data

1 Was an adequate conceptual model of the site included?

2 Were data quality objectives stated?

3 Were key site characteristics documented?

4 Were all appropriate media sampled?

5 Were all key areas sampled?

6 Did sampling include media along potential routes of migration?

7 Were sampling locations consistent with the nature of contamination?

8 Were sampling efforts consistent with field screening and visual observations in locating hot spots?

9 Were detailed sampling maps provided, including the location, type and numerical code of each sample?

10 Did sampling include appropriate QA/QC measures?

11 Were background samples collected from appropriate areas?

12 Were any site-related chemicals eliminated from analysis without appropriate justification?

13 Were appropriate analytical methods employed for collection data?

14 Did the data meet the stated data quality objectives?

15 Were appropriate data qualifiers used for the analytical data?

The results of this evaluation are summarized in this appendix under Data Useability Worksheets In reviewing these worksheets it became clear that the available data would not support a quantitative risk assessment Therefore the risk assessment that was developed for IHSS 199 was performed to determine if there was the presence/absence of an imminent hazard to the public A second goal was to identify data needs for a future workplan that would direct remedial investigation (RI) data collection

Some inherent uncertainty is associated with any numerical risk coefficient calculated in the development of a health risk assessment The historical data were not intended for use in a quantitative risk assessment and therefore meets few of the current standards for data useability as outlined in the EPA Guidance Document for Data Useability in Risk Assessment (1990) All the data reviewed attempt to characterize the location and magnitude of the soil concentration of 239 Pu (source term) at site 199 The source term is the linchpin upon which any risk assessment is based, and if the data cannot adequately be defended as valid, a quantitative risk assessment that has any validity is impossible to perform None of the IHSS 199 data reviewed meets the minimum criteria of data useability Instead, a preliminary qualitative risk assessment has been developed that evaluates the relative magnitude of the source term, and whether human receptors are currently experiencing any imminent hazard from this source term.

The following documents are listed in Appendix D, but they were not reviewed against all of the criteria found in the data useability guidance document due to the lack of information contained within them

- D-6 Rockwell International, "Comparison of Air Sampler Stations"
- D-12 Rockwell International, "Remedial Action Air Sampling Results"

- D-13 Rockwell International, "Station of Remedial Action on Jefferson Couny Lands East of Indiana"

- D-14 Rockwell International, "Status of Remedial Action Program on Jefferson County Open Space Land"

- D-15 EG&G Rock Flats, "Jefferson County Remedial Action Lands 1989 Remediation Status and Actions for 1990"

- D-16 EG&G Rocky Flats, "Jefferson County Remedial Action Lands Annual Report "

The following approach to the data useability evaluation for IHSS 199 is taken from the EPA Guidance Document for Data Useability in Risk Assessment

2.0 REPORT TO RISK ASSESSOR

As stated in the EPA Guidance for Data Useability in Risk Assessment, the minimum data, documentation and report materials needed to prepare a risk assessment are

- A description of the site, including a detailed map showing the location of each sample, the site location relative to surrounding structures, terrain features, receptor populations, indications of air and water flow, and a description of the operative industrial process (if any)
- A description and rationale of the sample design and sampling procedures
- A description of the analytical methods used
- Results for each analyte and each sample, qualified with respect to analytical limitations
- Sample-specific quantitation limits (SQLs) and detection limits for undetected analytes, with an explanation of the detection limits reported and detection limit qualification for analytical limitations
- A narrative explanation of the level of data review used and the resulting data qualifiers indicating direction of bias, based on the assessment of the results from quality control samples (i e , blanks, duplicates, and field and laboratory spikes
- A description of field conditions and physical parameter data as appropriate for the media involved in the exposure assessment

As stated in the guidance document, if any of this information is not available and cannot be obtained, it may not be possible to perform a quantitative baseline risk assessment

Soil Sample Collection and Analysis for Plutonium on Lands Adjacent to Great Western Reservoir for the City of Broomfield, April 10, 1985, prepared by C T Illsley, contains many of the data quality requirements necessary to perform a quantitative risk assessment However, the soil sampling locations were taken for Sites 200 and in areas that overlap site 199 and therefore may not be wholly applicable This report does have significant data gaps, such as measured concentrations of 239 Pu only rather than all radionuclides common to RFP Data qualifiers such as the lower limit of detection (LLD) and minimum detectable activity (MDA) also were not listed.

"Remedial Action Program on Jefferson County Open Space, January 15, 1987," prepared by C T Illsley, is the only IHSS 199 specific document reviewed that comes close to meeting data quality objectives Other documents reviewed do not even meet the basic data quality objectives However, even this document has significant data gaps such as LLD or MDA not listed, no sampling dates or chain of custody, measured concentrations of 239 Pu only rather than all radionuclides common to RFP, etc

3.0 ASSESSMENT OF DOCUMENTATION

According to the guidance document three types of documentation must be assessed Chain-of-Custody records, Standard Operating Procedures, and field and analytical records

Chain-of-custody records must document the sample locations and the date of sampling so that sample results can be related to geographic location and to specific sample containers If a sample result cannot be related to a sampling date and the point of sample collection, the results are unusable for a quantitative risk assessment Full scale chain-of-custody procedures (extending from sample collection through analysis) are not required for risk assessments, although they are required for other purposes, such as enforcement or cost recovery

In all cases, the reports reviewed had no chain-of-custody records Sample location records were poor, and sampling dates were not included. As stated above, if sampling results cannot be related to a sampling date and the point of sample collection, the results are unusable for a quantitative risk assessment

No field or analytical records were included with the documents reviewed, nor were SOPs available to allow comparison of the field and analytical records for each report. Since SOPs were not included, it is impossible to determine the level of systematic and random error associated with sampling and analysis within any of the reports reviewed

4.0 ASSESSMENT OF DATA SOURCES

Minimum analytical data requirements for a risk assessment as stated in the guidance document stipulate that one sample per medium exposure pathway be analyzed using a broad spectrum analytical technique, such as GC-MS methods for organic analytes, or ICP for inorganic analytes The lack of a broad spectrum analysis for any samples at IHSS 199 from a fixed laboratory source results in an increased probability of false negatives because all chemicals of potential concern at the site may not be identified. In the absence of a broad spectrum analysis, the best corrective action is to collect additional samples Since additional samples have not been obtained from IHSS 199, the probability of false negatives and positives should be considered high Therefore the level of certainty in performing a quantitative risk assessment is greatly decreased.

Field measurements of physical characteristics of the site, medium, or contamination source are critical data, whose omission can significantly affect the validity of a quantitative risk assessment Physical site information is required to perform exposure fate and transport modeling Examples of such data are particle size, pH, clay content and porosity of soils, wind direction and speed, topography and percent vegetation The EPA Risk Assessment Guidance (RAGS) describes minimum field measurements to be collected for site characterization RAGS Exhibit 4-2, "Examples of Modeling Parameters for Which Information May Need to be Obtained During a Site Sampling Investigation," provides a list of data elements according to medium modeling category If not collected during sampling, these parameters cannot be determined The use of default options and routines to estimate missing values allows the use of the model but increases the uncertainty associated with the exposure assessments

Although large amounts of this data exist for the RFP, none of the above parameters have been characterized for IHSS 199 The lack of field measurements directly applicable to IHSS 199 greatly reduces the level of certainty in the performance of a quantitative risk assessment Therefore general statements concerning physical site information were utilized for the qualitative risk assessment.

5.0 ANALYTICAL METHOD

A critical facet of data useability as described in the guidance document requires that the analytical methods used to measure plutonium contamination in soil have sufficient quality control measures built into the sample collection and analysis The preparation of samples prior to counting is an important consideration, which is a multi-step process that achieves the following objectives (1) the destruction of the sample matrix to reduce alpha-and beta particle absorption, (2) the separation and concentration of radionuclides of interest to increase resolution and sensitivity, and (3) the preparation of the sample in a suitable form for counting Appropriate radioactive tracers must be selected and added to both the field and laboratory samples before a radiochemical procedure is initiated Of the documents reviewed, only the Illsley 1987 report partially describes the above methods used for radiochemical analysis Most of the documents reviewed do not state whether analysis was performed by a laboratory participating in the EPA Environmental Radioactive Intercomparison Program, which provides quality assurance oversight for radiation measurement laboratories

6.0 DATA REVIEW

The EPA Data Useability Guidance Document lists two criteria for data review, that of timeliness, and the level and depth of review The first criteria is of little importance for this project, but the second criteria is a critical factor that the data must meet for it to be used in the risk assessment A statement concerning the data review process is absent from all documents that were used to develop the qualitative risk assessment The timeliness, level, and depth of review is unknown It can be assumed that all documents went through a normal quality assurance review, but even this is not stated. It is unclear if computer algorithm programs were validated, or if data entry was checked. Therefore based on the data review process criterion, all documents would be rejected.

7.0 ASSESSMENT OF SAMPLING DATA QUALITY INDICATORS

As stated in the Guidance Document, five basic data quality indicators must be assessed prior to utilizing data in a quantitative risk assessment.

1 Completeness

Completeness is a measure of the amount of useable data resulting from data collection activities A description of the number of samples required to adequately characterize each media should be included that at a minimum references Standard Operating Procedures (SOPs) and the Sampling and Analysis Plan (SAP)

The Illsley document uses the methodology of collecting a large number of sample locations per sector and compositing these into one sample per sector Although this is an accepted methodology for soil sample collection over large areas, not enough documentation was made available to determine if a sufficient number of samples were collected to adequately characterize the site

2 Comparability

Comparability expresses the confidence with which data are considered to be equivalent Analytical methods and sampling protocol must be stated in each report to allow comparison of each of the data sets, since field and laboratory variability may significantly affect the results

None of the reports reviewed are judged to be adequate based on an examination of comparability, since sample design and analytical methods vary greatly between reports

3 Representativeness

Representativeness expresses the extent to which data define the risk to human health and the environment Samples must be collected in a way that generates data which reflects the site characteristics, and must be analyzed in a way which represents the properties of the field sample Lack of representativeness in the media sampled may result in the detection of false negatives and may cause the omission of potential exposure pathways in the risk assessment

Although sample preparation procedures were similar for some of the reports, it is still unclear whether the process of compositing subsamples in each sector produces a sample data set representative of the exposure area in question Information concerning higher concentrations and hot spots is lost when analyzing soil composites

4 Precision

Precision is a measure of the variability of a set of measurements compared to the mean and is usually reported as a coefficient of variation or a standard deviation of the arithmetic mean

Here again, it is impossible to compare the data sets of the reports available for IHSS 199 because of the large variability in precision of the analytical results The two basic activities performed in the assessment of precision are estimating sample variability from the observed

spatial variation and estimating the measurement error attributed to the data collection process Neither one of these can be accomplished for IHSS 199, given the information presented in the reports and leads to an unacceptable level of uncertainty Therefore, the estimation of the average concentration of Pu may not be representative of the site

5 Accuracy

Accuracy is controlled primarily by the analytical process and is reported as bias The sample design plan and sample collection plan relates directly to this bias, and since neither of these documents were included for review, it is impossible to determine the accuracy of the reports The estimate of accuracy is further compromised by the exclusion of data relating to field and laboratory spike results Since an estimation of the accuracy of the data cannot be performed, the data should not be included for use in a quantitative risk assessment.

8 0 APPLICATION OF DATA TO RISK ASSESSMENT

The Data Useability worksheets provided in Appendix A provide a detailed examination of the data quality across the various assessment phases To summarize the data and determine useability the following four questions are applied to each data report, incorporating the data useability criterion evaluated in the worksheets These questions are taken directly from Chapter 6 of the EPA Guidance Document for Data Useability.

CRITERION		SUMMARY
1	What contamination is present and at what levels?	Analytical methods, data review, analytical precision and accuracy combine to allow for a probability of false negatives Criterion not met
2	Are site concentrations sufficiently different from background?	Although background measurements were not collected, the levels of Pu present are greater than what can be attributed to world-wide fallout. Therefore it is assumed that the plutonium measured at IHSS 199 originated from the RFP Criterion met.
3	Are all exposure pathways identified and examined?	The nature of the pathways to be examined is critical to the characterization of risk at the site None of the documents reviewed provide identification of exposure pathways Criterion not met.
4	Are exposure pathways fully characterized?	To be fully characterized, the exposure pathway must have been appropriately sampled Data Quality Indicators such as completeness, comparability, representativeness, precision, and accuracy all must be within acceptable limits for the exposure pathways to be accurately characterized The information listed above is lacking in all of the documentation provided Criterion not met.

Since none of the documents meets the basic criterion of data useability a quantitative risk assessment based on such data would not yield useful results and would not be defensible

9.0 SUMMARY

An examination of the data available for IHSS 199 indicates that few of the criteria found in the EPA Guidance Document for Data Useability are met. The data collected were of limited quality and specificity, a sampling design program was not initiated to collect representative samples from all media and exposure pathways, and no meaningful statistical analysis were conducted on the data set prior to publication of the reports, including Data Quality Indicators and sample specific quantitation limits (SQLs)

Therefore, based on the guidance found in the Data Useability for Risk Assessment only qualitative statements concerning risk are possible These statements are based on historical information and the general behavior and transport of plutonium in the environment No numerical measures can be derived to indicate the potential for adverse effects, and the level of certainty cannot be assessed. The risk to human health may thus be considered only in qualitative terms, which by the reference document is an acceptable method when data do not support a more rigorous quantitative analysis

TABLE A1.1

DATA SOURCES
OPERABLE UNIT NO. 3, IHSS 199, ROCKY FLATS PLANT

Data Source	Nature of Data
United States Atomic Energy Commission, "Plutonium in Soil Around the Rocky Flats Plant," by P W Krey and E P Hardy, Health and Safety Laboratory USAEC, New York, NY, HASL-235, 1 August 1970	Plutonium concentrations in soil samples collected in early 1970 from 33 sits extending as far as 40 miles from Rocky Flats Plant, including sites within and around IHSS 199
Dow Chemical USA, "Soil Sampling East of Indiana Avenue," by R W Loser and R L. Tibbals, Product and Health Physics Research Service Report No 317-72-186, 29 November 1972	Plutonium concentrations in soil samples collected on November 17, 1972 from 20 sites within and around IHSS 199
Rockwell International, "Results of Special Soil Samples Collected Adjacent to the Rocky Flats Plant Site," by C T Illsley, Environmental Analysis and Control, ES-376-77-201, 7 September 1977 (revised 30 November 1979)	Selected radionuclide concentrations (including plutonium) in soil samples collected in August, 1976 from 25 sites within and around IHSS 199
Colorado Department of Health, "Radioactive Soil Contamination (Cesium-137 and Plutonium) in the Environment Near the Rocky Flats Nuclear Weapons Plant," September 1977	Plutonium and cesium-137 concentrations in soil samples collected in 1977 from sites within and around IHSS 199
Rockwell International, "Plutonium Concentrations in Soil on Lands Adjacent to the Rocky Flats Plant," by C T Illsley and M W Hume, Energy Systems Group, LPR-1, 16 March 1979	Plutonium concentrations in soil samples collected in 1976 and 1977 from sites within and around IHSS 199
Rockwell International, "Disclosure to the City of Broomfield," 22 January 1985	Page 9 Average plutonium concentrations in soils on City of Broomfield acreage at IHSS 199 Page 15A Average annual plutonium concentrations in air and soil within and around IHSS 199
Rockwell International, "Soil Sample Collection and Analysis for Plutonium on Lands Adjacent to Great Western Reservoir for the City of Broomfield," by C T Illsley, EAC-47-85-1, 10 April 1985	Plutonium concentrations in 15 composite soil samples collected in 1985 from 10-acre plots within the City of Broomfield acreage at IHSS 199
Rockwell International, "Remedial Action Program on Jefferson County Open Space Land in Section 7, T2S, R69W, South of Great Western Reservoir," by C T Illsley, EAC-420-87-1, 15 January 1987	Plutonium concentrations in composite soil samples collected in 1977 and 1985 from 10-acre plots within IHSS 199
"Rocky Flats Plant Site Environmental Report," (published annually since 1971 by EG&G Rocky Flats, Inc and their predecessors, known prior to 1988 as "Annual Environmental Monitoring Report")	Summaries of all environmental investigations and monitoring conducted on and around the RFP during the current year (summarizes data included in monthly environmental monitoring reports)

TABLE A1.2

PLUTONIUM IN SOIL AROUND THE ROCKY FLATS PLANT, APRIL 1, 1970

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	Report only includes limited sampling data locations for IHSS 199 Majority of report applies to areas outside of IHSS 199 No data sets included, only data summary No interpretation of data useability No narrative describing specific sampling of analytical problems Results are qualified for analytical limitations Partial interpretation of QC data included. Soil sampling technique different than for other documents Document not generated for use in risk assessment.	Reject	
2	Documentation A WP/SAP/QAPjP	No work plan, sampling and analysis plan, or quality assurance project plan provided. Inadequate site description, no detailed map provided with sample locations	Reject	
	B SOPs	The data tables provided compare the results of different methods of soil collection. This supports the contention that a variation in sample collection procedures can have a significant effect on analytical results A description of sampling design is provided	Reject	
	C. Field and Analytical Records	No field logs or raw data available. No chain of custody records Selection and identification of sampling points not documented No documentation concerning deviation from sampling and analysis plan or standard operating procedures	Reject	
3	Data Sources A Analytical	Analytical results listed in Table A vary between laboratories Analytical results are listed by depth of sample.	Qualified Accept	
	B Non-analytical	Use CDH 1977 No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography, respirable Fraction of PU, depth of contamination in soil, etc	Reject	
4	Analytical Methods	Analytical methods not stated. Quality control measures mentioned but not described Replicate analysis performed but result not stated. Method detection limits percent recovery, LLD and MDA stated Laboratory performing analysis identified	Qualified Accept	
5	Data Review	Data review process prior to publication of document is unknown The timeliness, level and depth of review not stated in document. Level of quality assurance/quality control review unknown	Reject	
6.	Data Quality Indicators A. Completeness	No indication if data collection and analysis problems affected the completeness of data sets Assumption is that 100% of samples collected were correctly analyzed. No explanation why many more sampling points identified on map without corresponding analytical value No data qualifiers presented with data. Only PU and CS analyzed.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	This report points out the variability introduced in the analytical results due to change in sample collection procedures It is not possible to compare the results in this report with other reports Sampling not performed based on temporal or spatial variation In addition, analysis from different laboratories resulted in variation of the PU concentrations	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C Representativeness	The data cannot be used for a quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations of the site. Only one exposure pathway was sampled (soil) No air or water data is available directly related to the site	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	Table 8, duplicate soil sampling results given as mCi/km^2 Field blanks, trip blanks and internal standards collected. Counting error stated. No field blanks, trip blanks, internal standards, or standard soil analysis was performed. Replicate analysis was performed but the results were not listed in the report. Soil concentrations reported as averages rather than included as a complete data set. Counting error not stated.	Sampling	Qualified Accept
			Analytical	Qualified Accept
			Combined	Qualified Accept
	E Accuracy	Percent recovery analysis performed Description of minimum QA/QC data included No documented QA review	Sampling	Qualified Accept
			Analytical	Qualified Accept
			Combined	Qualified Accept

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.3

COMMITTEE EVALUATION OF PLUTONIUM LEVELS WITHIN AND SURROUNDING RFP, JULY 9, 1971

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	Report only includes limited sampling data locations for IHSS 199 Majority of report applies to areas outside of IHSS 199 No data sets included, only data summary No interpretation of data useability No narrative describing specific sampling or analytical problems Results are qualified for analytical limitations Interpretation of QC data included. Soil sampling technique different than for other documents Document not generated for use in risk assessment.	Qualified Accept	
2.	Documentation A. WP/SAP/QAPjP	No work plan, sampling and analysis plan, or quality assurance project plan provided. Inadequate site description, no detailed map provided with sample locations	Qualified Accept	
	B SOPs	The data tables provided compare the results of different methods of soil collection. This supports the contention that a variation in sample collection procedures can have a significant effect on analytical results A description of sampling design is provided	Reject	
	C. Field and Analytical Records	No field logs or raw data available No chain of custody records Selection and identification of sampling points not documented No documentation concerning deviation from sampling and analysis plan or standard operating procedures	Reject	
3	Data Sources A. Analytical	Analytical results listed vary between laboratories with no accompanying explanation.	Qualified Accept	
	B Non-analytical	No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography, respirable Fraction of PU, depth of contamination in soil, etc.	Reject	
4	Analytical Methods	Analytical methods stated Quality control measures described. Replicate analysis performed and results stated. Method detection limits percent recovery, LLD and MDA stated. Laboratory performing analysis identified.	Accept	
5	Data Review	Data review process prior to publication of document is unknown The timeliness, level and depth of review not stated in document. Level of quality assurance/quality control review unknown	Reject	
6.	Data Quality Indicators A. Completeness	No indication if data collection and analysis problems affected the completeness of data sets Assumption is that 100% of samples collected were correctly analyzed. No explanation why many more sampling points identified on map without corresponding analytical value No data qualifiers presented with data Only PU analyzed	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	This report points out the variability introduced in the analytical results due to difference in sample collection procedures It is not possible to compare the results in this report with other reports Sampling not performed based on temporal or spatial variation. In addition, analysis from different laboratories resulted in variation of the PU concentrations	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C Representativeness	The data cannot be used for a quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations of the site. Only one exposure pathway was sampled (soil) No air or water data is available directly related to the site.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	Results given as mCi/km^2 Field blanks, trip blanks and internal standards collected. Counting error stated. No field blanks, trip blanks, internal standards, or standard soil analysis was performed. Replicate analysis was performed but the results were not listed in the report. Soil concentrations reported as averages rather than included as a complete data set. Counting error not stated.	Sampling	Qualified Accept
			Analytical	Qualified Accept
			Combined	Qualified Accept
	E Accuracy	Percent recovery analysis performed Description of minimum QA/QC data included No documented QA review	Sampling	Qualified Accept
			Analytical	Qualified Accept
			Combined	Qualified Accept

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.4

SOIL SAMPLING EAST OF INDIANA AVENUE, NOVEMBER, 1972

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	Report includes only limited sample locations for IHSS 199 Majority of report applies to areas outside of IHSS 199 No data set included, only data summary No interpretation of data useability No narrative summary describing specific sampling or analytical problems Results not qualified for analytical limits Interpretation of QC data not included Document not generated for use in risk assessment.	Reject	
2	Documentation A WP/SAP/QAPjP	No work plan, sampling and analysis plan, or Quality Assurance Project Plan provided. Inadequate site description No detailed map provided for sampling locations from Table I. No map provided for sampling locations from Table II.	Reject	
	B SOPs	No description of sampling design Procedures omitted.	Reject	
	C Field and Analytical Records	No field logs or raw data available Selection and identification of sampling points not documented.	Reject	
3	Data Sources A Analytical	Analytical data reported as mCi/km^2 rather than as pCi/g, and is totally unusable for a risk assessment. No data available for samples listed in Table II Samples analyzed for PU only	Reject	
	B Non-analytical	No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography	Reject	
4	Analytical Methods	Analytical methods and procedures not referenced. Quality control measurements no described. Replicate Analysis not performed, Method detection limits percent recovery, LLD, and MDA not stated. Laboratory performing analysis not stated.	Reject	
5	Data Review	Data review process prior to publication of document is unknown The timeliness, level and depth of review not stated in document.	Reject	
6	Data Quality Indicators A Completeness	No data results for sampling locations in Table II. No indications if data collection and analysis problems affected the completeness of data set. No data qualifiers presented with data.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	Data reported in mCi/km^2 and is not comparable with other reports This report points out the variability introduced in the analytical results due to change in sample collection procedures It is not possible to compare the results in this report with other reports Sampling not performed based on temporal or spatial variation.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C. Representativeness	Data reported in mCi/km2 and is not comparable with other reports The data cannot be used for a quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations of the site. Only one exposure pathway was sampled (soil). No air or water data is available directly related to the site	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	Data reported in mCi/km2 and is not comparable with other reports No field blanks, trip blanks, internal standards, or standard soil analysis was performed. Replicate analysis was performed but the results were not listed in the report. Soil concentrations reported as averages rather than included as a complete data set. Counting error not stated.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	E Accuracy	Data reported in mCi/km2 and is not comparable with other reports Percent recovery analysis not performed Description of minimum QA/QC data not included. No documented QA review	Sampling	Reject
			Analytical	Reject
			Combined	Reject

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.5

RADIO ACTIVE SOIL CONTAMINATION IN THE ENVIRONMENT NEAR THE ROCKY FLATS NUCLEAR WEAPONS PLANT, CDH 1977

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	Report only includes limited sample locations for IHSS 199 Majority of report applies to areas outside of IHSS 199 No data set included, only data summary No interpretation of data useability No narrative summary describing specific sampling of analytical problems Results not qualified for analytical limitations Interpretation of QC costs not included Document not generated for use in risk assessment	Reject	
2.	Documentation A. WP/SAP/QAPjP	No work plan, sampling end analysis plan or Quality Assurance project plan provided. Inadequate site description, no detailed map provided with sample locations Many sample points are shown on map in Figure 5 but have no corresponding analytical value	Reject	
	B SOPs	The data tables provided compare the results of different methods of soil collection. This supports the contention that a variation in sample collection procedures can have a significant effect on analytical results A description of sampling design is provided	Accept	
	C. Field and Analytical Records	No field logs or raw data available. No chain of custody records Selection and identification of sampling points not documented. No documentation concerning deviation from sampling and analysis plan or standard operating procedures	Reject	
3	Data Sources A Analytical	Analytical data results reported as averages rather than including hot spot values Samples analyzed for 239 PU and 147 Cs only No chemical analysis performed? Solubility class for a PU not determined.	Reject	
	B Non-analytical	No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography, respirable Fraction of PU, depth of contamination in soil, etc.	Reject	
4	Analytical Methods	Analytical methods listed. Quality control measures mentioned but no described Replicate analysis performed but no data stated Method detection limits percent recovery, LLD, MDA not stated. Unknown if laboratory performing analysis participating in Intercomparison program	Reject	
5	Data Review	Data review process prior to publication of document is unknown The timeliness, level and depth of review not stated in document. Level of quality assurance/quality control review unknown	Reject	
6	Data Quality Indicators A Completeness	No indication if data collection and analysis problems affected the completeness of data sets Assumption is that 100% of samples collected were correctly analyzed. No explanation why many more sampling points identified on map without corresponding analytical value. No data qualifiers presented with data. Only PU and CS analyzed	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	This report points out the variability introduced in the analytical results due to change in sample collection procedures It is not possible to compare the results in this report with other reports Sampling not performed based on temporal or spatial variation	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C. Representativeness	The data cannot be used for a quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations of the site. Only one exposure pathway was sampled (soil) No air or water data is available directly related to the site	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	No field blanks, trip blanks, internal standards, or standard soil analysis was performed. Replicate analysis was performed but the results were not listed in the report. Soil concentrations reported as averages rather than included as a complete data set. Counting error not stated.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	E Accuracy	Percent recovery analysis not performed. Description of minimum QA/QC data not included. No documented QA review	Sampling	Reject
			Analytical	Reject
			Combined	Reject

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.6

RESULTS OF ANALYSIS FOR SPECIAL SOIL SAMPLES COLLECTED ADJACENT TO THE ROCKY FLATS PLANT SITE, SEPTEMBER, 1977

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	Report may include sample locations outside of IHSS 199 No map included to locate sample points No data set included, only data summary No interpretation of data useability No narrative summary describing specific sampling or analytical problems Results not qualified for analytical limits Interpretation of QC data not included. Document not generated for use in risk assessment.	Reject	
2.	Documentation A WP/SAP/QAPjP	No work plan, sampling and analysis plan or Quality Assurance project plan provided. No site description. No detailed sampling map provided	Reject	
	B SOPs	No description of sampling design, no procedures included.	Reject	
	C. Field and Analytical Records	No field logs or raw instrument data available. No chain of custody records Selection and identification of sampling points not documented. No documentation concerning deviation from sampling plan or standard operating procedures	Reject	
3	Data Sources A Analytical	No raw analytical data provided only data summaries No high or hot spot data provided only averages Data reported as disintegrations per minute per gram of soil. Samples not analyzed for 241 Am	Reject	
	B Non analytical	No field measurement date available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography	Reject	
4	Analytical Methods	Analytical methods and procedures not adequately described. Method detection limits sample quantitation limits percent recovery not stated in report laboratory identified that performed analysis Table II Comparative Analysis indicates an unacceptable variation for analysis of certain radionuclides	Reject	
5	Data Review	Data review prior to publication of document is unknown The timeliness, level, and depth of review not stated in document	Reject	
6	Data Quality Indicators A. Completeness	Based on the data presented it is not possible to compare or equivocate the results in this report with other reports Sampling not performed based on special or temporal variation.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	The data collected cannot be used for quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations at the site. Only one exposure pathway was sampled (soil) no air data is available directly relating to the site	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C. Representativeness	Field blanks, duplicates, and standard soil analysis were performed but the results were reported as a summary rather than a complete data set.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	Field blanks, duplicates, replicates and standard soil analysis were not collected. No complete data sets, only data summary Counting error not stated.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	E Accuracy	Isotopic tracer was added to determine percent recovery, but not during sample collection phase. The report states a plutonium tracer was 236 PU was added to the soil samples after compositing to determine percent recovery However, no tracer was added to the field samples to assure 100% recovery during the soil collection and compositing process	Sampling	Reject
			Analytical	Reject
			Combined	Reject

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.7

PLUTONIUM CONCENTRATIONS IN SOIL ON LANDS ADJACENT TO THE ROCKY FLATS SITE, MARCH 1979

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	No data set included, only data summary No interpretation of data useability, no narrative summary describing specific sampling or analytical problems results not qualified for analytical limitations Interpretation of QC data is included. Document not generated for use in risk assessment	Reject	
2.	Documentation A. WP/SAP/QAPjP	No work plan, sampling and analysis plan, or Quality Assurance project plan provided. Inadequate site description, no detailed map w/sample locations.	Reject	
	B SOPs	No detailed description of sampling design Procedures omitted, vegetative cover may have been removed prior to soil sampling, thus biasing the sample. Samples collect on random basis, rather than by using a low energy gamma detector such as a FIDLER to locate potential sample points	Reject	
	C Field and Analytical Records	Report states that sample collection logbook used. No field logs or raw instrument data available. No chain of custody records, selection and identification of sampling points not document, no documentation concerning deviation from sampling and analysis plan or standard operating procedures	Qualified Accept	
3	Data Sources A. Analytical	Analytical data results for composite soil samples only no high or hot spot data, samples analyzed for 239 PU only, no chemical analysis performed and solubility class for 239 PU not determined.	Reject	
	B Non-analytical	No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography	Reject	
4	Analytical Methods	Analytical methods and procedures and quality control measures listed. Method detection limits, sample specific quantitation limits percent recovery not stated in report. Laboratory performing analysis certified by EMSL-LV (EPA Environmental Radioactivity Intercomparison Program	Qualified Accept	
5	Data Review	Data review process prior to publication of document is unknown The timeliness, level, and depth of review not stated in document.	Reject	
6	Data Quality Indicators A Completeness	No indication if data collection and analysis problems affected the completeness of data set. Assumption is the 100% of samples collected were correctly analyzed. No data qualifiers presented with data	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	Based on the data presented it is not possible to compare or equivocate the results in this report with other reports Sampling not performed based on special or temporal variation.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C Representativeness	The data collected cannot be used for quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations at the site. Only one exposure pathway was sampled (soil) no air data is available directly relating to the site	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	Field blanks, duplicates, and standard soil analysis were performed but the results were reported as a summary rather than a complete data set.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	E Accuracy	The report states a plutonium tracer was 236 PU was added to the soil samples after compositing to determine percent recovery However, no tracer was added to the field samples to assure 100% recovery during the soil collection and compositing process	Sampling	Reject
			Analytical	Reject
			Combined	Reject

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.8

DISCLOSURE TO THE CITY OF BROOMFIELD, JANUARY 22, 1985

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	No data set included, only data summary No interpretation of data useability, no narrative summary describing specific sampling or analytical problems results not qualified for analytical limitations Interpretation of QC data is included. Document not generated for use in risk assessment. A table is included that relates soil concentrations and airborne concentrations of Pu at IHSS 199, but is not qualified with the needed information for data useability	Reject	
2.	Documentation A. WP/SAP/QAPjP	No work plan, sampling and analysis plan, or Quality Assurance project plan provided Inadequate site description, no detailed map w/sample locations	Reject	
	B SOPs	No detailed description of sampling design Procedures omitted, vegetative cover may have been removed prior to soil sampling, thus biasing the sample Samples collect on random basis, rather than by using a low energy gamma detector such as a FIDLER to locate potential sample points	Reject	
	C Field and Analytical Records	No field logs or raw instrument data available. No chain of custody records, selection and identification of sampling points not document, no documentation concerning deviation from sampling and analysis plan or standard operating procedures.	Reject	
3	Data Sources A Analytical	Analytical data sources reported as summary rather than as data sets	Reject	
	B Non-analytical	No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography	Reject	
4	Analytical Methods	Analytical methods and procedures and quality control measures not listed.	Reject	
5	Data Review	Data review process prior to publication of document is unknown. The timeliness, level, and depth of review not stated in document.	Reject	
6	Data Quality Indicators A Completeness	No indication if data collection and analysis problems affected the completeness of data set. Assumption is the 100% of samples collected were correctly analyzed. No data qualifiers presented with data.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	Based on the data presented it is not possible to compare or equivocate the results in this report with other reports Sampling not performed based on special or temporal variation.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C Representativeness	The data collected cannot be used for quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations at the site. Only one exposure pathway was sampled (soil) no air data is available directly relating to the site	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	No indication of the number of field blanks, duplicates and standard soil analysis, or if they were even collected. Results reported as summary rather than complete data set.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	E Accuracy	Data summary does not include information concerning percent recovery both for the field and analytical samples	Sampling	Reject
			Analytical	Reject
			Combined	Reject

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.9

SOIL SAMPLING COLLECTION AND ANALYSIS FOR PLUTONIUM ON LANDS ADJACENT TO GREAT WESTERN RESERVOIR FOR THE CITY OF BROOMFIELD APRIL 10, 1985

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	Report includes partial sample locations for IHSS 199 No data set included, only data summary No interpretation of data useability No narrative summary describing specific sampling or analytical problems Results not qualified for analytical limitations interpretation of QC data not included. Document not generated for use in risk assessment.	Reject	
2.	Documentation A WP/SAP/QAPjP	No work plan, sampling and analysis or Quality Assurance project plan provided. Quality control statements duplicated in Illsley 1987 document. Inadequate site description, no detailed map provided with sample locations	Reject	
	B SOPs	No detailed description of sampling design Procedures omitted, vegetative cover may have been removed prior to soil sampling thus biasing the sample. Samples collected on a random basis, rather than by using a low energy gamma detector such as a FIDLER to locate potential sample points	Reject	
	C. Field and Analytical Records	No field logs or raw data available. No chain of custody records Selection and identification of sampling points not documented No documentation concerning deviation from sampling and analysis plan or standard operating procedures	Reject	
3	Data Sources A Analytical	Analytical data results reported as averages rather than including hot spot values Composite soil samples taken, samples analyzed for 239 PU only No chemical analysis performed. Solubility class for 239 PU not determined.	Qualified Accept	
	B Non-analytical	No field measurement data available for site such as particle size, pH, clay content porosity of soil, wind direction, topography, respirable fraction of PU, depth of contamination in soil.	Reject	
4	Analytical Methods	Analytical methods and procedures referenced. Quality control measures stated but not described. Method detection limits, sample specific quantitation limits are percent recovery not stated in report. Laboratory performing analysis certified by EMSL-LV (EPA Environmental Radioactivity Intercomparison Program	Qualified Accept	
5	Data Review	Data review process prior to publication of document is unknown The timeliness, level and depth of review not stated in document. Level of quality assurance/quality control review unknown.	Reject	
6	Data Quality Indicators A Completeness	No indication if data collection and analysis problems affected the completeness of data sets Assumption is that 100% of samples collected were correctly analyzed. No data qualifiers presented with data. Only PU analyzed.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	Based on the data presented it is not possible to compare or equivocate the results in this report with other reports Sampling not performed based on special or temporal variation.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C Representativeness	The data cannot be used for a comprehensive quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations at the site. Only one exposure pathway was sampled (soil). No air or water data is available directly related to the site	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	Field blanks, duplicates, and standard soil analysis were performed but the results were reported as a summary rather than a complete data set.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	E Accuracy	The report states a plutonium tracer was 236 PU was added to the soil samples after compositing to determine percent recovery However, no tracer was added to the field samples to assure 100% recovery during the soil collection and compositing process	Sampling	Reject
			Analytical	Reject
			Combined	Reject

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.10

REMEDIAL ACTION PROGRAM ON JEFFERSON COUNTY OPEN SPACE LAND IN SECTION 7, T2S, R69W SOUTH OF GREAT WESTERN RESERVOIR JAN. 15, 1987

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	No data set included, only data summary No interpretation of data useability, no narrative summary describing specific sampling or analytical problems results not qualified for analytical limitations Interpretation of QC data is included. Document not generated for use in risk assessment.	Reject	
2	Documentation A WP/SAP/QAPjP	No work plan, sampling and analysis plan, or Quality Assurance project plan provided Inadequate site description, no detailed map w/sample locations.	Reject	
	B SOPs	No detailed description of sampling design Procedures omitted, vegetative cover may have been removed prior to soil sampling, thus biasing the sample. Samples collect on random basis, rather than by using a low energy gamma detector such as a FIDLER to locate potential sample points	Reject	
	C. Field and Analytical Records	No field logs or raw instrument data available. No chain of custody records, selection and identification of sampling points not document, no documentation concerning deviation from sampling and analysis plan or standard operating procedures	Reject	
3	Data Sources A. Analytical	Analytical data results for composite soil samples only no high or hot spot data, samples analyzed for 239 PU only, no chemical analysis performed and solubility class for 239 PU not determined	Qualified Accept	
	B Non analytical	No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography	Reject	
4	Analytical Methods	Analytical methods and procedures and quality control measures listed. Method detection limits, sample specific quantitation limits percent recovery not stated in report. Laboratory performing analysis certified by EMSL-LV (EPA Environmental Radioactivity Intercomparison Program	Qualified Accept	
5	Data Review	Data review process prior to publication of document is unknown The timeliness, level, and depth of review not stated in document.	Reject	
6	Data Quality Indicators A Completeness	No indication if data collection and analysis problems affected the completeness of data set. Assumption is the 100% of samples collected were correctly analyzed. No data qualifiers presented with data	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	Based on the data presented it is not possible to compare or equivocate the results in this report with other reports Sampling not performed based on special or temporal variation.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C. Representativeness	The data collected cannot be used for quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations at the site. Only one exposure pathway was sampled (soil) no air data is available directly relating to the site.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	Field blanks, duplicates, and standard soil analysis were performed but the results were reported as a summary rather than a complete data set.	Sampling	Qualified Accept
			Analytical	Qualified Accept
			Combined	Qualified Accept
	E Accuracy	The report states a plutonium tracer was 236 PU was added to the soil samples after compositing to determine percent recovery However, no tracer was added to the field samples to assure 100% recovery during the soil collection and compositing process	Sampling	Qualified Accept
			Analytical	Qualified Accept
			Combined	Qualified Accept

[1] Decision Accept, Qualified Accept, Reject

TABLE A1.11

SPECIAL REPORT 1989 CDH SURFACE SOIL SURVEY RESULTS

Data Useability Criteria		Comments	Decision[1]	
1	Reports to Risk Assessor	No data set included, only data summary No interpretation of data useability, no narrative summary describing specific sampling or analytical problems results not qualified for analytical limitations Interpretation of QC data is included. Document not generated for use in risk assessment.	Reject	
2.	Documentation A. WP/SAP/QAPjP	No work plan, sampling and analysis plan, or Quality Assurance project plan provided Inadequate site description, no detailed map w/sample locations.	Reject	
	B SOPs	No detailed description of sampling design Procedures omitted, vegetative cover may have been removed prior to soil sampling, thus biasing the sample. Samples collect on random basis, rather than by using a low energy gamma detector such as a FIDLER to locate potential sample points	Reject	
	C. Field and Analytical Records	No field logs or raw instrument data available. No chain of custody records, selection and identification of sampling points not document, no documentation concerning deviation from sampling and analysis plan or standard operating procedures.	Reject	
3	Data Sources A Analytical	No indication as to the analysis performed.	Reject	
	B Non-analytical	No field measurement data available for site such as particle size, pH, clay content, porosity of soil, wind direction, topography	Reject	
4	Analytical Methods	No analytical methods listed. Laboratory performing analysis not stated.	Reject	
5	Data Review	Data review process prior to publication of document is unknown. The timeliness, level, and depth of review not stated in document.	Reject	
6	Data Quality Indicators A Completeness	No indication if data collection and analysis problems affected the completeness of data set. Assumption is the 100% of samples collected were correctly analyzed. No data qualifiers presented with data	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	B Comparability	Based on the data presented it is not possible to compare or equivocate the results in this report with other reports Sampling not performed based on special or temporal variation. Some data reported as dpm/g other data reported as parts per trillion	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	C Representativeness	The data collected cannot be used for quantitative risk assessment because only soil media was sampled, and collected in a manner that may not represent the true PU concentrations at the site. Only one exposure pathway was sampled (soil) no air data is available directly relating to the site.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	D Precision	No indication of the number of field blank duplicates and standard soil analysis or if they were even collected. Results reported as summary rather than completed data set.	Sampling	Reject
			Analytical	Reject
			Combined	Reject
	E Accuracy	Data summary does not include information concerning percent recovery both for the field and analytical samples	Sampling	Reject
			Analytical	Reject
			Combined	Reject

[1] Decision Accept, Qualified Accept, Reject

APPENDIX B

GENERAL GUIDELINES FOR DEVELOPMENT OF A RISK ASSESSMENT

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1.0 THE NATURE OF RISK ASSESSMENT

Regulatory actions are based on two distinct elements, risk assessment, the subject of this study, and risk management. Risk assessment is the use of the factual base to estimate the potential health effects of possible exposure of individuals or populations to hazardous materials and situations Risk management is the process of weighing policy alternatives and selecting the most appropriate regulatory action, integrating the results of risk assessment with engineering data and with social, economic, and political concerns to reach a decision

Risk assessments contain some or all of the following five steps

- Hazard identification The evaluation of whether a particular chemical is or is not causally linked to particular health effects
- Dose-response assessment The evaluation of the relation between the magnitude of exposure and the probability of occurrence of the health effects in question
- Exposure assessment The evaluation of the extent of human exposure before or after application of remedial controls
- Risk characterization The description of the nature and often the magnitude of human risk, including attendant uncertainty
- Uncertainty analysis

In each step, a number of decision points (components) occur where risk to human health can only be inferred from the available evidence Both scientific judgements and policy choices may be involved in selecting from among possible inferential bridges, therefore the term "risk assessment policy" is used to differentiate those judgements and choices from the broader social and economic policy issues that are inherent in risk management decisions

2.0 TERMINOLOGY

Despite the fact that risk assessment has become a subject that has been extensively discussed in recent years, no standard definitions have evolved, and the same concepts are encountered under different names The following sections discuss the various terms and components common to risk assessments and risk management studies

2 1 RISK ASSESSMENT AND RISK MANAGEMENT

Risk assessment is used to mean the characterization of the potential adverse health effects of human exposures to environmental hazards Risk assessments include several elements description of the potential adverse health effects based on an evaluation of results of epidemiologic, clinical, toxicologic, and environmental research, extrapolation from those results to predict the type and estimate the extent of health effects in humans under given conditions of exposure, judgements as to the number and characteristics of persons exposed at various intensities and durations, and summary judgements on the existence and overall magnitude of the public-health problem. Risk assessment also includes characterization of the uncertainties inherent in the process of inferring risk

The term risk assessment is often given narrower and broader meanings than adopted here For some observers, the term is synonymous with quantitative risk assessment and emphasizes reliance on numerical results A broader definition includes quantification, but also includes qualitative expressions of risk Quantitative estimates of risk are not always feasible, and they may be eschewed by agencies for policy reasons Broader uses of the term also embrace analysis of perceived risks, comparisons of risks associated with different regulatory strategies, and occasionally analysis of the economic and social implications of regulatory decisions -- functions that are assigned to risk management.

The term risk management is used to describe the process of evaluating alternative regulatory actions and selecting among them Risk management, which is carried out by regulatory agencies under various legislative mandates, is an agency decision-making process that entails consideration of political, social, economic, and engineering information with risk-related

information to develop, analyze, and compare regulatory options and to select the appropriate regulatory response to a potential chronic health hazard. The selection process necessarily requires the use of value judgements on such issues as the acceptability of risk and the reasonableness of the costs of control

2 2 RISK ASSESSMENT COMPONENTS

Risk assessment can be divided into four major steps hazard identification, dose-response assessment, exposure assessment, and risk characterization A risk assessment might stop with the first step, hazard identification, if no adverse effect is found or if an agency elects to take regulatory action without further analysis, for reasons of policy or statutory mandate For this site, the hazard identification, although incomplete, has definitely established that plutonium is present, and thus must continue through the subsequent steps

Of the four steps, hazard identification is the most easily recognized in the actions of regulatory agencies It is defined here as the process of determining whether exposure to an agent can cause an increase in the incidence of a health condition (cancer, birth defect, etc) It involves characterizing the nature and strength of the evidence of causation Although the question of whether a substance causes cancer or other adverse health effects is theoretically a yes-no question, there are few chemicals on which the human data are definitive Therefore, the question is often restated in terms of effects in laboratory animals or other test systems, e g , "Does the agent induce cancer in test animals?" Positive answers to such questions are typically taken as evidence that an agent may pose a cancer risk for any exposed humans Information from short-term in vitro tests and on structural similarity to known chemical hazards may also be considered

Dose-response assessment is the process of characterizing the relation between the dose of an agent administered or received and the incidence of an adverse health effect in exposed populations and estimating the incidence of the effect as a function of human exposure to the agent It takes account of intensity of exposure, age pattern of exposure, and possibly other variables that might affect response, such as sex, lifestyle, and other modifying factors A dose-response assessment usually requires extrapolation from high to low dose and extrapolation from

animals to humans A dose-response assessment should describe and justify the methods of extrapolation used to predict incidence and should characterize the statistical and biologic uncertainties in these methods.

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of human exposures to an agent currently present in the environment or of estimating hypothetical exposures that might arise from the release of new chemicals into the environment. In its most complete form, it describes the magnitude, duration, schedule, and route of exposure, the size, nature, and classes of the human populations exposed, and the uncertainties in all estimates Exposure assessment is often used to identify feasible prospective control options and to predict the effects of available control technologies on exposure

Risk characterization is the process of estimating the incidence of health effects under the various conditions of human exposure described in exposure assessment It is performed by combining the exposure and dose-response assessments The summary effects of the uncertainties in the preceding steps are described in this step

The relations among the four steps of risk assessment and between risk assessment and risk management are depicted in Figure B-1 The type of research information needed for each step is also illustrated

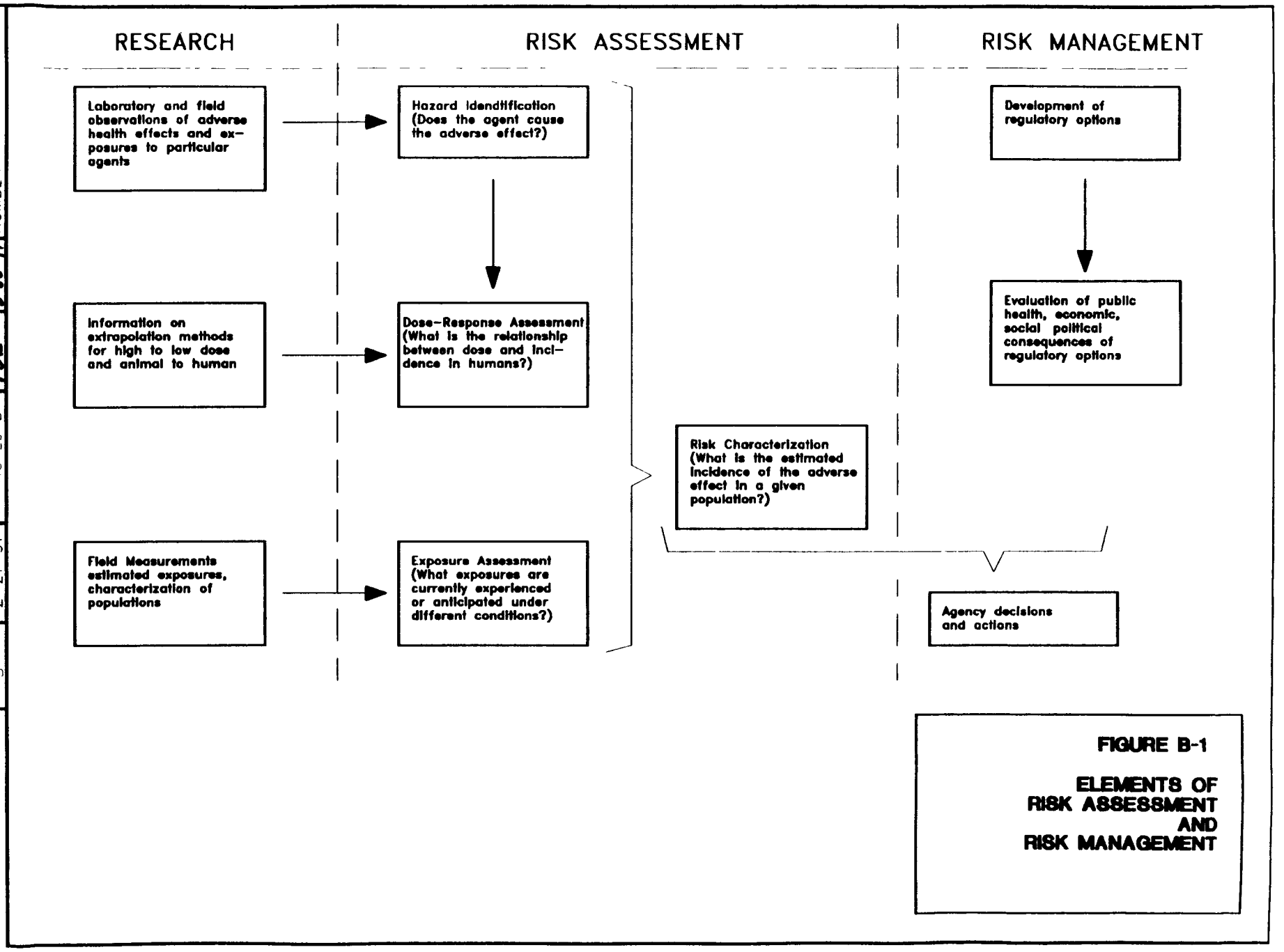

FIGURE B-1

ELEMENTS OF RISK ASSESSMENT AND RISK MANAGEMENT

3.0 SCIENTIFIC BASIS FOR RISK ASSESSMENT

3 1 STEP 1 HAZARD IDENTIFICATION

Although the risk assessment process as it is currently practiced by federal agencies for the estimation of carcinogenic risk contains several relatively new features, the scientific basis for much of the analysis done in risk assessment is well established This is especially true of the first step in the assessment process, hazard identification Four general classes of information may be used in this step epidemiologic data, animal-bioassay data, short-term studies, and comparisons of molecular structure

3 1 1 Epidemiologic data

Well-conducted studies that show a positive association between an agent and a disease are accepted as the most convincing evidence about human risk This evidence is, however, difficult to accumulate, often the risk is low, the number of persons exposed is small, the latent period between exposure and disease is long, and exposures are mixed and multiple Thus, epidemiologic data require careful interpretation Even if these problems are solved satisfactorily, the preponderance of chemicals in the environment has not been studied with epidemiologic methods, and we would not wish to release newly produced substances only to discover years later that they were powerful carcinogenic agents These limitations require reliance on less direct evidence that a health hazard exists

3 1 2 Animal Bioassay Data

The most commonly available data in hazard identification are those obtained from animal bioassays The interference that results from animal experiments are applicable to humans is fundamental to toxicologic research, this premise underlies much of experimental biology and medicine and is logically extended to the experimental observation of carcinogenic effects Despite the apparent validity of such inferences and their acceptability by most cancer researchers, there are no doubt occasions in which observations in animals may be of highly uncertain relevance to humans

Consistently positive results in the two sexes and in several strains and species and higher incidences at higher doses constitute the best evidence of carcinogenicity More often than not, however, such data are not available Instead, because of the nature of the effect and the limits of detection of animal tests as they are usually conducted, experimental data leading to a positive finding sometimes barely exceed a statistical threshold and may involve tumor types of uncertain relation to human carcinogenesis. Interpretation of some animal data may therefore be difficult. Notwithstanding uncertainties associated with interpretation of some animal tests, they have, in general, proved to be reliable indicators of carcinogenic properties and will continue to play a pivotal role in efforts to identify carcinogens

3 1 3 Short-Term Studies

Considerable experimental evidence supports the proposition that most chemical carcinogens are mutagens and that many mutagens are carcinogens As a result, a positive response in a mutagenicity assay is supportive evidence that the agent tested is likely to be carcinogenic Such data, in the absence of a positive animal bioassay, are rarely, if ever, sufficient to support a conclusion that an agent is carcinogenic Because short-term tests are rapid and inexpensive, they are valuable for screening chemicals for potential carcinogenicity and lending additional support to observations from animal and epidemiologic investigations.

3 1 4 Comparisons of Molecular Structure

Comparisons of an agent's chemical or physical properties with those of known carcinogens provides some evidence of potential carcinogenicity Experimental data support such associations for a few structural classes, however, such studies are best used to identify potential carcinogens for further investigation and may be useful in priority-setting for carcinogenicity testing

3 2 STEP 2 DOSE-RESPONSE ASSESSMENT

In a small number of instances, epidemiologic data permit a dose-response relation to be developed directly from observations of exposure and health effects in humans If epidemiologic data are available, extrapolations from the exposures observed in the study to lower exposures experienced by the general population are often necessary Such extrapolations introduce uncertainty into the estimates of risk for the general population Uncertainties also arise because

the general population includes some people, such as children, who may be more susceptible than people in the sample from which the epidemiologic data were developed.

The absence of useful data is common for most chemicals being assessed for carcinogenic effect, and dose-response assessment usually entails evaluating tests that were performed on rats or mice The tests, however, typically have been designed for hazard identification, rather than for determining dose-response relations Under current testing practice, one group of animals is given the highest dose that can be tolerated, a second group is exposed at half that dose, and a control group is not exposed. (The use of high doses is necessary to maximize the sensitivity of the study for determining whether the agent being tested has carcinogenic potential) A finding in such studies that increased exposure leads to an increased incidence has been used primarily to corroborate hazard identification, that is, to show that the agent does indeed induce the adverse health effect.

The testing of chemicals at high doses has been challenged by some scientists who argue that metabolism, or chemicals differ at high and low doses; i e , high doses may overwhelm normal detoxification mechanisms and provide results that would not occur at the lower doses to which humans are exposed An additional factor that is often raised to challenge the validity of animal data to indicate effects in man is that metabolic differences among animal species should be considered when animal test results are analyzed Metabolic differences can have important effects on the validity of extrapolating from animals to man if, for example, the actual carcinogen is a metabolite of the administered chemical and the animals tested differ markedly from humans in their production of that metabolite A related point is that the actual dose of carcinogen reaching the affected tissue or organ is usually not known, thus, dose-response information, of necessity, is based on administered dose and not tissue dose Although data of these types would certainly improve the basis for extrapolating from high to low doses and from one species to another, they are difficult to acquire and often unavailable

Regulators are interested in doses to which humans might be exposed, and such doses usually are much lower than those administered in animal studies Therefore, dose-response assessment often requires extrapolating an expected response curve over a wide range of doses from one or

two actual data points In addition, differences in size and metabolic rates between man and laboratory animals require that doses used experimentally be converted to reflect these differences

3 3 STEP 3 EXPOSURE ASSESSMENT

The first task of an exposure assessment is the determination of the concentration of the chemical to which humans are exposed. This may be known from direct measurement, but more typically exposure data are incomplete and must be estimated. Models for estimating exposure can be complex, even in the case of structured activity, as occurs in the workplace Exposure measurements made on a small group (e g , workers in a particular industrial firm) are often applied to other segments of the worker population

Exposure assessment in an occupational setting consists primarily of estimation of long-term airborne exposures in the workplace, however, because an agent may be present at various concentrations in diverse occupational settings, a census of exposures is difficult and costly to conduct In the community environment, the ambient concentrations of chemicals to which people may be exposed can be estimated from emission rates only if the transport and fate processes are known Alternative engineering control options require different estimates of the reduction in exposure that may be achieved For new chemicals with no measurement data at all, rough estimations of exposure are necessary

Some chemical agents are of concern because they are present in foods or may be absorbed when a consumer product is used. Assessments of exposure to such agents are complicated by variations in diet and personal habits among different groups in the population Even when the amount of an agent in a food can be measured, differences in food storage practices, food preparation, and dietary frequency often lead to a wide variation in the amount of the agent that individuals ingest. Patterns of use affect exposure to many consumer products, for example, a solvent whose vapor is potentially toxic may be used outdoors or it may be used in a small, poorly ventilated room, where the concentrations of vapor in the air is much higher

4.0 USER'S GUIDE: RADIONUCLIDE CARCINOGENICITY

The Health Effects Assessment Summary (HEAST) Table C summarizes the cancer slope factors and unit risk values for selected radionuclides of potential concern at Superfund sites contaminated with radioactive materials. These values were calculated by the Office of Radiation Programs (ORP) and are intended for use by EPA risk assessors during human health risk assessments conducted as part of the Superfund remedial investigation/feasibility study (RI/FS) process HEAST users should apply these values as specified by the radiation risk assessment guidance provided in this section and in Chapter 10 of the Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A (EPA/540/1-89/002), which is available from the Center for Environmental Research Information at (513) 569-7562 As risk assessment methodologies are refined, slope factors and unit risk values will be revised and updated in Table B 1

EPA classifies all radionuclides as Group A carcinogens based on their property of emitting ionizing radiation and on the extensive weight of evidence provided by epidemiological studies of radiation-induced cancers in humans. Data derived from both human studies and animal experiments are used by EPA to construct mathematical models of exposure, dose, and risk to estimate radionuclide slope factor values These models consider pathways of exposure, the distinct metabolic behavior of each element by compound and the radiological characteristics of each nuclide of concern, the time and duration of exposure, the radiosensitivity of each target organ in the body, the latency period for cancer expression in these organs, and the age and sex of individuals in the exposed population

Similar to chemical risk models, radiation models extrapolate cancer risks at low dose and dose rate exposures from risks observed at higher doses using non-threshold, linear dose-response relationships Because of the radiation risk models employed, slope factors for radionuclides are characterized as best estimates (i e , maximum likelihood estimates) of the age-averaged lifetime total excess cancer risk per unit intake or exposure HEAST users should consult Volume I of the Background Information Document for the Draft Environmental Impact Statement for

TABLE B.1

HEALTH EFFECTS ASSESSMENT SUMMARY TABLE
RADIONUCLIDE CARCINOGENICITY

Nuclide	ICRP Lung Class	GI Absorption Factor (F_1)	Slope Factor Age-averaged lifetime excess total cancer risk per unit intake or exposure			Pathway-Specific Unit Risk Age-averaged lifetime excess total cancer risk per unit daily intake or exposure for 70 years			
			Inhalation (pCi)[1]	Ingestion (pCi)[1]	Ground Surface (yr/[pCi/m²])[1]	Air (pCi/m³)[1]	Drinking Water (pCi/L)[1]	External Exposure (pCi/g)[1]	Soil Ingestion (pCi/g)[1]
Am-241	W	1 OE-03	4 OE-08	3.1E-10	1 6E-02	2.1E-02	1 6E-05	1 6E-05	8 4E-07
Pu-238	Y	1 OE-03	4 2E-08	2.BE-10	6 1E 14	2.1E-02	1 4E-05	5 9E-07	7 6E-07
Pu 239	Y	1 OE-04	4 1E-08	3.1E 11	2.6E-14	2.6E-02	1 6E-06	2.6E-07	8 4E-08
Pu-240	Y	1 OE-04	4 1E-08	3 1E 11	5 9E 14	2.1E-02	1 6E-06	5 9E-07	8 4E-08
Pu 241	Y	1 OE-03	2.9E 10	4 BE 12	0 0E+00	1 5E-04	2.5E-07	0 0E+00	1 3E-08
Pu-242	Y	1 OE-04	3 9E-08	3.0E 11	4 9E 14	2.1E-02	1 5E-06	4 8E-07	8 1E-08

Proposed NESHAPs for Radionuclides (EPA 520/1-89-005) for a more detailed discussion of EPA's current radiation risk assessment methodology

Quantitative carcinogenic factors listed in Table B 1 include the following

> slope factor = risk per unit intake of exposure = risk per pCi inhaled or ingested or as risk per year per pCi/m^2 due to external exposure
>
> pathway-specific unit risk = risk per unit concentration in air, drinking water or soil (external exposure) = risk per pCi/m^3 (air), risk per pCi/L (water), risk per pCi/g (external exposure), or risk pCi/g (soil ingestion)

Unit risk estimates for air, inhalation, drinking water, and soil ingestion pathways provided in Table C were calculated by multiplying the appropriate inhalation and ingestion slope factors by the inhalation rate (20 m^3/day), the water ingestion rate (2 L/day), or the soil ingestion rate (109 mg/day), respectively, and by multiplying all values by the total number of days in 70 years (i e , by the lifetime exposure = 365 days/yr x 70 yrs = 25,550 days) Hence

risk per pCi/m^3 (air)	=	slope factor (risk per pCi inhaled) x 20 m^3/day x 25,550 days
risk per pCi/L (water)	=	slope factor (risk per pCi ingested) x 2 L/day x 25,550 days
risk per pCi/g (soil) (soil ingested)	=	slope factor (risk per pCi ingested) x ([0 2 g/day x 1,825 days] + [0 1 g/day x 23,360 days])

The designations "D," "W," and "Y" presented under the heading "ICRP Lung Class" in Table C refer to the lung clearance times for inhaled particulate radionuclides expressed as days (D), weeks (W), or years (Y), as recommended by the International Commission on Radiological Protection (ICRP) Gaseous radionuclides, e g , Rn-222, are assigned to class "g " "GI Absorption Factors, f," are the fractional amounts of each radionuclide that may be absorbed from the gastrointestinal (GI) tract into blood following an oral intake The ICRP lung clearance rates and GI absorption factors provided in Table C are default values used by the EPA to calculate radionuclide slope factors for inhalation and ingestion exposures, respectively Application of values other than those specified in Table C will result in slope factors and unit risk estimates

different from those provided in the table At this time, EPA recommends that risk assessors should not replace or substitute for the default values listed

Values listed in Table C for external exposure are best estimates of the lifetime cancer risk due to the irradiation of an individual exposed to gamma-emitting radionuclides uniformly mixed in soil Unit risk estimates for this pathway were calculated by multiplying the appropriate ground surface slope factors by the effective surface density of soil (i e , 143 kg/m^2 = 0 10 m [soil depth] x 1 43x10^3 kg/m^3 [soil density]), and by multiplying all values by 70 years (i e , by the lifetime exposure) Hence,

risk per pCi/g (soil) = slope factor (risk per year per pCi/m^2) x 143 kg/m^2 x 10^3 (g/kg) x 70 years

To estimate risk-specific concentrations in air from the unit risk in air as presented in Table C, the specified level of risk is divided by the unit risk for air Hence, the air concentration (in pCi/m^3) corresponding to a best estimate of the increased lifetime cancer risk of $1x10^{-5}$ is calculated as follows

$$pCi/m^3 \text{ in air} = \frac{1x10^{-5}}{\text{unit risk in } (pCi/m^3)^{-1}}$$

Similarly, to estimate risk-specific concentrations in water and in soil (ingestion exposure), the specified level of risk is divided by the unit risk for drinking water or soil ingestion Hence, the water concentration (in pCi/L) corresponding to a best estimate of the increased lifetime cancer risk of $1x10^{-5}$ is calculated as follows

$$pCi/L \text{ in water} = \frac{1x10^{-5}}{\text{unit risk in } (pCi/L)^{-1}}$$

and the soil concentration (in pCi/g) corresponding to a best estimate of the increased lifetime cancer risk of $1x10^{-5}$ is calculated as follows

$$\text{pCi/g in soil (ingestion exposure)} = \frac{1x10^{5}}{\text{unit risk in (pCi/g)}^{1} \text{ (soil ingestion)}}$$

To estimate risk-specific concentrations in soil from the unit risk from external exposure as presented in Table C, the specified level of risk is divided by the unit risk for soil Hence, the soil concentration (in pCi/g) corresponding to a best estimate of the increased lifetime cancer risk of $1x10^{5}$ is calculated as follows

$$\text{pCi/g in soil (external exposure)} = \frac{1x10^{5}}{\text{unit risk in (pCi/g)}^{-1} \text{ (external exposure)}}$$

4 1 RISK CALCULATION - USE OF SLOPE FACTORS

The radionuclide slope factors in Table C of HEAST are the age-averaged lifetime excess total cancer risks per unit intake or exposure An estimate of the total lifetime excess cancer risk due to continuous internal lifetime exposure (i e , a 70-year average lifespan) to a radionuclide is therefore

$$R_L = (SF_L)\ (I)\ T_L)$$

where

R_L = total lifetime excess cancer risk
SF_L = HEAST radionuclide intake slope factor $(pCi)^{1}$
I = annual radionuclide activity intake (pCi/yr)
T_L = 70-year lifetime exposure (years)

An estimate of the total lifetime excess cancer risk due to continuous external exposure to a radionuclide deposited on ground surfaces is

$$R_L = (SF_L)\ (C)\ (T)$$

where

R_L = total lifetime excess cancer risk
SF_L = HEAST radionuclide external exposure slope factor (yr - pCi)[1]
C = radionuclide concentration in soil (pCi/g)
T_L = 70-year lifetime exposure (years)

External slope factors do not include contributions from decay products In some cases, these contributions can be substantial and should be factored into the risk calculations For example, to estimate the total lifetime excess cancer risk due to continuous, lifetime external exposure to soil contaminated with Pu-239, and Pu-240 (assuming secular equilibrium) should be calculated as the summation of the risks contributed by Pu-240 and the decay product that emits photon radiation, such as Am-241

The content of slope factors for chemicals has been well established by toxicologists to quantify risks of chemical-induced cancer based on chemical intake-response curves EPA recently adopted this methodology to quantify radiation-induced cancer risks for radionuclides in HEAST, Table C This is novel for all radiological risk assessors The HEAST slope factors for radionuclides that are potential chemicals of concern at IHSS are presented in Table B 1 Before introducing EPA's methodology for radionuclide slope factors, it is necessary to describe the conventional approach to risk assessment A description of internal exposure is presented because the calculation for this route of exposure is sufficient to furnish a clear paradigm of this standard methodology

4 2 DESCRIPTION OF CONVENTIONAL METHODOLOGY FOR RADIOLOGICAL RISK ASSESSMENT

Conventional risk estimation for chronic intake of a radionuclide involves two independent and separate steps The first step is to calculate the lifetime Committed Effective Dose Equivalent (CEDE) from the chronic lifetime intake of the radionuclide The CEDE is the weighted sum

of the total dose equivalent in target organ(s) deposited over the 50-year period following the intake of a radionuclide The absorbed dose in the target organ(s) is calculated using ICRP respiratory and GI tract models (ICRP, 1979) The second step is to estimate the risk associated with the lifetime CEDE

In the first step, the lifetime CEDE is obtained by multiplying the dose conversion factor (DCF), the CEDE per unit intake, by the total intake over the 70-year lifetime

$$CEDE_L = (I)(T_L)(DCF)$$

where

$CEDE_L$ = lifetime committed effective dose equivalent (mrem)
I = annual radionuclide activity intake (pCi/yr)
T_L = 70-year lifetime exposure (years)
DCF = dose conversion factor (mrem/pCi)

In the second step, the radiation-induced cancer risk is estimated using a risk coefficient (excess fatal cancers/mrem) to relate the lifetime CEDE (mrem) to the lifetime excess radiogenic cancer deaths ICRP Publication 26 (ICRP, 1977) and NCRP Publication 91 (NCRP, 1987) recommend the use of age-independent risk coefficients of 125×10^{-6} and 100×10^{-6} excess cancer deaths, respectively, for every unit CEDE (mrem) received to assess the lifetime excess fatal cancer risk Following is this recommendation

$$R_L = (RC_L)(CEDE_L)$$

where

R_L = lifetime excess fatal cancer risk
RC_L = lifetime fatal cancer risk per unit dose (mrem) [1]
$CEDE_L$ = lifetime committed effective dose equivalent (mrem)

Thus, based on the DCF that uses the 50-year dose commitment model, the CEDE from a constant chronic exposure is considered to be invariant over the individual's 70-year lifetime Because each step estimates cumulative dose and risk over 70 years, both the lifetime dose equivalent and the lifetime radiation-induced risks are obtained and can be utilized independently in the decision-making process

The following is a description of EPA's methodology to calculate the slope factors for both internal and external exposure to radionuclides

4 3 DESCRIPTION OF EPA'S METHODOLOGY FOR SLOPE FACTORS

4 3 1 Internal Exposure

There are three main steps involved in EPA's estimation of the risks due to exposure to unit intake of a radionuclide (1) the annual dose to susceptible organ(s) in each year of life is calculated, (2) the annual dose in each year of life is related to the age-dependent cancer risk, and (3) the lifetime cancer risk is obtained by summing the annual risks to a hypothetical cohort with an actuarial life table

In the first step, EPA calculates instantaneous high- and low-linear energy transfer (LET) absorbed dose rates and annual doses for each organ following one unit of inhaled or ingested radionuclide at a constant rate for a lifetime exposure The internal dose models (GI tract and lung models) that EPA uses to calculate doses are age-independent and are similar or identical to the models used in ICRP (1979, 1980, 1981)

In the second step, the risk of fatal cancer from each year's dose is calculated using age- and organ-specific risk models adapted from the BEIR III report (National Academy of Sciences [NAS] 1980) These risk models used by EPA are described in the following paragraphs

To project the number of radiation-induced leukemia and bone cancer fatalities, EPA uses an absolute risk model, a 2-year latency period, and a 25-year expression period. An absolute risk model predicts an absolute annual number of excess fatal cancers in future years in the case of a population exposed at a given age per unit dose

To estimate the number of fatalities resulting from other cancers, EPA uses a relative risk model, a 10-year latency period, and the remainder of an exposed person's lifetime as the expression period The relative risk model projects the currently observed percentage increase in annual fatal cancer risk per unit dose into future years (i e , the increase is proportional to the underlying [background] fatal cancer risk)

A central feature of this methodology is that it allows for other causes of death, so-called "competing risks" occurring within the latent period, in the estimation of lifetime radiation risks If an individual that had been exposed to radiation in a given population died either accidentally or from natural causes, before the cancers resulting from irradiation are expressed, this death would not be counted as a radiation-induced fatality A life table consists of data describing age-specific mortality rates from all these competing risks A life table consists of data describing age-specific mortality rates from all causes of death for a given population EPA uses mortality data from 1969 to 1971 United States population (National Center for Health Statistics [NCHS] 1975) in this risk estimation

To implement the lifetime risk estimation, EPA uses both absolute and relative risk models (as in the second step) in conjunction with actuarial life tables (as in the third step) to estimate the number of incremental fatalities in a given population, or "cohort," due to radiation-induced cancer in the reference organ as a result of the annual dose of each year of life The hypothetical EPA cohort consists of 100,000 persons born at the same time and all subject to the same competing risks of death throughout their lifetimes Radiation exposure is assumed to begin at birth and continue throughout the lifetime of each individual By applying the 1970 age-specific mortality data for all causes, this population of 100,000 persons is reduced for each year of life until all members of the cohort have died at 110 years

The incremental number of deaths in the cohort due to radiation-induced cancer for a given organ is estimated for each year using appropriate risk models and the calculated doses during that year and relevant preceding years The total number of incremental deaths for the cohort is obtained by summing the incremental number of deaths for each year over all organs for 110 years Therefore, the age-averaged lifetime excess fatal cancer risk per unit intake of the radionuclide is simply the average number of incremental deaths over the 110 years for each individual in the cohort

The radionuclide slope factors in HEAST, Table C, are the age-averaged lifetime excess total cancer risks, instead of fatal cancer risks, per unit intake Each slope factor has been calculated

by dividing the excess fatal cancer risks for the radionuclide by the mortality to incidence risk ratio for the type(s) of cancer induced by the radionuclide

4 3 2 External Exposure

EPA risk estimation for exposure to soil contaminated with gamma-emitting radionuclides is based on the scenario that an individual stands on an infinitely thick slab of soil with a uniform source concentration for his entire life (e g , a 70-year average life span) This EPA scenario involves three main steps

In the first step, the absorbed dose rate in air at 1 m above ground (which represents the average height of body organs for an individual standing on the ground) must be calculated. To manage complicated calculations for photon attenuation and scattering soil, EPA simplifies the situation by assuming that instead of standing on the infinitely thick slab of soil, this individual stands on a smooth infinite plane source with a certain uniform surface concentration This surface concentration is obtained by confining the entire quantity of radioactivity within the top 10 cm of the soil slab to the very ground surface (zero depth) instead of uniformly dispersing it in the soil Consequently, EPA's hypothetical plane source with the zero-depth activity considers no soil shielding for the individual EPA's air and organ dose rate(s) calculation and the associated risk estimations, which will be discussed later, are therefore based on the hypothetical plane source model instead of the infinitely thick slab source model The conversion between the soil concentration (pCi/g) in the soil slab and the EPA hypothetical surface concentration can be obtained from the soil density of $1\ 43 \times 10^3$ (kg/m^3) and EPA's 10 cm soil depth concern One unit of soil concentration (1 pCi/g) in the slab would correspond to a hypothetical surface concentration in the following manner

$$1\ 43 \times 10^5\ (\text{pCi/m}^2) = (\text{pCi/g}) \times 0\ 1\ (\text{m})\ (\text{depth}) \times 1\ 43 \times 10^3\ (\text{kg/m}^3)\ (\text{density}) \times 10^3\ (\text{g/kg})$$

where 0 1 m (soil depth) x $1\ 43 \times 10^3$ kg/m^3 (soil density) = 143 kg/m^2 is the effective surface density of soil

One unit of surface concentration (1 pCi/m^2) on the soil surface would correspond to a concentration in the slab in the following manner

$$(1\ 43 \times 10^5)^{1} = 7 \times 10^{-6}\ (\text{pCi/g})$$

Thus, instead of calculating the air dose at 1 m above an infinitely thick soil slab source, EPA calculates the air dose rate at 1 m above a hypothetical infinite plane source If an individual is actually standing on a uniform slab source with a soil concentration of 1 pCi/g, EPA would report the 1 m air dose rate, his organ dose rate(s), and the associated cancer risks the same as those obtained from a plane source with a surface concentration of $1\ 43 \times 10^5$ pCi/m^2 On the other hand, EPA's report for the cancer risks from one unit of surface concentration (1 pCi/cm^2) is meant to be for the actual situation if the individual is exposed to a uniform slab source with a soil concentration of 7×10^{-6} pCi/g

In the second step, the absorbed rate in air must be converted to an organ dose rate The ratio of the organ dose rate has been calculated for various organs at various photon energies for the case of immersion in contaminated air Ideally, a separate set of the ratio values would be used for the angular and spectral distributions of incident photons from a uniform plane source Because these data are not available, EPA uses the same set of the ratio values for the air immersion case as for the ground surface case

In the third step, the annual dose in each year of life is related to the age-dependent cancer risk, and the lifetime cancer risk is obtained by summing the annual risks to a hypothetical cohort with an actuarial life table This step is a combination of steps (2) and (3) described in Section 4 3 1 The risk from each year's dose for each organ as obtained from step (2) is again calculated using EPA's life table concept in conjunction with the age- and organ-specific risk models The total number of incremental deaths from lifetime ground surface exposure in the 100,000-person cohort is also obtained by summing the incremental number of deaths for each year for 100 years The age-averaged lifetime excess fatal cancer risks per unit surface concentration of a radionuclide is the average number of incremental cancer deaths over the 110 years for each individual in the cohort Using the mortality-to-incidence risk ratio for the significant types of cancer that the external exposure may induce, EPA converts the fatal cancer risks to the total cancer risks as required for the slope factors.

4 4 COMPARISON BETWEEN CONVENTIONAL AND EPA'S METHODOLOGIES FOR RISK ASSESSMENT

There are two principal differences between the conventional and EPA methodologies for radiological risk assessment. First, the conventional risk estimation method produces an estimate of the risk of radiogenic cancers that are fatal and uses an age-independent risk coefficient The EPA risk estimation method produces an estimate of the risk of all cancer incidence and employs age-dependent risk coefficients Second, the conventional risk estimation method involves calculation of dose (CEDE) before calculation of cancer risk The EPA risk estimation methodology using HEAST slope factors estimates cancer risk directly from estimated radionuclide intake and bypasses calculation of CEDE Calculating the CEDE involves much less uncertain models than estimating radiogenic risk This is one main reason why the conventional risk assessment for a lifetime radiation exposure involves calculation of lifetime CEDE The conventional methodology separates the more certain step (lifetime CEDE calculation) from the less certain step (lifetime risk estimation) in the risk assessment process This enables the radiological risk assessors and remedial action decision makers to use both dose and risk parameters, taking into consideration the degree of confidence and certainty in each

The conventional method provides a fundamental parameter (i e , the lifetime CEDE from a chronic exposure to a radionuclide) that provides for comparison of the lifetime CEDE with established dose limits The lifetime risks associated with the lifetime CEDE depend on only one factor the risk per unit effective dose equivalent, which is subject to variation as new scientific information used to develop risk coefficients becomes available In EPA's methodology for estimating the lifetime radiogenic risk using slope factors, the step involving dose estimation is indistinct, therefore, the calculated lifetime dose equivalent is not available Thus, the radionuclide slope factors only provide the relationship between the lifetime radiogenic risk, which has a relatively high magnitude of uncertainty, and the radioactivity intake Superfund radiological risk assessors also need to calculate the lifetime CEDE as used in the conventional approach to furnish more scientific information for decision makers This is even more important at present because the slope factors for radionuclides are undergoing review and revision in HEAST, Table C

APPENDIX C

GENERIC RISK ASSESSMENT FOR EXPOSURE TO PLUTONIUM CONTAMINATION IN SOIL

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ATTACHMENT 1 CALCULATIONS AND IDENTIFICATION OF EXPOSURE FACTORS

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1.0 SOME CONCEPTS OF RISK ASSESSMENT

The principal aim of radiation protection is to reduce the risk of detrimental health effects from radiation exposure Risk has been defined as the probability that a detrimental health effect will occur in an individual or population Mortality risk factors are helpful in identifying levels of risk associated with various activities and occupations Mortality risk factors are listed in Table C 1 for various events Almost every aspect of modern living exposes people to health risks This table lists the estimated risk of death to an individual from various human-caused and natural events In all cases the numbers listed in this table are only estimates based on the best guesses that can be made with our present knowledge

Risk is usually expressed as either absolute risk or relative risk. When applied to radiation exposure an individual's absolute risk of mortality for a specific cause such as cancer is the excess risk from exposure added to his/her background risk of death from cancer The term lifetime excess cancer risk is used to describe the portion of absolute risk resulting from exposure

The carcinogenic risk or the cancer risk factor (lifetime excess cancer risk) provides an estimate of the additional incidence of cancer that may be expected in a population exposed to a given contaminant. A risk of 10^{-5}, for example, indicates a probability of one additional case of cancer for every 100,000 people exposed. A risk of 10^{-6} would be 1 case in 1 million people exposed (EPA, 1985) On an individual basis the cancer risk factor describes the additional risk or probability of death from cancer incurred as a result of exposure

TABLE C.1

PROBABILITY OF DEATH BY VARIOUS CAUSES[a]
(U S Population Average for 1978)

Cause	Total Number of Deaths	Individual Risk (Lifetime Probability)[b]
Accidents		
Motor Vehicle	52,411	1.28×10^{-2}
Air Transport	1,880	6.0×10^{-4}
Railway	602	2.0×10^{-4}
Falls	13,690	4.4×10^{-3}
Fire	6,163	2.0×10^{-3}
Drowning	5,784	1.9×10^{-3}
Industrial	5,168	1.7×10^{-4}
Electrocution	984	3.2×10^{-4}
Explosion	562	1.8×10^{-4}
Firearms	1,806	5.8×10^{-4}
Diseases		
Cardiovascular	964,000	3.1×10^{-1}
Malignancies (cancer)	396,720	1.3×10^{-1}
Influenza/Pneumonia	58,230	1.9×10^{-2}
Diabetes	33,800	1.1×10^{-2}
Natural Events		
Lightning	160	5.1×10^{-5}
Tornadoes	118[c]	3.8×10^{-5}
Hurricanes	90[d]	2.9×10^{-5}

[a] Compiled from Transurania documents, EPA 52011-90-015
[b] Based on total U S population
[c] 1953-75 average
[d] 1901-71 average

UNDERSTANDING EXPONENTS

Exponential Notation	Decimal Notation	Probability
10^{0}	1.0	1 in 1
10^{1}	0.1	1 in 10
10^{2}	0.01	1 in 100
10^{3}	0.001	1 in 1,000
10^{-4}	0.0001	1 in 10,000
10^{5}	0.00001	1 in 100,000
10^{6}	0.000001	1 in 1,000,000
10^{7}	0.0000001	1 in 10,000,000

The carcinogenic risk posed by exposure to a radionuclide depends upon three factors dosage (estimated intake), the carcinogenic potency of the chemical (Potency Factor), and the exposure duration

The carcinogenic potency of a substance depends, in part, upon its route of entry into the body (e g , ingestion, inhalation, or dermal) Therefore, cancer slope factors (CSFs) are classified according to the route of administration that is applicable to the experimental or epidemiological data from which they were derived. The EPA and other organizations have developed potency factors for the ingestion and/or inhalation routes for some carcinogens

The length of exposure to a radionuclide must also be taken into account in the calculation of carcinogenic risk since carcinogenic potency factors are based on long-term, low-dose exposure and carcinogenic risk is assumed to be proportional to dose

Absolute risk takes into account the added risk from exposure and background risk, exposure-specific absolute risk (AR) (such as that from plutonium in soil) can thus be defined as

AR (cancer death) = Background Risk + Risk from Exposure to Plutonium

Based on the conservative assumptions presented in the generic risk assessment, the added risk from residential home construction in an area of plutonium contamination would result in an increase of $2\ 2 \times 10^{-7}$ risk for a plutonium concentration of 1 pCi/g and would result in an increase of $2\ 2 \times 10^{-6}$ risk for a concentration of 10 pCi/g, and an increase of $2\ 2 \times 10^{-5}$ risk for a concentration of 100 Pci/g

Theoretical Calculated Generic Risk Assessment for Pu-239*	
Average Soil Concentration	Individual Risk (Lifetime Probability)
1 pCi/g	$2\ 2 \times 10^{-7}$
10 pCi/g	$2\ 2 \times 10^{-6}$
100 pCi/g	$2\ 2 \times 10^{-5}$

*Conservative residential exposure scenario (future use)

Figure C-1 is a generic "risk curve" for plutonium-239 in soils covering the range of 1 to 100 pCi/g The hypothetical future use residential exposure scenario is illustrated along with a hypothetical recreational use scenario

To put this risk in perspective, we will use the natural cancer mortality rate stated by EPA in Table C 1 of 13 percent (about one in eight) An individual's absolute risk of dying from cancer after 70 years from a 30-year exposure to plutonium in soils in a 70-year lifetime would increase from 0 13 to 0 1300003 at 1 pCi/g and 0 130003 for 10 pCi/g based on generic risk assessment assumptions Table C 2 lists the overall increase in absolute risk resulting from long-term exposure to plutonium in a residential setting

TABLE C.2

OVERALL INCREASE IN ABSOLUTE RISK FROM EXPOSURE TO PLUTONIUM IN SOILS

Plutonium Concentration in Soil	Added Risk	Background	Absolute Risk	Increased Risk from Plutonium
1 pCi/g	2.2×10^{7}	1.3×10^{1}	0.1300002	0.000015 percent
10 pCi/g	2.2×10^{-6}	1.3×10^{1}	0.130002	0.00015 percent
100 pCi/g	2.2×10^{-5}	1.3×10^{1}	0.13002	0.0015 percent

DRAWN BY	KRONER	CHECKED BY		DRAWING NUMBER
	2-21-91	APPROVED BY		304923-A10

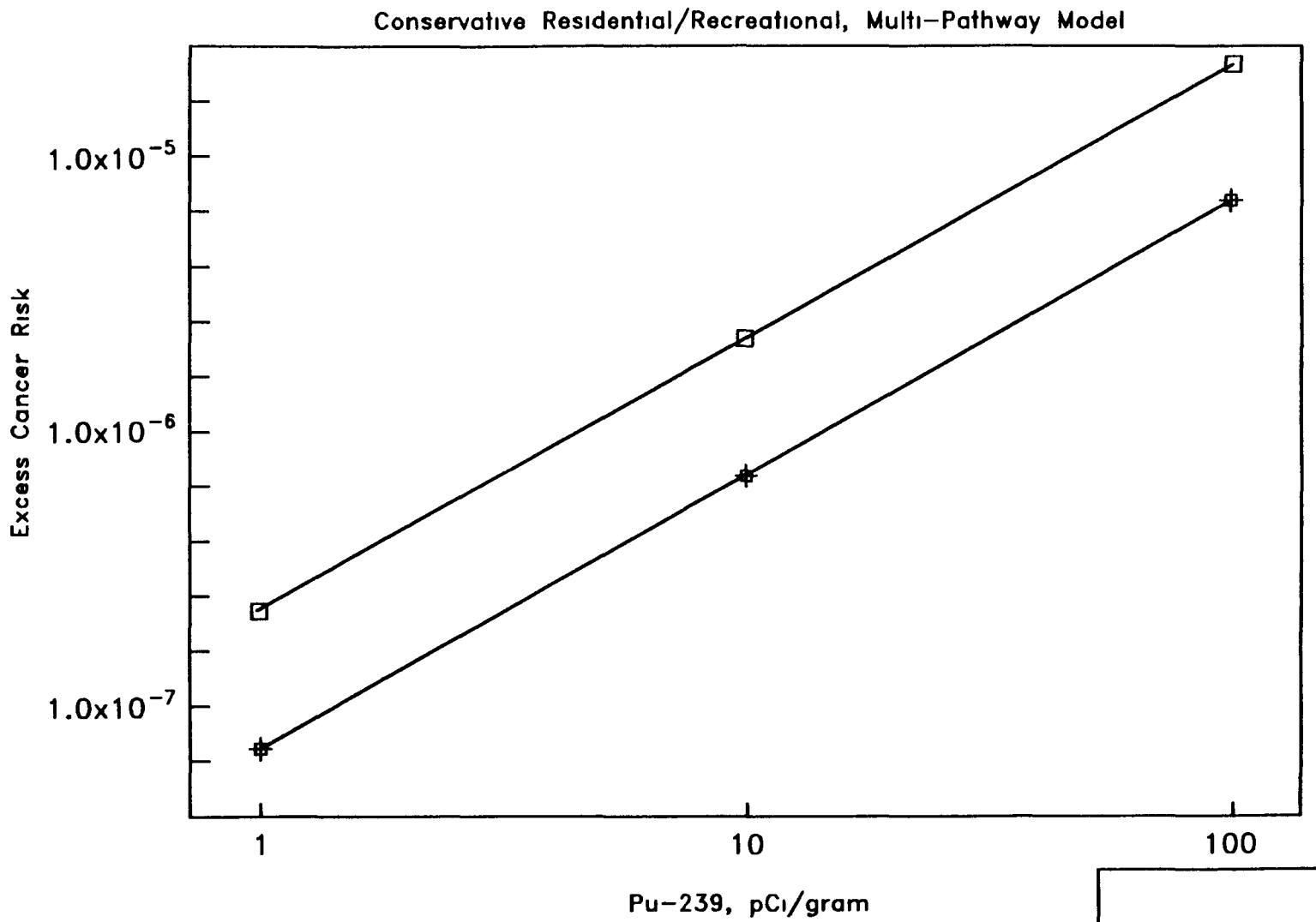


FIGURE C-1

EXCESS CANCER RISK FOR PU-239 IN SOILS

CONSERVATIVE MODEL

Risk Calculations based on values taken from
EPA Exposure Factors Handbook, EPA/600/8-889/043, May 1989

2.0 GENERIC RISK CHARACTERIZATION

The EPA has requested that a generic risk characterization be developed to assist the reader in placing the potential risk from plutonium in soils in perspective Two EPA documents were principally utilized to obtain general emission, transport, and human uptake values The two documents were the "Transuranic Elements," EPA 520/1-90-015 and 016, June 1990, U S EPA Air and Radiation Programs (EPA, 1990b), and the "Exposure Factors Handbook," EPA/600/8-89/043, May 1989, U S EPA Office of Health and Environmental Assessment These values were then used to perform calculations based on the formulas found in Chapter 10 of the Risk Assessment Guidance (RAG) for Superfund Human Health Evaluation Manual, Part A, Interim Final, U S EPA Office of Emergency and Remedial Response, September 1989 In addition, the Health Effects Summary Table (HEAST) was utilized to calculate pathway-specific risk Detailed calculations and identification of all exposure factors for the generic risk assessment can be found in Attachment 1 The dispersion and modeling used in the generic risk assessment is taken from Cowherd (1984) for the PM_{10} emission rate estimation, and Turner (1970) for the atmospheric dispersion estimation

For estimation of PM_{10} emissions from vehicle traffic over unpaved surfaces, the following equation has been used in this assessment

$$E_{10} = 0\ 85 \left(\frac{S}{10}\right) \left(\frac{S}{24}\right)^{0\ 8} \left(\frac{W}{7}\right)^{0\ 3} \left(\frac{w}{6}\right)^{1\ 2} \left(\frac{365-p}{365}\right) \quad (4\text{-}7)$$

where. E_{10} = PM_{10} emission factor, i e , the quantity of PM_{10} emissions from an unpaved road per vehicle-kilometer of travel (kg/VKT)
s = silt content of road surface material (percent)
S = mean vehicle speed (km/hr)
W = mean vehicle weight (Mg)
w = mean number of wheels
p = number of days with at least 0 25 mm (0 01 in) of precipitation per year

The atmospheric dispersion estimation uses the following standard assumptions

- The plume spread has a Gaussian distribution in both the horizontal and vertical planes

- Uniform emission rate occurs

For this ground level source with no effective plume rise the following equation has been used in this assessment

$$\chi(X,0,0,0) = \frac{Q}{\pi \delta_y \delta_z \mu}$$

where X = downwind distance
χ = mean concentration
$\delta_y \delta_z \mu$ = standard deviation of plume concentration in the vertical and horizontal planes
μ = mean windspeed affecting plume

Plant and vegetable uptake coefficients used were those cited by Burley (EPA, 1990b), since these values represent conservative assumptions, and may in fact overestimate the risk from plant and food crop ingestion As stated previously (Section 4 6 2), although americium is potentially more mobile in the environment, and more readily bioconcentrated, it is not included in this generic risk assessment due to the inherent uncertainty of the actual concentrations at IHSS 199

2 1 EXPOSURE PATHWAYS

The generic risk assessment uses human uptake values published in previously cited EPA documents

The following exposure pathways have been retained in the generic risk assessment because of their potential to be available to human receptors based on the future land use condition of residential home setting

- Inhalation of plutonium-contaminated dust
- Ingestion of plutonium in soil
- Ingestion of leafy fruits and vegetables grown in an on-site garden
- Ingestion of root and tuber vegetables grown in an on-site garden
- Ingestion of home-raised beef (muscle)
- Ingestion of home-raised beef (liver)
- Ingestion of milk from home-raised cows

2 2 EXPOSURE PATHWAY ASSUMPTIONS

In calculating risks to the general public in this report, the estimates of exposure are performed considering an appropriate individual that is presumed to remain at the point of specific potential exposure (1 pCi/g, 10 pCi/g, 100 pCi/g) at all times for a 30-year duration -- 24 hours per day, 365 days per year -- and makes ordinary use of the contaminated media For example, this hypothetical individual could breath only air at the specified contamination level on-site boundary or eat vegetables from their garden which is assumed to be planted at the specified exposure to contaminants Thus, the estimate of exposure or risk to the general public approximates the reasonable maximum exposure scenario (RME) identified by EPA guidance

Intakes of plutonium have been estimated on the basis of the RME scenarios for both current (i e , recreational) and future (i e , residential) land use conditions The RME is defined by the EPA (1989) as "the highest exposure that is reasonably expected to occur at the site This concept is also set forth in EPA's preamble to the adoption of the National Contingency Plan In the preamble, the EPA explains that the concept of RME is designed to include all exposures that can be reasonably expected to occur; it does not focus on worst-case exposure assumptions Only potential exposures that are likely to occur are to be included in the assessment of exposures The EPA further cautions against the use of unrealistic exposure scenarios and assumptions The RME is the product of factors that are an appropriate mixture of values that are conservative in that they tend to overestimate risk, but they are within a realistic range of potential exposure The selection of parameter values is based on a mixture of values characteristic of either average individuals or within a 95 percentile distribution for the public to determine a reasonable overall assessment of potential exposures to individuals

Parameters that were common for all scenarios were used in the calculation of risk as follows

1 Future land use scenario of residential home setting

2 On-site concentration of plutonium in transport media does not increase nor decrease over time

3 An on-site air intake of 20 cubic meters per day for a 70 Kg adult received over a 30-year duration

4 An average soil intake rate of 0 12 grams per day for a 70 Kg adult received over a 30-year duration (this represents a combined 200 mg/day soil ingestion rate for years 0-6 and a 100 mg/day soil ingestion rate for years 7-30)

5 A plutonium in soil bioavailability of 100 percent based on the soil ingestion and foodstuff pathway

6 A cancer slope factor of 3 1E-11/pCi ingested, and a slope factor of 4 1E-08/pCi inhaled These are taken from the EPA HEAST values that correspond to the GI absorption factors for plutonium oxide

Table C 3 details the individual pathway risks and relative contributions for the possible current use recreational setting and the hypothetical future use residential setting

2 3 GENERIC RISK CHARACTERIZATION FOR CONDITIONS BEFORE, DURING AND AFTER REMEDY

Court-mandated institutional controls have been set as limiting conditions for remedial action to occur at IHSS 199 Exceeding the parameters of wind speed, soil moisture, and airborne plutonium concentrations would require a shut-down of the remedial action The following assumptions have been made in the calculation of risk to workers and the public

1 Tilling and discing will occur for a six-week period

2 No reduction in plutonium transport concentrations will be taken as a result of institutional controls

3 The maximum allowable airborne plutonium value will be used for both worker and public exposure

4 The public will be exposed 12 hours per day 5 days per week to 0 02 pCi/m^3 of plutonium^{239} in air and have a daily intake of 500 mg of soil during the remedy period

5 No ingestion of plutonium contaminated foodstuffs will occur

Table C 4 presents the hypothetical risk characterization based on conservative current and future use scenarios Table C 5 presents the hypothetical risk assessment based on the generic exposure conditions and risk estimation curve discussed above The "Before Remedy" assessment assumes a steady-state plutonium^{239} soil concentration of 7 7 pCi/g During remedy estimates are based

TABLE C.3

MAJOR ASSUMPTIONS USED IN THE GENERIC RISK ASSESSMENT FOR PLUTONIUM IN SOILS

Current Use (Recreational Setting)		
Exposure Pathway	**Variable**	**Conservative**
Inhalation Suspended Particulate	Exp Duration Exp Frequency	40 years 56 day/year
Soil Ingestion	Exp Duration Exp Frequency	40 years 56 day/year

Future Use (Residential Setting)		
Exposure Pathway	**Variable**	**RME[b]**
Soil Ingestion	Exp[a] Duration	30 years
Inhalation Suspended Particulate	Exp Duration Exp Fraction	30 years 0 46[c]
Ingestion Leafy Fruits & Vegetables	Exp Duration Intake	30 years 33 gr/day
Ingestion Root & Tuber Fruits & Vegetables	Exp Duration Intake	30 years 89 gr/day
Ingestion Home-Raised Beef (Muscle)	Exp Duration Intake	30 years 118 gr/day
Ingestion Home-Raised Beef (Liver)	Exp Duration Intake	30 years 6 gr/day
Ingestion Milk from Home-Raised Cows	Exp Duration Intake	30 years 305 gr/day

[a] EXP - exposure
[b] RME - Reasonable Maximum Exposure
[c] Based on long-term wind patterns near Rocky Flats Plant

TABLE C.4

RISK CHARACTERIZATION FOR CONSERVATIVE SCENARIOS

Conservative Current Use (Recreational) Exposure Scenario				
	Hypothetical 239 Pu Soil Concentrations			Percent Contribution
Pathway	1 pCi/g	10 pCi/g	100 pCi/g	
Inhalation of dust	7 0E-08	7 0E-07	7 0E-06	96 5
Ingestion of soil	2 0E-09	2 0E-08	2 0E-07	3 5
Total Risk	7 0E-08	7 0E-07	7 0E-06	100

Conservative Future Use (Residential) Scenario				
	Hypothetical 239 Pu Soil Concentrations			Percent Contribution
Pathway	1 pCi/g	10 pCi/g	100 pCi/g	
Ingestion of soil	4 1E-08	4 1E-07	4 1E-06	18 7
Inhalation of dust	3 0E-08	3 0E-07	3 0E-06	13 8
Ingestion of Leafy Vegetable	1 1E-07	1 1E-06	1 1E-05	51 9
Ingestion of Tuber	3 3E-08	3 3E-07	3 3E-06	15 3
Ingestion of Muscle	4 0E-10	4 0E-09	4 0E-08	0 2
Ingestion of Liver	4 1E-10	4 1E-09	4.1E-08	0 2
Ingestion of Milk	3 3E-12	3 3E-11	3 3E-10	0 0
Total Risk	2 2E-07	2 2E-06	2 2E-05	100

on the conservative exposure assumptions presented above After remedy estimates of risk assume a steady-state plutonium^{239} soil concentration of 0 9 pCi/g which is the court mandated remedy action level

Review of Table C 5 suggests that the added lifetime excess cancer risk for all potentially exposed members of the public during any phase of the remedy program would be in the range of $2x10^{7}$ to $6x10^{8}$ These generic estimates of lifetime excess cancer risk are all below the U S. EPA's target risk range of $1x10^{-4}$ to $1x10^{-6}$ The effect of remedy actions can be observed by contrasting the before remedy recreational use risk estimate of $5\ 4x10^{-7}$ with the after remedy estimate of $6.3x10^{-8}$ The reduction in risk from remedy efforts is proportional to the reduction in plutonium concentrations in soil from 7 7 pCi/g to 0 9 pCi/g

2 4 SUMMARY

The risk values calculated for all of the various scenarios and exposure pathways indicate that no imminent threat to the public is produced from plutonium^{239} concentrations of 1 pCi/g, 10 pCi/g, or 100 pCi/g

TABLE C 5

HYPOTHETICAL RISK ASSESSMENTS DERIVED FROM THE GENERIC RISK ASSESSMENT[a]

Exposure Scenario	Before Remedy	During Remedy	After Remedy
Recreational Use	$5\ 4 \times 10^{-7}$ [b]	$7\ 4 \times 10^{8}$ [c]	$6\ 3 \times 10^{8}$ [d]
Residential Use	NA	NA	$2\ 0 \times 10^{-7}$ [d]

[a] The risk estimates presented in this table are hypothetical and are based on the generic curve presented in Figure C-1 in conjunction with estimates of soil concentration that have been judged to be unacceptable for performing a Baseline Risk Assessment See Appendix A for a discussion of the limitations on all data presented in this report

[b] Based on a Pu-239 soil concentration of 7 7 pCi/g 7 7 pCi/g is the highest soil plutonium concentration in the off-site areas reported in Table 4 2 The higher concentrations reported in Table 4 2 represent RFP on-site sampling points

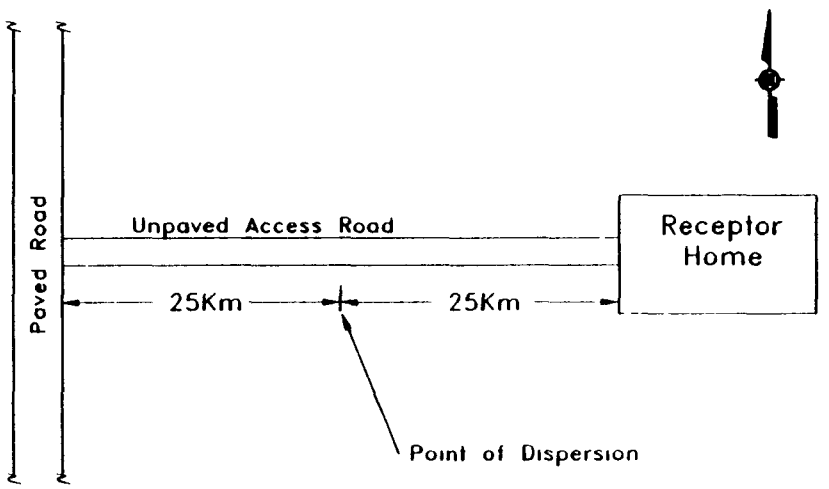
[c] Public receptor exposure at the edge of the remedy acreage is based on soil plutonium concentration of 10 pCi/g for a 6-week period (the actual remedy action period), 12 hours per day, 5 days per week with a 500 mg/day soil ingestion and 0 02 pCi/m^3 inhalation exposure

[d] Based on a Pu-239 soil concentration of 0 9 pCi/g 0 9 pCi/g is the soil plutonium remediation objective It is the highest permissible residual concentration It is likely that many portions of the remediated will have plutonium concentrations less than 0 1 pCi/g

NA - based on conditions at the site, these exposure conditions did not exist during the remedy phase specified.

DRAWN BY	KRONER	CHECKED BY	APPROVED BY	DRAWING NUMBER
	3-19-91			304923-A24

I Conceptual Source/Dispersion/Receptor Configuration for Estimating The Risk from Inhalation of Suspended Soils



1) Dust is released mechanically by vehicular motion

2) 5 round trips/day over the 0 5Km access road

3) Entire emission length (0 5Km) is dispersed over the average travel distance (0 25Km)

4) Wind disperses dust toward receptor (W→E) 46% of the time based on RFP longterm windrose

II PM-10 Emission Rate Estimation (1)

Parameter	Unit	Value	Remark
Silt Content	%	15	Typical
Vehicle Speed	Km/hr	48	30 miles/hour
Vehicle Weight	Mega gram	2 7	3 Ton Vehicle
No Wheels	Integer	4	Typical Truck or Car
Days/Yr with ppt > 0 254mm	Integer	98	NOAA for Stapleton Airport
Vehicle Kilometers per day	Kilometer/day	5	10 One-way Trips @ 0 5 km

III Atmosphere Dispersion Estimation (2)

Parameter	Unit	Value	Remark
Stability Class	None	C	Typical for RFP
Dispersion Distance	m	250	0 25km is 1/2 the Vehicle Distance/Trip
Wind Speed	m/s	4	Long Term RFP Average
σ_y	m	28	Figure 3-2 (2)
σ_z	m	17	Figure 3-3 (2)
Leeward Fraction	None	0 46	Fractional Time Wind Blows From Source to Receptor

(1) Cowherd et al 1984 Midwest Research Institute US EPA Office of Health and Assessments

(2) Turner 1970 Workbook of Atmospheric Dispersion Estimate US EPA Air Programs

THIS SPREADSHEET COMPUTES GENERIC RISKS FROM Pu 239 IN SOILS

These computations are generic and are based soley on the application of standard exposure and toxicity factors These computations are intended to reflect conditions potentially representative of generic conditions

DATA TABLE

1) Common

Variable	Estimate
EF (day/y	365
ED (yrs)	30
BW (kg)	70
AT (days)	25500

2) Scenario Specific

Variable	Estimate
Ingestion of S Soil	
IR (mg/day)	120
Particulate Inhnhalation	
IhlR (m 3/day)	20
Vegetable Ingestion	
Dist/Coef/Leaf	0 0101
Dist/Coef/Root	0 0011
Bio Avail	1
Beef Ingestion	
Dist/Coef/Muscle	0 00001
Dist/Coef/Liver	0 002
Dist/Coef/Milk	3 2E-08
Bio Avail	1

3) Compound Specific

Variable	Estimate	
Plutonium-239		
FI (Fraction)	1	
Burley, G , EPA/520/1-90-015		
Burley, G , EPA/520/1-90-015		
Burley, G , EPA/520/1-90-015		
Burley, G , EPA/520/1-90 015		
Burley, G , EPA/520/1-90-015		

PRIMARILY EXPOSURE FACTORS HANDBOOK INTAKES (EPA 600 8-89 043)

I CONSERVATIVE RESIDENTIAL EXPOSURE SETTING

A INGESTION OF CHEMICALS IN SOIL

Parameter	Unit	Constants	Pu 239	Pu-239	Pu-239
Soil Activity Conc	pCi/gr		1	10	100
Intake (30 yr avg)	mg /day	120 0			
Exp Frequency	day/yr	365			
Exp Duration	yr	30			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	1			
Exp Period Intake	pCi		1314	13140	131400
Avg Dose/Day	pCi/kg-day		7 4E 04	7 4E-03	7 4E-02
Potency Slope (EPA)	/pCi		3 1E 11	3 1E-11	3 1E-11
L E C R @	unitless		4E-08	4E-07	4E-06
Log10 L E C R			7 39004	-6 39004	-5 39004

@ Lifetime Excess Cancer Risk

B) INHALATION OF RESUSPENDED SOIL

Parameter	Unit	Constants	Pu-239	Pu 239	Pu-239
Soil Activity Conc	pCi/gr		1	10	100
Particulate Conc	ug/m 3	7 26			
Activity Particulate	pCi/m 3		7 3E-06	7 3E-05	7 3E-04
* E10 (emission rate)	ug/sec	4 34E+04			
Leeward Exp Fraction	unitless	0 46			
Chi/Q (C-stab, 0 25km)	m 3/sec	5979			
Intake (30 yr avg)	m 3/day	20 0			
Exp Frequency	day/yr	365			
Exp Duration	yr	30			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	0			
Exp Period Intake	pCi		7 3E-01	7 3E+00	7 3E+01
Avg Dose/Day	pCi/kg-day		8 9E-07	8 9E-06	8 9E-05
Potency Slope (EPA)	/pCi		4 1E-08	4 1E 08	4 1E-08
L E C R	unitless		3E-08	3E 07	3E 06
Log10 L E C R			-7 52303	-6 52303	-5 52303

Note Exposure is averaged over 24 continuous hours

B) COMPUTATION OF RESUSPENDED SOIL (Cowherd's Rapid Assessment Model #)

1) PM10 emission rate

Parameter	Unit	Value
s, silt content	%	15
S, vehicle speed	km/hr	48
W, vehicle wt	mg	2 7E+00
w, no wheels	none	4
p, no day of ppt	none	98
E10, PM10 emission	kg/V-KT	0 75
V-KT	kt/day	5
* E10 PM10 emission	kg/sec	4 34E-05
Chi/Q ##	m 3/sec	5979
Fraction Leeward	unitless	0 46

Midwest Research Inst /EPA Office of Env & Assess , 1984
Rapid Assessment of Exposure to Particualte Emissions
from Surface Sites

Class C Stability
W S 4 m/sec (Longtime RFP avg)
Dispersion distance=250m
Sigma y=28m
Sigma z=17m
Pi=3 14
Turner's Workbook of Atmospheric
Dispersion Estimates, EPA/1970

C) INGESTION OF FRUITS & VEGETABLES (Leafy)

Parameter	Unit	Constants	Pu 239	Pu-239	Pu-239
Soil Activity Conc	pCi/gr		1	10	100
Intake (30 yr avg)	mg /day	33000 0			
Exp Frequency	day/yr	365			
Exp Duration	yr	30			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	1			
Distribution coef	fraction	0 0101			
Exp Period Intake	pCi		3649 635	36496 35	364963 5
Avg Dose/Day	pCi/kg-day		2 0E-03	2 0E 02	2 0E-01
Potency Slope (EPA)	/pCi		3 1E-11	3 1E-11	3 1E-11
L E C R	unitless		1E-07	1E-06	1E-05
Log10 L E C R			-6 94638	-5 94638	-4 94638

D) INGESTION OF FRUITS & VEGETABLES (Root & Tuber)

Parameter	Unit	Constants	Pu 239	Pu-239	Pu-239
Soil Activity Conc	pCi/gr		1	10	100
Intake (30 yr avg)	mg /day	89000 0			
Exp Frequency	day/yr	365			
Exp Duration	yr	30			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	1			
Distribution coef	fraction	0 0011			
Exp Period Intake	pCi		1072 005	10720 05	107200 5
Avg Dose/Day	pCi/kg-day		7 4E-04	7 4E-03	7 4E-02
Potency Slope (EPA)	/pCi		3 1E-11	3 1E-11	3 1E-11
L E C R	unitless		3E-08	3E-07	3E-06
Log10 L E C R			-7 47844	-6 47844	-5 47844

E) INGESTION OF HOME RAISED BEEF (Muscle)

Parameter	Unit	Constants	Pu 239	Pu 239	Pu 239
Soil Activity Conc	pCi/gr		1	10	100
Intake (30 yr avg)	mg /day	118000 0			
Exp Frequency	day/yr	365			
Exp Duration	yr	30			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	1			
Distribution coef	fraction	0 00001			
Exp Period Intake	pCi		12 921	129 21	1292 1
Avg Dose/Day	pCi/kg day		7 4E-04	7 4E-03	7 4E-02
Potency Slope (EPA)	/pCi		3 1E-11	3 1E-11	3 1E-11
L E C R	unitless		4E-10	4E-09	4E-08
Log10 L E C R			-9 39734	-8 39734	-7 39734

F) INGESTION OF HOME-RAISED BEEF (Liver)

Parameter	Unit	Constants	Pu-239	Pu-239	Pu 239	
Soil Activity Conc	pCi/gr		1	10	100	
Intake (30 yr avg)	mg /day	600 0				
Exp Frequency	day/yr	365				
Exp Duration	yr	30				
Avg Time	day	25500				
Body Weight	kg	70				
Fract From Soil	fraction	1				
Distribution coef	fraction	0 002				
Exp Period Intake	pCi		13 14	131 4	1314	
Avg Dose/Day	pCi/kg-day		7 4E-06	7 4E-05	7 4E-04	**
Potency Slope (EPA)	/pCi		3 1E-11	3 1E-11	3 1E-11	
L E C R	unitless		4E-10	4E-09	4E-08	
Log10 L E C R			-9 39004	-8 39004	-7 39004	

G) INGESTION OF MILK FROM HOME-RAISED COWS

Parameter	Unit	Constants	Pu 239	Pu-239	Pu-239
Soil Activity Conc	pCi/gr		1	10	100
Intake (30 yr avg)	mg /day	305000 0			
Exp Frequency	day/yr	365			
Exp Duration	yr	30			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	1			
Distribution coef	fraction	3 2E-08			
Exp Period Intake	pCi		0 105870	1 058700	10 58700
Avg Dose/Day	pCi/kg-day		5 9E-08	5 9E-07	5 9E-06
Potency Slope (EPA)	/pCi		3 1E-11	3 1E-11	3 1E-11
L E C R	unitless		3E-12	3E-11	3E-10
Log10 L E C R			-11 4838	-10 4838	-9 48386
Sumation Rollup			-6 66173	-5 66173	-4 66173

Contributions Pathway	@ 1 pCi/gr Individual	%
Ingest soil	4 1E-08	18 7%
Inhal dust	3 0E-08	13 8%
Ingest leafy	1 1E-07	51 9%
Ingest tuber	3 3E-08	15 3%
Ingest muscle	4 0E-10	0.2%
Ingest liver	4 1E 10	0 2%
Ingest milk	3 3E-12	0 0%
Total	2 2E 07	100 0%

A) INHALATION OF RESUSPENDED SOIL

Parameter	Unit	Constants	Pu-239	Pu 239	Pu 239
Soil Activity Conc	pCi/gr		1	10	100
Particulate Conc	ug/m 3	72 61			
Activity-Particulate	pCi/m 3		7 3E-05	7 3E 04	7 3E-03
* E10 (emission rate)	ug/sec	4 34E+04			
Chi/Q (C-stab, 0 25km)*	m 3/sec	598	This is an arbitrary 10% of residential		
Intake (8 hr/day)	m^3/day	10 0			
Exp Frequency	day/yr	56			
Exp Duration	yr	40			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	1			
Exp Period Intake	pCi		1 6E+00	1 6E+01	1 6E+02
Avg Dose/Day	pCi/kg-day		8 9E-06	8 9E-05	8 9E-04
Potency Slope (EPA)	/pCi		4 1E-08	4 1E-08	4 1E-08
L E C R	unitless		7E 08	7E 07	7E-06
Log10 L E C R			-7 17598	-6 17598	-5 17598

* Arbitrary scaling from the residential which yields a 10 forld increase in exposure concentration

B) INGESTION OF CHEMICALS IN SOIL

Parameter	Unit	Constants	Pu-239	Pu-239	Pu 239
Soil Activity Conc	pCi/gr		1	10	100
Intake (40 yr avg)	mg /day	115 0			
Exp Frequency	day/yr	56			
Exp Duration	yr	40			
Avg Time	day	25500			
Body Weight	kg	70			
Fract From Soil	fraction	0 3			
Exp Period Intake	pCi		77 28	772 8	7728
Avg Dose/Day	pCi/kg-day		4 3E-05	4 3E-04	4 3E-03
Potency Slope (EPA)	/pCi		3 1E-11	3 1E-11	3 1E-11
L E C R	unitless		2E-09	2E 08	2E-07
Log10 L E C R			-8 62057	-7 62057	-6 62057
SUMMATION			6 9E-08	6 9E-07	6 9E-06
Log Summation			-7 16065	-6 16065	-5 16065

APPENDIX D
IHSS 199 DATA SOURCES

Document	Data Source	Nature of Data
D-1	United States Atomic Energy Commission, "Plutonium in Soil Around the Rocky Flats Plant," by P W Krey and E P Hardy, Health and Safety Laboratory USAEC, New York, NY, HASL-235, 1 August 1970	Plutonium concentrations in soil samples collected in early 1970 from 33 sites extending as far as 40 miles from the Rocky Flats Plant
D-2	Dow Chemical, "Committee Evaluation of Plutonium Levels in Soil Within and Surrounding USAEC Installation at Rocky Flats, Colorado," by J R Seed et al , RFP-INV-10, 9 July 1971	Plutonium concentrations in soil samples collected in 1969 and 1970 from 135 locations within and around the Rocky Flats Plant
D-3	Dow Chemical, "Soil Sampling East of Indiana Avenue," by R W Loser and R L Tibbals, Product and Health Physics Research Service Report No 317-72-186, 29 November 1972	Plutonium concentrations in soil samples collected on November 17, 1972 from 20 sites within and around the IHSS 199 lawsuit acreage
D-4	Rockwell International, "Results of Special Soil Samples Collected Adjacent to the Rocky Flats Plant Site," by C T Illsley, Environmental Analysis and Control, ES-376-77-201, 7 September 1977 (revised 30 November 1979)	Selected radionuclide concentrations (including plutonium and americium) in soil samples collected in August, 1976 from 25 sites within the IHSS 199 lawsuit acreage
D-5	Colorado Department of Health, "Radioactive Soil Contamination (Cesium-137 and Plutonium) in the Environment Near the Rocky Flats Nuclear Weapons Plant," September 1977	Plutonium and cesium-137 concentrations in soil samples collected in 1977 from sites within the IHSS 199 lawsuit acreage
D-6	Rockwell International, "Comparison of Air Sampler Stations," internal letter from M W Hume, Statistics Laboratory, to C T Illsley, 22 November 1978	Plutonium concentrations in ambient air samples collected between November 1976 and August 1978 from special air monitoring stations on and near the IHSS 199 lawsuit acreage

APPENDIX D
IHSS 199 DATA SOURCES
(continued)

Document	Data Source	Nature of Data
D-7	Rockwell International, "Plutonium Concentrations in Soil on Lands Adjacent to the Rocky Flats Plant," by C T Illsley and M W Hume, Energy Systems Group, LPR-1, 16 March 1979	Plutonium concentrations in soil samples collected in 1976 and 1977 from sites within the IHSS 199 lawsuit acreage
D-8	Rockwell International, "Disclosure to the City of Broomfield," 22 January 1985	Page 9 Average plutonium concentrations in soils on City of Broomfield remedy acreage Page 15A Average annual plutonium concentrations in air and soil within and around the IHSS 199 lawsuit acreage
D-9	Rockwell International, "Soil Sample Collection and Analysis for Plutonium on Lands Adjacent to Great Western Reservoir for the City of Broomfield," by C T. Illsley, EAC-47-85-1, 10 April 1985	Plutonium concentrations in 15 composite soil samples collected in 1985 from ten-acre plots within the City of Broomfield remedy acreage
D-10	Rockwell International, "Remedial Action Program on Jefferson County Open Space Land in Section 7, T2S, R69W, South of Great Western Reservoir," by C T Illsley, EAC-420-87-1, 15 January 1987	Summary of remedy actions through 1986 on Jefferson County remedy acreage, including plutonium concentrations in composite soil samples collected in 1977 and 1985 from ten-acre plots within the remedy acreage, and average soil plutonium concentrations on eleven strips of land after tilling in June and July 1986
D-11	Rockwell International, "Remedial Action Program on Jefferson County Open Space Land Status Report for Period January 15, 1987 to October 15, 1987," EAC-420-87-3, 15 October 1987	Summary of remedy actions for report period on Jefferson County remedy acreage, including average soil plutonium concentrations on four strips of land after tilling in July 1987

APPENDIX D
IHSS 199 DATA SOURCES
(continued)

Document	Data Source	Nature of Data
D-12	Rockwell International, "Remedial Action Air Sampling Results - 1987," data table only, not dated (approximate date early 1988)	Plutonium concentrations in ambient air samples collected downwind of Jefferson County remedy acreage during court-ordered tilling in 1987
D-13	Rockwell International, "Status of Remedial Action on Jefferson County Lands East of Indiana Street, November, 1987 to November, 1988"	Summary of remedy actions for report period on Jefferson County remedy acreage, including average soil plutonium concentrations on a strip of land retilled in July 1987 after earlier tilling failed to reduce plutonium to court-ordered action level
D-14	Rockwell International, "Status of Remedial Action Program on Jefferson County Open Space Land, January 1989 to August 1989"	Summary of all remedy actions taken through August 1989 on Jefferson County remedy acreage (contains no newly generated soil plutonium concentration data)
D-15	EG&G Rocky Flats, Inc , "Jefferson County Remedial Action Lands 1989 Remediation Status and Actions for 1990"	Summary of 1989 remedy actions taken on Jefferson County remedy acreage (contains no soil plutonium concentration data)
D-16	EG&G Rocky Flats, Inc , "Jefferson County Remedial Action Lands Annual Report - January, 1991," 90-RF-7449	Summary of 1990 status of Jefferson County remedy acreage (contains no soil plutonium concentration data)
D-17	Rockwell International, "Radioactive Ambient Air Monitoring Data," data table with attached air sampler location maps, not dated (approximate date early 1989)	Average annual plutonium concentrations in ambient air samples collected near Jefferson County remedy acreage during court-ordered remedial activities between 1985-1988
D-18	Colorado Department of Health Radiation Division, "Rocky Flats Surface Soil Survey 1970-1989," February, 1990	Summary of CDH Rocky Flats Plant monitoring program results for plutonium in soil between 1970-1989

APPENDIX D
IHSS 199 DATA SOURCES
(continued)

The following documents are published periodically and are available from a number of public information repositories Copies of the individual documents are not included in this appendix

"Rocky Flats Plant Site Environmental Report" (published annually since 1971 by EG&G Rocky Flats, Inc and their predecessors, known prior to 1988 as "Annual Environmental Monitoring Report")	Summaries of all environmental investigations and monitoring conducted on and around the RFP during the current year (summarizes data included in monthly environmental monitoring reports--see comment below)
"Rocky Flats Plant Monthly Environmental Monitoring Report" (published monthly since the late 1960s by EG&G Rocky Flats, Inc and their predecessors)	Summaries of air quality monitoring data collected on and around the RFP during the current month
"Environmental Surveillance Report on the U S Department of Energy's Rocky Flats Plant" (published monthly since 1970 by the Colorado Department of Health and presented at monthly information exchange meetings)	Summaries of air quality monitoring data collected on and around the RFP during the current month

DOCUMENT D-1

"Plutonium in Soil Around the Rocky Flats Plant"
(1970)

by

P W Krey and E P Hardy
USAEC Health & Safety Laboratory

DWR- 1525

MASTER

HASL-235

PLUTONIUM IN SOIL AROUND THE ROCKY FLATS PLANT

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August 1, 1970

Health and Safety Laboratory USAEC
New York, New York

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HASL-235
HEALTH AND SAFETY (TID-4500)

PLUTONIUM IN SOIL AROUND THE ROCKY FLATS PLANT

by

P. W. Krey and E. P. Hardy

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August 1, 1970

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SUMMARY OF FINDINGS

Soil samples were collected to a depth of 20 cm at 33 sites extending as far as 40 miles from the Dow Chemical Co.'s Rocky Flats plant in Colorado. Deposition concentrations of Pu-239 as high as 2000 mCi/km^2 were found off the plant site but these high concentrations decreased rapidly with distance. The contamination pattern extends eastward from the plant in the direction of the resultant wind vector and has virtually no westward component. The pattern is incompatible with the wind direction on the day of the May 11, 1969 fire. Leaking barrels of plutonium laden cutting oil stored in the southeast corner of the plant are considered the likely source of the contaminant

Three mCi/km^2 of Pu-239 is the lowest contour readily discernible in the contamination pattern and extends about 8 miles east and southeast of the plant. The inventory of Rocky Flats Pu-239 within the mCi/km^2 contour but excluding AEC controlled land is 2.6 Ci. The extent of the Rocky Flats Pu-239 beyond this contour is difficult to determine because the deposition of Pu-239 from nuclear weapon tests fallout is not precisely known in the Denver area. Our best estimate of the cumulative fallout Pu-239 is 1.5 mCi/km^2 based upon a 1965

soil sample from nearby Derby, Colorado. The most distant sites at 40 miles to the east and north of the plant show a slightly higher value of 2.0 mCi/km^2. The intervening sites average 2.4 mCi/km^2. If the extreme and unlikely assumption is made that the entire area lying 40 miles to the east and north of the plant is contaminated with 1 mCi/km^2, an additional 3.2 Ci of Rocky Flats plutonium could have been released to these remote areas. Sr-90 analyses of the Rocky Flats soils and other studies are in process which might resolve this uncertainty in the remote areas, but additional sampling may be required to thoroughly solve the problem.

The plutonium has been shown to move down into the soil as far as 13 cm, although the distribution shows wide variability apparently depending upon soil chemistry. In several cases there is as much as 60% of the total plutonium below 5 cm. The analytical precision of aliquoting the sample and analysis was shown to be ±20%. Analyses of duplicate samples taken from the same location showed similar precision indicating that the soil sampling was representative of the area studied.

INTRODUCTION

On May 11, 1969 a serious fire broke out at the Atomic Energy Commission's plutonium processing plant at Rocky Flats, Colorado[1]. Stimulated by the possible release of plutonium to the environment by this fire, Dr. Martell demonstrated the presence of Rocky Flats plutonium in soil around the plant[2]. On further investigation it appeared that there were three other plausible sources for this off-site plutonium, i.e.:

1. the September 11, 1957 fire;
2. leaking drums of contaminated cutting oil in a storage area in the southeast corner of the plant complex;
3. a chronic low level stack effluent.

Because of our expertise in soil sampling for radionuclides and their analyses, HASL was invited to perform an initial study of the distribution of Pu-239 in soil around the plant. The objectives of this initial study were to:

(a) confirm and broadly quantify the levels of Rocky Flats plutonium in the soil;

(b) define the maximum distances from the plant at which significant Rocky Flats plutonium could be detected; and

(c) if possible, determine the quantity of Rocky Flats plutonium in the soil off-site; that is, off AEC property.

Preoperational Survey

To assist us in designing a sampling program, we requested Dr. I. Van der Hoven, Chief, ERL, ESSA, Washington, D.C. to make a meteorological examination of the Rocky Flats area. In response C. R. Dickson and G. E. Start surveyed the area during the week of January 26, 1970, and in their memorandum to the files [3] made the following observations and recommendations:

1. More if not most of the Rocky Flats plutonium in the soil around the plant was contributed by the 1957 fire and the leakage from the contaminated drums.

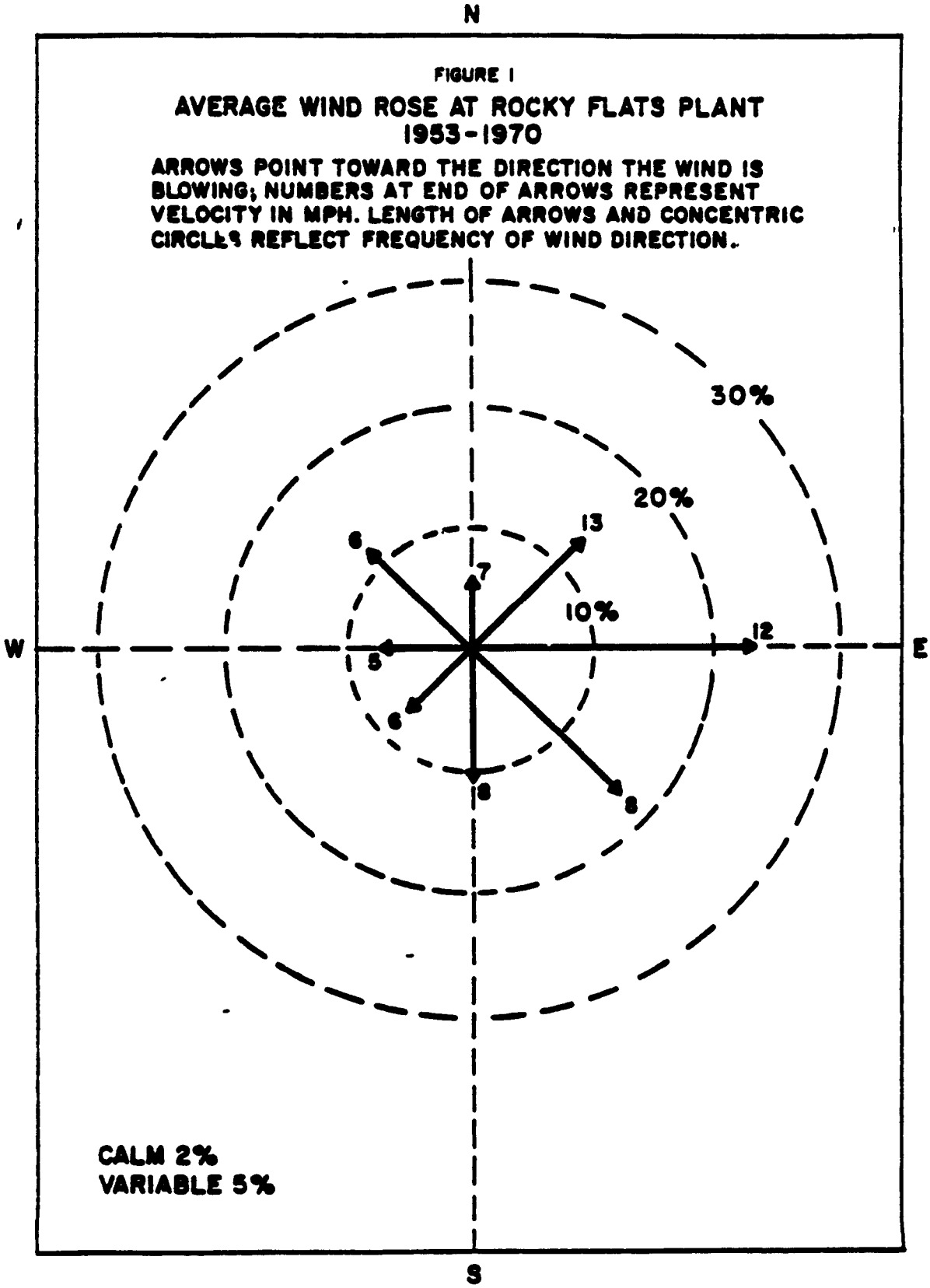
2. These drums were placed in outside storage from 1958 until 1968. Initial leakage was detected in 1964. The change in the distribution of this contamination on the plant property during a period of one year suggested that a gradual southeastward movement may have taken place.

3. The wind rose averaged over a 17-year interval at the Rocky Flats plant is given in Figure 1. West winds occur almost 25% of the time; over 50% of the winds have a westerly component. The strongest gusts and the directions of the most frequent strong gusts (speeds greater than 40 mph) are from the west. The resultant wind vector (derived from the wind rose frequencies and mean speeds) points almost exactly eastward.

FIGURE I

AVERAGE WIND ROSE AT ROCKY FLATS PLANT 1953-1970

ARROWS POINT TOWARD THE DIRECTION THE WIND IS BLOWING; NUMBERS AT END OF ARROWS REPRESENT VELOCITY IN MPH. LENGTH OF ARROWS AND CONCENTRIC CIRCLES REFLECT FREQUENCY OF WIND DIRECTION.



CALM 2%
VARIABLE 5%

The Denver wind rose shows that southerly to southwesterly winds are most frequent. Air flowing eastward from Rocky Flats should merge with the southerly air flow across Denver and be carried north-north eastward. The South Platte River Valley, about 20 miles east of Rocky Flats, is the logical terrain feature along which this transition from westerly flow should approach completion.

The wind direction on 5/11/69, the day of the last serious fire, was mostly from the north - northeast at speeds from 2 - 10 mph. Figure 2 gives mean hourly winds during that fire. The wind directions during the 9/11/57 fire are shown in Fig. 3[4].

4. Strong gusty winds frequently occur in the lee of the mountains at Rocky Flats; several days each year wind gusts exceed 70 to 80 mph. Consequently, wind erosion has removed much of the fine soil and alluvium leaving mostly rock and sand particles at the ground surface. Two creeks, Walnut and Woman Creeks, pass to the north and south of the plant in an easterly direction. These creeks begin to flow through significantly deep gullies (several hundred yards wide) as they flow by the eastern limits of the plant. The soil in the gullies which was wind eroded from the flats is finer and deeper, and is more likely to become a trap for windborne particles of plutonium.

FIGURE 2

AVERAGE HOURLY WINDS DURING FIRE OF MAY 11, 1969

ARROWS POINT TOWARD THE DIRECTION THE AVERAGE HOURLY WINDS WERE BLOWING. THE LENGTH OF THE ARROWS AND THE CONCENTRIC CIRCLES REFLECT THE WIND VELOCITY IN MPH.

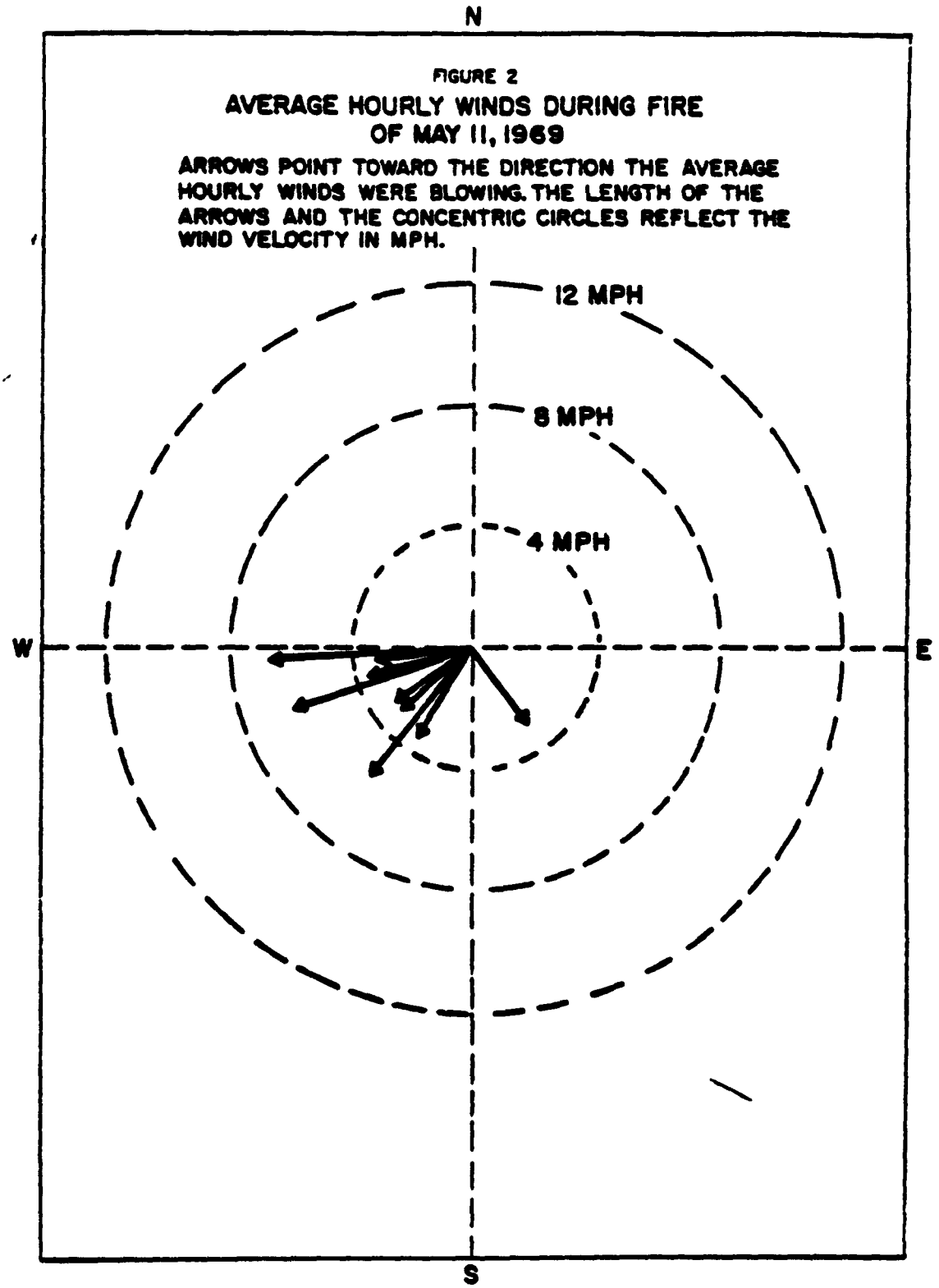
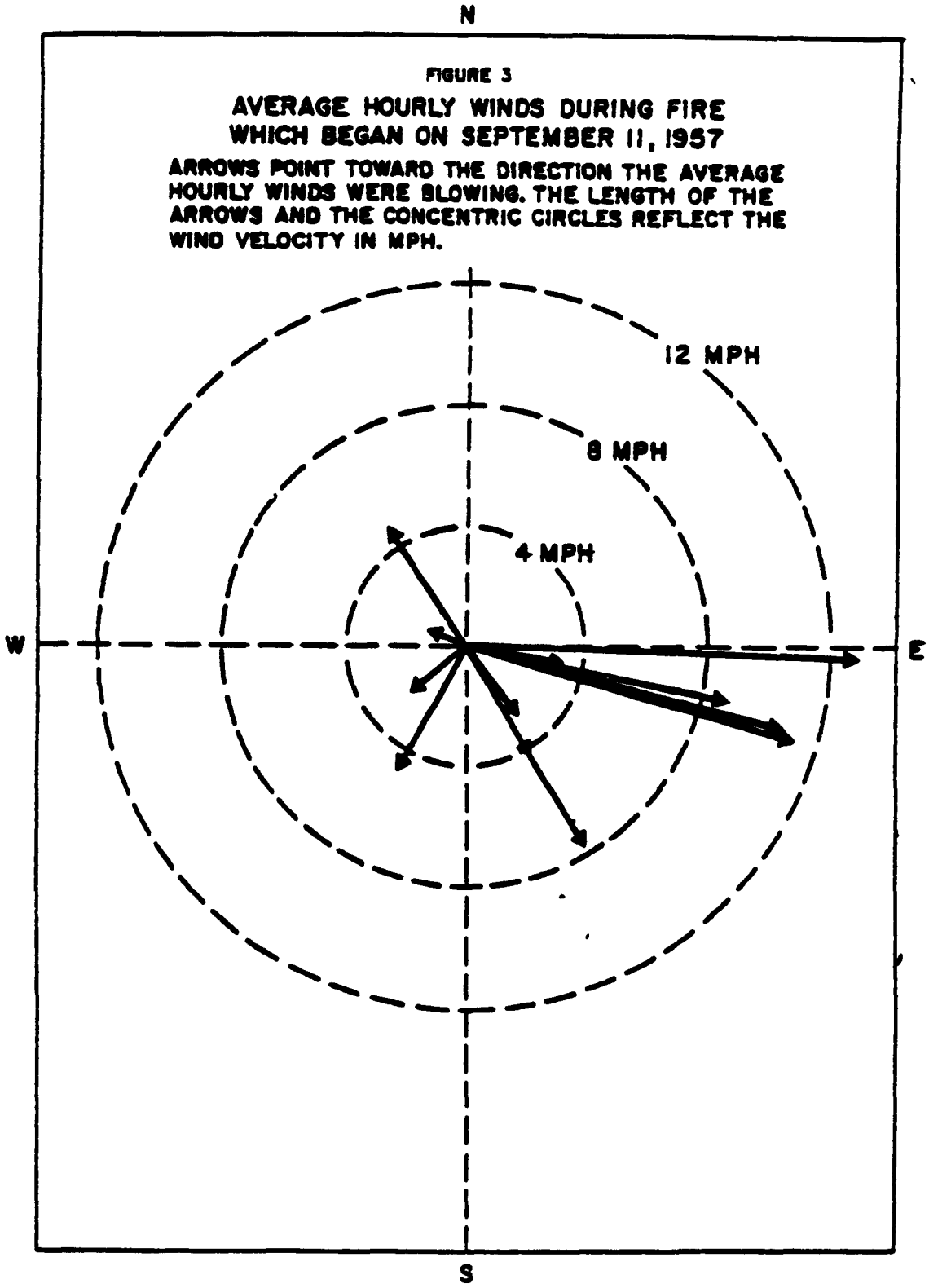


FIGURE 3

AVERAGE HOURLY WINDS DURING FIRE WHICH BEGAN ON SEPTEMBER 11, 1957

ARROWS POINT TOWARD THE DIRECTION THE AVERAGE HOURLY WINDS WERE BLOWING. THE LENGTH OF THE ARROWS AND THE CONCENTRIC CIRCLES REFLECT THE WIND VELOCITY IN MPH.



Sampling Site Location

The week of February 9, 1970 was set aside for the collection of the soil samples. Based upon the pre-operational survey, emphasis was given to site location in the downwind direction from the plant. If the results of this limited one week sampling revealed serious deficiencies, the intent was to collect additional samples later to satisfy the need. The selected sampling sites and their description are given in Table 1 and plotted in Figure 4.

SOIL SAMPLING

The sampling techniques used in the Rocky Flats area were primarily dependent upon the rockiness of the soil. In those areas where rocks did not pose a problem, we used the core sampling method[5]. In the immediate vicinity of the Rocky Flats plant, core sampling was not possible. Here it was necessary to cut out a one square foot area sample to the required depth. We tried to select sites for sampling that had been undisturbed since the plant started operations in 1953. The sites were vegetated and in large flat open areas where it could reasonably be assumed that deposited material would not have been removed by water erosion. We avoided sites where debris might have accumulated such as in depressions, at the foot of slopes, or in flooded areas. Our objective was to take samples that would

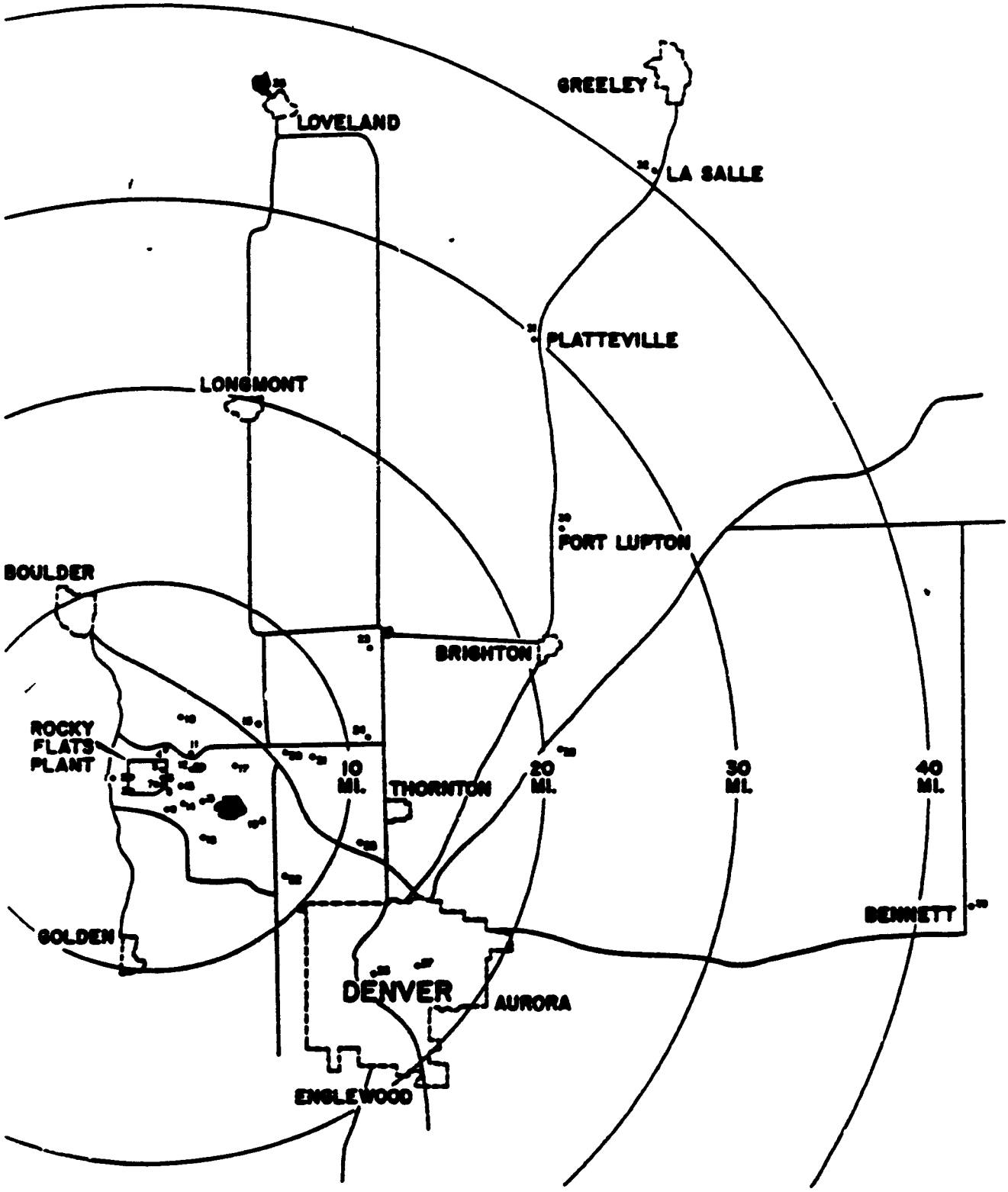
HASL SOIL SAMPLING SITES Table 1

DOW CHEMICAL CO., ROCKY FLATS PLANT, COLORADO

Map Site	Sample	Area and Depth of Sample	Site Description
1	1	12" x 12½" x 8" deep	Church property No 9
2	2	12½" x 13" x 8" deep	Dow property - near west fence
3	3	12½" x 12½" x 8" deep	Dow property - near west fence
4	4	10. 3½" d cores. 0-8"	Off Rt. 128
5	5	10. 3½" d cores. 0-6"	Dow property - high ridge near east fence
6	6	12" x 12" x 8" deep	Dow property - near east fence
	7	12½" x 12½" x 8" deep	duplicate of sample 6
	8	12" x 12" x 2" deep	Dow property - near east fence
	9	2 - 3"	sub-soil of above
	10	3 - 4"	" " " "
	11	4 - 5"	" " " "
	12	5 - 6"	" " " "
	13	6 - 7"	" " " "
7	14	10. 3½" d cores. 0-8"	Dow property - near Woman Creek
	15	10. 3½" d cores. 0-8"	duplicate of sample 14
8	16	10. 3½" d cores. 0-2"	Dow property - Woman Creek near east fence
	17	10. 3½" d cores. 2-8"	sub-soil of above
	18	1. 4" d cores. 0-2½"	Dow property - Woman Creek near east fence
	19	1. 4" d cores. 2½" - 3½"	sub-soil of above
	20	1. 3" d cores. 3½" - 5"	" " " "
	21	1. 3½" d. cores. 5" - 8"	" " " "
9	22	12" x 12" x 8" deep	Church property No. 23
10	23	12" x 12½" x 8" deep	Hardway property No 25
11	24	10. 3½" d. cores. 0-8"	off Rt. 128
12	25	10. 3½" d. cores. 0-2"	Great Western Reservoir
	26	10. 3½" d cores. 2-8"	sub-soil of above
	27	1. 3½" d cores. 0 - 4"	Great Western Reservoir
13	28	12½" x 12½" x 8" deep	Church property No 13
14	29	10. 3½" d. cores. 0-2"	Church property No. 13
	30	10. 3½" d cores. 2-8"	sub soil above
15	31	12" x 12" x 8" deep	S.E. corner of Schnder property No. 18
16	32	10. 3½" d cores. 0-8"	Alkire and 88nd Ave
17	33	12½" x 12½" x 8" deep	108 Ave and Simms
18	34	10. 3½" d cores. 0-8"	Swann Hereford Ranch
19	35	10. 3½" d. cores. 0-8"	Calkins Lake near W 80th Ave.
20	36	12½" x 12½" x 8" deep	N.E. of Jefferson A P near Wadsworth
21	37	10. 3½" d cores. 0-8"	Sheridan and 112th Ave . Murray property
22	38	10. 3½" d. cores. 0-8"	Somerset El Sch Quay & 64th Ave.
23	39	10. 3½" d cores. 0-8"	Roy Baxter Farm. Huron and 160th Ave.
24	40	10. 3½" d cores. 0-8"	Wesley Chapel Cemetery. Huron & 120th Ave
25	41	10. 3½" d. cores. 0-8"	Rausch El.Sch . Pecos and Elmwood
26	42	10. 3½" d cores. 0-2"	Denver Civic Center
	43	10. 3½" d cores. 2-8"	sub-soil of above
27	44	10. 3½" d cores. 0-2"	Denver City Park
	45	10. 3½" d cores. 2-8"	sub-soil of above
28	46	10. 3½" d cores. 0-8"	Hallson Farm. 120th Ave and Chambers
29	47	10. 3½" d cores. 0-4"	Walt Schroth Farm. Bennett. Colo
	48	10. 3½" d cores. 4-8"	sub-soil of above
30	49	11. 3½" d cores. 0-8"	Town Park. Ft Lupton. Colo.
31	50	10. 3½" d cores. 0-8"	Town Park. Platteville Colo.
32	51	10. 3½" d cores. 0-8"	Sylvester Farm. LaSalle. Colo
33	52	10 3½" d cores. 0-8"	Lakeside Park. Loveland Colo

Figure 4

HASL SOIL SAMPLING SITES NEAR DOW CHEMICAL CO., ROCKY FLATS PLANT



measure the total amount of plutonium that had fallen out. At the time, we arbitrarily decided to sample from the surface down to 20 centimeters, expecting that at this depth we would include all the plutonium. We shall briefly describe the sampling techniques used.

In those areas where core sampling was possible, we first laid out a straight line transect about 5 meters long. With about 30 cm (one foot) spacings in between cores, we cut out ten 8.9 cm (3.5 in.) diameter plugs from the surface to 5 cm, including the vegetation and root mat. In this way we sampled an area of 622 cm^2 (0.67 ft^2). Next we removed the soil from 5 to 20 cm with an auger which bores an 8.9 cm diameter hole. At some sites, we separated the 0 - 5 cm and 5 - 20 cm samples. In most cases, however, the two fractions were combined. Further sampling details and descriptions of the tools are given elsewhere[5].

At map site No. 8, we sampled a one hole depth profile by mechanically drilling with hole saws to a depth of 13 cm. Sampling from 13 to 20 cm was done with the hand auger.

At those sites where there was a preponderance of rocks in the soil, the preferred method of core sampling could not be done. Instead we placed a 930 square centimeter (one square foot) metal

template on top of the spot selected for sampling and cut out the sample with chisels and scoops. The rocks were included with the sample.

At map site No. 6, we took samples of soil at various depths down to 20 cm. This was a very rocky area so that we had to use the one square foot template and chisel out the samples as carefully as possible. The first 5 cm were relatively easy to sample but as we went down in depth it was necessary to taper toward the center of the 930 cm^2 area to avoid contaminating with soil from the upper levels. Consequently we could not get an accurate area measurement below 5 cm. To convert from the measured concentrations (dpm per gram) to activity per unit area we assumed a soil density of 1.2 grams per cm^3 down to 15 cm and 2.4 grams per cm^3 from 15 to 18 cm. These density values were obtained as averages of a considerable body of data accumulated at HASL over a 15 year period. As we sampled the depth profile at this site, we removed and discarded the rocks.

Ten of the Rocky Flats samples required the removal of the larger rocks. We assumed that an insignificant amount of plutonium would be in the rock fraction and consequently based the calculated activity per unit area on the weight of the soil fraction. To be

sure this was proper, we analyzed the separated rock fraction of the soil containing the highest concentration of plutonium. We found only 0.2 percent of the total plutonium associated with the separated rocks and therefore neglected the rock fraction in the remaining samples.

RADIOCHEMICAL ANALYSIS

Sample Preparation

When the soil samples arrived at HASL, they were spread out on plastic sheets and allowed to air dry for several days. During the drying process, we broke up soil aggregates and pulled apart the top soil plugs consisting of vegetation and root mat. We cut up the vegetation so that it could be distributed homogeneously throughout the sample. When the sample was completely dry it was weighed in its entirety. Then, when necessary, any rocks were removed and weighed separately.

The sample was then crushed and transferred to a blender. After mixing, we spread the sample out on a piece of plastic, marked off quarters, and took scoop fulls from each quarter in a consecutive manner until about a kilogram had been collected. This sub-sample was then pulverized in a rotary hammer mill and transferred to a polyethylene bottle.

One hundred gram aliquots of the pulverized material were aliquoted at various times for submission to the analytical laboratory. This soil sample preparation procedure and equipment used for crushing, blending, and pulverizing are described elsewhere [5].

Radiochemical Procedure

The radiochemical procedure for plutonium in soil was developed by Norton Chu at the Health and Safety Laboratory It involves leaching a 100 gram aliquot of soil with hydrochloric and nitric acids. We show below that this method effectively removes all the plutonium. Plutonium is isolated by anion exchange (nitrate form) and electrodeposited on a platinum disc. The plutonium isotopes are resolved by alpha spectrometry and yielded with Pu-236. This procedure is described in detail elsewhere [5].

Most of the analyses of the Rocky Flats soils were done by two contractor laboratories: Teledyne Isotopes of Palo Alto, California (designated here as IPA) and Trapelo Division West of Richmond, California (TLW).

Complete dissolution of a sample for radiochemical analysis is the classical and most dependable method of analysis. However, in the case of soil, it is also most difficult, tedious, and time consuming. The HASL leach method was developed to eliminate the need

for complete dissolution but to provide accurate, dependable results. To show that the leach method fulfilled its objectives, many samples were analyzed by both leaching and complete dissolution and gave comparable results.

Three different samples from Rocky Flats were selected as representing widely different soil types. Duplicate aliquots of each were analyzed for Pu-239 by the leach and fusion methods. The fusion method affords complete dissolution of the sample by decomposing it in molten sodium carbonate. Table 2 gives the results of these analyses and shows that the mean percent deviation between the methods was 13% with no obvious bias.

Other soils were similarly analyzed and the results are also reported in Table 2. A second method of complete dissolution was used for some of these samples, and is indicated as HF dissolution in the table. This technique affects complete dissolution by prolonged digestion of the sample with hudrofluoric and perchloric acids. The mean percent deviation between methods for these soils is 12% which is not statistically different from the pattern in the Rocky Flats soils. These data convincingly demonstrate that the leach procedure permits an accurate assessment of the plutonium content in many, if

Table 2

COMPLETE DISSOLUTION VERSUS LEACHING
Rocky Flats Soils

Map Site	Sample	Lab	Method	Pu-239 dpm/g ±%σ	% Deviation Between Methods
7	14	HASL	leach	3.08±4	3.2
		"	fusion	3.18±4	
6	6	HASL	leach	18 7±4	
		"	"	16.3±5	8.9
		"	fusion	16 0±5	
4	4	HASL	leach	0.060±4	28
		"	fusion	0.080±4	
				mean:	13.
		Other Soils			
N.Y.C. 6/67	0-20 cm	IBA	leach	0.0167±4	
		"	"	0.0165±5	0
		HASL	fusion	0.0166±4	
N.Y.C. 12/69	0-2.5 cm	TLW	leach	0.22±10	
		"	"	0.20±5	11
		"	HF dissolution	0.23±8	
		"	"	0.24±5	
N.Y C. 12/69	0-5 cm	TLW	leach	0.091±6	
		"	"	0.096±5	3.3
		"	HF dissolution	0.090±6	
		"	"	0.092±5	
N.Y.C. 12/69	5-20 cm	TLW	leach	0.0048±20	
		"	"	0.0041±16	
		"	HF dissolution	0.0035±42	7.1
		"	"	0.0049±13	
		HASL	fusion	0.0041±5	
"Black" Soil, 1958		TLW	leach	0.0074±35	37.
		HASL	fusion	0.0051±4	
				mean:	12.

not all, soils and certainly in the soils encountered in the Rocky Flats area.

The deviations between methods reported in Table 2 include the error terms attendant to aliquoting and analytical precision. If the sample is not homogenized, deviations between aliquots will be high. By minimizing the error due to analytical precision, the data in Table (2) suggests that the error due to aliquoting is ±13% or less.

RESULTS

The Pu-238 and Pu-239 analyses of all the Rocky Flats samples plus additional reference samples are given in Tables A and B of the Appendix. Complete information regarding the collection area, the depth and weight of sample or fraction thereof, the analytical laboratory, and Pu-238/Pu-239 ratios are also reported. The mCi/km^2 of Pu-239 and Pu-238 integrated from 0 - 20 cm at each map site was calculated from Table A and is summarized in Table 3 along with the integrated Pu-238/Pu-239 ratio. When duplicate analyses were reported, the average of the duplicates were used in calculating the map site value unless otherwise specified in Table A. The deposition contours derived from Table 3 are plotted in Figure 5.

Since a number of earlier reports gave their data only in units of dpm/g soil, these values are also shown in Table A. These units are not at all useful for our study, and are difficult to compare without specifying depth of sampling and sample pretreatment.

The results of the depth profile studies are summarized in Table 4 as percent of the integrated activity down to 20 cm found in each incremental depth sampled. Profiles of fallout plutonium in New York City and Waynesville, Ohio are included for comparison.

*Footnote: From Table A it can be seen that at map site No. 8 the 13 - 20 cm increment contained more plutonium than the preceding increment. In evaluating this depth profile in Table 4 we summed the 9 - 13 cm and the 13 - 20 cm values and reported the total activity per unit area from 9 - 20 cm. Similarly at map site No. 6 we combined the 13 - 15 cm and 15 - 18 cm values for presentation in Table 4.

Table 3

TOTAL PLUTONIUM DEPOSITED AT SOIL SAMPLING SITES IN THE ROCKY FLATS AREA

MAP Site	nCi per km^2 Pu-239	Pu-238	Pu^{238}/Pu^{239}
1	2.4	0 07	0.029
2	3.1	0.06	0.019
3	4.2	0 12	0.028
4	11	0.23	0.021
5	15.	0.36	0.024
6	1950.	37 7	0 019
7	480	8 9	0 018
8	630	12.5	0.020
9	2.6	0 07	0.027
10	2.2	0 63	0 29
11	5.4	0 25	0.046
12	47.	1.2	0.026
13	50.	0 94	0.019
14	17.	0.39	0 023
15	18.	0.32	0.018
16	19.	0.41	0.022
17	14.	0.23	0.016
18	2.0	0.06	0.030
19	8.0	0.20	0 025
20	2.6	0.13	0.050
21	2.7	0.06	0.022
22	2.2	0 13	0.059
23	3.0	0.07	0.023
24	2.6	0 06	0 023
25	2.4	0 07	0 029
26	2 3	0.16	0.070
27	2.0	0 05	0.025
28	2.5	0 20	0.080
29	2.0	0 15	0.075
30	2 8	0.15	0.054
31	2 1	0 06	0.028
32	2 7	0 22	0.081
33	1 8	0 06	0.033

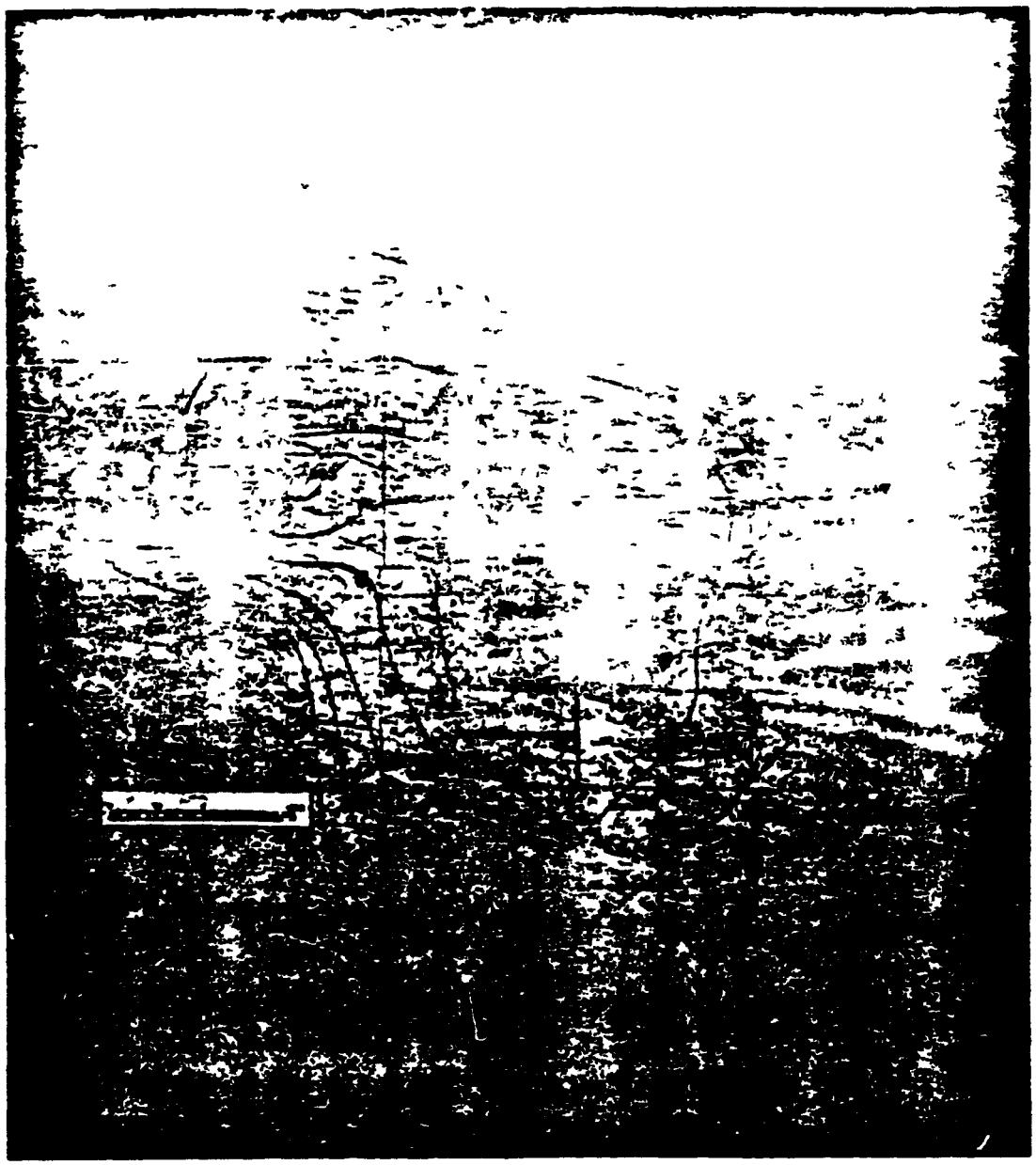


Figure 5:

PLUTONIUM-239 CONTOURS AROUND
ROCKY FLATS

Contour values in mCi per km^2
(light figures)
Numbered sampling sites
(bolder figures)
AEC property boundary - - - -
Dow Rocky Flats Plant --------

Table 4

DEPTH DISTRIBUTION OF PLUTONIUM
Rocky Flats Soils

Map Site	depth (cm)	% of total Pu^{239}
6	0-5	68
	5-8	24
	8-10	6
	10-13	1
	13-18	<1
8	0-6	66
	6-9	21
	9-20	13
8	0-5	67
	5-20	33
12	0-5	91
	5-20	9
14	0-5	61
	5-20	39
26	0-5	39
	5-20	61
27	0-5	45
	5-20	55
29	0-10	92
	10-20	8

Other Soils

Site	Sampling date		
New York City	Dec. 1969	0-2½	66
		0-5	81
		5-20	19
Waynesville, Ohio	Apr. 1970	0-6	47
		6-20	53

QUALITY CONTROL

HASL carries on an elaborate and extensive quality control program, both internally and with its contractors, to assure the validity of reported analyses. Since this particular study differs from our fallout programs, the quality control procedures and results are reported here in detail.

To monitor the quality of the analytical results, blind control samples were admixed with the normal schedule of routine samples. These controls included blank or low level Pu-239 samples, duplicate aliquots of prepared samples, and several reference samples.

Blank and Low level Samples

Two low level samples were used. One was a pre-bomb soil, that is a soil collected prior to 1945 which is the birth year of nuclear weaponry. A second was a soil sample retrieved from the town of Woodcliff Lake, New Jersey in March 1970 at a depth below 90 cm which was processed along with the other samples. The results of the analyses of these two samples are given in Table 5.

In general, the results in Table 5 show no detectable plutonium activity in the pre-bomb sample and a surprising value of about 0.005 dpm per gram Pu-239 for the Woodcliff Lake sample. Either a

Table 5

PLUTONIUM IN BLANK AND LOW LEVEL SAMPLES

Sample	Lab	dpm per gram Pu-239	Pu-238
Pre-bomb (collected before 1945)	HASL	0.0003 ± 100%	0.0002 ± 100%
"	IPA	0.0001 ± 100%	0.0001 ± 100%
"	IPA	0.0001 ± 100%	0.0001 ± 100%
"	TLW*	0.0196 ± 7%	0.0054 ± 14%
"	TLW	0.0001 ± 100%	0.0001 ± 100%
Woodcliff Lake, N.J.	IPA	0.0046 ± 7%	0.0001 ± 100%
(Collected below 90 cm	IPA	0.0043 ± 6%	0.0001 ± 100%
in March 1970)	TLW	0.0071 ± 9%	0.0009 ± 53%
	TLW*	0.0468 ± 5%	0.0001 ± 100%
	TLW	0.0055 ± 25%	0.0002 ± 100%

*Suspect value

small amount of Pu-239 penetrated to that depth or more reasonably the sample was slightly contaminated during collection or subsequent pre-analyses treatment. However, in one of the replicate analyses of each of these samples, Trapelo appears to have introduced from 2 to 4 dpm of Pu-239 contamination (100 gram aliquots were analyzed). This can represent a major portion of the total activity found in samples remote from the Rocky Flats plant; although the data in Table 5 also suggest that this contamination at Trapelo is not consistent. Examination of Table 5 and Tables A and B in the Appendix indicates that, on balance, contamination by laboratory handling and analyses was not measurable or was relatively unimportant to the outcome of this study.

Analytical Precision

The percent deviation between aliquots of a prepared sample, which represents the difference between aliquots divided by the mean, was calculated for each set of duplicates in Tables A and B. The data were subdivided into the internal replication at IPA, TLW, and HASL and also into the replication between these laboratories. Then the mean percent deviation between aliquots for each subgroup was computed and is reported in Table 6. It should be noted that

the results of several samples reported by TLW were suspect, and duplicate aliquots of these samples were subsequently submitted to IPA for verification. These sets of duplicates were included in the compilation of Table 6 and reflect a slight bias against the random selection of duplicate sets.

Table 6 indicates that the precision of Pu-239 analysis both internally and between IPA and HASL ranged up to ±28% and averaged below ±20%. The internal precision at TLW and the precision between TLW and the other laboratories was 3 times higher. These uncertainties reflect not only the precision of analysis but also the representivity of aliquoting the prepared sample. For example, Table 2 suggests that aliquoting Rocky Flats soils gives an average uncertainty of less than 13%. Each of the results of the Rocky Flats soil analyses were examined in the light of expected results based upon location and comparison to neighboring samples. Reanalyses were performed when deemed necessary, and data were accepted depending upon their reasonableness and the laboratory conducting the analysis. Therefore, the overall analytical precision was about ±20%.

The level of Pu-238 in many of the samples was so low as to incur large counting errors. If either aliquot had a counting error

Table 6

MEAN PERCENT DEVIATION BETWEEN ALIQUOTS

Laboratory	Pu-239 No. of Sets	Pu-239 % Deviation
IPA	5	14
TLW	8	73
HASL	1	14
IPA/HASL	3	28
TLW/HASL	1	56
TLW/ IPA	9	58

greater than ±30%, that duplicate set was omitted from further consideration With that limitation, the mean percent deviation between aliquots for Pu-238 analyses was very similar to the behavior of Pu-239.

Analytical Accuracy

The accuracy of the Pu-239 analyses is difficult to establish because of the lack of a standard soil sample. However, several reference samples were analyzed in which the plutonium levels can be approximated from their Sr-90 content. Table 7 identifies these samples giving the Sr-90 measurements, the expected Pu-239 values based upon a Pu-239/Sr-90 ratio of 0.02 [6], and the reported Pu-239 measurements. The "red" and "black" soils which were collected in 1958 at Raleigh, North Carolina and McHenry County, Illinois, respectively, were prepared as reference soil samples and were analyzed many times for Sr-90 content. The initial Pu-239 analyses of the "red" and "black" soils by TLW reflected the laboratory contamination discussed earlier. The re-analyses gave values which are about twice the expected values but in agreement with HASL's estimate of the "black" soil using the fusion treatment. The measured Pu-239 in the Derby, Colorado (1965) and New York City (1967)

Table 7

ANALYSES OF REFERENCE SAMPLES

Sample	Collection date	dpm/g ± Stnd Dev. %				
			Expected[1]	Measured Pu-239 (dpm per gram)		
		Sr-90	Pu-239	TLW	IPA	HASL
"Red Soil"	1958	0.14±6	0.0028	0.0567±8[3] 0.0061±14		
"Black Soil"	1958	0.18±4	0.0036	0.0399±9[3] 0.0074±35		0.0051±4[2]
Derby, Colorado	1965	0.43±7	0.0086	0.0110±7	0.0112±4	
New York City	1967	0.66±3	0.0132		0.0167±4 0.0165±5	

[1] Assuming Pu-239/Sr-90 = 0.02
[2] Analysis performed by fusion of sample
[3] Suspect value

samples are also higher than the expected values but by less than a factor of two. While these results cannot quantify the accuracy of analysis, they do demonstrate the acceptability of the method.

The laboratories performing these analyses were in good calibration with standard solutions of Pu-238 and Pu-239 made available by HASL. From these quality control studies it appears that the precision of replicate aliquoting and analysis is the determining factor in the uncertainty of the analytical results, and that the overall reliability of the analyses is within ±25%.

Representivity of Soil Sampling

To demonstrate that the sample collected was representative of the soil contamination at the sampling site, duplicate samples were collected by each of the two methods of sampling, and the results of these analyses are shown in Table 8. One sample of each duplicate sample was analyzed in replicate while the second duplicate was analyzed only once.

The template sampling method at map site 6 reflected a ±31% deviation between duplicate samples for Pu-239 while the coring method at map site 7 showed only a ±11% deviation. The Pu-238 results were similar because the Pu-238/Pu-239 ratio for all samples

Table 8

DUPLICATE SOIL SAMPLING IN THE ROCKY FLATS AREA

Map Site	depth (cm)	Sampling method	No. of analyses	mCi per km^2 Pu-239	Pu-238	Pu^{238}/Pu^{239}
6	0-20	Template	4	2050	40.3	0.020
			1	1500	27.4	0.018
7	0-20	Cores	3	490	9.4	0.019
			1	437	7.5	0.017

was remarkably constant. This precision is not unlike the precision of replicate analyses of identical samples. We conclude that the representivity of soil sampling is good and that the uncertainty of the final data is due largely to the imprecision of aliquoting and analysis.

D I S C U S S I O N

Distribution with depth

Significant quantities of Pu-239 are below the top 5 cm of soil and vegetation. Table 4 shows that between 9 and 61 percent of the Pu-239 from the surface to 20 cm in depth is below 5 cm, depending upon the particular type of soil. At map sites nos. 6 and 8 we sampled three or more increments to see how the plutonium was distributed with depth. Although about 90% was in the top 9 cm we were able to measure Pu-239 as far down as 13 cm. We would conclude, however, that at these sites less than 1% is below this depth.

At five other sites we separated the 0 - 5 cm and 5 - 20 cm fractions and found widely varying percentages of the total Pu-239 measured, below 5 cm. Undoubtedly the base exchange capacity and perhaps other characteristics of the soil are important factors in determining the extent to which deposited plutonium will penetrate below the surface. Sites Nos. 26 and 27 were in city parks where

liming and fertilization may enhance the downward movement. Lacking better definition of the plutonium distribution with depth at these other sites we assumed that in sampling to 20 cm we removed essentially all of the plutonium that had fallen out.

Inventory

The areas within the various contours of Figure 5 were determined by planimetry, and the total Rocky Flats Pu-239 burden in the soil bounded by the 3 mCi/km^2 contour is estimated to be 4.5 Ci. One objective of this study was to determine the quantity of Pu-239 released to property not controlled by the AEC. The sampling plan reflected this objective by collecting few samples on the plant site. Consequently, our estimates of the Pu-239 within the plant area is poor and may be low. The Rocky Flats Pu-239 on public and private lands not controlled by the AEC and within the 3 mCi/km^2 contour is estimated to be 2.6 Ci.

There is no question that Rocky Flats plutonium extended beyond the 3 mCi/km^2 contour, but the extent of this low level contamination is difficult to define. Table B shows that the fallout Pu-239 in 1965 at Derby, Colorado which is only 17 miles east of Rocky Flats was 1.5 mCi/km^2. Additional nuclear weapons fallout from 1965 to 1970 would add little Pu-239 to this value. The observed values of

2.0 and 1.8 mCi/km^2 at map site Nos. 29 and 33 which were about 40 miles to the east and north of Rocky Flats, respectively, began to approach the expected fallout level of 1.5 mCi/km^2. The intervening sites were somewhat higher and averaged about 2.5 mCi/km^2. Taking the extreme and unlikely view that the entire area was contaminated with the difference (1 mCi/km^2) indicates that, as an upper limit, an additional 3.2 Ci of Pu-239 could have been released from the plant to the remote areas beyond the 3 mCi/km^2 contour. The total released to non AEC controlled property would then increase to 5.8 Ci.

This calculation of the remote contamination relies heavily upon the 1.5 mCi/km^2 estimate of fallout plutonium in the area. The one measurement at Derby in 1965 is not sufficient for a sound argument. Sr-90 analyses of the remote site samples and other studies are in progress which might resolve the problem. However, a thorough solution may require additional sampling in the Colorado area.

The Pu-238 measurements serve little useful purpose except to document the Pu-238/Pu-239 ratio of the Rocky Flats debris. The average ratio of this debris is about 0.020. At the remote sites where there is a greater proportion of fallout plutonium, the ratio is higher reflecting the debris from the 1964 re-entry burn-up of the SNAP-9A generator.

Source of Contamination

The distribution of Rocky Flats plutonium within the 3 mCi/km^2 contour suggests that the leaking barrels were the source of the contamination. The average wind behavior over the 17 years of record (Figure 1) should distribute a chronic low-level stack effluent in a directorial pattern similar to the contamination contours shown in Figure 5. However, the downwind extent of the stack effluent would depend largely on the particle size of the plutonium. Even if only gravitational settling is considered for the PuO_2 emitted from the 250 foot stack at the Dow plant, and if an average westerly wind of 12 miles per hour is assumed (Figure 1), then the plutonium within the 3 mCi/km^2 contour must have had a particle size in excess of 10μ diameter. The particle size distribution of the plutonium influent to the stack is not available, although measurements are in progress to determine it (4). Moreover, stack monitoring from the start of plutonium operations in 1953 through 1968 indicate an integrated release of only 38 mCi (7) of plutonium - far below what we found.

The May 11, 1969 fire can be exonerated as the source because the winds on that day (Figure 2) were almost directly opposite to the

ontamination pattern leaving the plant site (Figure 5). The de-
ection of plutonium at 13 cm below the soil surface would further
and to rule out a significant contribution from this event. The
eptember 11, 1957 fire can not be eliminated on the basis of the
inds at the time of that fire (Figure 3). However the particle
ize of the dioxide from burning plutonium is estimated to be sub-
icron (2). The sharp gradient and relatively short downwind ex-
ent of the contours in Figure 5 are not compatible with deposition
f sub-micron particles.

There are several observations about the plutonium distribu-
ion which link the contamination to the leaking barrels. The
lutonium laden oil from the corroded barrels contaminated the soil
n and around the storage area. As the oil seeped underground or
vaporated, strong gusty winds which occur predominantly from the
est, resuspended the contaminated soil carrying it eastward. Be-
ause the efficiency for resuspending particulates decreases with
ower wind velocities, the relatively light easterly winds would not
istribute much contamination to the west of the plant site.

The barrel storage area was in a region on Rocky Flats where
he ground was mostly course rock and sand particles. If these

particles are resuspended they would fall back to the ground rather quickly The rapid decrease of the high level contours east of the plant site supports this view. Similarly the contamination did not concentrate in the creek ravines as do the fine particles of soil and alluvium.'

It is interesting and probably meaningful that the surveys of the barrel storage area on the plant site suggested a southeasterly migration of the contamination. The contours off the plant site in Figure 5 also show a strong southerly component.

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Acknowledgments

The soil sampling of the Rocky Flats area was carried out with the full cooperation of Mr. Stanley E. Hammond, Industrial Hygiene Manager, Dow Chemical Co., Rocky Flats Plant. Two men from Mr. Hammond's group, Charles Thornberg and Duane Leonard, assisted us in the sampling over a two-day period.

We are grateful to the numerous property owners, and city and town officials who gave us permission to sample and helped us select suitable sites.

We wish to express our appreciation to Dr. John H. Harley, Director of the Health and Safety Laboratory, for his support in this work, for many useful discussions about the data, and for his help in preparing this report.

The preparation of the soil samples for analysis was carried out under the supervision of Gustave Farnham who was assisted by Aaron Frankel and John Weber.

Finally we acknowledge the contribution of Norton Chu who developed the analytical and assay procedure for plutonium in soil.

ANALYTICAL RESULTS : Rocky Flats Soils

Table A

Map Site	Sample	Sampling date	depth (cm)	area (km^2)	air dried wt. - kg total	rocks	soil	anal lab.	dpm per gram dried soil[3] Pu-239	Pu-238	mCi per km^2 Pu-239	Pu-238	Pu-238/Pu-239
1	1	2/11/70	0-30	986	30.29	17.60	30.69	IDA	0.0240 ± 3%	0.0000 ± 25%	2.3	0.08	0.033 ± 25%
2	2	2/11/70	0-30	1000	44.30	20.20	24.38	IDA	0.0295 ± 2%	0.0006 ± 25%	3.1	0.06	0.020 ± 25%
3	3	2/11/70	0-30	1000	35.94	14.30	21.56	IDA	0.0433 ± 3%	0.0012 ± 20%	4.2	0.12	0.028 ± 20%
4	4	2/10/70	0-30	622	18.44		18.44	HASL	0.0600 ± 4%	0.0019 ± 5%	8.0	0.25	0.031 ± 6%
								HASL (1)	0.0000 ± 4%	0.0013 ± 8%	10.7	0.18	0.016 ± 9%
								IDA	0.102 ± 2%	0.0020 ± 15%	13.6	0.27	0.020 ± 15%
5	5	2/10/70	0-15	622	16.46	0.85	15.61	IDA	0.134 ± 2%	0.0032 ± 9%	15.1	0.36	0.024 ± 10%
6	6	2/10/70	0-30	920	33.83	8.73	25.10	HASL	16.7 ± 4%	0.336 ± 4%	2270	40.9	0.018 ± 5%
								HASL(1)	16.0 ± 5%	0.352 ± 4%	1950	42.8	0.022 ± 6%
								HASL	16.3 ± 5%	0.310 ± 6%	1982	38.7	0.020 ± 7%
								TLM(2)	22.4 ± 3%	0.394 ± 6%	2725	47.9	0.018 ± 7%
								TLM(2)	39.8 ± 3%	0.866 ± 4%	4842	105	0.022 ± 5%
								IDA	16.6 ± 2%	0.310 ± 4%	2014	38.7	0.019 ± 5%
6	7	2/15/70	0-30	1000	37.39	5.99	31.40	TLM	15.4 ± 2%	0.285 ± 4%	1498	27.4	0.018 ± 5%
6	8	2/14/70	0-5	526			1.72	IDA	171. ± 3%	3.35 ± 3%	1425	27.9	0.020 ± 4%
								IDA	151. ± 3%	2.64 ± 3%	1260	22.0	0.018 ± 4%
6	9	2/14/70	5-8				1.35	IDA	35.8 ± 3%	0.659 ± 4%	402.(3)	8.7(3)	0.018 ± 5%
6	10	2/14/70	8-10				1.77	IDA	8.50 ± 6%	0.180 ± 6%	119 (3)	2.5(3)	0.021 ± 8%
6	11	2/14/70	10-13				1.10	IDA	1.20 ± 4%	0.0216 ± 4%	16 (3)	0.3(3)	0.018 ± 6%
6	12	2/14/70	13-15				0.70	IDA	0.287 ± 2%	0.0056 ± 8%	4 (3)	0.08(3)	0.020 ± 9%
6	13	2/14/70	15-18				0.63	IDA	0.290 ± 2%	0.0053 ± 16%	0 (3)	0.1(3)	0.018 ± 11%
7	14	2/10/70	0-30	622	19.81		19.81	HASL	3.08 ± 4%	0.059 ± 3%	442	8.47	0.019 ± 4%
								HASL(1)	3.18 ± 4%	0.066 ± 4%	456.	9.46	0.021 ± 5%
								IDA	4.00 ± 2%	0.072 ± 3%	574	10.3	0.018 ± 4%
7	15	2/15/70	0-30	622	19.19		19.19	IDA	3.15 ± 1%	0.054 ± 5%	437	7.50	0.017 ± 6%
8	16	2/10/70	0-5	622	2.31		2.31	TLM	29.4 ± 4%	0.586 ± 5%	424	8.42	0.020 ± 6%
8	17	2/10/70	5-30	622	17.68		17.68	TLM	1.64 ± 3%	0.0324 ± 6%	207	4.09	0.020 ± 6%
8	18	2/15/70	0-5	81	0.39		0.39	TLM	11.6 ± 3%	0.250 ± 3%	232	7.61	0.030 ± 4%
								TLM	13.0 ± 3%	0.390 ± 4%	282.	8.64	0.031 ± 5%
8	19	2/15/70	5-9	81	0.22		0.22	TLM	6.72 ± 3%	0.131 ± 4%	82.3	1.60	0.020 ± 4%
8	20	2/15/70	9-13	46	0.22		0.22	TLM	0.395 ± 3%	0.0080 ± 10%	7.7	0.17	0.022 ± 11%
8	21	2/15/70	13-30	62	0.67		0.67	TLM	0.748 ± 3%	0.0157 ± 8%	46.8	0.99	0.021 ± 8%

ANALYTICAL RESULTS: Rocky Flats Soils cont'd

Table A - cont'd

Grp Site	Sample	Sampling date	depth (cm)	area (cm^2)	air dried wt.-kg total	rocks	soil	anal lab.	dpm per gram dried soil Pu-239	Pu-238	pCi per m^2 Pu-239	Pu-238	Pu^{238}/Pu^{239}
9	22	2/11/70	0-20	929	20.41	3.50	17.03	IDA	0.0320±3%	0.0009±19%	3.8	0.08	0.027±15%
								IDA	0.0366±4%	0.0008±30%	3.3	0.07	0.020±30%
10	23	2/12/70	0-20	964	22.99	1.65	21.34	TLM	0.0220±5%	0.0063±10%	2.2	0.62[2]	0.29±11%
11	24	2/10/70	0-20	622	17.60		17.60	IDA	0.0420±4%	0.0020±100%	3.4	0.25	0.048±100%
12	25	2/9/70	0-5	622	2.98		2.98	TLM	2.14±3%	0.0409±3%	46.2	0.88	0.019±6%
								IDA	1.03±3%	0.0401±6%	39.5	0.84	0.022±7%
12	26	2/9/70	5-20	622	14.28		14.28	TLM	0.0443±4%	0.0033±11%	4.6	0.34	0.12±12%
								IDA	0.0361±5%	0.0010±40%	3.7	0.10	0.028±40%
12	27[4]	2/9/70	0-10										
13	28	2/11/70	0-20	1003	21.08	1.76	20.12	IDA	0.559±3%	0.0107±11%	50.5	0.96	0.019±12%
14	29	2/11/70	0-5	622	2.02		2.02	TLM	0.517±2%	0.0113±16%	10.5	0.23	0.022±16%
								IDA	0.510±2%	0.0105±10%	10.4	0.21	0.020±11%
14	30	2/11/70	5-20	622	13.94		13.94	TLM	0.100±4%	0.0024±20%	10.1	0.24	0.024±20%
								IDA	0.0332±5%	0.0010±30%	3.4	0.10	0.030±30%
15	31	2/12/70	0-20	929	26.41		26.41	IDA	0.130±4%	0.0023±30%	17.7	0.32	0.018±30%
16	32	2/12/70	6-20	622	14.52		14.52	TLM[2]	0.483±3%	0.0113±9%	50.7	1.19	0.023±10%
								IDA	0.182±3%	0.0030±19%	19.2	0.41	0.021±15%
17	33	2/12/70	0-20	1003	36.56	12.30	24.26	IDA	0.126±2%	0.0021±17%	47.0	0.23	0.017±17%
18	34	2/13/70	0-20	622	16.08		16.08	TLM	0.0176±7%	0.0005±99%	2.0	0.06	0.028±100%
19	35	2/13/70	0-20	622	15.90		15.90	IDA	0.0698±5%	0.0017±30%	8.0	0.20	0.024±30%
20	36	2/13/70	0-20	1003	22.47		22.47	IDA	0.0262±6%	0.0013±30%	2.6	0.13	0.050±30%
21	37	2/13/70	0-20	622	16.68		16.68	IDA	0.0188±4%	0.0004±100%	2.3	0.05	0.021±100%
								IDA	0.0253±3%	0.0007±30%	3.0	0.08	0.028±30%
22	38	2/13/70	0-20	622	17.17		17.17	TLM	0.0174±7%	0.0010±40%	2.2	0.13	0.057±40%
23	39	2/14/70	0-20	622	16.41		16.41	IDA	0.0254±6%	0.0006±100%	3.0	0.07	0.024±100%
24	40	2/14/70	0-20	622	16.52		16.52	IDA	0.0220±7%	0.0003±100%	2.6	0.04	0.013±100%
25	41	2/14/70	0-20	622	16.09		16.09	IDA	0.0205±6%	0.0006±100%	2.4	0.07	0.029±100%
26	42	2/12/70	0-5	622	3.55		3.55	TLM	0.0343±4%	0.0022±25%	0.08	0.06	0.064±25%
26	43	2/12/70	5-20	622	17.61		17.61	TLM	0.0136±7%	0.0009±50%	1.7	0.12	0.066±50%
								IDA	0.0083±6%	0.0007±40%	1.1	0.09	0.082±40%

Table A - cont'd

ANALYTICAL RESULTS: Rocky Flats Soils cont'd

Map Site	Sample	Sampling date	depth (cm)	area (cm^2)	air dried wt. - kg total	rocks	soil	anal. lab.	dpm per gram dried soil Pu-239	Pu-238	mCi per km^2 Pu-239	Pu-238	Pu-238 / Pu-239
27	44	2/12/70	0-5	622	2.72		2.72	ISA	0.0453 ± 3%	0.0010 ± 20%	0.89	0.02	0.022 ± 20%
27	45	2/12/70	5-20	622	13.94		13.94	ISA	0.0107 ± 5%	0.0003 ± 40%	1.1	0.03	0.028 ± 40%
28	46	2/13/70	0-20	622	20.69		20.69	TLW	0.0166 ± 6%	0.0013 ± 35%	2.5	0.20	0.078 ± 35%
29	47	2/12/70	0-10	622	6.04		6.04	ISA	0.0422 ± 3%	0.0018 ± 20%	1.8	0.08	0.042 ± 20%
29	48	2/12/70	10-20	622	13.90		13.90	ISA	0.0016 ± 14%	0.0007 ± 30%	0.16	0.07	0.44 ± 30%
30	49	2/13/70	0-20	670	22.08		22.08	TLW	0.0190 ± 7%	0.0010 ± 57%	2.8	0.15	0.053 ± 57%
31	50	2/13/70	0-20	622	17.44		17.44	ISA	0.0170 ± 4%	0.0005 ± 30%	2.1	0.06	0.029 ± 30%
32	51	2/13/70	0-20	622	21.34		21.34	TLW	0.0192 ± 6%	0.0022 ± 26%	3.0	0.34	0.11 ± 26%
								TLW(2)	0.734 ± 2%	0.0134 ± 7%	113	2.1	0.018 ± 7%
								ISA	0.0153 ± 5%	0.0006 ± 100%	2.4	0.09	0.039 ± 100%
33	52	2/13/70	0-20	622	16.94		16.94	ISA	0.0144 ± 4%	0.0005 ± 30%	1.8	0.06	0.035 ± 30%

(1) sodium carbonate fusion

(2) plutonium results not used in averaging

(3) calculated from estimates of soil density

(4) sample not analyzed

(5) 100 gram aliquot of air dried soil leached by HASL method

Table 9

ANALYTICAL RESULTS: Reference Soils

Reference Soil	Sampling date	depth (cm)	area (cm^2)	Total air-dried weight (kg)	anal lab.	dpm per gram dried soil[3] Pu-239	dpm per gram dried soil[3] Pu-238	mCi per km^2 Pu-239	mCi per km^2 Pu-238	Pu^{238}/Pu^{239}
Derby, Colo	Sept 1965	0 - 20	622	18.30	IRA	0.0112 ± 4%	0.0003 ± 30%	1.5	0.04	0.027 ± 30%
					TLM	0.0110 ± 7%	0.0041 ± 12%	1.4	0.54[2]	0.37 ± 17%
New York, N Y	June 1967	0 - 20	622	17.55	IRA	0.0167 ± 4%	0.0004 ± 30%	2.1	0.05	0.024 ± 30%
					IRA	0.0165 ± 5%	0.0003 ± 30%	2.1	0.04	0.018 ± 30%
					HASL[1]	0.0164 ± 4%		2.1		
New York, N Y	Dec 1969	0 - 2.5	186	0.24	TLM[4]	0.22 ± 10%	0.012 ± 63%	1.3	0.07	0.053 ± 63%
					TLM[4]	0.20 ± 5%	0.012 ± 25%	1.2	0.07	0.057 ± 25%
					TLM[5]	0.23 ± 9%	0.011 ± 45%	1.4	0.06	0.047 ± 45%
					TLM[5]	0.24 ± 5%	0.013 ± 28%	1.4	0.08	0.053 ± 28%
New York, N.Y	Dec 1969	0 - 5	622	2.41	TLM[4]	0.091 ± 6%	0.0006 ± 100%	1.6	0.02	0.006 ± 100%
					TLM[4]	0.096 ± 5%	0.0070 ± 22%	1.7	0.14	0.066 ± 25%
					TLM[5]	0.090 ± 6%	0.0040 ± 52%	1.6	0.07	0.044 ± 52%
					TLM[5]	0.092 ± 5%	0.0028 ± 68%	1.6	0.05	0.031 ± 68%
					HASL[1]	0.093 ± 4%		1.6		
New York, N Y.	Dec 1969	5 - 20	622	11.86	TLM[4]	0.0040 ± 20%	0.0037 ± 22%	0.41	0.74	1.8 ± 22%
					TLM[4]	0.0041 ± 16%	0.0021 ± 77%	0.36	0.18	0.50 ± 77%
					TLM[5]	0.0035 ± 42%	0.0009 ± 100%	0.31	0.08	0.26 ± 100%
					TLM[5]	0.0049 ± 13%	0.0004 ± 100%	0.43	0.03	0.09 ± 100%
					HASL[1]	0.0041 ± 5%	0.0003 ± 67%	0.35	0.03	0.07 ± 67%
"Black" Soil	Nov 1958	0 - 5			TLM[2]	0.0399 ± 9%	0.0042 ± 30%			0.11 ± 30%
					TLM	0.0074 ± 33%	0.0036 ± 62%			0.49 ± 62%
					HASL[1]	0.0051 ± 4%	0.0002 ± 100%			0.04 ± 100%
"Red" Soil	Nov 1958	0 - 5			TLM[2]	0.0567 ± 8%	0.0016 ± 95%			0.03 ± 95%
					TLM	0.0061 ± 14%	0.0008 ± 123%			0.08 ± 123%
Waynesville, O	Apr 1970	0 - 6	622	3.60	TLM	0.0440 ± 4%	0.0064 ± 11%	1.1	0.17	0.14 ± 11%
					IRA	0.0420 ± 3%	0.0020 ± 30%	1.1	0.05	0.05 ± 30%
Waynesville, O	Apr 1970	6 - 20	622	14.35	TLM	0.0132 ± 7%	0.0011 ± 44%	1.4	0.11	0.08 ± 44%
					IRA	0.0109 ± 10%	0.0005 ± 100%	1.1	0.05	0.05 ± 100%

(1) Sodium carbonate fusion
(2) value suspect
(3) 100 gram aliquot of air dried soil leached by HASL method
(4) " " " " " " " " TLM "
(5) " " " " " " " completely dissolved in acid and HF.

DOCUMENT D-2

"Committee Evaluation of Plutonium Levels in Soil
Within and Surrounding USAEC Installation at Rocky Flats, Colorado"
(1971)

by

J R Seed et al
Dow Chemical

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RFP-INV-10
July 9, 1971

COMMITTEE EVALUATION OF PLUTONIUM LEVELS IN SOIL WITHIN AND SURROUNDING USAEC INSTALLATION AT ROCKY FLATS, COLORADO

J R Seed, Chairman

K. W Calkins

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Publication Date

[redacted]

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Prepared under Contract AT(29-1)-1106
for the
Albuquerque Operations Office
U S Atomic Energy Commission

"REVIEWED FOR CLASSIFICATION
By R B Hoffman (U)
Date 2 25 91

[redacted]

[redacted]

ACKNOWLEDGMENTS

The committee would like to acknowledge the technical assistance of M R Boss of Rocky Flats Health Physics Group and D D Hornbacher R W Loser R N Chanda and D E Michels of the Rocky Flats Research and Development Group It would also like to express appreciation for the editorial assistance of G A Riordan and for the assistance rendered by the Rocky Flats Illustrations Department

[redacted]

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[redacted]

ABSTRACT

On August 19 1970 a committee was appointed by Lloyd M Joshel General Manager of the Rocky Flats Division of Dow Chemical U S A to assess the long term potential hazard of plutonium contaminated soil under and around an asphalt pad at Rocky Flats The committee was also to make recommendations for disposition of the contaminated soil The area covered by the asphalt pad had been used as an outside storage area for plutonium contaminated oil drums This report contains the essential information relating to the evaluation The evaluation indicated that there is no health hazard associated with the levels of plutonium soil contamination found in the vicinity of the asphalt pad The report reviews the pertinent published literature and presents the results of research initiated in support of the investigation

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COMMITTEE EVALUATION OF PLUTONIUM LEVELS IN SOIL WITHIN AND SURROUNDING USAEC INSTALLATION AT ROCKY FLATS COLORADO

F R Seed Chairman

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PART I STATUS

1 INTRODUCTION

In July 1958 at the USAEC Rocky Flats Installation an area on the plant site was designated as a temporary storage area for contaminated oil drums Subsequently some of the drums developed oil leaks and some plutonium contaminated oil was deposited on the soil The area was later covered by an asphalt pad

After a fire on May 11 1969 at Rocky Flats studies were conducted by the Health and Safety Laboratory (HASL) of the USAEC and by the Colorado Committee on Environmental Information (CCEI) concerning the possible release of plutonium These investigations detected measurable amounts of plutonium in the soil around the Rocky Flats Plant The epicenter quite clearly shows that this contamination could not be attributed to the May 1969 fire but is due to the resuspension and redistribution of contaminated soil from the oil drum storage area

A Committee was appointed by Lloyd M Joshel General Manager of the Rocky Flats Division of Dow Chemical U S A on August 19 1970 to assess the long term potential hazard and make recommendations for disposition of the plutonium contaminated soil under and around the asphalt pad, which covered the area that had served as an outdoor plutonium contaminated oil drum storage area

Members of the committee assembled over 3 000 pages of pertinent published literature Contacts were established with personnel throughout the AEC complex having similar problems and responsibilities (plutonium in soil)

In general the committee assembled and studied reports concerning

1 Rocky Flats historical information on the oil drum storage area

2 The HASL Report on *Plutonium in Soil Around the Rocky Flats Plant* August 1 1970

3 Colorado State Department of Health soil survey data

4 A CCEI report by L A Martell entitled Report on the Dow Rocky Flats Fire Implications of Plutonium Releases to the Public Health and Safety January 13 1970

5 The Palomares Accident

6 The Thule Accident

7 Operation Plumbbob

8 Operation Roller Coaster

9 Soil analytical techniques

10 Techniques for plutonium removal from soil and contaminated soil disposition

11 Plutonium biological assimilation data

12 U S and other governments recommended limits for plutonium contamination

13 Techniques for soil stabilization

14 Radiation survey instruments whose sensitivity and discrimination allowed for detection of plutonium surface contamination

[redacted]

15 Reports on world wide fall out

Specific programs were initiated to evaluate the plutonium contamination data available from HASL and CCEI reports as well as the soil analysis data being collected by the Rocky Flats Health Physics Department Action was initiated to core sample and analyze the soil covered by the asphalt pad Action was also initiated to evaluate soil stabilization techniques Contacts were established with some of the other AEC sites that had potential problems with plutonium contamination in soil

The committee directed special attention to contamination standards that had been used in previous incidents of plutonium contamination in soil particularly the most recently proposed standards These standard are used in assessing the potential consequences of the level of plutonium contamination originating from the Rocky Flats oil drum storage area

2 ASSESSMENT OF POTENTIAL HAZARD

A reasonably thorough reading of the literature available on biological assimilation redistribution deposition and effects does not reveal any health hazard associated with the levels of plutonium soil contamination found in the vicinity of the asphalt pad There are unanswered questions relative to high LET radiation associated with low level internal exposure This is an area of radiation research which is being actively pursued by Los Alamos Scientific Laboratory Battelle Northwest Lovelace Foundation Lawrence Radiation Laboratory the University of Utah and the University of Rochester

The standards that have been used for plutonium soil contamination are based on sets of assumptions including resuspension data and an acceptable risk of 1 5 REM/yr to the adult pulmonary lumph nodes Although specific standards have been recommended in the past disaster or emergency situations have not used specific guidelines but rather a process of judicious decision making has been employed The main guideline for the judicious decision making has been to maintain an 'actual dose as near zero as possible This freedom ' of interpretation however is shortly coming to an end It is this committee s opinion that the last data in the following table have been reasonably developed are realistic and have a high probability of being adopted by the USAEC for plutonium in soil The assessment of hazard and our recommended actions should be consistent with these interim recom mended standards It should be noted that the contour lines established using the HASL Report 235 data and the data from the CCEI report as well as the da a

MAXIMUM PERMISSIBLE ALPHA CONTAMINATION

Country	$\mu Ci/m^2$	mCi/km^2 [a]	d/m/gram [b]	Remarks
United Kingdom (Dunster)	0 1	100	22 2	Widespread areas contaiminated with plutonium
United Kingdom	0 1	100	22 2	Inactive areas
	1 0	1000	222	Active areas
Czechoslovakia	0 11	110	24 4	Workplaces after decontamination
France	0 1	100	22 2	Equipment and workplaces in inactive areas
	1 0	1000	222	Equipment and workplaces in active areas
Poland	0 1	100	22 2	Labs restricted to using 100 μ Ci or less
	1 0	1000	222	Labs permitted to use more than 100 μ Ci
South Africa	0 1	100	22 2	Body personal clothing inactive areas
	1 0	1000	222	Equipment and workplaces inside controlled areas
United States ICC	0 02	20	4 44	Interstate Commerce Commission (Dept of Transportation) pertains to interior of vehicles previously used for transpor tation of materials
U S S R	0 015	15	3 33	Work clothing and surfaces before cleaning
	0 002	2	0 444	Hands and work underclothing before cleaning
	0 006	6	1 33	Work Surfaces after cleaning
United States [c]	0 04	40	8 8	Urban suburban recreation areas.
	0 4	400	88	Rural truck farming annual food crops grazing land milk-shed etc
	4 0	4000	888	Rural deep root perennials (e g nuts, certain fruits)
	40 0	40000	8888	Remote or Controlled desert forest, fenced or limited access areas.

[a] Units used in HASL report No 235
[b] Units used by Rocky Flats in reporting soil analysis (in most cases a specific gravity of one (1) was assumed for conversion of units
[c] Recommended at an International Symposium on Radiological Protection of the Public in a Nuclear Mass Disaster (June 1968)

obtained by the Rocky Flats Health Physics Department show values in excess of the recommended limits extending beyond our property boundaries

Other significant regulations that should be considered in assessment of hazard are

1 Criterion I of 10 CFR 140 84 (Financial Protection Requirements and Indemnity Agreements) which considers surface contamination values above 0 35 $\mu Ci/m^2$ (77 dpm/cm^2 350 mCi/km^2) over 100 m^2 of property as the minimum level of transuranic radio nuclides that would comprise a substantial discharge of radioactive material from its intended place of confinement In the HASL report there are contour lines extending beyond the plant boundary that show plutonium concentrations in excess of this value

A Colorado State Board of Health Regulation should be considered

Radiation Regulation No 2

Requiring stabilization of uranium and thorium mill tailing piles This regulation applies to *all* uranium and thorium mill tailing piles and could be interpreted by the courts to apply to our radioactive pile It states that all such piles shall be stabilized against wind and water erosion It states that any recognized technique might be employed such as concrete petroleum products etc so as to ensure proper protection from wind and water erosion Access to the stabilized area shall be controlled by the operator or owner

Although the plutonium contamination of soil in and near Rocky Flats can not be considered a 'mill tailing pile, this Regulation gives an indication of the State s thinking in a somewhat analogous situation

Initial estimates made by Rocky Flats Manufacturing personnel based on total number of leaking barrels and average plutonium concentration in the oil led to a value of approximately 85 grams total plutonium deposited in the soil beneath the barrels

Making use of all the soil analysis data one can calculate an estimate of 7 6 grams over 5 63 km^2 (1 393 acres) outside the plant boundary down to the 13 mCi/km^2 contour The authors of the HASL 235 report estimate between 2 6 and 5 8 Ci off AEC property (38 to 85 grams Rocky Flats plutonium)

After taking all aspects into consideration the committee concludes that additional land should be purchased as proposed separately

3 HISTORY OF PLUTONIUM CONTAMINATED OIL DRUM STORAGE AREA

From the beginning of operations of the Rocky Flats Plant organic liquids contaminated with radioactive materials were generated in various manufacturing operations In the initial design of the facilities very little attention was given to this particular radioactive waste problem The volumes were very low and it had been assumed that this form of contaminated waste could be either burned or packaged in some manner and shipped for burial as were the low level solid wastes In the early days of the Rocky Flats operation some uranium contaminated oil was buried and some incinerated In 1957 a small quantity of uranium contaminated oil was shipped to the Idaho burial site but shipment of contaminated liquid wastes was not continued

Changes in weapons design and in manufacturing processes significantly increased the amount of contaminated oils being generated This particularly significant in the manufacturing of plutonium components The problems of permanent disposals and of storage of the increasing quantities generated were recognized in 1956

As a result of one study the Part IV addition (completed in 1957) to the plant included a high speed centrifuge in Building 776 to process plutonium contaminated organic liquids The operation was disappointing and resulted in a recommendation made in 1958 that a substitute process be developed for disposal This investigation was initiated immediately by the Technical Staff predecessor of the existing Research and Development Organization at Rocky Flats Considerably more comprehensive than the earlier studies the processes investigated for disposal included distillation steam stripping ion exchange filtration ion exclusion evaporation solvent extraction and other approaches

The outside plutonium contaminated oil drum storage area was first established in July 1958

Most of the drums transferred to the field were nominal 55 gallon drums but a significant number were 30-gallon drums Not all were completely full Approximately three fourths of the drums were plutonium contaminated whereas most of the balance contained uranium Of those containing plutonium most included lathe coolant consisting of a straight-chain hydrocarbon mineral oil (Shell Vitrea) and carbon tetrachloride in varying proportions Other liquids were involved however including hydraulic oils vacuum pump oil trichloroethylene perchloroethylene silicone oils acetone still bottoms etc Originally contents of the drums were indicated on the outside but some of these markings became illegible through weathering and adequate records were not kept of the specific contents of each barrel Leakage of the oil was recognized early and in 1959 ethanolamine was added to the oil to reduce the corrosion rate of the steel drums

Development work on a potential process to dispose and/or reclaim the materials continued As a result of the development studies which had been initiated however a recommendation was issued in December of 1959 that a still be constructed for the separation purification and reuse of the carbon tetrachloride and the Shell Vitrea A process design was forwarded to Plant Engineering The process was set up in Building 771 Because of time and funding problems surplus stainless steel equipment was used On May 15 1960 test runs on this equipment were begun and shortly afterward drums of currently generated oil together with some transferred from the field were processed through the system

Concurrently processes to dispose of the still bottoms from this operation and of other liquids were being pursued with incineration receiving the most favorable attention In this system the waste heat would be utilized to evaporate aqueous wastes which were also beginning to be a problem

In June of 1960 corrosion of the stainless equipment caused by hydrolysis of the CCl_4 to HCl became a problem and in September the operation was discontinued because of severe corrosion

After additional development work to solve the corrosion and other problems a revised design was submitted to Engineering in December 1961 The process was included in the project Additional Processing Facilities Contract AT(29 2) - 1298 which was an expansion of the plutonium chemical operation During this period development of a sludging process for disposing of the still bottoms and other wastes by mixing with an activated silica was also completed In June 1963 a decision was made to delete the CCl_4 still and other features from the expansion project because of funding problems Because of this the design capacity of the sludging process was increased to provide for processing all contaminated liquids and funds for this project based on a mixer extruder system called the 'jelly factory' were requested Installation of the mixer extruder system was completed in January 1964 but start up work revealed major deficiencies which required extensive modification in the installation These modifications were not completed until late in 1965

When this equipment was finally ready for operation a further delay was encountered when it was determined desirable to provide a facility to perform the dual purposes of transferring the oil to new drums for safe transfer to the mixing equipment and filtering through one micron filters for plutonium removal and recovery. As a result FY 1966 expense funds were provided to build a temporary facility for these purposes.

After more start up problems, the final phase of emptying the drum field began on January 23, 1967. By this time the field contained about 5,240 drums, of which approximately 3,570 contained plutonium contamination. The oldest drums and those containing plutonium were processed first. To the best of our knowledge, the last of the plutonium contaminated oil was removed on January 25, 1968. The last of the uranium contaminated oil was transferred to a new drum on May 28, 1968, and shipped to the disposal plant in June 5, 1968.

Original estimates of plutonium content had indicated that the plutonium bearing drums averaged about 4.5 grams of plutonium per drum. The material balance after processing however showed that less than half this amount was present. Of the plutonium found, only 594 grams were recovered, 2471 grams were processed with the oil, and 5152 grams remained in the emptied drums.

An estimate of leakage based upon a material balance around the drums indicated that 5,000 gallons of oil containing about 86 grams of plutonium leaked from the drums into the soil.

The significant or pertinent events associated with the Plutonium Contaminated Drum Storage Area can be summarized as follows:

Date		Information
July	1958	Drum storage area established. During subsequent years, drums were continually added which primarily contained plutonium contaminated machining oils.
July	1959	First drum leakage discovered. Rust inhibitor, ethanolamine, was added to drums prior to storage to minimize corrosion.
January	1964	First evidence of large scale deterioration of drums reported. Soil contamination reported as increasing.
January	1966	Small building added to filter and transfer contaminated oil from leaking drums to new drums.
January	1967	First drums added to storage area and removal to 774 begin. Oldest drums shipped first.
June	1968	Last drum shipped to Building 774 for processing. High winds spread some contamination.
July	1968	Radiation monitoring and mapping of area completed. Levels of 2×10^5 d/m/g to over 3×10^7 d/m/g reported. Penetration of from 1 inch to 8 inches reported.
September	1968	Preliminary proposal for containment cover prepared by Rocky Flats Facilities Engineering.
July	1969	First coat of fill material applied.
August	1969	Fill work completed, paving contract let.
September	1969	Overlay material, soil sterilant and asphalt prime coat completed.
November	1969	Asphalt containment cover completed including four sampling wells.

The deposition of the contamination in the soil of the drum storage area began shortly after the drums were placed in the area. Resuspension and redistribution of the contamination however was certainly not a simple mathematical function of time. The quantity redistributed was directly associated with removal of the drums which exposed the contaminated soil, physical activity in the area, and the periodic high winds found at Rocky Flats. This can best be seen if we study data from air samples collected directly east of the storage area. The Rocky Flats Health Physics Department conducts an extensive air sampling program to determine the presence of airborne radioactive contaminants in and around the Rocky Flats Plant site. One of these air samplers (designated S-8) is situated directly east of the 903 drum storage area at the east perimeter fence. The contamination levels determined by analysis of samples collected daily from this location have, through the years, been higher than the levels measured at other locations.

Monthly averages of the individual daily contamination levels show a very close correlation to physical activity in the drum storage area. Figure 3.1 shows a graph of the monthly average airborne contamination levels determined at air

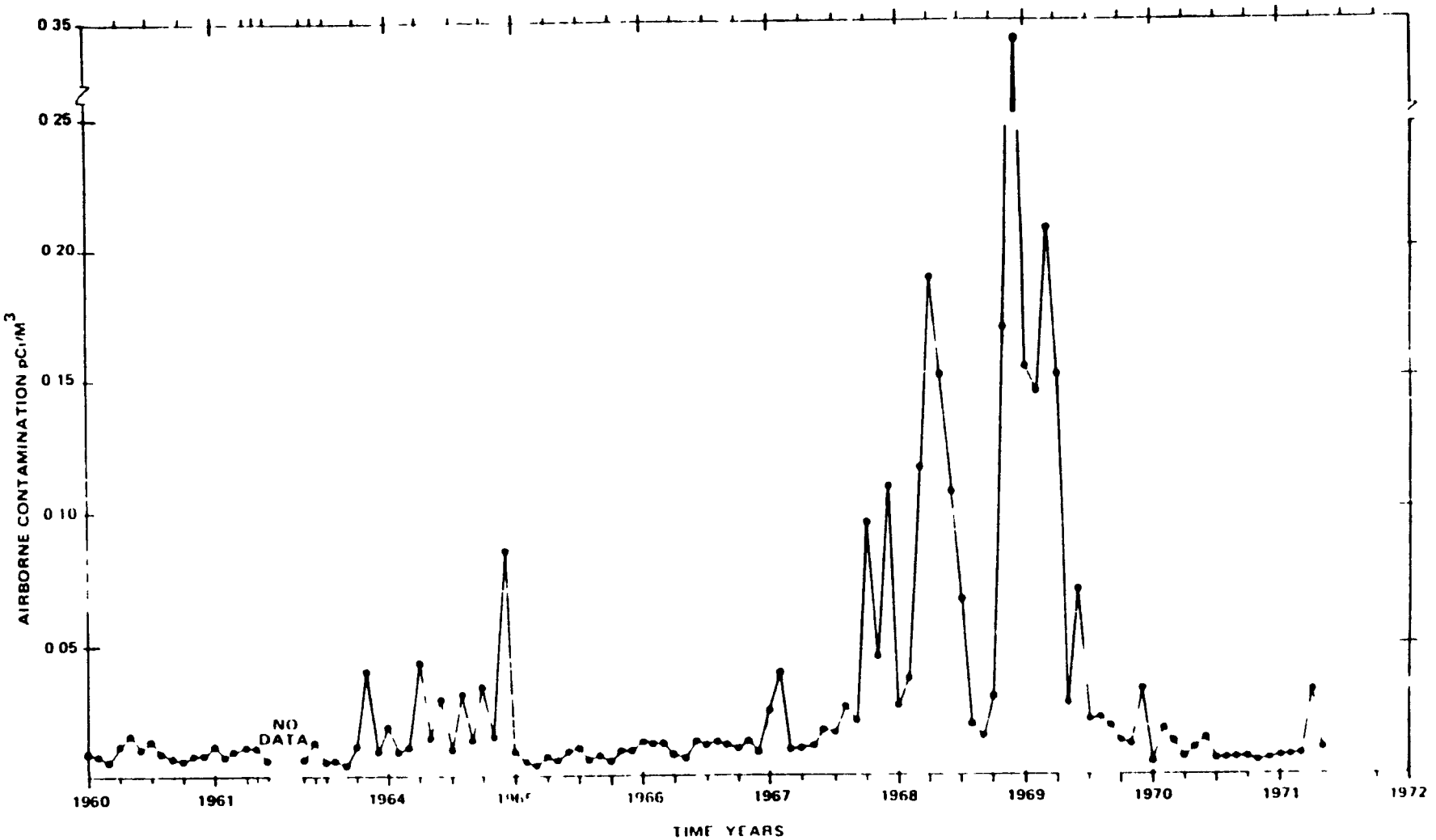


Figure 3 1 Monthly Averages of Daily Airborne Contamination Values from Air Sampler S 8 Located just East of the Drum Storage Area

sample [illegible] When analyzing these data it is worth noting that from [illegible] 1963 to 1965 large scale deterioration of the drums was taking place An exclusion fence was added (to limit physical activity in the area) One drum was punctured by a fork lift and some soil was added to cover certain contaminated areas These physical activities corresponded to the higher readings reported during the 1963 through 1965 period Starting in January 1967 a great deal of activity in the area was associated with drum removal The contamination level measured in 1968 paralleled the drum removal activity In late 1968 activity associated with weeds being burned and grading of the area can be correlated with high contamination readings In April of 1969 when the large rocks and stakes were removed for filling and leveling the area increased contamination levels were reported

In November of 1969 the four sample wells were dug and the increases in contamination level are attributed to the activity in the area In April of 1971 a new drainage ditch was completed just west of this area and again higher contamination values were observed

At no time did the values from air samples indicate that permissible levels of plutonium contamination in air had been exceeded However these data do indicate the most probable period when maximum resuspension and redistribution of the contaminated soil took place

4 ATOMIC ENERGY COMMISSION CONTACTS

To collect as much information as possible concerning contaminated soil problems knowledgeable individuals throughout the AEC complex were contacted The following is a summary of these contacts

LASL

Wright Langham (Health Division) discussed availability of reports on plutonium contamination of soils especially reports related to the Palomares and Thule accidents Langham reported that this information is not readily available because it had not yet been published by the Air Force Langham reviewed HASL report 235 for the AEC and said he was reasonably impressed that a professional job had been done He mentioned by telephone communications and later suggested in writing that the Dow committee might profit by a visit to Los Alamos to talk to people familiar with foreign contamination incidents as well as with contamination incidents at Los Alamos It was suggested that Dean Meyer John Healy and William Kennedy could provide information concerning contamination levels in the LASL area

USAEC

Philip Krey (HASL) discussed HASL report 235 Two errors one on the contour map of Rocky Flats area soil survey and one typographical error in the data table on plutonium concentration in soil at one sample site were corrected It was agreed that neither correction significantly changed the total plutonium inventory in the area surrounding Rocky Flats

John S Harley (HASL) mentioned that he had participated in a meeting at the AEC Headquarters on July 6 7 1970 to draw up guidelines for sampling and analyzing soils for plutonium Harley also discussed the possibility of HASL personnel returning to Colorado for a supplemental program to include (1) more detailed surveys in the immediate vicinity of Rocky Flats and (2) specific field studied on resuspension of plutonium contaminated soil particles

Don Ross (Health Protection – Operational Safety) discussed in great detail the AEC guidelines (prepared July 6 and 7) for plutonium sample collection and analysis This discussion with Ross reviewed the initial request from ALO (W B Johnston) for such a meeting the membership of the committee which developed the guidelines, how the guidelines were arrived at and a summary of the nine guidelines This document has been routed to Dow through ALO

Art Whitman (NVO – Rad Op) discussed the availability of NVO reports It was suggested that we obtain a copy of a special bibliography on plutonium soil contamination (this bibliography has been received Also Whitman suggested that someone from Dow visit NVO to discuss details of NTS plutonium-contamination experience and to scan their files of classified reports and miscellaneous data for information pertinent to the Rocky Flats situation Therefore a trip was taken to Nevada The following is a list of persons contacted at the Nevada Operations Office United States Public Health Service and Reynolds Electrical and Engineering Co A trip report summarizing this activity is given in Appendix E

USAEC

Arthur J Whitman	Radiological Safety Branch
Donald W Hendricks	Radiological Safety Branch
Ross L Kinnaman	Effects Evaluation Office
Paul J Mudra	Operations Division

USPHS SWRHL

Mel W Carter	Laboratory Director
Jim Mullins	Deputy Chief Analytical Division
Les Dunn	Environmental Survey

REECO (Test Site)

Arden E Bicker	Environmental Services
Derek Engstrom	Chemistry Laboratory
Leonard Svgitowicz	Chemistry Laboratory
Terry Roy	Site Survey

ORNL

F R Bruce (Safety and Radiation Control) and W S Snyder (Health Physics) were contacted Discussions were held concerning a contamination release which ocurred in 1957 An explosion in a process tank allowed the release of a uranium plutonium solution Most of the contamination was confined within a building However some contamination to the environment resulted by personnel tracking it outside and the escape of airborne contamination It was estimated that about 1 gram of plutonium was lost Some gravel and top soil were removed and placed in drums for disposal

NEVADA

C A Pelletier (Environmental Health Services Laboratory) stated that work was being conducted concerning the deposition of radioactive material from the air to soil However resuspension of plutonium from the soil and soil stabilization have not been investigated

Claude Sill discussed the Idaho method (fusion and total dissolution) for analysis of plutonium in the soil

5 REVIEW OF CURRENT ANALYTICAL METHODS FOR PLUTONIUM IN SOIL

Measuring plutonium in soils especially at very low levels is a difficult analytical problem It is imperative that the analytical methods have good accuracy precision and reproducibility of information

Various methods have been used for the analysis of plutonium in soils They differ primarily in the method by which the plutonium is released from the soil These methods vary from acid leaching to complete dissolution of the soil by fusion

The specific methods used by various sites for plutonium analysis have been collected Three of these (Rocky Flats Health Physics Laboratory and Building 881 Analytical Laboratory and the AEC s Health and Safety Laboratory) are summarized below Following these summaries there is a discussion of the reproducibilities of the various methods comments on the two Rocky Flats Laboratories that have the capabilities for analysis of plutonium in soils and a summary of the AEC guidelines for soil sampling and analysis

Methods Summary

1 Rocky Flats (Health Physics)

The soil samples (10g) are ignited a ^{236}Pu spike (used to measure the recovery of all the plutonium in the sample) is added and the samples are evaporated (leached) alternately with HNO_3 and HCl This is followed by a leach with HF and $HClO_4$ The solids are then removed by filtration the acidity of the solution is adjusted with HCl and the Pu is separated by anion exchange The plutonium concentration is then determined by alpha spectrometry

2 Rocky Flats (Building 881 Analytical Laboratory)

A ^{236}Pu spike is added to 100g of soil and the sample is leached twice with a 1 to 3 mixture of HCl and HNO_3 Plutonium is removed from the leaching solution on a column of anion exchange resin After stripping the plutonium from the resin with a dilute HNO_3 HF mixture the acidity and plutonium valence are adjusted and the plutonium is extracted with TTA The plutonium-containing organic solution is then evaporated on a planchet and the plutonium determined by alpha spectroscopy

3 AEC Health and Safety Laboratory (HASL)

A ^{236}Pu spike is added and the samples (100g) are leached with a HNO_3 HCl mixture first at room temperature then at an elevated temperature The solution is decanted and any organic matter is decomposed by heating Silicic material if present is removed by filtration and decomposed by heating with HF The remaining material is dissolved in HNO_3 and combined with the initial filtrate The acidity is adjusted with HNO_3 and the plutonium is separated using anion exchange The plutonium is then plated on a disk and the concentration determined by alpha spectrometry

Other methods for determining plutonium in soils involve complete dissolution of the soil by fusion then separation of the plutonium from the fused mass In the AEC complex Claude Sill of the Idaho Operations Office is a proponent of this method The primary drawback of the fusion method is the extensive time required to process each sample and the relatively small sample size (1 to 5g usually) that can be handled conveniently Those favoring the fusion method are convinced however that it is the only sure way of getting all of the plutonium in solution and available for analysis

The amount of plutonium that will dissolve by leaching depends on its form in the soil In analytical methods ^{236}Pu spikes are added in solution form As a result this spike of plutonium will be more easily removed from soil than plutonium in the form of oxide especially oxide that is high fired Although there is probably no better way to spike a soil sample those using soil analysis data should be aware of the limitations and the data should be evaluated accordingly

Fuming a soil sample with an HF $HClO_4$ mixture is another method that has been used for complete soil dissolution It too is a lengthy process The use of this method has been reported by HASL (HASL 235) The current Rocky Flats method uses a HF $HClO_4$ acid treatment but not to the point of complete dissolution of the sample

Reproducibility of Analytical Methods

There are no analytical standards for plutonium in soil The only way that analytical methods can be compared therefore is by percent recovery of spikes the precision of these spike recoveries and interlaboratory analysis of the same sample Data on spike recovery and the precision of this recovery are summarized below for the Rocky Flats and the HASL methods This is followed by a discussion of results on interlaboratory sample exchange programs and a comparison of different methods on the same samples

SPIKE RECOVERY

1 Rocky Flats Health Physics Laboratory

In mid 1970 a series of soils from LRL was analyzed at Rocky Flats The plutonium content ranged from 0 3 to 500 d/m/g with 5 samples ≤1 d/m/g one sample at 10 d/m/g and one sample at 500 d/m/g The average percent recovery of the spikes for all replicates was 76% with a standard deviation of 7%

2 AEC Health and Safety Laboratory (HASL)

J H Harley provided data on spike recovery for their method On ten soil samples analyzed the average recovery was 84% with a standard deviation of 6% The data supplied were in the form of spike recoveries only the amount of plutonium in the samples was not reported

Comparison of Different Analytical Methods

HASL has compared their leach method a carbonate fusion method and a HF $HClO_4$ dissolution method all on Rocky Flats soils The results are shown in Tables 5 1 and 5 2 These results indicate that the methods are reasonably comparable (not significantly different according to the HASL report) It should be noted however that there is no indication of the chemical form of plutonium in the soil used to obtain the results in either of these tables

Table 5-1 Comparison of Plutonium Analysis in Soil by Nitric Hydrochloric Acid Leach and Sodium Carbonate Fusion Methods.

Soil Type	Method	dpm/100g Pu 239 + 240	dpm/100g Pu 238	Percent Chemical Yield
1A	Leach	308 ±11	5 9 0 2	53
1B	Fusion	318 ±12	6 6 ±0 3	59
2A	Leach	1629 ±87	32 ±2	56
2B	Fusion	1607 ±82	35 ±2	66
3A	Leach	6 0 ±0 2	0 19 ±0 01	58
3B	Fusion	8 0 ±0 3	0 13 ±0 01	61

This information received from J H Harley HASL September 3 1970

Table 5 2 Complete Dissolution versus Leaching

Map Site	Sample	Rocky Flats Soils Lab	Method	Pu 239 dpm/g ± σ	Deviation Between Methods
7	14	HASL	leach	3 08 ±4	3 2
		HASL	fusion	3 18 ±4	
6	6	HASL	leach	18 7 ±4	
		HASL	leach	16 3 ±5	8 9
		HASL	fusion	16 0 ±5	
4	4	HASL	leach	0 060 ±4	28
		HASL	fusion	0 080 ±4	
					mean 13
		Other Soils			
N Y C 6/67	0 20 cm	IPA	leach	0 0167 ±4	
		IPA	leach	0 0165 ±5	0
		HASL	fusion	0 0166 ±4	
N Y C 12/69	0 2 5 cm	TLW	leach	0 22 ±10	
		TLW	leach	0 20 ±5	11
		TLW	HF dissolution	0 23 ±8	
		TLW	HF dissolution	0 24 ±5	
N Y C 12/69	0 5 cm	TLW	leach	0 091 ±6	
		TLW	leach	0 096 ±5	3 3
		TLW	HF dissolution	0 090 ±6	
		TLW	HF dissolution	0 092 ±5	
N Y C 12/69	5 20 cm	TLW	leach	0 0048 ±20	
		TLW	leach	0 0041 ±16	7 1
		TLW	HF dissolution	0 0035 ±42	
		TLW	HF dissolution	0 0049 ±13	
		HASL	fusion	0 0041 ±5	
Black Soil 1958		TLW	leach	0 0074 ±35	37
		HASL	fusion	0 0051 ±4	
					mean 12

Comparison of Interlaboratory Results

LRL supplied analyses on the samples they sent to Rocky Flats and mentioned above The results are tabulated below Qualitatively the agreement between the two series of results is quite good

Sample Number	d/m/g LRL	d/m/g Rocky Flats[a]
1	0 06	0 29 ±0 19
2	0 67	0 82 ±0 22
3	0 4	0 71 ±0 22
4	0 2	0 44 ±0 15
5	0 14 0 91	1 08 ±1 07
6	550	493 ±33
7	13	10 9 ±0 8

(a) $\text{mean} \pm \frac{\text{range}}{2}$

The Rocky Flats Health Physics Laboratory was involved in an interlaboratory sample exchange in mid 1970 using samples prepared by Claude Sill of Idaho The soil samples were apparently fused after preparation so that the plutonium was present in the form of a high fired oxide On the first two of these there was a recovery of 65 and 100% (the analytical method used includes leaching with HF which will dissolve high fired oxides better than any other treatment) This recovery was better than that obtained by either HASL or Los Alamos Subsequently two other Sill prepared samples were analyzed The Laboratory obtained an 85% recovery on a sample containing 23 d/m/g and a 71% recovery on a sample containing 39 d/m/g

Currently the Rocky Flats Health Physics Laboratory is involved in a ^{239}Pu Soil Cross-Check Program being administered by the Southwestern Radiological Health Laboratory Five samples have been received and three were analyzed The concentration of plutonium in these samples is in the range of 5 to 30 d/m/g Verbal information has been obtained on the first sample analyzed and indicates a recovery of between 95 100% of the plutonium present (~33 d/m/g) Three aliquants were run The precision as measured from the three aliquant results was ±5%

HASL has conducted interlaboratory comparison of methods They are summarized in Table 5 3 For the most part the results from the various laboratories appear to be within reasonable agreement

Table 5 3 Interlaboratory Comparison Analysis of Plutonium in Soil

Sample Location	Lab	Method	dpm/100c Pu 239 + 240	Pu 238
Colorado (1)	A	HNO_3 HCl Leach	400 ±4	7 2 ±0 2
	HASL	HNO_3 HCl Leach	308 ±11	5 9 ±0 2
	HASL	Na_2CO_3 Fusion	318 ±12	6 6 ±0 3
Colorado (2)	A	HNO_3 HCl Leach	1660 ±33	31 8 ±1 3
	HASL	HNO_3 HCl Leach	1629 ±87	31 8 ±2 0
	HASL	Na_2CO_3 Fusion	1607 82	35 3 ±1 6
Colorado (3)	A	HNO_3 HCl Leach	10 2 ±0 2	0 20 ±0 03
	HASL	HNO_3 HCl Leach	6 0 ±0 2	0 20 ±0 01
	HASL	Na_2CO_3 Fusion	8 0 ±0 3	0 13 ±0 01
New York (1)	A	HNO_3 HCl Leach	1 7 ±0 1	0 04 ±0 01
	HASL	Na_2CO_3 Fusion	1 7 ±0 1	0 41 ±0 02
New York (2)	B	HNO_3 HCl Leach	0 41 ±0 07	0 27 ±0 21
	B	HF Dissolution	0 35 ±0 15	0 09 ±0 18
	B	HF Dissolution	0 49 ±0 07	0 04 ±0 04
	HASL	Na_2CO_3 Fusion	0 41 ±0 02	0 03 ±0 02
Illinois (1)	B	HNO_3 HCl Leach	0 74 ±0 25	–
	HASL	Na_2CO_3 Fusion	0 51 ±0 03	–

Table 5 3 (continued)

Sample Location	Lab	Method	dpm/50c Pu 239 240	Pu 238
New York (3)	B	HNO_3 HCl Leach	4 82 ±0 23	0 03 ±0 03
	B	HNO_3 HCl Leach	4 53 ±0 30	0 39 ±0 10
	B	HF Dissolution	4 58 ±0 25	0 20 ±0 10
	B	HF Dissolution	4 49 ±0 24	0 14 ±0 09
	HASL	HNO_3 HCl Leach	4 13 ±0 17	0 32 ±0 02

General Comments

ROCKY FLATS HEALTH PHYSICS LABORATORY

The laboratory personnel are currently investigating a total dissolution method using a Teflon lined Parr Bomb Pressures as high as 1200 psi can be obtained in this bomb It is hoped that with this high pressure and a mixture of HF and HCl it will be possible to dissolve a greater fraction of the sample

The back log of samples in the Laboratory is being reduced The average elapsed time for a sample analysis is now one month however the time depends on the priority of the sample It takes about a week from the time analytical work begins on a sample until the results are available

BUILDING 881 ANALYTICAL LABORATORY

The Building 881 Analytical Laboratory has been developing a capability for plutonium analysis in soils over the last six to eight months They currently have a method developed [Methods Summary (2)] and have obtained the necessary counting equipment Analyses of soil samples taken from the Pad are in the range of 0 001 to 7 7 μg/100 g soil They estimate their precision on these samples to have been ±20%

To investigate the effect of the form of plutonium on its recovery they spiked a large soil sample with plutonium and heated it to 400° 600° 800° and 1000°C They analyzed samples heated to each temperature by their method (which includes an HCl HNO_3 leach) and recovered 105 109 85, and 13% respectively of the plutonium This graphically demonstrates the influence that the form of plutonium has on its recovery This is a important observation The nature of the plutonium in the soil sample should dictate the dissolution technique used If is is suspected that a high fired' oxide is involved, the fusion method recommended by Claude Sill (or near complete dissolution) might be necessary for reasonable quantitative results

AEC Guidelines for Soil Sampling and Chemical Analyses

It is apparent from the information above that there is not general agreement between various sites on the best analytical method to use for soil analysis. The same situation exists for soil sampling techniques.

During the course of this committee's investigation, the AEC issued a set of guidelines for soil sampling and sample analysis (copy received October 26, 1970). Criteria are given for determining locations for sample taking, the number and frequency of samples to be taken, the procedure for taking the samples, and the preparation of the samples for subsequent analysis. Rocky Flats procedures (within the limits imposed by the nature of our rocky soil) have taken cognizance of these guidelines.

The criteria for sample analysis are general and the methods now in use appear to comply with the AEC recommendation.

[redacted]

6 SIGNIFICANT PERTINENT INFORMATION FROM PREVIOUS INCIDENTS OF PLUTONIUM CONTAMINATION

There have been several instances of plutonium contamination of the environment outside of a government (AEC) controlled area Two of these - Palomares Spain January 1966 and Thule Greenland January 1968 - involved major plutonium contamination of significant land areas There were also significant political and public relation overtones It is instructive to examine these two accidents to see what can be learned about the extent of contamination the methods used to decontaminate and the amount of residual activity remaining after decontamination was completed The Palomares accident will be examined first since it more closely resembles the Rocky Flats situation with contaminated soil

Palomares

EXTENT OF CONTAMINATION

The accident at Palomares took place at 32 800 feet with pieces of the plane falling over a very wide area Plutonium was released by the non nuclear explosions of two bombs A total of approximately 558 acres was contaminated A total of 5 4 acres had an alpha contamination of more than 700 000 d/m/100 cm^2 (See Appendix D for simplified conversion to other common units found in this report) An area of approximately 42 acres showed contamination of between 700 000 and 70 000 d/m/100 cm^2 and the rest some 511 acres showed contamination of less than 70 000 d/m/100 cm^2 More than half of these 511 acres were contaminated to less than 7 000 d/m 100 cm

DISPOSITION OF CONTAMINATED SOIL

The disposition of the contaminated soil is summarized as follows

DISTRIBUTION OF PLUTONIUM ON THE SURFACE IN THE VICINITY OF THE PALOMARES ACCIDENT

Initial Plutonium Contamination			Area	
μCi/100 cm	mCi/km^2	d/m/100 cm	acres	Disposition
>0 32	>32 000	>700 000	5 4	Surface soil (2 3) removed and buried at Savannah River
0 32 0 032	32 000	700 000	42 [a]	
	3 200	70 000		Deep plowed watered and some vegetation removed
<0 032	<3 200	<70 000	511 [b]	
	Detectable		558	Deep plowed and watered

[a] From one report it could be concluded that this soil was also removed to Savannah River for burial but this does not seem likely when we analyze all the reports on this topic

[b] Rather more than half is less than 0 0032 μCi/100 cm^2

The removal of soil from the 5 4 acres where the activity was highest resulted in 1100 cubic yards of soil which were buried at Savannah River in the same manner as other low level radioactive material (To help gain a perspective the soil buried contained about 10^3 to 10^4 times the amount of plutonium found in the remaining area) Also removed from the site and buried at Savannah River were about 400 cubic yards of vegetation It was planned initially to deep plow only 300 acres of land having low but discernible amounts of contamination However the operation was found to be so easily performed that the area was extended to include an additional 558 acres Plowing was done to a depth of approximately 10 to 15 inches the soil was primarily sandy although some places were rocky This process reduced the surface contamination in this area to undetectable amounts and it was concluded essentially eliminated significant resuspension of plutonium into the air

The total cost for the operation in Spain has been estimated as 50 million dollars This does not include the political and public relations cost of the incident

A comparison can be made between the quantities of plutonium found in the soil at Palomares and the amount found in the vicinity of the barrel storage area at Rocky Flats This comparison should be considered only an order-of magnitude comparison since details of soil sampling at Palomares are not available to us An assumption is made that the reported results from Palomares are from surface sampling only At Palomares soil was actually removed (and shipped to the United States for burial where contamination levels were greater than 0 32 μCi 100 cm (32 000 mCi/km^2) All soil containing measurable contamination up to the value of 0 32 μCi/100 cm was deep plowed Data from the HASL Report 235 indicated that the two hottest spots found at Rocky Flats were east of the barrel storage area These spots (indicated as sites 6 and 8 in HASL Report 235) contained totals of 2000 and 620 mCi/km respectively in the 0 20 cm depth Of the total plutonium reported from these sampling sites 1320 and 415 mCi/km^2 were reported as occurring in the 0 5 cm depth Rocky Flats Health Physics Department sampling and analysis give results in excess of 3 000 mCi/km^2 on AEC land The highest isocurie contour that extends on private property surrounding AEC land was found to be between 400 to 1000 mCi/km^2 The plutonium contamination levels of concern at Rocky Flats are substantially below those levels at Palomares where soil removal was deemed necessary

CURRENT LEVELS OF CONTAMINATION

Sampling of the soil has been done on a yearly schedule in the Palomares region since the accident in 1966 Core samples are taken in areas that had varying initial contamination These cores are divided into segments of 5 to 10 cm

[redacted]

for a total depth of 45 cm The conclusions reported at a conference in 1968 are as follows

1 In the area where the 2 3 inch layer of contaminated soil was removed and sent to Savannah River the contamination is nil

2 In the areas where there was deep plowing contamination has been found to a depth of 13 inches Generally highest contamination levels were found between 6 and 10 inches down but there was a very unhomogeneous distribution of the contamination

3 The maximum average value of alpha activity found in the areas studied is approximately 50 times higher than the minimum value of natural alpha activity found in the background soil in the area

A network of four air sampling stations was set up within the accident area Air samplers were placed 5 5 feet above the ground They operated 24 hours a day throughout the year Cellulose filters with a pore size of 1 2 microns were used for the sampling Gross alpha as well as ^{239}Pu content were determined on the filters The results of these air samples were reported at meetings in 1968 and 1970 They are summarized as follows

1 Activity has been found at all sampling areas This means that some radioactive material has become resuspended However removal of the most contaminated surface soil and the dilution of the remainder by plowing has proven effective in reducing the mean value for ^{239}Pu in the air to levels consistently below the permissible maximum

2 The ^{239}Pu concentration in the air was normally less than 0 1 of the maximum permissible concentration (MPC) for the general public (The MPC used was from the Radiation Protection Norms of the European Nuclear Energy Agency revised edition 1968 For insoluble compounds of ^{239}Pu in air for the general public it is 10^{12} μCi/cm^3 for soluble compounds it is 6×10^4 μCi/cm^3 Although the plutonium compounds are known to be insoluble plutonium dioxide the soluble compound limit was used to provide a guarantee of maximum safety) Concentrations exceeding 0 1 the MPC were recorded on only 7 occasions two of which exceeded the MPC Both of these values did not exceed 0 1 of the MPC for insoluble ^{239}Pu compounds however

3 On days when maximum air sample values were found the winds in the area had speeds of between 7 and 13 miles per hour

Since the weather can influence the behavior of plutonium in the soil it is interesting to compare rainfall wind velocity and temperature at Palomares with those at Rocky Flats This is tabulated as follows

	Palomares	Rocky Flats
Mean annual rainfall	7 9 inches	14 4 inches
Mean annual temperature	64 8°F	49 0°F
Velocity of most frequent strong wind gusts	43 mph	40 mph

Although Rocky Flats has a higher rainfall and a lower temperature the weather conditions are not extremely different

Thule

The accident at Thule was different from that at Palomares in that the bombs came down with the plane and were involved in a fire which was fueled by JP-4 jet fuel Also there was no soil involved just ice and snow

Contamination was spread over a drop shaped area of 26 acres with the distribution in that area as shown in the following tabulation

DISTRIBUTION OF PLUTONIUM ON THE SURFACE IN THE VICINITY OF THE THULE CRASH[a]

Initial Plutonium Contamination		Area	
μCi/100 cm	mCi/km	acres	Disposition
278	27776×10^3	0 49	Crust and packed
140	13969×10^3	2 23	snow removed to
9	912×10^3	3 43	an average
3	295×10^3	3 46	depth of
1	93×10^3	5 12	4 inches

[a] Excluding plutonium picked up on aircraft debris and that beyond blackened ice area

When fuel burned a blackened area was produced on the snow Approximately 99% of the total plutonium found (3150 ± 630 g) was within this blackened area

This black crust contained unburned jet fuel It was estimated that as much as 18% of the fuel remained unburned Sedimentation studies showed that up to 80% of the plutonium was associated with low specific gravity debris that remained suspended in this jet fuel This debris included such things as metal glass and nylon fibers plastic rubber, and flecks of paint The plutonium itself was in the form of oxide particles with a very wide size distribution

Core samples of the ice indicated that on the average 13% of the total plutonium was in the top 2 inches, 6 in the top 4 inches and 45% in the top 6 inches. About 15% was in the bottom 10 inches and the remaining 40 was distributed between 6 inches from the top and 10 inches from the bottom. The total ice thickness was 54 inches. The plutonium was distributed throughout the ice because the ice was fractured on impact of the plane with the ice. It subsequently refroze. It was estimated that there was a total of 350 grams of plutonium in the fractured ice area (approximately 0.5 acres).

A radiological survey made soon after the accident showed that most of the plutonium was confined to a limited area. After the debris of the crash was removed another survey showed that the only significant plutonium contamination was confined to the snow and ice of the area where the fire had taken place.

To determine if radioactivity had been spread via wind over large distances, samples were taken from airplanes bound for Thule or passing across Greenland on ordinary traffic routes. None of these samples showed activity above background. The same was found for snow samples taken at places far from Thule.

Contamination was removed by removing the contaminated snow – approximately 9000 cubic yards – and storing in empty steel fuel containers. The radioactive water was returned to the United States.

The amount of plutonium found in the ice was deemed low enough that dilution by melting would reduce its concentration to safe levels. This melting was hastened by covering the area with ~~black~~ sand.

DARK

7 RESULTS AND EVALUATION OF ROCKY FLATS PLUTONIUM SOIL SAMPLE ANALYSIS

Four Different Agencies Have Conducted Soil Sampling and Plutonium Analysis in the Soil Surrounding the Rocky Flats Site

Agency 1 Colorado Committee on Environmental Information (CCEI)

Remarks

This is not a state sanctioned agency but rather a group of interested citizens The actual work was performed by E A Martell and S E Poet of the National Center for Atmospheric Research Copies of a report by this group were mailed on January 13 1970 to the following

E B Giller Director DMA AEC Lloyd Joshel General Manager Dow Rocky Flats A R Tamplin UCLRL Wright Langham LASL J – Harley HASL R J Engelmann DEM AEC H P Metzger President CCEI

Later this report was released to the press and copies sent to the Governor of Colorado The data from that report are not inconsistent with other findings and were used in constructing models of plutonium soil contours constructed by Rocky Flats

Agency 2 The Health and Safety Laboratory (HASL) USAEC

Remarks

These soil analyses data were consistent with the findings from this study by Rocky Flats The soil analysis data were used in constructing the model of plutonium soil contours A statistical analysis of the data from this report is found in Appendix B The HASL authors took considerable liberty in constructing their plutonium soil contours and also in making their estimates of total plutonium found in the soil The values for total plutonium calculated from the Rocky Flats study are somewhat lower than those estimated by HASL

Agency 3 The Rocky Flats Health Physics Department

Remarks

Sampling and analysis specifically for plutonium in soil began in August 1969

Agency 4 The Colorado Department of Public Health

Remarks

Their technique of taking a large number of samples from a large area and combining prior to analysis rendered their data inappropriate for inclusion in the model constructed in this study However analysis shows the data they reported are consistent with the findings of the Rocky Flats study

The first soil samples were taken in August of 1969 by The Rocky Flats Health Physics Department The sampling continued through June of 1970 A total of 99 sites extending as far as 10 kilometers (about 6 miles) from the plant were sampled In August of 1969 The Colorado Committee on Environmental Information under E A Martell took samples from about 18 sites Finally in February of 1970 The Health and Safety Laboratory sampled and analyzed soil from 33 sites Only 18 of the 33 HASL samples were evaluated for this study The other 15 samples were taken beyond the Rocky Flats region and were not considered

The 135 soil sample sites were located by markers on a large contour map of Rocky Flats. The radial distance of each site from the barrel storage area was determined by measuring the distance between each marker on the map and the barrel storage area then using the scale division of the map As a result radial distances in kilometers were obtained to correspond to the soil sample analyses in mCi/km^2

The soil sample data were evaluated primarily to determine if specific levels of plutonium activity could be calculated. It was also necessary to determine whether or not the soil sample data could be processed for meaningful results. A theoretical basis for the study was a model constructed mathematically to represent observed data.

Results

Figure 7.1 gives the first estimate of the dispersion of plutonium in soil over the Rocky Flats area and over land east of the Rocky Flats plant. The isocurie contour lines give changes in plutonium activity continually from the 2000 mCi/km^2 level to the 13 mCi/km^2 level. It can be seen that plutonium concentrations greater than 350 mCi/km^2 or 77.8 d/m/g dry soil (disintegrations per minute per gram of dry soil) cross the Rocky Flats boundary into private property.

The isodose contour lines were constructed in the following manner. First, the contour map of Rocky Flats which contains all of the soil sample locations was divided into sectors. The soil sample data for each sector were curve fitted using the method of least squares. This resulted in a mathematical expression for each sector which gives the activity of the plutonium in the soil as a function of radial distance from the barrel storage area. Specific levels of plutonium activity, such as 2000 mCi/km^2 (444.4 d/m/g dry soil), followed by 1000 (222.2), 400 (88.9), 350 (77.8), 100 (22.2), 50 (11.1) and 20 mCi/km^2 (4.4 d/m/g dry soil) were selected. The radial distance of each activity from the barrel storage area was then computed for each sector of the map. An arc was struck across the sector at that distance and a center point was located on the arc. The center points were then connected with a smooth but reasonably accurate curve for the level of activity desired.

Additional Data

The most immediate result from having constructed the isocurie contour lines was the need for additional soil samples to be taken east of the Rocky Flats plant. In December of 1970 after an interval of five months, The Rocky Flats Health Physics Department sampled and analyzed soil from 38 new sites. The samples were taken on private property between the Rocky Flats boundary and Indiana Avenue and on both sides of the access road leading to and from the plant. Radial distances from the barrel storage area were determined and the new analytical data were incorporated into the model for isocurie contour lines. As a result the isocurie contour lines were recalculated using 173 soil sample analyses. Figure 7.2 shows the most accurate outline to date of plutonium in soil in and beyond Rocky Flats.

From comparison of the isocurie contour lines in Figure 7.1 the outer most contours to the east and southeast appear not to have changed. In contrast to the outer levels, the regions which are described by levels of plutonium activity from 2000 mCi/km^2 to 350 mCi/km^2 (from 444.4 d/m/g dry soil to 77.8 d/m/g dry soil) show a slight easterly migration. It is felt that the migration may be due to the gradual dissipation of plutonium contamination which is near the barrel storage area. The area within the 2000 mCi/km^2 contour which shows activities greater than 2000 mCi/km^2 did not change significantly. This may imply that the release of plutonium from the barrel storage area is now negligible. It is also possible that the gradual dissipation of plutonium from within the 2000 mCi/km^2 contour may cause continued dispersion of plutonium at reduced activities, particularly within the 1000, 400 and 350 mCi/km^2 contours.

In general, the contours were less extensive in every direction except for two localized regions of plutonium activity. The first has already been described (the 1000, 400 and 350 mCi/km^2 contours beyond the Rocky Flats boundary). The second is the protruding finger of plutonium activity in Sector 1-A of Figure 7.2. The activity resulted from a relatively high value reported in a soil sample taken near Walnut Creek just north of the plant. The protruding contours did not change significantly from the initial study but appear exaggerated because the contours in the adjacent sectors are less extensive.

To better define the present isodose contour lines, additional soil samples will be taken on private property southeast of the Rocky Flats boundary toward Standley Lake and the upper and lower Twin Lakes. Also, soil samples will be taken just north of the Rocky Flats plant near Walnut Creek which is northeast of the plutonium process recovery complex on Atomic Energy Commission property.

Quantities of Plutonium

The burden of plutonium in soil inside and outside the Rocky Flats boundary was determined mathematically by applying integral calculus to the equations used to project plutonium activity. The total quantity of plutonium 239 dispersed in soil other than that contained by the asphalt pad was calculated to be 14.3 ± 2.0 grams. The dispersion is over 8.35 km^2 of land (2063 acres). The quantity of plutonium 239 inside the Rocky Flats boundary is 6.7 ± 0.4 grams over 2.72 km^2 of land (672 acres). The amount of plutonium 239 on public and private property is 7.6 ± 1.8 grams over 5.63 km^2 of land (1391 acres). The quantities of plutonium were calculated by integrating the areas between the 2000 mCi/km^2 contour and the 13 mCi/km^2 contour. The 13 mCi/km^2 contour was the

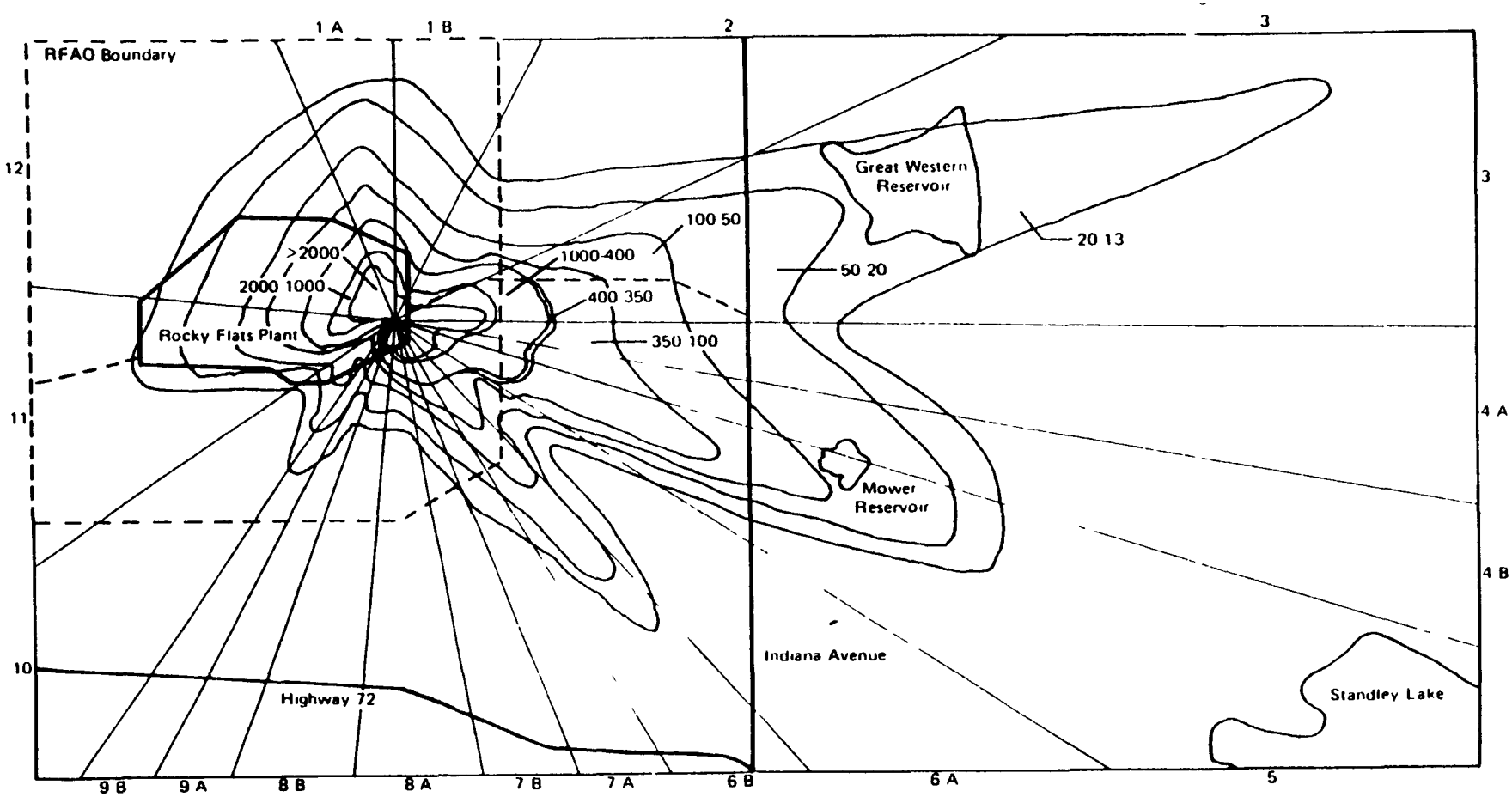


Figure 7 1 An Outline of Rocky Flats Showing the Levels of Plutonium Activity in the Soil in mCi/km² Soil Sample Data for the Contours were Evaluated per Sector of the Outline One Inch of the Outline is about 3600 Feet

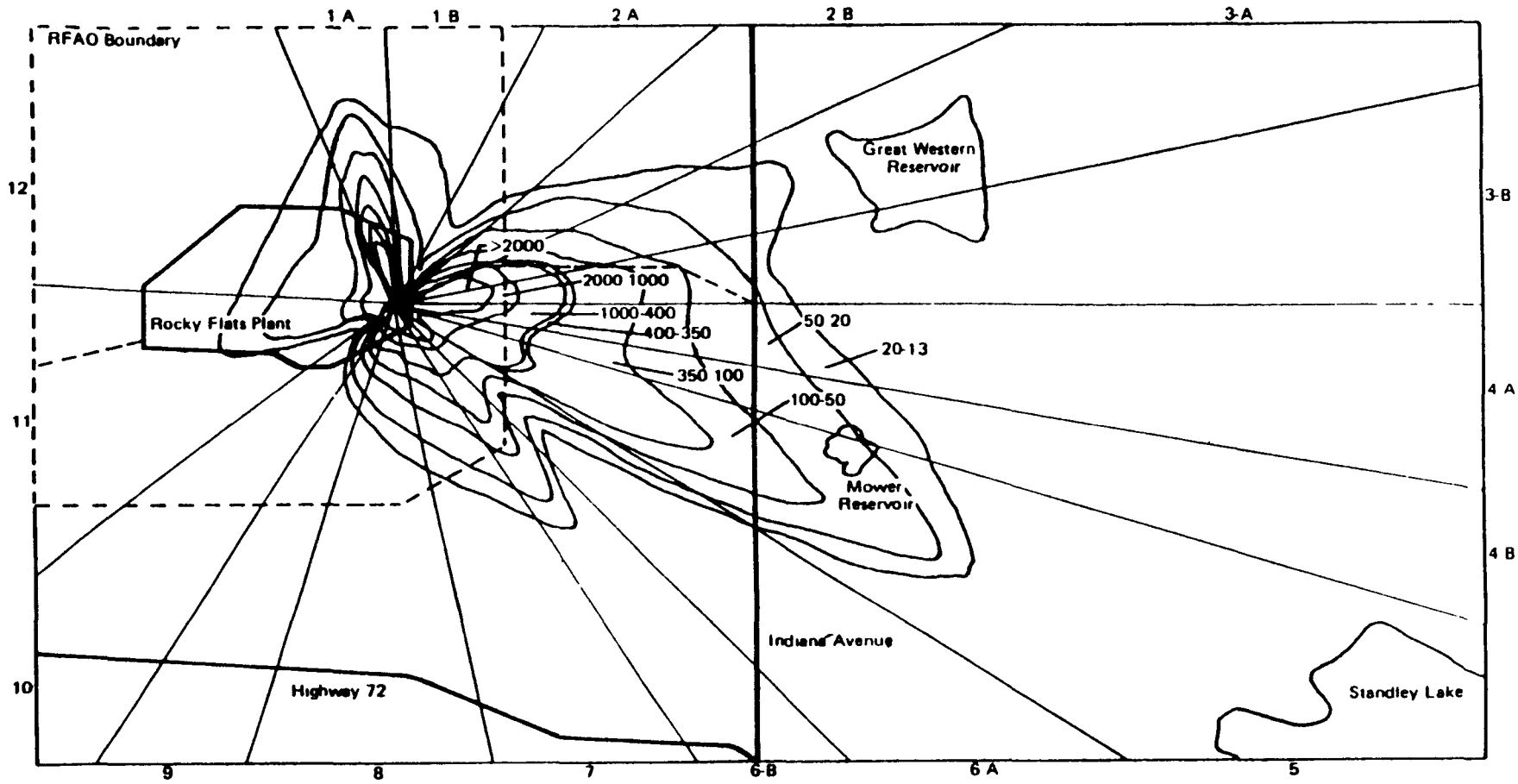


Figure 7 2 The Recalculated Isocurie Contour Lines Showing the Levels of Plutonium Activity in the Soil in mCi/km² Soil Sample Date for the Contour Lines were Evaluated per Sector of the Outline One Inch of the Outline is about 3600 Feet

minimum level considered Contours beyond this level actually reach background which is about 1 mCi/km

The amount of plutonium which was deposited on the soil of the barrel storage area is estimated to be about 55 grams Considering the maximum quantity of plutonium that may have been dispersed it is possible that about 80% of this amount of plutonium is still at the barrel storage area

A comparison of the quantities of Pu 239 per sector of the outline in Figure 7 2 shows that Sector 3 B has the greatest burden of plutonium per km² of land The value is 3 55 ±0 91 gms/km Sector 1 A contains 3 12 ±0 94 gms/km

As a final estimate of the quantity of plutonium which is dispersed in soil east of the Rocky Flats boundary the burden of plutonium per contour *outside* the boundary is given in Table 7 1

Table 7 1 Quantities of Plutonium Per Contour Outside the Rocky Flats Boundary *

Activity in mCi/km	Pu 239 in Gram	Area in km	Average d/m/g Dry Soil
2000-1000	0 29 ± 0 0	0 02	198
1000-400	1 25 0 0	0 13	131
400 350	0 32 0 0	0 05	87
350 100	3 10 0 5	1 06	40
100 50	1 26 0 46	1 09	16
50 20	1 04 0 5	1 96	7
20-13	0 34 0	1 30	4
13 1	-	-	2***
TOTAL	7 6 - 0		

In the calculations that convert the plutonium analytical data from d/m/gm to quantity of plutonium in grams it is assumed that we are looking at the pure plutonium 239 isotope Because of the distribution of isotope in Rocky Flats plutonium the radiometric counting data will yield slightly higher values This assumption that we are making in the calculations of the total plutonium inventory will give a result in grams that is slightly higher than the actual gram quantity found in the soil

** Assuming a density of dry soil of 1 gm/cm and a soil sample depth of 1 cm

*** Background plutonium activity is considered by the Rocky Flats Health Physics Department to be 0 2 d/m/g dry soil The Colorado Department of Health has on record a background activity of from 0 04 d/m/g to 0 11 d/m/g dry soil See Appendix B for an estimate of background using the HASL data

How the Dispersion of Plutonium in Soil was Estimated

The method of least squares[1] was used as a means to project plutonium activity given a set of soil sample data The technique consists of deriving a mathematical equation to express the soil sample results This is done by first selecting a general equation which gives the dosage d as a function of radial distance r The constants of the equation are solved using the data Then theoretical calculations are made and compared to the actual values of d The differences between the theoretical and experimental values are tabulated for a measure of how well the equation works

To demonstrate the effectiveness of the method consider the linear equation

$$d = a + br. \qquad (1)$$

We wish to use Equation (1) to curve fit a set of soil sample data From applying the method of least squares to Equation (1) normal equations in the form of

$$a \cdot n + b\Sigma r_i = \Sigma d_i$$

and

$$a\Sigma r_i + b\Sigma r_i^2 = \Sigma r_i d_i \qquad (2)$$

can be derived Here a and b are the constants to be solved r_i and d_i for i = 1 2 n are the radial distances in kilometers from the barrel storage area and the radioactive dosages in mCi/km² respectively and n is the number of samples Solving Equation (2) for the constant a results with

$$a = \frac{\Sigma r_i^2 \Sigma d_i - \Sigma r_i \Sigma r_i d_i}{n\Sigma r_i^2 - (\Sigma r_i)^2}$$

and for b

$$b = \frac{n\Sigma r_i d_i - \Sigma r_i \Sigma d_i}{n\Sigma r_i^2 - (\Sigma r_i)^2}$$

Now Equation (1) becomes meaningful in that the constants have been determined from the various summations and products of the soil sample data Equation (1) can be used to project plutonium activity by simply computing the distance to correspond to some value d Linear functions however do not readily express soil sample results Therefore many possible equations including nonlinear functions which are solvable by the least squares method were tested

Table 7 2 gives the equations which were programmed and used in a digital computer to curve fit soil sample data The results were immediate Four hyperbolic equations (those equations indicated by an asterisk) were selected by the computer to be the most effective equations By evaluating discrete sets of data hyperbolic equations were readily derived for the dispersion of plutonium in soil Sets of soil sample data were obtained by dividing the soil sample

[1] D D McCracken and W S Dorn Numerical Methods and FORTRAN Programming John Wiley and Sons Inc New York 1964 p 262

map of Rocky Flats into sectors. This limited the number of points in a set of data. In this manner the formidable problem of evaluating over a hundred data points all at once was avoided. Also, as will be seen, the use of map sectors made the integration for total quantities of plutonium quite simple.

Map sectors were made by originating lines at the barrel storage area then extending the lines across the face of the map. The size of a sector was made to depend upon the dispersion of the points and to more or less follow a specific direction, e.g. Sector 1 is the northern sector. If the number of points in a sector were too numerous or the data too poor to successfully determine a workable equation then the sector was subdivided into two parts and a second attempt at curve fitting the data was made. The hyperbolic equations used to construct the isodose contour lines shown in Figure 7.2 are summarized in Table 7.3.

Table 7.2 Equations Programmed to Evaluate Soil Sample Data

Function	Type	Results
$d=a+br$	linear	poor
$d=a+br^{1/2}$	parabolic	poor
$d^2=a+br$	parabolic	rejected
$d=a+br+cr^2$	parabolic	poor
$d=a+br^{1/3}$	cubical parabolic	poor
$d^3=a+br$	cubic	rejected
$d=a+b^{1/4}$	quartic	poor
$d^4=a+br$	quartic	rejected
$d=a+b\ \ln(r+1)$	logarithmic	poor
$d=a+b\ \ln(r)$	logarithmic	poor
$d=1/[a+b\ \ln(r)]$	inverse logarithmic	poor
$d=ae^{br}$	exponential	poor
$d=ae^{br^2}$	exponential	poor
$d=ae^{br}/r^2$	exponential	poor
$d=e^{(a+br+cr^2)}$	exponential	poor
$d=ae^{b/r}$	exponential	possible
$d=ae^{br}/r$	exponential	possible
$d=ae^{br^2}/r$	exponential	possible
$d=ar^b$	hyperbolic	possible
$d=a+b/r$*	hyperbloic	usable
$d=a+b/r^2$*	hyperbolic	usable
$d=a+b/r^3$*	hyperbolic	usable
$d=a+b/r^4$*	hyperbolic	usable
$d=1/(a+br)$	hyperbolic	poor
$d^2=a+br^2$	hyperbolic	rejected
$d=r/(b+ar)$	hyperbolic	poor
$d=r/(a+br+cr)^2$	–	poor

*The most effective equations

As can be seen from Table 7.3, the value of k in the hyperbolic equation

$$d = a + \frac{b}{r^k}$$

is either 1, 2, 3, or 4. The value of k is data oriented to give the best results. For example, if soil samples which are taken near the barrel storage area show high concentrations of plutonium and the concentrations diminish rapidly with soil samples taken further away from the barrel storage area then the dispersion of plutonium can best be expressed by k = 3 or k = 4. On the other hand, if the concentration diminishes slowly and is considerable, say at two kilometers from the barrel storage area, then k = 1 or k = 2 gives the best values of d. Finally, if the dosage is so insignificant that d does not appear to increase or decrease over a given radial distance r, then k = 1.

Table 7.3 Plutonium Activity d as a Function of the Radial Distance r from the Barrel Storage Area per Sector of the Contour Map of Rocky Flats

Sector	Function	No. of Points	General Direction of the Sector
1 A	$d=73/r^4-7$	5	N
1 B	$d=11/r+3$	7	N
2 A	$d=5/r+5$	12	NNE
2 B	$d=106/r-60$	7	NE
3 A	$d=133/r^4+11$	17	ENE
3 B	$d=689/r^3-32$	15	E
4 A	$d=451/r^3-6$	15	E
4 B	$d=275/r-9$	11	ESE
5	$d=463/r-95$	13	SE
6 A	$d=135/r^4-1$	6	SE
6 B	$d=133/r^2-[illegible]$	5	SSE
7	$d=23/r^3+4$	11	S
8	$d=7/r^3+3$	9	S
9	$d=1/r^4-6$	12	SSW
10	$d=1/r+5$	8	W
11	$d=18/r-2$	7	W
12	$d=11/r+1$	13	NW

Considerable effort was spent in determining the value of k and hence the hyperbolic equation to use for each sector of the map. This is due to the fact that soil sample data are complicated and difficult to evaluate. In all cases calculated values of d were compared to the actual soil sample results. By assuming that high concentrations of plutonium are limited to a localized region and that the dispersion of plutonium in soil diminishes with greater distances from the barrel storage area, it was possible to select the value of k based upon the nature of the data. The activity of the barrel storage area which was estimated to be about 3.7×10^5 mCi/km^2 was also used as a point source to determine k.

How the Effectiveness of the Curve Fitting Method Was Estimated

The additional soil samples provided by The Rocky Flats Health Physics Department were used to estimate the effectiveness of the curve fitting method This was done by comparing projected values of dose to the actual soil sample analyses Table 7 4 gives the results for all 38 samples It can be seen that some of the larger doses were underestimated by the model used previously while at the same time the smaller doses were overestimated The projected activity amounts to a [illegible] increase over the actual activity Using the additional soil sample analyses along with those obtained earlier the recalculated isodose contour lines now show an increase of only 5 27 over the additional soil samples

In evaluating all of the soil sample data which follow Table 7 6 an attempt to simulate the natural conditions which spread plutonium in soil was not made Wind direction and velocity were not considered neither were natural washes in the foothills which dilute or accumulate plutonium concentrations The source of plutonium in the soil was assumed strictly to be the barrel storage area Other sources such as stack effluent world wide plutonium fallout and the September 11 1957 fire were not considered

Table 7 4 The Comparison of Projected Plutonium Activity to Actual Soil Sample Results

Map Site No	Dose in mCi/km	Projected Value	Error	Value Using the Present Contours *
B-107	1397 2	769 8	-627 4	1050
B-115	772 2	406 5	-365 7	546
B-116	564 8	394 9	-169 9	362
B-110	414 4	418 8	4 4	380
B 108	369 4	769 8	400 4	703
B-109	324 4	368 4	44 0	338
B-105	262 4	341 9	79 5	181
B-117	252 9	244 3	-8 6	223
B-106	212 0	428 1	216 1	242
B 126	199 4	61 2	-138 2	58
B-113	127 8	201 9	74 1	92
B-118	112 0	332 7	220 7	301
B-121	103 0	100 5	-2 5	89
B 114	76 0	229 5	153 5	514
B-104	73 8	12 2	61 6	41
B 125	56 7	50 7	6 0	65
B 120	55 8	100 4	44 6	94
B-112	54 9	192 0	137 1	87
B 124	49 0	49 5	0 5	62
B-127	45 0	61 2	16 2	58
B-128	32 8	69 0	36 2	56
B-111	26 1	6 4	-19 7	27
B-129	21 6	72 8	51 2	63
B-130	11 7	27 8	16 1	14
B-131	11 4	28 9	17 5	14
B-132	11 1	30 2	19 1	14
B-133	11 0	30 9	19 9	15
B-138	10 9	46 0	35 1	38
B-134	10 8	31 8	21 0	18
B 136	10 8	26 3	15 5	27
B 137	10 8	25 9	15 1	26
B-135	10 7	26 8	16 1	27
B-123	8 6	53 2	44 6	22
B-119	7 6	81 5	73 9	32
B 102	7 2	5 4	-1 8	8
B-103	5 8	8 8	3 0	9
B 122	3 6	42 4	38 8	18
B-101	3 2	3 4	0 2	8

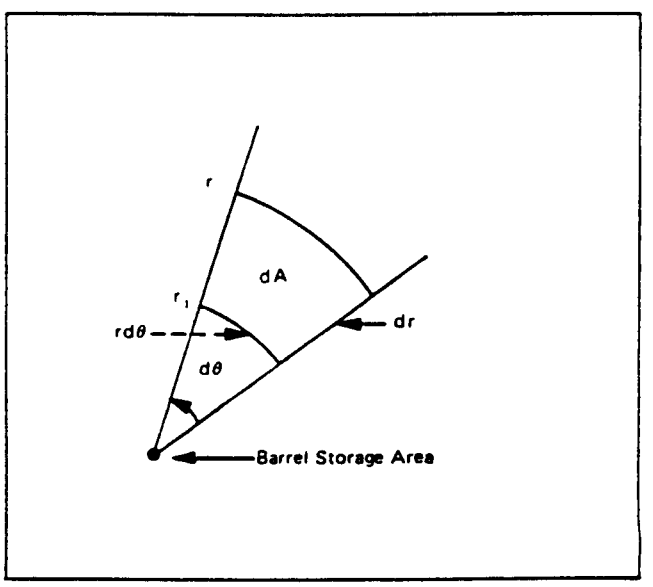
*Based on model using data obtained earlier

**This model uses the additional soil sample data along with that obtained earlier

How Quantities of Plutonium were Determined

The quantity of plutonium between two levels of plutonium activity was determined by integrating the area between the two levels The levels were drawn by first selecting a specific activity for each level with one level being closer to the barrel storage area than the other Figure 7 3 shows the two levels for any sector of the soil sample map of Rocky Flats The element of area dA between r_1 and [illegible] is the area to be integrated Regarding the element of area dA as a rectangle its area will be the product of a pair of

Figure 7 3 The Element of Area dA in Polar Coordinates.



adjacent sides sides dr and $rd\theta$ where $d\theta$ indicates the size of the sector. The result is

$$dA = rdrd\theta \qquad (3)$$

Integrating Equation (3) with respect to dr and $d\theta$ gives

$$A = \int_0^{\theta} \int_{r_1}^{r_2} rdrd\theta$$

or

$$A = \frac{\theta}{2}(r_2^2 - r_1^2), \qquad (4)^*$$

where θ = the angle between each side of the sector

The area A will be in units of km

To determine the quantity of plutonium over the area A the integrand of Equation (4) is modified to contain the hyperbolic function which gives dose as a function of radial distance r. It is stated as

$$Q = \int_0^{\theta} \int_{r_1}^{r_2} f(r,\theta)rdrd\theta, \qquad (5)$$

where Q = the quantity of Pu 239 in millicuries. Using the actual hyperbolic equation, Equation (5) becomes

$$Q = \int_0^{\theta} \int_{r_1}^{r_2} \left(a + \frac{b}{r^2}\right) rdrd\theta$$

or

$$Q = \theta b \int_{r_1}^{r_2} \frac{rdr}{r^2} - \frac{\theta a}{2}\left[(r_2^2 - r_1^2)\right] \qquad (6)^*$$

The area of each sector was integrated from the maximum plutonium activity of 2000 mCi/km^2 to the minimum plutonium activity of 13 mCi/km^2. The partial quantities of plutonium were then summarized for the total dispersed over the area of the contours. In soil surrounding the Rocky Flats plant there are 14.3 grams of plutonium 239. The quantity, of course, extends from the 2000 mCi/km level. The area affected is 8.35 km^2 or about 2063 acres.

The integration was extended to determine the quantity of plutonium inside and outside the boundary of Rocky Flats. These calculations give the burden of plutonium in soil on public and private property. Figure 7-4 shows a sector being divided by the boundary.

The area inside the boundary was determined by subtracting the area of the shaded triangle from the element of area dA. The triangle was formed by striking an arc at the junction of the boundary and one side of the sector.

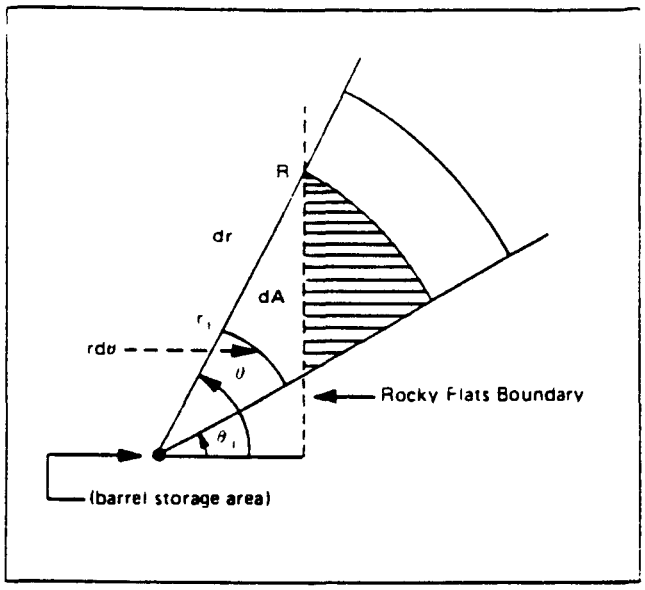


Figure 4 The Element of Area dA Divided by the Boundary of Rocky Flats

The area of the shaded triangle was determined from the calculus. The formula is

$$A_t = \int_{\theta_1}^{\theta_2} \int_{\frac{x}{\cos(\theta)}}^{R} rdrd\theta \qquad (7)$$

Integrating Equation (7) gives

$$A_t = \frac{R^2}{2}(\theta_2 - \theta_1) - \frac{x^2}{2}(\tan(\theta_2) - \tan(\theta_1)), \qquad (8)^*$$

where A_t = the area in km^2
R = the junction radius in kilometers
x = the perpendicular distance of the Rocky Flats boundary in kilometers from the barrel storage area

By modifying Equation (7) the quantity of plutonium in the shaded triangle is determined by

$$Q_t = \int_{\theta_1}^{\theta_2} \int_{\frac{x}{\cos(\theta)}}^{R} \left(a + \frac{b}{r^2}\right) rdrd\theta$$

* Programmed for the digital computer

or

$$Q_t = \int_{\theta_1}^{\theta_2} \left[b \int_{\frac{x}{\cos(\theta)}}^{R} \frac{r}{r^k}\, dr + a \int_{\frac{x}{\cos(\theta)}}^{R} r\,dr \right] d\theta \qquad (9)^*$$

The junction radius R the angles θ_1 and θ_2 and the perpendicular distance x are all measured for a sector of the map Equation (9) therefore gives the quantity of plutonium in the described triangle of the sector By considering in the same manner each sector that is divided by the Rocky Flats boundary partial quantities of plutonium were determined inside and outside the boundary Finally the partial quantities were summarized The quantity of plutonium 239 inside the boundary of the Rocky Flats plant from the plutonium activity level of 2000 mCi/km^2 was calculated to be 6 7 grams The area of land affected is 2 72 km^2 which is about 672 acres Beyond the boundary on public and private property up to the 13 mCi/km^2 level there are 7 6 grams of plutonium over 5 63 km^2 of land which is about 1 591 acres

Of particular interest is the quantity of plutonium within each specific contour east of the Rocky Flats boundary By using the element of area dA between individual levels and considering those segments of land that are divided by the boundary partial quantities of plutonium in each sector were summarized for the total amount of plutonium per contour Table 7 5 gives the results

Table 5 Quantities of Plutonium 239 Per Contour East of the Rocky Flats Boundary

Activity in mCi/km^2	239 Pu in Grams	Area in km^2
2000 1000	0 29	0 02
1000-400	1 25	0 13
400-350	0 32	0 05
350-100	3 10	1 06
100-50	1 26	1 09
50-20	1 04	1 98
20-13	0 34	1 30

How Probable Error was Computed

The calculation of probable error was taken as a necessary measure to determine the maximum and minimum quantities of plutonium in soil Probable error is determined by the variation in soil sample data and can be calculated directly from what is known as the normal law of error This concerns primarily the standard deviation of each of the least squares constants a and b of the general equation

$$d = a + \frac{b}{r^k} .$$

From the defining equation for probable error the standard deviation S_a of the constant a is determined by

$$S_a = \left[\frac{\sum \frac{1}{r_i^{2k}}}{n \sum \frac{1}{r_i^{2k}} - \left(\sum \frac{1}{r_i^k} \right)^2} \right]^{\frac{1}{2}} \times \left[\frac{\sum \left(d_i - a - \frac{b}{r_i^k} \right)^2}{n - 2} \right]^{\frac{1}{2}} \qquad (10)^*$$

and the standard deviation S_b of the constant b is determined by

$$S_b = \left[\frac{n}{n \sum \frac{1}{r_i^{2k}} - \left(\sum \frac{1}{r_i} \right)^2} \right]^{\frac{1}{2}} \times \left[\frac{\sum \left(d_i - a - \frac{b}{r_i^k} \right)^2}{n - 2} \right]^{\frac{1}{2}} \qquad (11)^*$$

Here r_i and d_i for $i = 1, 2 \quad n$ data points are the data points in the set of data

[2] A G Worthing and J Geffner Treatment of Experimental Data 8th ed John Wiley and Sons Inc New York 1959 p 249

* Programmed for the digital computer

The standard deviations S_a and S_b are combined to give the maximum and minimum quantities of plutonium in soil. The formula used is called the propagation of error equation and is given by

$$S^2(Q) = \left(\frac{\partial Q}{\partial a}\right)^2 S_a^2 + \left(\frac{\partial Q}{\partial b}\right)^2 S_b^2 \qquad (12)^*$$

Here $S^2(Q)$ is the variance in the quantity of plutonium. The partial derivative terms $(\partial Q/\partial a)$ and $(\partial Q/\partial b)$ are solved by taking the partial derivatives of

$$Q = \theta b \int_{r_1}^{r_2} \frac{r\,dr}{r^2} + \theta a \int_{r_1}^{r_2} r\,dr$$

which is the expression for the quantity of plutonium in a given sector of the soil sample map. By the same token the variance $S^2(Q_t)$ in Q_t, the quantity of plutonium in a described triangle, is given by

$$S^2(Q_t) = \left(\frac{\partial(Q_t)}{\partial a}\right)^2 S_a^2 + \left(\frac{\partial(Q_t)}{\partial b}\right)^2 S_b^2 \qquad (13)^*$$

where

$$Q = \int_{\theta_1}^{\theta_2} \left[b \int_{\frac{x}{\cos(\theta)}}^{R} \frac{r}{r^2}\,dr + a \int_{\frac{x}{\cos(\theta)}}^{R} r\,dr \right] d\theta$$

Finally, the standard deviation S for some total quantity of plutonium, e.g. the total quantity of plutonium outside the Rocky Flats boundary, is determined by combining the variances of plutonium quantities in all of the sectors considered. This can be stated as follows:

$$S = = \left[S^2(Q_1) + S^2(Q_2) - S^2(Q_t) - \cdots \right]^{\frac{1}{2}} \qquad (14)^*$$

The calculations for probable error give the result Q ± S for quantities of plutonium. This means that inside the Rocky Flats boundary there are 6.7 ± 0.4 grams of plutonium 239. The burden of plutonium outside the Rocky Flats boundary on public and private property is 7.6 ± 1.8 grams. The total to be expected is 14.3 ± 2.0 grams of plutonium 239.

The mathematical methods used to determine probable error are based entirely on the soil sample data. No attempt was made to consolidate the systematic errors to be expected from the radiochemical analysis of the soil nor the error involved in determining the general location of each soil sample from the barrel storage area. For the calculations for probable error, the soil sample data were assumed to be unbiased and to follow a normal distribution about some mean.

Specific Activity, Density of Soil, and Conversion Factors

The specific activity of plutonium 239 was used extensively to (1) determine the activity of the barrel storage area, (2) convert dose in millicuries to total quantity in grams of plutonium 239, and (3) calculate quantities in grams of plutonium 239 to correspond to the levels of activity in mCi/km.

The specific activity of any radioactive isotope is defined as $g \cdot \lambda$, where g is the number of active nuclei per unit weight of the isotope and λ is the decay constant. The decay constant is given by .693/T, where T is the α particle half life of the isotope. For plutonium 239 the specific activity is calculated to be

$$\text{Sp Act}_{239} = g \cdot \lambda = \left[\frac{6.02\text{x}10^{23}}{239.052}\text{gms}\right] \times \left[\frac{.693}{2.436\text{x}10^4 \text{ yrs}}\right]\left[\frac{\text{yr}}{3.156\text{x}10^7 \text{ sec}}\right] = 2.270\text{x}10^9 \frac{\text{dis}}{\text{gm sec}}.$$

Programmed for the digital computer

The activity of the barrel storage area was determined and used as a point source to facilitate the evaluation of soil sample data From an estimate of the contaminated waste that was once stored in barrels over the area the amount of plutonium lost is considered to be about 85 grams Considering the major isotope (Pu 239) the activity of the barrel storage area in mCi/km² becomes

$$\text{Sp Act} = \left[\frac{2.27\times10^{9}\ \text{dis}}{\text{gm sec}}\right]\left[\frac{85\ \text{gms}}{380\times400\ \text{ft}^2}\right] \times \left[\frac{\text{mCi}}{3.7\times10^{7}\ \text{dis/sec}}\right]\left[\frac{\text{ft}^2}{9.29\times10^{-8}\ \text{km}^2}\right]$$

$$\simeq 3.7\times10^{5}\ \text{mCi/km}^2$$

Quantities of plutonium 239 in millicuries can be converted to quantities in grams by the relationship 1 gram = 61 35 millicuries This is determined by

$$\text{Sp Act}_{239} = \left[\frac{2.27\times10^{9}\ \text{dis}}{\text{gm sec}}\right] \times \left[\frac{\text{mCi}}{3\ 7\times10^{7}\ \text{dis/sec}}\right]$$

$$= 61.35\ \text{mCi/gm Pu-239}$$

Measured concentrations of plutonium in soil are given in units of d/m/g dry soil or disintegrations per minute per gram of dry soil To convert from d/m/g dry soil to units of activity per area or to millicuries per square kilometer the density of the soil and the depth of the soil sample must be considered The relationship is

$$1\ \text{d/m/g} = \left[\frac{1\ \text{dis}}{\text{gm}\cdot\text{min}}\right]\left[\frac{\text{mCi}}{3.7\times10^{7}\ \text{dis/sec}}\right] \times \left[\frac{\text{min}}{60\ \text{sec}}\right]\left[\frac{10^{10}\ \text{cm}^2}{\text{km}^2}\right]\ \rho h$$

or

$$1\ \text{d/m/g} = 4.5\ \rho h\ \text{mCi/km}^2$$

where ρ = the density dry soil in gms/cm³

and h = the depth of the soil sample in centimeters

To convert the soil sample analyses The Rocky Flats Health Physics Department used a density of 1 gm/cm³ and a soil sample depth of 1 centimeter The additional soil samples obtained in December of 1970 were actually taken to a depth of 1 centimeter Previous soil samples however were taken to depths ranging from 3 to 5 centimeters These samples were obtained between August of 1969 and June of 1970

The Colorado Committee on Environmental Information used a density of 1 gm/cm³ and a soil sample depth of 1 centimeter Their soil samples were also taken to a depth of 1 centimeter but in August of 1969

Finally The Health and Safety Laboratory USAEC used a density of 1 2 gm/cm³ down to a depth of 15 centimeters and a density of 2 4 gm/cm³ below 15 centimeters For the most part the soil samples were taken to a depth of 20 centimeters [3] Appropriate calculations were made for the changes in soil sample depth The soil samples were obtained in February of 1970

The accumulation of plutonium is affected by its vertical distribution in soil For the purpose of converting data in this study and except for the HASL soil samples the dispersion of plutonium was assumed to be within the first centimeter of topsoil

To demonstrate the trace quantities of plutonium that are associated with the levels of activity used in the study the levels of activity were converted to grams of plutonium using the specific activity of plutonium 239 a soil sample density of 1 gm/cm³ and a soil sample depth of 1 centimeter The results are given in Table 7 6

Table 6 Specific Activity in Grams of Plutonium 239

mCi/km²	d/m/g dry soil	Pu 239/gram of dry soil
2000	444 4	3 26X10 [illegible]
1000	222 2	1 63X10 [illegible]
400	88 9	6 54X10 [illegible]
350	77 8	5 72X10 [illegible]
100	22 2	1 63X10 [illegible]
50	11 1	8 16X10 [illegible]
20	4 4	3 24X10 [illegible]

[3] P W Krey and E. P Hardy Plutonium in Soil Around The Rocky Flats Plant HASL 235 The Health and Safety Laboratory USAEC New York 1 August 1970

Soil Sample Data

The Rocky Flats Health Physics Results of Soil Samples Taken August 1969 June 1970 on Atomic Energy Commission Property

Map Site	Pu Activity in mCi/km²	Pu Activity in d/m/g Dry Soil
C 1	20 7	4 6
G 2	33 3	7 4
C 3	2 7	0 6
C 4	13 1	2 9
G 5	17 6	3 9
C 6	270 9	60 2
C 7	9 0	2 0
G 9	2 7	0 6
G 10	18 0	4 0
G 11	9 5	2 1
G 12	5 0	1 1
G 13	14 9	3 3
C 14	373 5	83 0
G 15	2128 5	473 0
G 18	5 4	1 2
G 19	35 1	7 8
G 20	1377 0	306 0
C 22	1431 0	318 0
C 23	48 6	10 8
C 25	396 0	88 0
C 26	6 3	1 4
C 27	8 1	1 8
G 28	39 6	8 8
G 29	117 0	26 0
G 30	7 2	1 6
C 31	8 6	1 9
G 32	26 1	5 8
G 33	10 8	2 4
G 34	9 0	2 0
G 35	9 0	2 0
G 36	5 9	1 3
C 37	3 2	0 7
G 38	0 9	0 2
B 18	6 3	1 4
B 19	6 3	1 4
B 20	10 4	2 [illegible]
B 21	1 3	0 3
B 22	6 3	1 4
B 23	6 8	1 5
B 24	6 8	1 5
B 30	5 4	1 2
B 32	5 4	1 2
B 33	69 8	15 5
B 34	16 7	3 7

The Rocky Flats Health Physics Results of Soil Samples Taken August 1969 June 1970 on Public and Private Property within a Six Mile Radius of the Rocky Flats Plant

Map Site	Pu Activity in mCi/km²	Pu Activity in d/m/g Dry Soil
B 1	3 8	0 8
B 2	1 1	0 2
B 3	4 5	1 0
B 4	4 3	0 6
B 6	2 3	0 5
B 7	4 1	0 9
B 8	0 5	0 1
B 9	5 0	1 1
B 10	1 8	0 4
B 12	9 0	2 0
B 13	1 8	0 4
B-14	0 5	0 1
B 15	11 7	2 6
B-16	4 3	1 0
B-17	27 9	6 2
B 25	2 3	0 5
B-26	9 5	2 1
B-27	11 3	2 5
B-28	5 4	1 2
B-29	5 0	1 1
B-35	2 3	0 5
B-36	0 5	0 1
B 37	3 2	0 7
B 38	3 6	0 8
B-39	8 1	1 8
B 40	3 6	0 8
B 41	0 5	0 1
B 42	4 1	0 9
B 43	9 9	2 2
B 44	2 7	0 6
B 45	12 2	2 7
B 46	0 5	0 1
B 47	5 4	1 2
B-48	3 6	0 8
B-49	5 9	1 3
B 50	3 6	0 8
B 51	9 5	2 1
B 52	17 6	3 9
B 53	6 3	1 4
B 54	3 2	0 7
B 55	3 6	0 8
B-56	37 8	8 4
B-57	4 1	0 9
B 58	20 7	4 6
B 59	3 6	0 8
B-60	5 0	1 1
B 61	9 0	2 0
B-62	20 7	4 6
B 64	14 9	3 3
B-65	5 0	1 1
B-66	5 9	1 3
B 67	6 8	1 5
B-68	6 3	1 4
B-71	4 1	0 9
B 79	0 9	0 2

The Rocky Flats Health Physics Results of Additional Soil Samples Taken in December 1970 on Private Property east of the Rocky Flats Plant

Map Site	Pu Activity in mCi/km	Pu Activity in d/m/g Dry Soil
B-107	1397 2	310 5
B 115	772 2	171 6
B-116	564 8	125 5
B 110	414 4	92 1
B 108	369 4	82 1
B 109	324 4	72 1
B-105	262 4	58 3
B 117	252 9	56 2
B-106	212 0	47 1
B-126	199 4	44 3
B-113	127 8	28 4
B-118	112 0	24 9
B 121	103 0	22 9
B 114	76 0	16 9
B 104	73 8	16 4
[illegible]	[illegible]	[illegible]
B 1[illegible] 0	[illegible] 8	[illegible] 4
B 112	54 9	12 2
B 124	49 0	10 9
B 127	45 0	10 0
B 128	32 8	7 3
B 111	26 1	5 8
B 129	21 6	4 8
B 130	11 7	2 6
B 131	11 4	2 5
B 132	11 1	2 5
B 133	11 0	2 4
B 138	10 9	2 4
B 134	10 8	2 4
B 136	10 8	2 4
B 137	10 8	2 4
B 135	10 7	2 4
B 123	8 6	1 9
B-119	7 6	1 7
B 103	7 2	1 6
B 122	3 6	0 8
B 101	3 2	0 7

The Colorado Committee on Environmental Information Results of Soil Samples Taken in August of 1969 on Public and Private Property within a Seven Mile Radius of The Rocky Flats Plant

Map Site	Pu Activity in mCi/km	Pu Activity in d/m/g Dry Soil
A	5 8	1 3
B	60 8	13 5
C	0 4	0 1
D	0 6	0 1
E	1 3	0 3
F	1 3	0 3
G	1 4	0 3
H	0 6	0 1
I	7 7	1 7
J	5 2	1 2
K	4 0	0 9
L	0 5	0 1
M	1 7	0 4
U	1 5	0 3
V	2 4	0 5
W	0 2	<0 1
X	0 8	0 2
Y	1 9	0 4

The USAFC Health and Safety Laboratory Results of Soil Samples Taken in February of 1970 on Public and Private Property within a Seven Mile Radius of the Rocky Flats Plant

Map Site	Pu Activity in mCi/km²	Pu Activity in d/m/g Dry Soil
R 1	2 4	<0 1
R 2*	3 1	<0 1
R 3	4 2	<0 1
R 4	11 0	0 1
R 5	15 0	0 1
R 6*	1950 0	16 0
R 7*	480 0	3 2
R 8	630 0	-
R 9	2 6	<0 1
R 11	5 4	<0 1
R 12	47 0	2 1
R 13	50 0	0 6
R 14	17 0	<0 1
R 15	18 0	0 1
R 17	14 0	0 1
R 18	2 0	<0 1
R 19	8 0	<0 1
R 21	2 7	<0 1

* Samples taken on Atomic Energy Commission Property

8 CURRENT RADIATION LEVELS IN THE OIL STORAGE AREA

A gross gamma survey was performed on the entire surface of the asphalt pad Data from this survey were converted from relative radiation intensities into integers and transposed to a graphic scale for evaluation Based on the results obtained by the gamma survey four areas were selected for excavation soil sampling and analysis of the samples for radioactive contaminants

For the γ ray mapping four 4 inch by 2 inch NaI(Tl) detectors arranged in a horizontal array on 18 inch centers were suspended from the rear of an IHC Scout With detector faces approximately 3 inches from the ground the detector output was monitored and recorded via a ratemeter strip chart recorder and the vehicle traveled at a slow and constant speed The entire Pad was scanned in 6 foot increments with a 9 to 10 inch overlap on each pass

The strip chart recorder data were reduced by dividing the relative readings into integers from one to twenty five and transposing these integers to a scale graph The relative gross gamma profile thus obtained is shown in Figure 8 1 The numbers represent only the relative gamma ray readings at the pad surface Each integer increment on the figure represents a change in counting rate of 1 to 2% As seen in the figure several highly localized areas (shown in red) were found which showed γ readings significantly above the general background Two of these labeled 17 21 and 25 in Figure 8 1 were deemed hot spots that is showed activity levels >15% above the general background Another significant feature of the profile is the large areas of similar activity levels over the entire pad

Additional verification of these gamma activity levels was provided by a survey performed by P H Dodd and R F Droullard of the AEC s Geophysical Branch from the Grand Junction Office Utilizing gamma ray analysis equipment in a mobile laboratory designed for uranium ore evaluation and modified for soil monitoring this survey made measurements at the hot spots at other locations on the pad off the pad and north across the street The measurements indicated activity levels at the hot spots to be at least twice those elsewhere on the pad or off the pad Attempts to identify the source of the anomalies were partly successful Ratios of two gamma ray energy ranges (1 00 to 2 80 MeV and 0 600 to 1 00 MeV) were measured at several sites The results showed a ratio lower by a factor of approximately 2 at the hot spots This is interpreted to mean a slightly higher concentration of either ^{239}Pu or ^{235}U is contributing a higher percentage of low energy gamma rays to the natural activity levels

Table 8 1 Lab Analyses of Test Hole Samples

Sample	Wt of Sample (grams)	Total Uranium	U	Wt U (kg)
14	7294	0 6	<0 01	0 043
14 23	7065	0 9	<0 01	0 06
14 24	6893	28	0 12	1 93
14 25	6503	17	0 07	1 1
14 26	7334	42	0 15	3 1
14 27	7850	43	0 15	3 8
14 28	7797	41	0 14	3 2
14 29	8242	41	0 14	3 4
14 30	7056	34	0 11	2 4
14 31	7520	26	0 08	1 9
14 32	7450	35	0 15	2 6
14 33	7162	20	0 09	1 4
				~25 kg
17 11	7805	0 8	<0 01	0 06
17 12	7978	18	0 07	1 4
17 13	7750	26	0 10	2 0
17 14	7585	10	0 04	0 8
17 15	7369	6	0 02	0 4
17 16	7097	5	0 01	0 3
17 17	7677	7	0 02	0 5
17 18	7323	3	<0 01	0 2
17 19	6949	3	<0 01	0 2
				~6 kg

Sample	Wt of Sample (grams)	Plutonium ppb	Wt Pu (μg)
SW	8378	0 01	0 084
SW 10	7833	36	282
SW 15	7578	70	530
SW 20	6373	34	216
SW 24	7620	2 5	19
			~1047 μg
NC 4	7809	0 003	0 023
NC 7	7385	0 033	0 24
NC 8	7395	0 74	5 5
NC 10	7391	11	81
NC 13	6582	0 89	5 8
			~92 6 μg

To quantitatively evaluate the measurements taken on the pad similar gross gamma readings were taken at the pad and at several other site locations For these a single 4 inch by 2 inch NaI(Tl) crystal was placed on the surface and the counts recorded on a scaler timer unit The new parking lot east of 111 Building the 750 Building parking lot and the asphalt in front of the 881 guard post gave similar readings of 13 000 to 16 000 counts per minute Furthermore the asphalt in all areas including the pad counted 25 to 30% higher than nearby shoulder or gravel areas Pad readings were in the range of 15 000 to 16 000 counts per minute with the exception of areas near

and on the hot spots Therefore the gamma profile of the pad indicates a general level of activity similar to other asphalt areas That the asphalt appears to be 25 30% hotter than nearby gravel surfaces may be due to a concentration of natural uranium and/or its daughters which occurs during the asphalt production process It is known that the front range shows a high natural uranium content in the soil Also it is noteworthy that highways offsite in this area show γ ray readings similar to those found on site Thus with the exception of the hot spots ' on the pad it appears that a sensitive measurement of the asphalt thickness may have been performed

Following the γ ray mapping the two hot spots were γ ray pulse height analyzed in an effort to determine whether or not the activity detected was emanating from ^{239}Pu or natural/enriched uranium These efforts were unsuccessful If plutonium or uranium were spilled on the original ground layer the γ ray emissions would have to penetrate 6 inches to 8 inches of gravel fill plus 3 inches to 5 inches of asphalt to be detected The low energy plutonium γ rays are severely attenuated A simple experiment was performed to see if high-energy gamma rays could be used to distinguish between uranium and plutonium Spectra were taken using (NaI(Tl) detectors of natural uranium enriched uranium and ~5 year-old WR plutonium sources with 4 inch and 8 inch concrete slabs interposed between the sources and detector The 5 year-old plutonium source was chosen to simulate the average age of plutonium released in the drum storage area There were no readily distinguishable differences in the spectra

It was then decided by the Committee to excavate four selected areas Areas No 14 and No 17 represent the two hot spots labeled 17 21 and 25 respectively in Figure 8 1 Hole SW an area thought to be a likely spot for plutonium and Hole NC a possible background area The areas (2 to 4 sq ft) were covered with a tent the asphalt removed and holes excavated Material removed was placed in 1 gallon polyethylene bottles and sent to Building 881 Analytical Laboratories for analysis Digging was continued until the NaI(Tl) and/or alpha monitors indicated background levels The holes were refilled with new fill material and resealed with asphalt

The results of the wet chemical analyses are summarized in in Table 8 1 Holes No 14 and No 17 contained large amounts of depleted uranium Based upon these percentages we removed approximately 25 kg of depleted uranium from No 14 and 6 kg from No 17 A sample from each hole was γ ray scanned with a Ge(Li) detector and no evidence for plutonium was seen Holes No SW and No NC conversely showed no uranium but did show detectable amounts of plutonium The total plutonium removed from holes No SW and No NC was estimated from five analyses and therefore should be considered as only an order of magnitude number These values are ~10 mg for No SW and ~200 300 μg for No NC

In the summary the following statements can be made concerning the pad survey

a The γ ray mapping indeed detected areas of activity above background ' levels Two areas of significant activity were located

b The γ mapping further showed large general patterns of similar activity These patterns may indicate activity on the old ground layer or may merely be a measure of the natural uranium content and thus the thickness of the asphalt layer

c Two of the localized activity areas which were excavated No 14 and No 17 resulted from depleted uranium This was further evidenced by the presence of a very concentrated depleted uranium contaminated oil layer at 18 in and 30 in depth for holes No 17 and No 14 respectively (Table 8 2)

d Analysis of the four test holes (Table 8 1) showed little or no mixing between Pu and U Thus reasonably rigid segregation of barrels must have been maintained during the lifetime of the storage area

e In no case was activity found to be migrating upwards from the original ground level into the fill material

f While activity in holes No 14 and No SW extended several inches into the soil (Table 8 2) in all four cases no activity was found more than 1 in into the clay layer Thus the clay layer which varies in depth from 4 inches to 15 inches below the original ground level, appears to serve as a natural barrier to the further vertical migration of the radioactive material

Table 8 2 Summary of Results

Hole	Activity From γ Map Thru Asphalt (cpm)	Maximum γ Reading in Hole (cpm)	Maximum α Reading in Hole (dpm)	Active Material	Where Activity Firs Detected	Vertical Thickness of Activity Layer (inches)	Location of Clay Layer (below to of pad) (inches)
No 32	55 000	3×10^6	5000	Depleted U	original ground layer	6 8	30
SW	16 000	<16 000	20 000	Pu	original ground layer	4 6	16
No 17	35 000	2×10^6	5000	Depleted U	original ground layer	1 2	18
NC	16 000	20 000	1000	Pu	original ground layer	<1	26

9 SOIL STABILIZATION

In order to have an additional tool available during any future contamination control and removal operations and to specifically assist in minimizing resuspension during the removal of the soil under the asphalt pad a study of soil stabilizers in Rocky Flats soil was initiated

Several methods exist for stabilizing fine grained particles of soil or dust which are potential sources of air and water pollution Soil stabilization can be accomplished by physical chemical and vegetative methods or by combinations thereof

Stabilization by chemical and/or combined chemical and vegetative means can serve several useful purposes at Rocky Flats The following are some possible uses

1 Immobilization of contaminated soil which might result from a spill

2 Prevention of contaminated soil dispersion during removal of the asphalt pad

3 Enhance the establishment of permanent vegetation in and around Rocky Flats

4 Reduce soil erosion and subsequent property damage by airborne debris during periods of high velocity winds

Evaluation of soil stabilizers has been in progress for approximately one year Preliminary results[1] suggested that J 197 a product commercially available from Dowell Division Dow Chemical U S A showed some degree of effectiveness in stabilizing the soil when applied at a concentration between 60 and 100 pounds per acre It was recommended that further evaluation of J 197 should be performed

A survey of available literature[2-6] showed that many chemicals have been evaluated by the United States Bureau of Mines and others In addition to J 197 two soil stabilizing products (Coherex® and Peneprime®) cited in the literature are being evaluated at Rocky Flats Methods of application have been developed and stability tests have been underway for approximately 9 months [7]

Following preliminary evaluation of the three soil stabilizing chemicals combined chemical and vegetative soil stabilizing experiments[8] are in progress The following is a review of the results obtained during evaluation of chemical soil stabilizers and the results of recent combined chemical and vegetative soil stabilization research at Rocky Flats

General information describing the three soil stabilizers of interest is given in Table 9 1 Evaluation of these chemicals has been conducted in test plots of varying sizes all within the general vicinity of the asphalt pad (903 storage area) Figures 9 1 and 9 2 show the location of six plots utilized to develop application methods and to evaluate the stabilizing qualities of each chemical These plots were established between October and December 1970

Table 9-1 General Information On Three Soil Stabilizing Chemicals.

Product Name	Manufacturer	General Description of Product
Coherex®	Golden Bear Division Witco Chemical Co	Non volatile emulsion consisting of 60% semi liquid natural petroleum products and 40% wetting agents
J 197	Dowell Division Dow Chemical U S A	Poly acrylamide a plastic material similar to surfactant chemicals and thickening agents contains 1% violet dye for marking purposes
Peneprime	Empire Petroleum Co	Asphalt derivative of petroleum crude bottoms

J 197 was applied at concentrations varying from 17 to 75 pounds per acre (test plots 1 2 3, and 6) A water solution of Coherex was applied to test plot number 4 (1 part Coherex to 4 parts water) at a concentration of 0 5 gallons per square yard Test plot number 5 was stabilized with Peneprime (1 gallon per square yard)

To gain more experience on the feasibility of stabilizing large areas of soil with varying surface features a plot (number 6) about 0 9 acre in size was stabilized Surface features included coarse gravel fine soil and grassy areas A total of 7 500 gallons of J 197 solution was applied with a portable pump and fire hose The concentration of J-197 powder was 70 pounds per acre

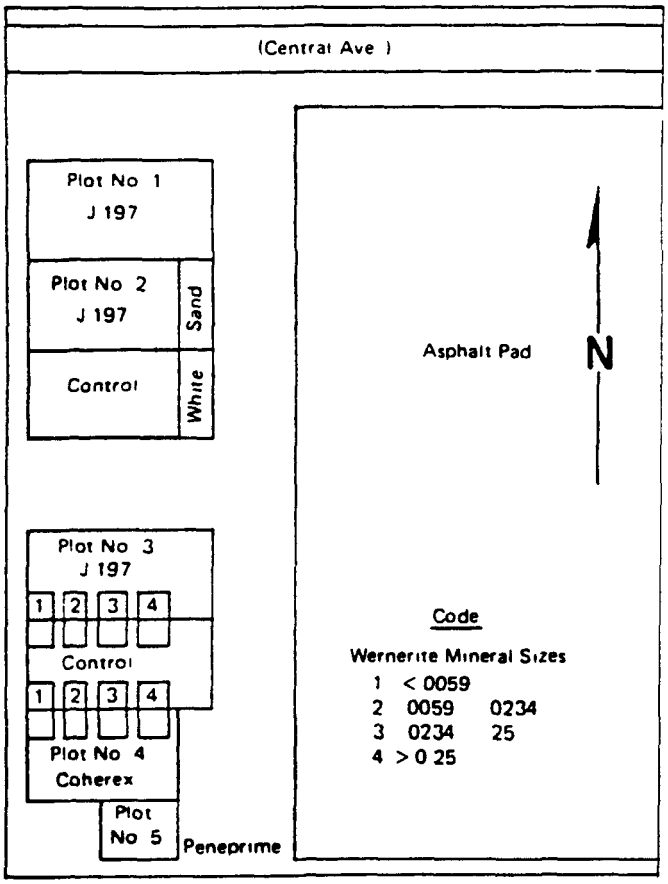


Figure 9-1 Soil Stabilization Test Plot Locations.

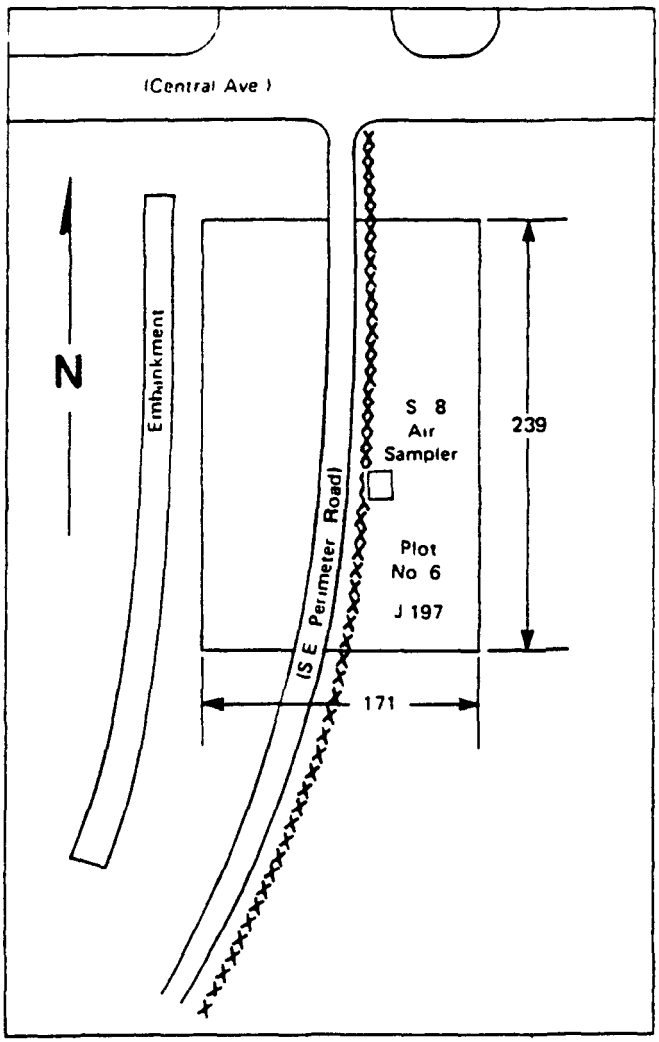


Figure 9 2 Soil Stabilization Test Plot Locations

Test plot number 6 surrounds a Health Physics air sampler (number S-8) This air sampler has consistently indicated relatively higher amounts of airborne radioactive contaminants when compared to other air samplers located along the east perimeter fence Therefore data from this air sampler might be used to evaluate the effectiveness of J 197 on this test plot

Criteria for evaluation of each chemical soil stabilizer consisted of

1 Ease of solution preparation and distribution

2 Visual observation

3 Depth of penetration

4 Ability to prevent particle dispersion (test plots 2 3 and 4)

5 Effectiveness on various soil types (coarse gravel to fine soil)

6 Permanence (weather resistance)

7 Ecological and aesthetic considerations

8 Effect on established vegetation

9 Evaluation of air sample data (test plot number 6 only)

Evaluation of particle dispersion prevention (criteria number 3) was conducted by using an underlay of white sand (test plot number 2) which could be visually observed Wernerite a fluorescent mineral was used as an underlay on test plot numbers 3 and 4 It was also used on the common edges of the intervening control plot Four different particle sizes were used Erosion of this mineral was followed by observation with the aid of ultraviolet light

Visual inspection of test plot number 2 (stabilized with J 197) indicated temporary stability. The white sand remained in place somewhat longer than the sand on the adjacent unstabilized control plot. However, the stabilized sand did dissipate within two months. The method of application and total concentration (17 pounds of J 197/acre) of stabilizer applied was far from optimum. The J 197 was applied manually which accounts for the low concentration. Before further work was conducted, a method of spraying the J 197 solution was developed. This method employs a portable pump, fire hose, and adjustable nozzle to distribute the solution (see Figures 9-3 and 9-4).

Evaluation of test plots number 3 and 4 indicates that both J 197 and Coherex have been fairly successful in retaining the fluorescent mineral. The mineral on these plots was examined on March 30, 1971 (using ultraviolet light). After 4½ months of exposure to the high winds and precipitation, some erosion of the smaller mineral particles from the plot stabilized with J 197 was evident, but considerable more loss occurred on the control plot. Table 9-2 compares the mineral retention on these two test plots and the control plot.

Table 9-2 Wernerite Mineral Retention On Two Stabilized Test Plots And A Control Plot (a)

Mineral Size (in.)	J 197 Test Plot No. 3	Coherex Test Plot No. 4	Unstabilized Control Plot
< .0059	~20%	~90%	~10%
.0059 - .0234	~50%	~90%	~20%
.0234 - .25	~80%	~95	~60
.25	95%	95	95

(a) The percents given are estimates based on visual examination and serve only as a relative guide for comparison of J 197 and Coherex stabilizing products.

Test plot number 5 was effectively stabilized with Peneprime. However, as described previously (see Table 9-1), this chemical is an asphalt product and is undesirable from several standpoints. It is difficult to apply, detrimental to established vegetation, and has no aesthetic appeal.

The airborne contamination data obtained from the air sampler located in the center of test plot number 6 (S-8 air sampler) did not show any significant change. It appears that the test plot was not large enough to have an effect. S-8 air sampler data from November 12, 1970 to the present can be reviewed in Figure 3-1, in Section 3. Visual examination of this plot of S-8 air sampling data coupled with a knowledge of the wind pattern and velocity and a knowledge of activity in the area indicated that J 197 will stabilize all types of Rocky Flats soil. A crust of varying thickness is formed when this chemical is applied. Also, relatively large particles will be held in place by the crust. Figures 9-5, 9-6, and 9-7 show the type crust formed in gravel, fill soil, and grassy areas. This protective crust was found to be friable and will deteriorate in time. Therefore, it appears that this stabilizer would be excellent for short term stabilization, but semiannual application may be necessary if long term stability is required.

Evaluation of J 197, Coherex, and Peneprime as chemical stabilizers is summarized in Table 9-3. Based on these results, J 197 and Coherex were considered favorable for further testing.

Table 9-3 Evaluation Of Three Soil Stabilizing Chemicals

Information	J 197	Coherex	Peneprime
Solution preparation and distribution	Excellent	Excellent	Warm weather only (>70°F)
Visual Observations	Forms crust of varying thickness	Soil appears to be undisturbed after application	Similar to asphalt
Depth of Penetration	Approximately 1/32 to 1/2 inch	Approximately 1/8 to 3/4 inch	Approximately 1/2 inch
Prevention of Particle Dispersion	Good to Excellent	Good to Excellent	Excellent
Effectiveness on various soil types	Good on gravel and top soil	Good on gravel and top soil	Only test was on gravel fill excellent
Weather resistance	Crust is friable semi annual application may be necessary if long term stabilization is needed	Unaffected by weather	Unaffected by weather
Ecological and aesthetic considerations	Excellent	Good	Poor
Effect on Established Vegetation	No effect	No effect	Covers vegetation completely
Overall Rating	Good	Good	Poor

In May 1971 combined chemical and vegetative test plots were established in an area just east of the asphalt pad The area consisted of several inches of gravel fill material To provide a good base for vegetation an overlay of 3 inches of local top soil was added Three plots 8100 square feet in size were marked off Each plot was cross fertilized (350 pounds/acre) cross dragged cross seeded with Fairway crested wheat grass (25 pounds/acre) and final cross dragged

Chemical stabilization was performed on two of the plots using solutions of Coherex and J 197 The third plot was used as a control plot for comparative evaluation A total of 2,000 gallons of J 197 solution was applied The resulting concentration was 110 pounds of J 197 per acre The Coherex solution was applied at a rate of 5 gallon per square yard A total of 450 gallons of solution consis ting of 1 gallon of Coherex per 4 gallons of water was used The control plot was treated with 2000 gallons of water

Preliminary results of the test plots stabilized by combined chemical and vegetative means are very encouraging The final preparation of the plots was completed on May 4 and 5, 1971 (see Figure 9-8) In less than two weeks seedlings were observed on both of the stabilized plots and the con trol plot Since that time, the growth of vegetation has been excellent Figure 9 9 shows the condition of the three plots one month after seeding The grass was about 3 inches tall on each plot with fairly uniform coverage Neither the Coherex nor J 197 were found to be detri mental to the establishment of vegetation If high winds occur little soil erosion and subsequent loss of vegetation is expected from the stabilized plots

The results of soil stabilization research show that both Coherex and J 197 can be used for chemical and/or combined chemical and vegetative stabilization Coherex appears to be more favorable for use on sand or gravel surfaces However, J 197 is believed to be somewhat better for stabilization of top soil and grassy areas Both chemicals can easily be prepared and distributed on all types of terrains Water sprinkling trucks portable pumps and perhaps even aerial application methods can be employed

The cost of stabilization including materials and labor will vary considerably depending on the area to be treated It is estimated that the two products evaluated will be com petitive in cost and will range from $200 to $400 per acre

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3 R Havens and K C Dean *Chemical Stabilization of the Uranium Tailings at Tuba City Arizona* USBM RI-7288 August 1969

4 *Disposition and Control of Uranium Mill Tailing Piles in The Colorado River Basin* NP 16094 USDHEW March 1966

5 *Dust Control Lessons Learned* DA PAM 525 5 U S Army 1969 Military Operations

6 J Peters and J Sciodrone *Stabilization of Sand Dunes at Vandenberg Air Force Base Jour Soil Mechanics and Foundations Division* Amer Soc Civil Engineers pp 97-016 July 1964

7 D D Hornbacher R M Saiki and C T Illsley *Status of Soil Stabilization Evaluation Program* Internal Report Number PRD 940474 107 Rocky Flats Division The Dow Chemical Company April 22 1971

8 Unpublished work by D D Hornbacher and R M Saiki Rocky Flats Division The Dow Chemical Company

9 Unpublished work by D E Michels Rocky Flats Division The Dow Chemical Company

[redacted]

Figure 9-9 View Of Test Plots 41 [illegible] Cohorex right)

[redacted]

10 POSSIBLE OPTIONS FOR DISPOSITION OF PLUTONIUM-CONTAMINATED SOIL

When considering the ultimate disposition of plutonium contaminated soil the following actions were evaluated

1 Chemical recovery of plutonium from soil

2 Chemical mining or *in situ* leaching

3 Soil removal and burial at an approved site

1 Chemical recovery of plutonium from the soil would be an enormous task Concentrated acids at room temperature have been shown to remove between 49 and 72% in 1 hour The time can be reduced to less than one half by processing at the solution boiling point This amount represents the plutonium held on the surface of the soil All the plutonium can be recovered by complete decomposition of the soil in an acid solution consisting of 15 8 *M* HNO_3 and >0 1 *M* HF With this method dissolution is completed in about one half hour at the solution boiling point These recovery rates are based on laboratory studies and would not be expected on a large system Much intermediate waste would be generated by chemical removal processes This does not seem practical

2 Chemical mining appears to be very difficult because of the thin large area and the varying plutonium concentration In addition this type of processing is not considered to be very efficient Solubilized plutonium could be carried into the water-courses and eventually to humans This does not seem practical

3 One possible burial location for Rocky Flats contaminated soil may be the salt mine near Lyons Kansas However this site will not be ready to receive contaminated material until at least 1975 Also the contamination level of Rocky Flats soil is so low that the soil may not be acceptable for burial

Commitments have been made by Dow (Rocky Flats) and the AEC to the Governor of Colorado that we would remove the Pad ' and the contaminated soil it entraps This can be accomplished whenever an approved AEC burial site can receive the material The cost associated with removal is estimated in the next section of this report (See Section 11) Decision on actions on additional contaminated soil such as the action of plowing that was used in Spain, can not be made without a better plutonium concentration depth profile The mechanism of plutonium transport in soil should be established before actions such as plowing can be considered

Soil stabilization studies were initiated and will be continued Data resulting from studies to this period are reported in Section 9 of this report

[redacted]

11 ESTIMATE OF THE COST OF REMOVAL OF PLUTONIUM CONTAMINATED SOIL UNDER THE ASPHALT "PAD"

Present information does not establish the exact depth or area from which the contaminated soil will be removed It is possible to estimate unit costs of labor packaging materials freight and burial or storage as follows

Unit	Cost per 55-Gallon Drum
Labor to Fill and Load Drums	$10 00
Packaging Materials	10 50
Freight Based on 600 Pounds Per Drum and Freight Rate of $2 10/100 Pounds	12 60
Burial of Storage Based on 7 4 Cubic Feet per Drum and Present NRTS Charges of $1 06/ Cubic Foot for Storage of Trans uranium Wastes	7 85
TOTAL	$40 95 ~ $41 00

Using this information and the following assumptions regarding area and depth of contamination it is possible to indicate the magnitude of the operation

Case I

1 Assume the removal of the asphalt pad as uncontaminated waste Remove the 10 inches of fill dirt and 8 inches of contaminated soil under the asphalt pad as con taminated waste	220 000 Cubic Feet
2 Remove 4 inches of fill dirt and 2 inches of contaminated soil from the area east of the asphalt pad to the security fence as con taminated waste	111 500 Cubic Feet
TOTAL	331 500 Cubic Feet
331 500 Cubic Feet / 7 4 Cubic Feet/Drum	~47 360 Drums
47 360 Drums X $41 00/Drum	~$1 950,000
Equipment Facilities	~ 50 000
TOTAL	~$2,000,000

Case II

1 Assume the removal of the asphalt pad as uncontaminated waste Remove 10 inches of fill dirt and 24 inches of con taminated soil under the asphalt pad as contaminated waste	414,000 Cubic Feet
2 Remove 4 inches of fill dirt and 8 inches of contaminated soil from the area east of the asphalt pad to the security fence as con taminated waste	223 000 Cubic Feet
TOTAL	637 000 Cubic Feet
637 000 Cubic Feet / 7 4 Cubic Feet/Drum	~91 000 Drums
91 000 Drums X $41 00/Drum	~$3 731 000
Equipment and Facilities	~ 50,000
TOTAL	~$3,781,000

[redacted]

12 ROCKY FLATS CURRENT HEALTH PHYSICS ENVIRONMENTAL SAMPLING PLAN

Vegetation Samples

ON SITE

Vegetation samples are collected at 6 month intervals from 16 locations within the security fence The samples are currently analyzed for total U + Pu activity (gross alpha) and specifically for plutonium

OFF SITE

Sixty seven locations with a 10-mile radius of the plant are collected at 6 month intervals All vegetation samples are collected from public right of way and confined to that normally consumed by grazing animals The samples are analyzed for gross alpha and specifically for plutonium

Water Samples

ON SITE

Water samples from holding ponds 1 5 and 9 (release points) are collected daily The samples are composited weekly and analyzed for uranium plutonium and americium

Monthly water samples from each of 14 sampling wells are analyzed for uranium and plutonium

OFF SITE

Thirty seven samples from lakes and streams surrounding the plant are collected at 6 month intervals The samples are analyzed for gross alpha content A plutonium determination is made if the sample activity exceeds 0 7 pCi/liter ($0\ 7 \times 10^{-9}$ μCi/ml)

Samples from four reservoirs and nine community tapwater supplies are collected bimonthly and analyzed for total uranium plus plutonium activity In addition these reservoir samples are analyzed specifically for plutonium Samples from Great Western (Broomfield water supply) and Standley (Westminster water supply) Reservoirs are analyzed specifically for americium

A weekly water sample collected from Walnut Creek at Indiana Avenue is analyzed for total uranium plus plutonium activity and specifically for plutonium and americium

Air Samples

ON SITE

Twelve on site continuous air samples are collected daily (except weekends and holidays) and analyzed for total long lived alpha activity An analysis is also performed for beryllium

Five weekly 6 hour high volume air samples taken east of the 903 Area are collected and analyzed for plutonium content

OFF SITE

Twelve high volume continuous air samples taken approximately 2 miles from the plant boundary are collected daily (except weekends and holidays), composited weekly and analyzed specifically for plutonium content In addition a 6 hour high volume air sample is collected weekly at each of Wagner site (located approximately 2 5 miles ESE of the plant) and Coal Creek Canyon These air samples are analyzed specifically for plutonium content

Biweekly air samples from nine additional locations are analyzed for total long lived alpha activity Samples from these locations are also analyzed for beryllium

Fallout (Dustfall) Samples

ON SITE

Five dustfall samples are collected bimonthly from locations on site and downwind from the production buildings One site is downwind from the 903 Area Fallout (dustfall) samples are analyzed specifically for plutonium

OFF SITE

Twelve dustfall samplers are located off site atop the air sample stations The samples are collected bimonthly

More remote samples are collected monthly from Berthoud and Castle Rock All dustfall samples are analyzed for plutonium content

Soil Sampling

The Rocky Flats Health Physics department maintains an extensive routine soil sampling program Soil samples are collected from locations both on and off the plant site

Analysis of soil samples is generally confined to plutonium however a capability for analysis of uranium and americium also exists An analysis for other than plutonium would be performed based on historical sample results and/or mode of contamination

ON SITE

1 903 Area

Forty-eight samples are collected at 100 150 and 500 ft distances from the nearest edge of the asphalt pad This area is presently being sampled four times per year It is planned to reduce this to twice per year in September 1971

2 Other Sites Within the Security Fence

Twenty nine locations on alternate grid points of the 500 ft Austin Company grid are sampled twice per year and analyzed specifically for plutonium

3 Samples Between the Security and Cattle Fences

Sixty locations (predominantly east and south of the plant proper but covering all areas) are sampled semiannually

OFF SITE

1 Grid Samples

There are 20 locations on each of three concentric circles of 1 2 and 5 mile distances from the plant center These samples are approximately equi spaced and are collected twice per year

In order to intensify the soil sampling in areas east and south of the plant boundary 30 additional locations in these areas are sampled along public right of way These samples are collected twice per year

2 Remote Off Site Samples

Twenty soil samples from Arvada Westminster and Denver locations between Boulder and Fort Collins Coal Creek Canyon locations between Leyden and Golden and along 104th Avenue are sampled twice per year

Sediment Samples

ON SITE

Sediment samples from each of the holding ponds are collected monthly for analysis of plutonium and americium This schedule will continue until any problems are adequately defined The schedule will then be reduced to twice per year

Sediment samples from Walnut Creek and Woman Creek effluent water courses are collected monthly These sediment samples are analyzed for plutonium and americium content

OFF SITE

Sediment samples from each of four reservoirs (Great Western Baseline Standley and Ralston) are collected twice each year and analyzed for plutonium An analysis specifically for americium is performed on Great Western and Standley Reservoir sediment samples

Chemical Contaminants

ON SITE

Water samples from holding ponds 1 5 and 9 are collected three times per week and analyzed for pH, NO_3^-, PO_4^{-3} F^- and total solids A daily water sample from the holding pond 5 is composited and analyzed for biological oxygen demand (BOD) These chemical analyses assure that all water leaving the plant is in compliance with presently accepted drinking water standards

Water from the 14 sampling wells is analyzed for pH NO_3^- PO_4^{-3} F^- and total solids

OFF SITE

Because of a recurrent problem with nitrates leaching into Walnut Creek from the solar evaporation ponds a weekly water sample from Walnut Creek at Indiana Avenue is collected and analyzed for NO_3^- concentration During periods of peak spring runoff a daily water sample from Walnut Creek at Indiana Avenue is analyzed for NO_3^- concentration

Presently, environmental sample analysis for plutonium and americium is restricted due to the lack of adequate alpha pulse height analysis instrumentation This condition will be relieved with the purchase of additional instrumentation for the performance of the analyses in Fiscal Years 1972 and 1973

13 CONTINUING RESEARCH SUPPORT AT ROCKY FLATS ON THE STUDY OF PLUTONIUM IN SOIL

This study pointed out several areas where information is needed if reasonable decisions are to be made pertaining to problems of plutonium in soil The following activities are being or will be pursued at Rocky Flats if sufficient funding is available

1 Sampling and analytical techniques will be improved

2 Standard samples will be generated and stored for future use

3 Sampling exchange programs with other laboratories will be continued

4 Plutonium soil depth profiles will be obtained

5 The mechanism of plutonium transport in soil will be studied

6 The chemical form of the plutonium in Rocky Flats soil should be identified

7 The solubility of the plutonium in Rocky Flats soil will be studied

8 The particle size of the plutonium species and the size of aggregate particles of plutonium and soil should be established

9 Emergency procedures to "fix" plutonium in soil for easy removal in event of any future accidents, will be established

10 New and improved air sampling systems will be devised and deployed that specifically measure resuspended plutonium particles from Rocky Flats soil

11 The significance of multiple resuspension of plutonium particles from Rocky Flats Soil will be established

[redacted]

PART II RECOMMENDATIONS

1 It is recommended that the AEC purchase additional property surrounding the Rocky Flats Plant site

2 It is recommended that areas in which the soil contains plutonium in excess of 350 mCi/km^2 be fenced and restricted from grazing

3 It is recommended that additional soil stabilization action be pursued on soil in and around the Rocky Flats plant where plutonium concentration exceeds 350 mCi/km^2

4 It is recommended that additional vegetative cover be considered for use in conjunction with soil stabilizers in the areas east and south of the drum storage area

5 It is recommended that the asphalt "Pad," which is an effective seal, not be disturbed until all questions of a disposal site for the contaminated soil have been resolved

6 It is recommended that specific responsibility be assigned for ultimate disposal of the soil under the pad

7 It is recommended that the diagnostic research and health physics support described in Part I (13) of this report be completed

8 It is recommended that close liaison be maintained with other AEC and commercial agencies or sites using plutonium so that all new plutonium environmental information can be shared

[redacted]

PART III APPENDICES

Appendix A Geology of Rocky Flats Plantsite

Appendix B Analysis of HASL Data

Appendix C Soil Contamination and Asphalt Pad

Appendix D Simplified Conversion Scale and Table for the Various Units Used in the Literature to Express the Levels of Plutonium Contamination in Soil

Appendix E Trip Report

GEOLOGY OF ROCKY FLATS PLANTSITE

C T Illsley December 1970

Th[redacted]ats Plant in Colorado is located on a gently [redacted] or outwash plain at the eastern edge of [redacted] Front Range of the Rocky Mountains [redacted] are extremely scarce in the immediate vicin[redacted] the site and most of the geologic descriptions are based on extrapolations from adjacent areas to the north and south Some information was obtained from surface rock outcrops west of the area and subsurface conditions were observed in the abandoned Capitol Mine (coal) which is only one half mile west of the plant Geologic information was obtained from the maps and reports referred to in the list of references

The surface soil is composed of 10 to 25 feet of alluvium or gravel which consists mostly of quartzite boulders and clay This surficial material is underlain by 700 800 feet of Laramie formation according to Spencer (1961) and shown in Figure A 1 Earlier reports indicated the presence of 25 to 30 feet of the Arapahoe formation but Spencer could not distinguish such a lithologic break in the Laramie formation in this area

The Laramie formation is divisible into two parts The lower part about 100 feet thick is composed chiefly of sandstone and sandy shale interbedded with lesser amounts

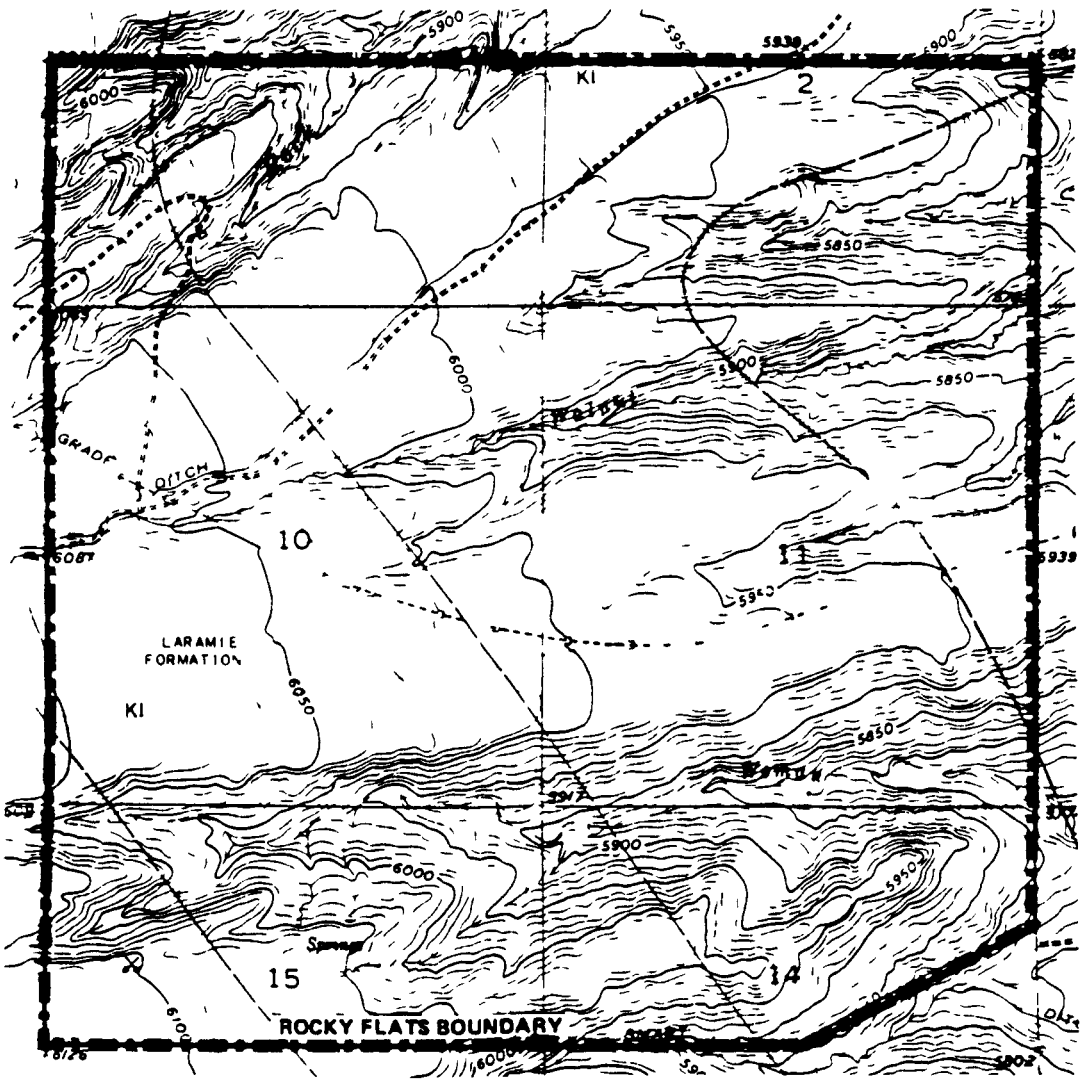


Figure A Geologic Map of Rocky Flats Plantsite

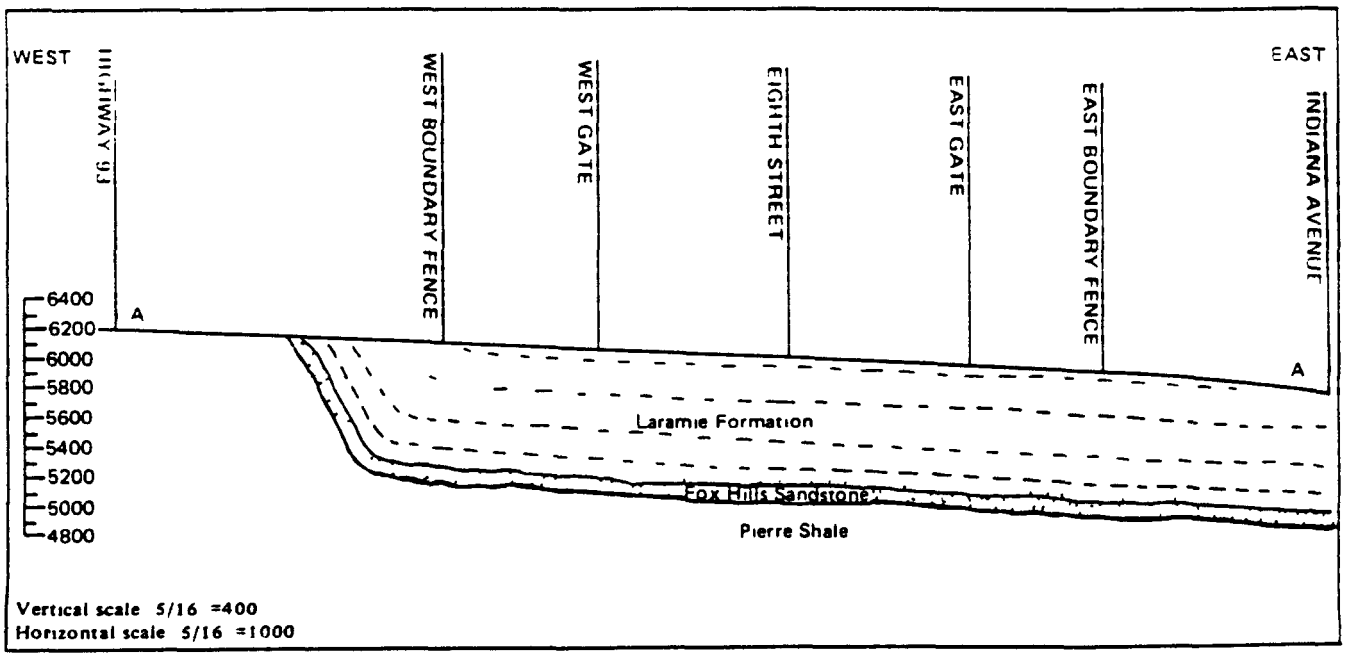
of clay fire clay shale and coal The upper part about 600 to 700 feet thick is composed chiefly of clay shale and sandy shale and some lenticular beds of sandstone and lignite

The Fox Hills sandstone underlies the Laramie formation The Fox Hills is a massive cross bedded and ripple marked sandstone that is conformable with the underlying Pierre shale The lower two thirds of the Fox Hills is a fine to coarse grained, slightly calcareous yellow to greenish buff sandstone The upper one third of the Fox Hills is a fine to medium grained light gray to light yellow mottled cross bedded sandstone The thickness of the Fox Hills sandstone varies from 60 to 250 feet between Ralston Creek and Superior beneath Rocky Flats site it is probably about 100 feet thick

The underlying Pierre shale is about 8000 feet thick It is a lead gray to brown and black shale of marine origin Although generally homogeneous the Pierre also contains some siltstone silty sandstone beds of limestone and limestone concretions

In contrast to the steeply dipping rock strata west of the plantsite the structure beneath the plantsite is almost level and rather uncomplicated A cross section drawn along an east west line from Indiana Avenue to Colorado High way 93 and based on data (from Spencer 1961) of structure contours on the top of the Fox Hills sandstone shows the generalized structure (See Figure A 2) The steeply dipping (~44° east) Fox Hills sandstone exposed on the surface one half mile east of Highway 93 is assumed to flatten out to less than 5° at a point close to the west gate of the plant It is logical to assume that the overlying conformable Laramie formation also is relatively flat under the plant site The structure is significant from a hydrology view point because steeply dipping strata would tend to restrict the ground water to great depths below the surface and extending many miles east of Rocky Flats Since the layered rocks are actually almost level water entering the ground water system from the Rocky Flats area would be more likely to reappear at the surface only a short distance downslope from the recharge area such as in the drainage patterns of Woman Creek or Walnut Creek An illustration of possible ground water movement is shown in Figure A 3 a cross section along a southwest northeast line through the area Evidence for such water migration is the presence of several intermittently flowing springs along the leading edge of the Rocky Flats pediments As indicated in Figure A 3 surface water entering the ground in the vicinity of 771 Building will likely emerge to the surface in Walnut Creek possibly in the Rocky Flats holding pond If the water were to percolate deeper, it should still reappear west of Indiana Avenue To migrate east of Indiana the ground water would have to penetrate more than 350 feet of the Laramie formation This would be unlikely because of the impermeable nature of the clay shale strata Faulting could create passageways for down ward flow of ground water but no evidence of faulting has been reported within the immediate area of Rocky Flats

Figure A 2 Geologic Cross Section of Rocky Flats Plantsite along Line AA



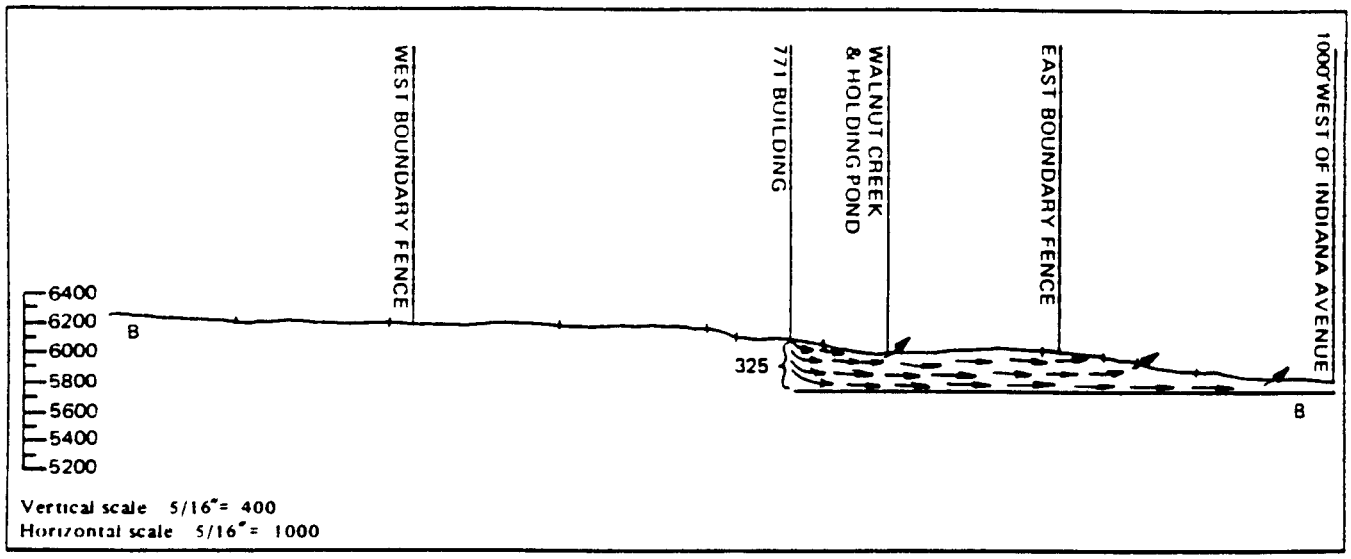


Figure A 3 Cross Section of Rocky Flats Plantsite along Line BB

References

1 F D Spencer 1961 *Bedrock Geology of the Louisville Quadrangle Colorado* U S Geol Survey Geol Quad Map GQ 151

2 R Van Horn 1957 *Bedrock Geology of the Golden Quadrangle Colorado* U S Geol Survey Geol Quad Map GQ 103

3 T S Lovering and E N Goddard 1950 *Geology and Ore Deposits of the Front Range Colorado* U S Geol Survey Prof Paper 223

4 C R Butler 1950 *Structure of Post Cambrian Formations in the Vicinity of Coal Creek Colorado* MS Thesis University of Colorado

5 O W Hampton 1957 *Structural Geology of the Foothills Region from Plainview to Golden Colorado* MS Thesis University of Colorado

6 F T Quiett 1951 *The Geology of the Plainview Area Jefferson County Colorado* MS Thesis Colorado School of Mines

ANALYSIS OF HASL DATA

Section 1

LOG NORMAL ANALYSIS OF PLUTONIUM DATA

D E Michels

Log normal analysis is a technique based on statistical considerations of how analytical values may vary from one another Data are plotted on probability paper such that the linearity of the array of plotted points yields statistical conclusions This technique applies to plutonium data and three kinds of conclusions result (1) When the array of plotted points is precisely linear the data are called homogeneous That is the plutonium in all samples of the group is overwhelmingly from a single source (2) The analytical value associated with the 50th percentile of the data is the average value for the group (3) The standard deviation for the group is given by the slope of the array of plotted points The conclusions described above depend on finding straight line plots when the data are plotted on probability paper Since required straight lines are obtained only when a logarithm scale is used for the analytical values (and not when a linear scale is used) the distributions are termed log normal Log normal distributions are generally obtained for a wide variety of trace materials studied by geochemists

This technique was applied to data reported by Health and Safety Laboratory (HASL 235) personnel since their 33 sample sites included some sites which would be expected not to include detectable amounts of plutonium from Rocky Flats Thus the HASL data involve two kinds of samples one kind dominated by world wide fallout the other kind dominated by Rocky Flats effluent The plot on probability paper permits a sharp distinction to be made between the two groups In addition an independent estimate is obtained for the plutonium background in Denver soils that is due to world wide fallout

Figure B 1 shows the probability plot for the HASL data which in Table B 1 are ranked in order of analytical values

The junction of the two components of the plot at about 3 0 mCi/km^2 is the natural division between the back ground distribution of plutonium and the plutonium derived from Rocky Flats On the basis of Figure B 1, the HASL data are divided into two sub groups which are replotted independently in Figure B-2 Each sub group gives a statistically satisfactory fit to a straight line and we therefore conclude that each subgroup is homogeneous

The higher content subgroup is clearly caused by Rocky Flats since the samples which comprise the subgroup were taken near and downwind of the plant Although it is tempting to select an "average" value for this group by correspondence with the 50th percentile that temptation should be resisted The anomaly has definite structural features which complicate the meaning of average value

However the lower-content subgroup if it truly is back ground should not have a complicating structure Hence this log normal analyses yields an average value of 2 4 mCi/km^2 associated with the 50th percentile and is a valid measure of the Denver background

Table B 1 Order and Percentiles for Plutonium in Soil Samples

Sample	mCi/km^2	Percentile	Sample	mCi/km^2	Percentile	Sample	mCi/km^2	Percentile
33	1 8	3 0	9	2 6	36 4	4	11	69 8
18	2 0	6 1	20	2 6	39 4	17	14	72 8
27	2 0	9 1	24	2 6	42 5	5	15	75 8
29	2 0	12 1	21	2 7	45 5	14	17	78 8
31	2 1	15 2	32	2 7	48 5	15	18	81 8
10	2 2	18 2	30	2 8	51 5	16	19	84 9
22	2 2	21 2	23	3 0	54 5	12	47	87 9
26	2 3	24 2	2	3 1	57 6	13	50	91 0
1	2 4	27 3	3	4 2	60 6	7	480	94 0
25	2 4	30 3	11	5 4	63 6	8	630	97 0
28	2 5	33 4	19	8 0	66 7	6	1950	–

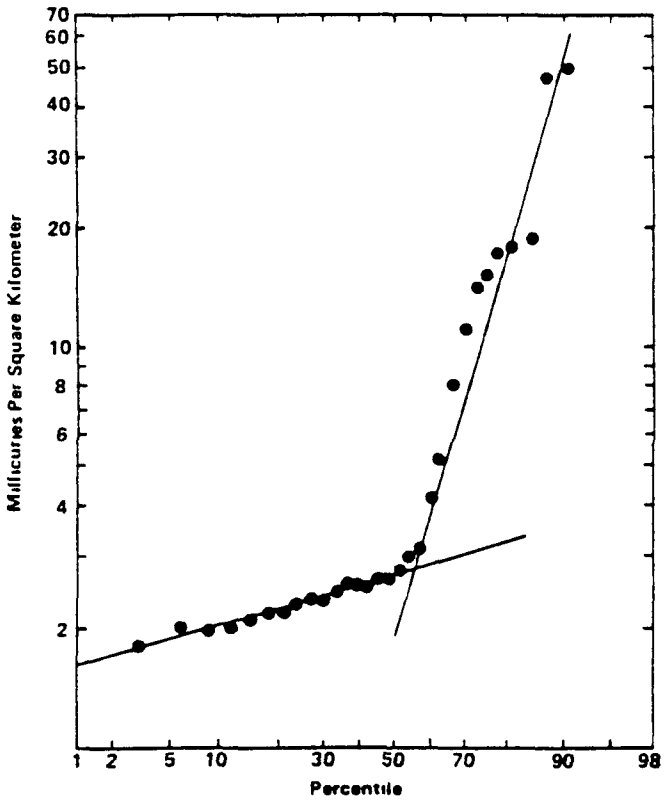


Figure B 1 Compound Distribution Containing Samples Dominated Either by Background Plutonium or By the Rocky Flats anomaly

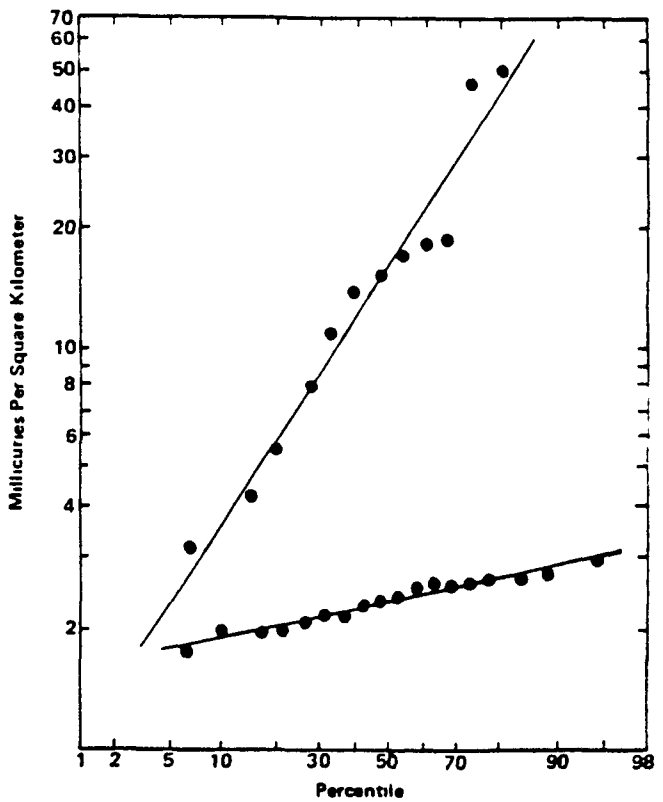


Figure B 2 Background Distribution of Plutonium (lower plot) Separated from the Rocky Flats anomaly

Table B 2 Order and Percentiles for Subgroups

Lower content			Higher content		
Sample	mCi/km	Percentile	Sample	mCi/km	Percentile
33	1 8	5 3	2	3 1	6 7
18	2 0	10 5	3	4 2	13 3
27	2 0	15 8	11	5 4	20 0
29	2 0	21 0	19	8 0	26 7
31	2 1	26 3	4	11	33 3
10	2 2	31 6	17	14	40 0
22	2 2	36 8	5	15	46 7
26	2 3	42 1	14	17	53 3
1	2 4	47 4	15	18	60 0
25	2 4	52 6	16	19	66 7
28	2 5	57 8	12	47	73 4
9	2 6	63 1	13	50	80 0
20	2 6	68 4	7	480	86 8
24	2 6	73 7	8	630	93 3
21	2 7	79 0	6	1950	–
32	2 7	84 2			
30	2 8	89 5			
23	3 0	94 8			
2	3 1	–			

The difference between the average value of 2 4 mCi/km^2 and the classification value of 3 0 mCi/km^2 is a joint c[illegible] sequence of both the natural variability of fallout near Denver and the variations inherent to the sampling and analytical procedures Samples indicating plutonium con tents of less than 3 0 mCi/km^2 contain no increment of plutonium from Rocky Flats In statistical terms the certainty is 95% since the 3 0 mCi/km^2 value corresponds to the 95th percentile of the background value (and to about the 8th percentile of the Rocky Flats anomaly as plotted)

Section 2

PLUTONIUM FALLOUT IN THE DENVER AREA

Donald E Michels

The log normal analysis described in Appendix B Section 1 yielded a value for plutonium fallout in Denver Since the

value is large compared to values used by other investigators (see Table B 3) the following discussion seems pertinent Two points are discussed as follows

Table B 3 Plutonium Fallout Near Denver

Source	Method	Value
Michels[a]	log normal plot of 19 HASL samples	2 4 mCi/km^2
Krey & Hardy[b]	single sample from Derby	1 4 mCi/km^2
CCEI[c]	single sample from Loveland	0 19 mCi/km^2 (d)

[a] Appendix B Section 1

[b] Health and Safety Laboratory report HASL 235 August 1 1970

[c] Colorado Committee for Environmental Information report on Dow Rocky Flats Fire January 13 1970

[d] By conversion 1 d/m/g = 4 5 mCi/km^2

1 Other workers have tended to be conservative and have chosen their background values from the lowest of their analytical values which involved samples remote from Rocky Flats This procedure both biases the selection toward low values and ignores whatever natural variation may exist in the overall background distribution Furthermore the analytical variances involved are not well documented hence the values chosen may be low for reasons independent of the natural variations

2 The plutonium background for the world is known independently from direct chemical analysis because of fission yield estimates maintained by workers at Los Alamos Their 1969 estimate of 500,000 curies of plutonium is equivalent to a world wide average value of 1 1 mCi/km^2 for a uniform distribution Variations from the world average values are expected because weather patterns and fission events are not distributed uniformily The magnitude of these world scale variations are documented for fission products such as strontium 90 which are more commonly analyzed for than plutonium A latitudinal variation in the ^{90}Sr fallout is documented which shows maximum in both hemispheres near latitudes of 40-50° The northern hemisphere maximum for ^{90}Sr is 2 34 times the world wide average value Since Denver latitude is 39° N we should not be surprised to find the plutonium fallout there to be more than twice the world wide average, or between 2 2 and 2 5 mCi/km^2

Presentation at
PROBLEMS ANALYSIS MEETING Rocky Flats
TIME 9 00 am May 25 1971

SOIL CONTAMINATION AND ASPHALT PAD

Speaker Dr James R Seed

Dr Seed has a Ph D from University of California in Physical Chemistry (1964) He is familiar to several members of the panel (H E Roser and D E Patterson) with whom he worked during the official investigation of the May 11 1969 fire at Rocky Flats Some of his early work while in Intelligence in the USAF involved separation and analysis of the actinide elements (primarily protactinium uranium and plutonium) from United States and other nations nuclear test shots Other USAF experience involved surveillance work on (plutonium and uranium) weapons at Manzano Base Albuquerque, New Mexico His specialty field was radiation chemistry His experience and research at Rocky Flats has resulted in expertise in areas of surveillance, product integrity corrosion problems in general plutonium ignition, and the chemistry and physics of plutonium that relates to plutonium handling and storage problems He was assigned by the Operating Board of the Rocky Flats plant as chairman of a special committee to investigate evaluate and recommend action relative to the plutonium that accumulated in the soil from the outside "Barrel Storage Area

Dr Seed is director of Product Research and Development at the Rocky Flats Division

SLIDE 1

A general comment was made that many of the problems that would be discussed throughout the two day meeting would involve environmental concerns

This slide (Slide 1) was a drawing of the theme that had been adopted by a local high school relative to environmental teaching and action programs

It was pointed out that our plant was approximately 20 years old— working in a technical field that for all practical purposes was only about 25 years old Our learning rate was approximately equal to the rate of the growth of knowledge in this new field

As we learned we obviously could look on problems we had faced in the past in light of current knowledge and clearly decide we could or should have acted differently had we known what we know now

Problems of plutonium contamination in soil were discussed in general

SLIDE 2

THERE ARE NO STANDARDS FOR PLUTONIUM IN SOIL

SLIDE 3

PRIMARY GUIDELINE MAINTAIN AN ACTUAL DOSE AS NEAR ZERO AS POSSIBLE

SLIDE 4

A PROCESS OF JUDICIOUS DECISION MAKING HAS BEEN EMPLOYED IN THE PAST THULE ACCIDENT PALOMARES ACCIDENT ETC

The various AEC sites which might face similar problems such as LASL Mound LRL NTS, BNW Pacific Islands as well as the areas where accidents had occurred, Palomares Spain and Thule Greenland were alluded to

With the growth of breeder reactors and fuels reprocessing plants the problems in this area will continue to grow

The problems associated with establishing plutonium soil standards were touched on

1 particle size
2 retention
3 critical organ
4 resuspension

SLIDES 5 AND 6

The accompanying table was divided into two slides (5 and 6)

Data were presented which showed some 'standards that had been adopted by other countries for plutonium in soil (Some liberties were taken in converting units to make cross reference between various papers a little easier)

Data were also presented in some 'reasonable proposed 'standards for the United States This information can be found in a paper presented at the *International Symposium on Radiological Protection of the Public in a Nuclear Mass Disaster* June 1968 The paper was authored by R L Kathren of Battelle Northwest The data relating to Criterion I of 10 CFR 140 84 (Financial Requirements and Indemnity Agreements) were also discussed This criterion considers surface contamination values above 0 35 $\mu Ci/m^2$ (approximately 77 dpm/cm^2 or 350 mCi/km^2) over 100 m^2 of property as the *minimum* level of trans uranic radio nuclides that would comprise a substantial discharge of radioactive material from its intended place of confinement

SLIDES 5 AND 6

MAXIMUM PERMISSIBLE ALPHA CONTAMINATION

Country	$\mu Ci/m^2$	mCi/km^2 [a]	d/m/gram [b]	Remarks
United Kingdom (Dunster)	0 1	100	22 2	Widespread areas contaiminated with plutonium
United Kingdom	0 1	100	22 2	Inactive areas
	1 0	1000	222	Active areas
Czechoslovakia	0 11	110	24 4	Workplaces after decontamination
France	0 1	100	22 2	Equipment and workplaces in inactive areas
	1 0	1000	222	Equipment and workplaces in active areas
Poland	0 1	100	22 2	Labs restricted to using 100 μ Ci or less
	1 0	1000	222	Labs permitted to use more than 100 μ Ci
South Africa	0 1	100	22 2	Body personal clothing inactive areas
	1 0	1000	222	Equipment and workplaces inside controlled areas
United States ICC	0 02	20	4 44	Interstate Commerce Commission (Dept of Transportation) pertains to interior of vehicles previously used for transportation of materials
U S S R	0 015	15	3 33	Work clothing and surfaces before cleaning
	0 002	2	0 444	Hands and work underclothing before cleaning
	0 006	6	1 33	Work Surfaces after cleaning
United States [c]	0 04	40	8 8	Urban suburban recreation areas
	0 4	400	88	Rural truck farming, annual food crops, grazing land milk shed etc
	4 0	4000	888	Rural deep root perennials (e g nuts certain fruits)
	40 0	40000	8888	Remote or Controlled desert forest fenced or limited access areas

[a] Units used in HASL report No 235
[b] Units used by Rocky Flats in reporting soil analysis (in most cases a specific gravity of one (1) was assumed for conversion of units
[c] Recommended at an International Symposium on Radiological Protection of the Public in a Nuclear Mass Disaster (June 1968)

SLIDE 7

HISTORICAL SEQUENCE

- JULY 1958
  DRUM STORAGE AREA ESTABLISHED DURING SUBSEQUENT YEARS DRUMS WERE CONTINUALLY ADDED PRIMARILY PLUTONIUM CONTAMINATED MACHINING OILS
- 1959
  FIRST DRUM LEAKAGE DISCOVERED–RUST INHIBITOR ETHANOLAMINE WAS ADDED TO DRUMS PRIOR TO STORAGE TO MINIMIZE CORROSION
- JANUARY 1964
  FIRST EVIDENCE OF LARGE SCALE DETERIORATION OF DRUMS REPORTED SOIL CONTAMINATION REPORTED AS INCREASING

SLIDE 8

HISTORICAL SEQUENCE (continued)

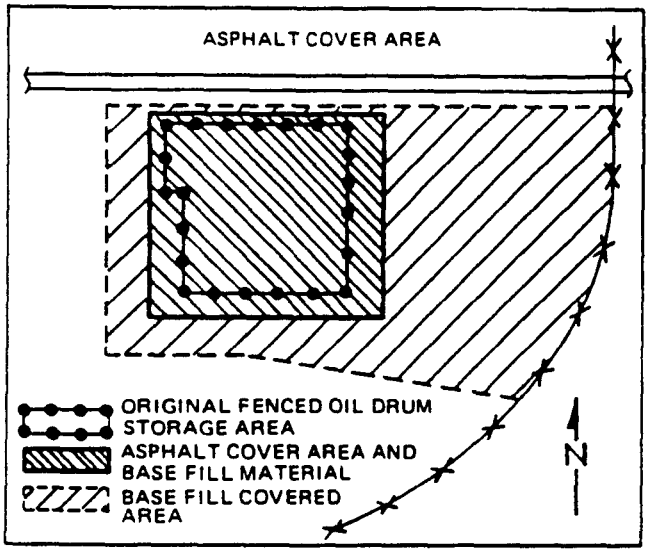
- 1966
  SMALL BUILDING ADDED TO FACILITATE TRANSFER OF CONTAMINATED OIL FROM LEAKING DRUMS TO NEW DRUMS
- JANUARY1967
  LAST DRUMS ADDED TO STORAGE AREA AND REMOVAL TO 774 BEGAN OLDEST DRUMS SHIPPED FIRST
- JUNE 1968
  LAST DRUM SHIPPED TO BUILDING 774 FOR PROCESSING HIGH WINDS SPREAD SOME CONTAMINATION
- JULY 1968
  RADIATION MONITORING AND MAPPING OF AREA COMPLETED LEVELS OF 2×10^5 d/m/gm TO OVER 3×10^7 d/m/gm REPORTED PENETRATION OF FROM 1 INCH TO 8 INCHES REPORTED

SLIDE 9

HISTORICAL SEQUENCE (continued)

- SEPTEMBER 1968
  PRELIMINARY PROPOSAL FOR CONTAINMENT COVER PREPARED BY ROCKY FLATS FACILITIES ENGINEERING
- JULY 1969
  FIRST COAT OF FILL MATERIAL APPLIED
- AUGUST 1969
  FILL WORK COMPLETED PAVING CONTRACT LET
- SEPTEMBER 1969
  OVERLAY MATERIAL SOIL STERILANT AND ASPHALT PRIME COAT COMPLETED
- NOVEMBER 1969
  ASPHALT CONTAINMENT COVER COMPLETED-INCLUDING FOUR SAMPLING WELLS

SLIDE 10



These three slides detailed the significant information relative to the development of the problem and also action taken up to the completion of the asphalt pad

The items on the slides were discussed pointing out that throughout this entire period development work was conducted on a process to treat (dispose reclaim etc) the contaminated oils An initial process was developed in December c 1959 but equipment and funding problems delayed the initial test runs until May of 1960 Further corrosion o equipment problems (hydrolysis and radiolysis of the CCl_4) HCl) delayed the process until December 1961 This process and project of treating the contaminated oils was included in the project Additional Processing Facilities Contract AT(29 2) 1298 which was an expansion of the plutonium chemical operations Later funding difficulties resulted in deletion of this portion of the project Actual processing of the oil commenced in January of 1967 At this time the field contained about 5 240 drums

In the discussion with the AEC participants of the meeting, the action taken to minimize drum corrosion was covered and the effort made to transfer oil from the older to newer drums was also discussed

SLIDE 10

A drawing of the actual area of the pad and additional base fill was presented and discussed (Slide 10)

SLIDE 11

A photograph of the pad area was presented (Not included in text)

SLIDE 12

A slide which consisted of colored contours depicting plutonium in the surface soil around Rocky Flats was presented These data were generated by using soil analysis from

1 Rocky Flats Health Physics Department

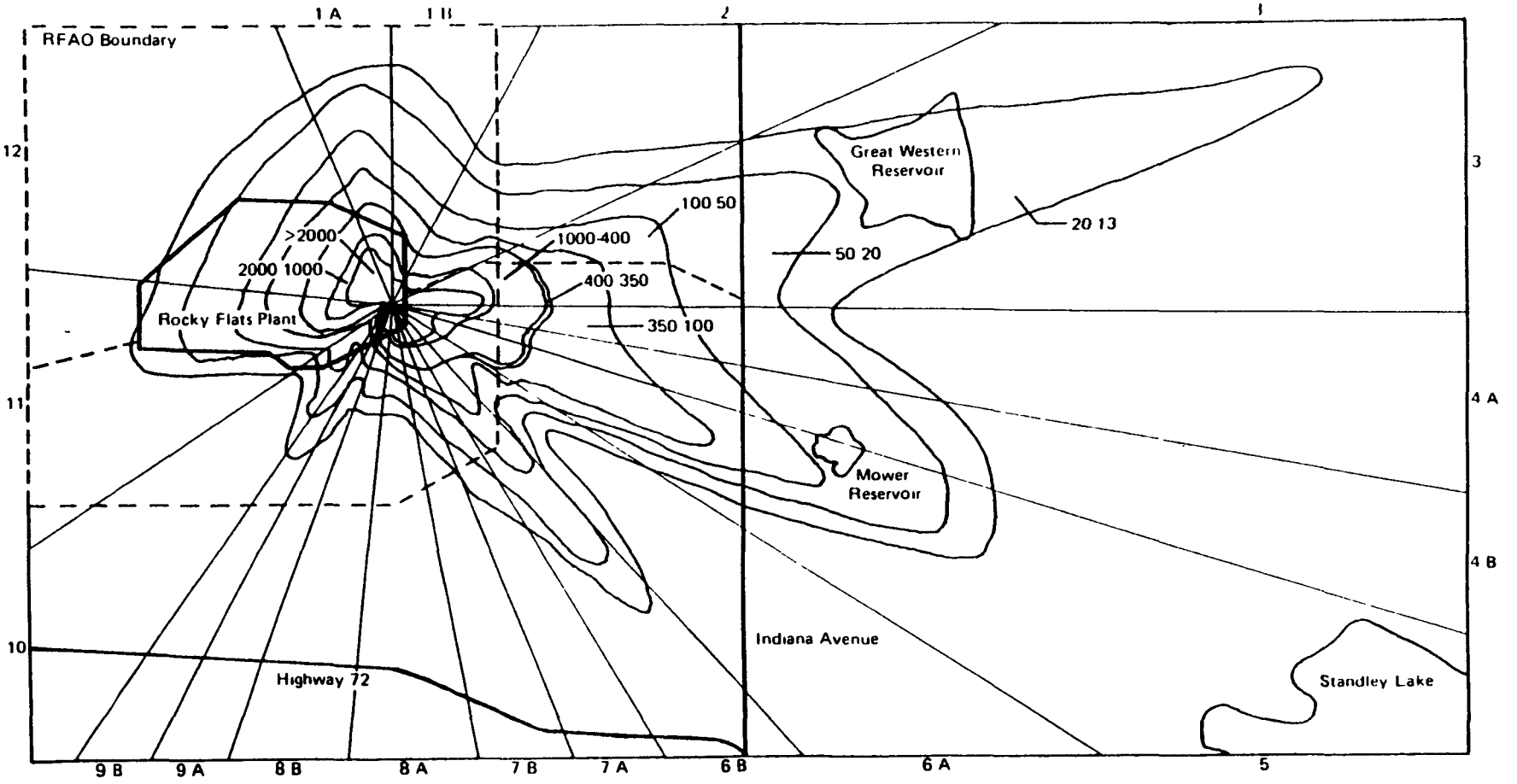
2 The Health and Safety Laboratories (HASL)

3 The Colorado Committee on Environmental Information (CCEI Martell)

This work had been completed *November 16 1970*

The model for the "contours" had been constructed from 135 soil sample analyses

1 Ninety nine samples taken on AEC property and on public and private property by the



Slide 12 An Outline of Rocky Flats Showing the Levels of Plutonium Activity in the Soil in mCi/km^2 Soil Sample Data for the Countours were Evaluated per Sector of the Outline One Inch of the Outline is about 3600 Feet

Rocky Flats Health Physics Department between *August of 1969 and July of 1970*

2 Eighteen samples taken by HASL in *February of 1970*

3 Eighteen samples taken by CCLI in *August of 1969*

SLIDE 13

This slide consisted of another set of contours for plutonium and incorporated into the model Thirty-eight additional soil samples taken during December 1970 (approximately 4 to 6 months after the initial Rocky Flats plutonium soil analysis) This new set of contours which was based on a total of 173 soil analyses showed very little change from the previous slide

Additional soil sample analyses showed that the level of plutonium contamination is *not* increasing

The total integrated quantity of plutonium (using simple integral calculus on the equations of the model) was estimated to be 14 3 grams over the 8 35 km (2 063 acres) covered by the orange (1000 → 2000 mCi/km^2) yellow green blue purple brown and gray (13 → 20 mCi/km) contour lines (Slide 13)*

There are approximately 6 7 grams over 2 72 km (672 acres) of land inside the boundary below the 2000 mCi km^2 contour

There are 7 6 grams over 5 63 km^2 (1 393 acres) outside the boundary down to the 13 mCi/km^2 contour

The details and the assumptions that were made in constructing these models can be seen in internal Rocky Flats Reports (Official Use Only)

*In this report Slide 13 is reproduced in black and white tones only

1 Service Report 482 70 2 November 16 1970

2 Service Report 482 71-4 April 26 1971

Copies of the latest report have been transmitted by the Rocky Flats Plant Manager through the local AEC area office to H E Roser Assistant Director Division of Military Application and J F Burke Assistant Manager for Operations Albuquerque

SLIDE 14

This slide consisted of a table which gave the integrated quantities and land area included in each contour

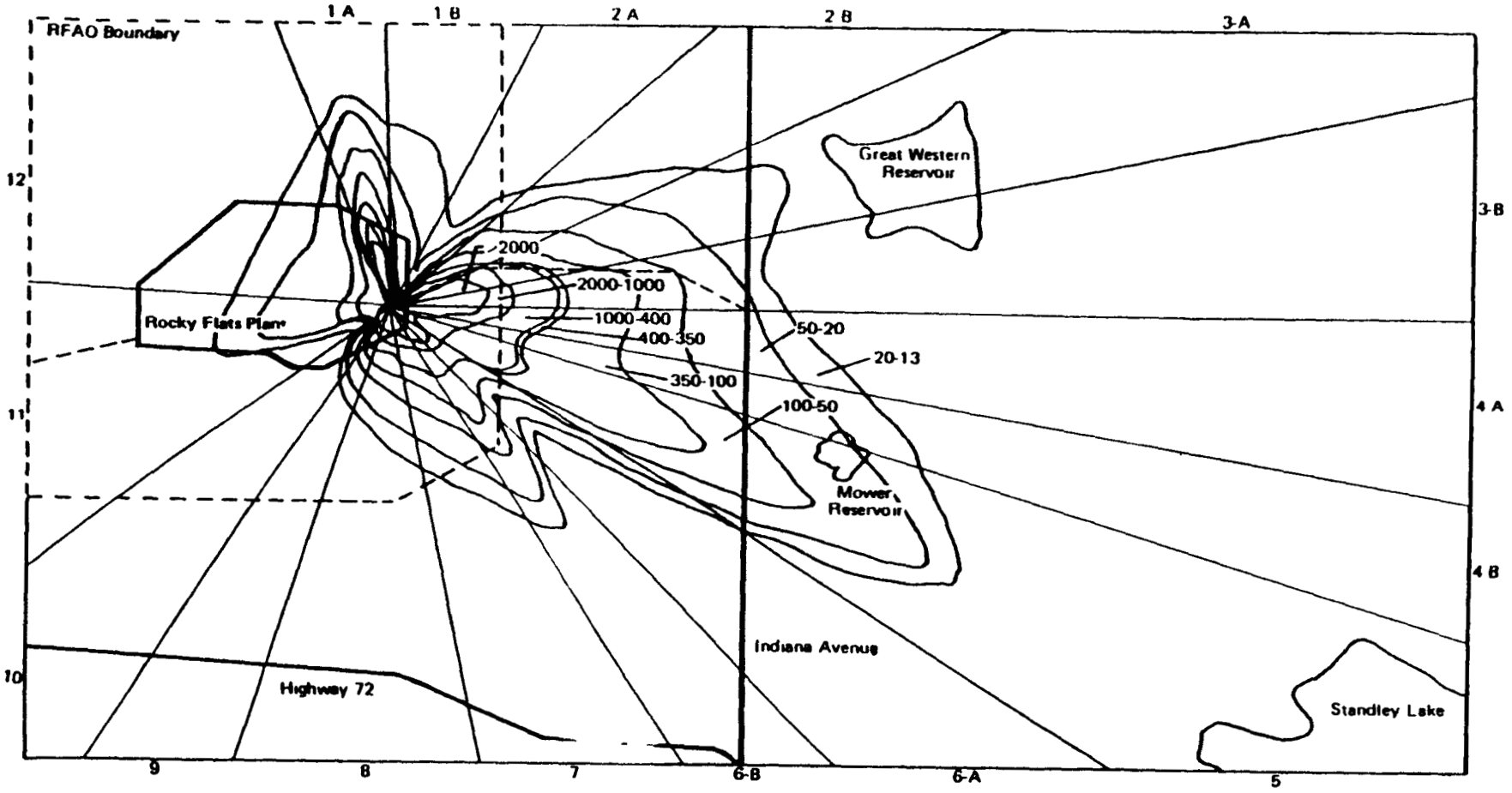
CONTOUR	ACTIVITY IN mCi/km^2	Pu 239 IN GRAMS	AVERAGE * d/m/g DRY SOIL	AREA IN km^2
ORANGE	2000 1000	0 29 ± 0 02	198	0 02
YELLOW	1000 400	1 25 ± 0 09	131	0 13
GREEN	400 350	0 32 ± 0 03	87	0 05
BLUE	350 100	3 10 ± 0 54	40	1 06
PURPLE	100 50	1 26 ± 0 46	16	1 09
BROWN	50 20	1 04 ± 0 59	7	1 98
GREY	20 13	0 34 ± 0 22	4	1 30
BEYOND GREY	13 1	–	≙ 2**	∞
TOTAL		7 6 ± 2 0		

ASSUMING A DENSITY OF DRY SOIL OF 1 GM/CM^3 AND A SOIL SAMPLE DEPTH OF 1 CM

** BACKGROUND PLUTONIUM ACTIVITY

SLIDE 15

This was a photograph of the area of the plant site involved in this discussion and introduced the participants of the meeting to the area they would physically tour later in the morning (Not included in text)



Slide 13 The Recalculated Isodose Contour Lines Showing the Levels of Plutonium Activity in the Soil in mCi/km² Soil Sample Data for the Contour Lines were Evaluated per Sector of the Outline One Inch of the Outline is about 3600 Feet

SIMPLIFIED CONVERSION SCALE AND TABLE FOR THE VARIOUS UNITS USED IN THE LITERATURE TO EXPRESS THE LEVELS OF PLUTONIUM CONTAMINATION IN SOIL

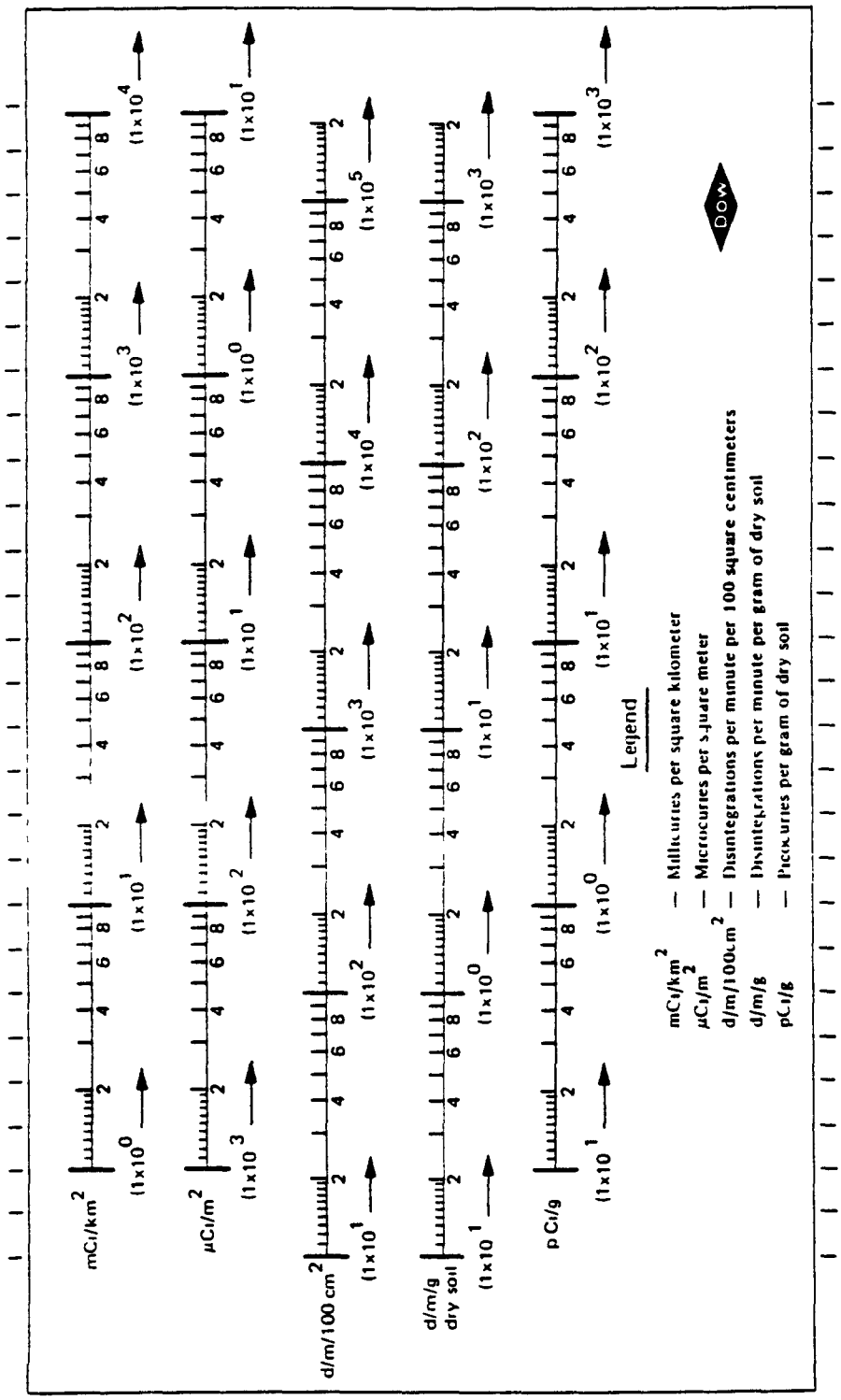


Figure D 1 Simplified Scale for the Various Units used in the Literature to Express the Levels of Plutonium Contamination in Soil

Table D 1 Simplified Conversion Table for the Various Units Used in the Literature to Express the Levels of Plutonium Contamination in Soil

Pu Activity* in mCi/km²	μCi/m²*	d/m/100 cm²**	d/m/g Dry Soil***	pCi/g†
2000	2 0	$4\ 4 \times 10^{4}$	$4\ 4 \times 10^{2}$	$2\ 0 \times 10^{3}$
1000	1 0	$2\ 2 \times 10^{4}$	$2\ 2 \times 10^{2}$	$1\ 0 \times 10^{2}$
400	$4\ 0 \times 10^{1}$	$8\ 9 \times 10^{3}$	$8\ 9 \times 10^{1}$	$4\ 0 \times 10^{1}$
350	$3\ 5 \times 10^{1}$	$7\ 8 \times 10^{3}$	$7\ 8 \times 10^{1}$	$3\ 5 \times 10^{1}$
100	$1\ 0 \times 10^{1}$	$2\ 2 \times 10^{3}$	$2\ 2 \times 10^{1}$	$1\ 0 \times 10^{1}$
50	$5\ 0 \times 10^{2}$	$1\ 1 \times 10^{3}$	$1\ 1 \times 10^{1}$	5 0
20	$2\ 0 \times 10^{2}$	$4\ 4 \times 10^{2}$	4 4	2 0
13	$1\ 3 \times 10^{2}$	$2\ 9 \times 10^{2}$	2 9	1 3
1	$1\ 0 \times 10^{3}$	$2\ 22 \times 10^{1}$	0 222	$1\ 0 \times 10^{1}$

*The values are based upon a soil density of 1 g/cm³ at a depth of 1 centimeter

**The values are based on the relation 1 d/m/g dry soil = d/m/cm² assuming a soil density of 1 g/cm³ at a depth of 1 centimeter

***The units in which the results of soil sample analyses are reported

†The values are based on the relation 1 pCi/g ≈ 2 2 d/m/g dry soil

Note The activity in mCi/km² will simply be increased by a factor equal to the depth of the sample e g 4 centimeters deep will give 4 times the activity assuming a uniform distribution of activity as a function of depth

[redacted]

TRIP REPORT

J R Seed

THE DOW CHEMICAL COMPANY

ROCKY FLATS DIVISION
P O BOX 888
GOLDEN COLORADO 80401

November 9 1970

L M Joshel

TRIP REPORT NEVADA OPERATIONS OFFICE
(PLUTONIUM IN SOIL PROBLEMS)
NOVEMBER 2 AND 3 1970

I Contacts

USAEC

Arthur J Whitman	Radiological Safety Branch
Donald W Hendricks	Radiological Safety Branch
Ross L Kinnaman	Effects Evaluation Office
Paul J Mudra	Operations Division

USPHS – SWRHL

Mel W Carter	Laboratory Director
Jim Mullins	Deputy Chief Analytical Division
Les Dunn	Environmental Survey

REECO (Test Site)

Arden E Bicker	Environmental Services
Derek Engstrom	Chemistry Laboratory
Leonard Sygitowicz	Chemistry Laboratory
Terry Roy	Site Survey

II Topics Covered

A Extent of Test Site Plutonium in Soil Problems On Site (REECO + NVO)

B Extent of Plutonium in Soil Problem 'Off Site (NVO + USPHS – SWRHL)

C Soil Analysis and Sampling Problems (REECO + USPHS – SWRHL)

D Soil Stabilization Activities (REECO)

E The Formation of a Nevada Applied Ecology Group – Subcommittee on Plutonium

Chairman	Wright Langham (LASL)
Members	Chet Richmond (LASL)
	W J Bair (BNWL)
	J L Olson (LRL)
	Evan M Romney (UCLA)
	J W Healy (LASL)
	Otto G Raabe (Lovelace)

III REECO Discussions

A Plutonium in soils analysis is being done by normal radiochemical procedures (2 per day at $65 each) and rapid liquid scintillation method (50 per day at $10 each) Mr Sygitowicz will send us a copy of the procedures used for the latter

B REECO at Mercury has a very modern well equipped and adequately staffed radiochemistry laboratory

C REECO uses unique electrodeposition cells in expensive and disposable

D REECO is evaluating chemical soil stabilizers as follows

(1) PETROSET (Phillips 66) applied in 1 5 and 1 10 dilutions Their contact at Phillips is Richard Bennett in Bartlesville

(2) DCA 70 (Union Carbide – $1 75/gallon) Applied in 1 40 water dilution Source is Tarrytown Technical Center, Saw Mill River Road at Route 100C, Tarrytown, New York 10591

[redacted]

(3) NORLIG A 11 (American Cyanamid Company) 4 cents per pound for powder and 25 cents per gallon for 50% liquid Contact is in Greenwich Connecticut and material is shipped from Green Bay Wisconsin

(4) They have decided to evaluate the Dowell products we are also considering

E REECO expressed interest in an information exchange meeting and soil sample exchange programs

IV PHS SWRHL Discussions

A Plutonium in soil analysis by standard radiochemical procedures at rate of 2 per day from 1 gram samples for $50 $75 per sample

B SWRHL has modern well equipped (AEC supplied) and adequately staffed laboratory

C SWRHL plans to collaborate with Claude Sill at NRTS (IDO) in preparation and distribution of standard plutonium in soil sample exchange They hope Rocky Flats will be involved

D SWRHL would like to send Rocky Flats cuts from soil samples collected at off site locations around NTS They also expressed interest in an information exchange meeting on these problems

V NVO Discussions

The people from the area office were very helpful They supplied us with large quantities of reading material on the topic much of which is not generally available Some more detailed reports on Roller Coaster and some unpublished follow up work was very valuable Staff reports on Bikini Atoll relating to rehabitation and plutonium levels in soil were useful One island which will not be rehabitated because of plutonium in soil (83→410 pCi/gm) is Eneman Island *Land that is contaminated with levels similar to that found around Rocky Flats is considered safe for rehabitation* The deepest penetration of plutonium in soil in the Bikini Islands (where the humidity is very high) was found to be 9 inches

A series of assumptions with regard to plutonium in soil on the Islands can be related to Rocky Flats

Assume an activity of 1 pCi/gm Assume *all* activity is on the surface Assume *all* particles one micron in diameter (Actually for effective inhalation particles should be 1 to 10 microns – project Roller Coaster showed 85% of particles to be greater than 10 microns)

Assume *all* particles are *available* for resuspension *initially* Assume 10^{-6} for resuspension factor

Conclusion Conservatively total lifetime dose due to this plutonium in soil will be less than 70 millirads a safe level

Project 57 in Nevada showed that the effective half life of high levels of plutonium in soil (based on resuspension data) was as short as 35 days Later studies on lower levels give much longer (unavailable) half lives

Some significant notes taken from the report by the Nevada Applied Ecology Group Steering Committee

1 Any extensive 'cleanup of plutonium contaminated area should not be initiated until extent health implications and radioecological significance has been evaluated

2 This project should have very high priority "It is *imperative* that the program proceed without interruption " The program referred to is the total evaluation, especially soil sampling coupled with a Fidler instrument (Gamma) type survey

3 Physical and chemical characteristics of plutonium in the environment must be studied particularly

(a) distribution within soil components
(b) radioactivity as a function of particle size
(c) solubility variables

VI Some Additional Reports were of interest

1 ' Radiochemical Procedures For The Determination of Plutonium in Environmental Samples ' April 1970 Danish AEC Research Establishment, Health Physics Department, Risoe, by Erik Kjaer Markussen

2 "Radiation Characteristics of Plutonium 238," LASL-3696, October 11, 1967, George M Mattack and Charles F Metz

3 "Documentation of Alpha Contamination at the Nevada Test Site," April 1961 unpublished internal

report from REECO to AEC data compiled by B L Brown J L Gardner K H Guinn C H Johnston and R J Scanlon edited by F W Wilcox

Report presents good summary of 2 year history (1959 and 1960) at four alpha contaminated sites Data show some alpha particle penetration down to 1 1/8 inches and only slight resuspension none to create significant inhalation health hazards '

4 NVO 162 28 "Radiological Conditions at Project Roller Coaster 1966 by the staff of Environmental Surveillance Group REECO January 1967

Conclusions reached were

(a) ' Contamination at the sites of Clean Slates 1 2 and 3 as well as Double Track is well fixed The ground average reading for the most part is 100 c/m over background

(b) It is reasonable to assume that the material has not been resuspended and redistributed On this basis there does not appear to be any health hazard to the civilian population living in the region at this time

(c) "It is strongly recommended, however, that the highly contaminated debris exposed by erosion be reburied or otherwise fixed *in situ* We now have a copy at Rocky Flats

5 Alpha Decontamination Proposal Nevada Test Site and Tonopah Test Range unpublished copy of a proposal from REECO to NVO AEC

Proposal discusses study of plutonium contaminated soils at NTS and Tonopah and testing of soil stabilization techniques Suggested materials are DCA 70 and Norlig A The former is a polymer works on the acidic fraction of soils and application might cost 8 12 cents per square yard The latter is a calcium liqnosulfate costing about 4 6 cents per square yard to apply Total costs are estimated at $335 per acre The data in this proposal were obtained from a U S Bureau of Mines report on work performed on uranium ore tailings at Tuba City, Arizona Actual development work by REECO at NTS is only just beginning with evaluation of several potential stabilizer chemicals

6 BNWL 1221, "Plutonium Inhalation Studies,' W J Bair, February 1970 A series of lectures given in Japan in 1969 (Rocky Flats Library has a copy)

7 USBMRI 7288 "Chemical Stabilization of Uranium Tailings at Tuba City Arizona ' Richard Havens and Karl Dean August 1969 (Rocky Flats Library will order a copy)

8 DA PAM 525 5 U S Army 1969 Military Operations 'Dust Control Lessons Learned," no authors listed (Rocky Flats Library will order a copy)

J R Seed
Product R & D

C T Illsley
R & D Business & Plans

JRS wj

cc

K W Calkins
D Hunt
D T Illsley
W H Lee
F J Miner
J B Owen
K Pocius
C W Piltingsrud
J F Willging

DOCUMENT D-3

"Soil Sampling East of Indiana Avenue"
(1972)

by

R W Loser and R L Tibbals
Dow Chemical

PRODUCT AND HEALTH PHYSICS RESEARCH
SERVICE REPORT

Report No: 317-72-186

Title: Soil Sampling East of Indiana Avenue

Work Requested by: J. F. Willging

Date Requested: November 13, 1972

Work Performed by: R. W. Loser and R. L. Tibbals

Manhours: 24

Date Work Started: November 17, 1972

Date Work Completed: November 28, 1972

Date This Report: November 29, 1972

Report Written by: R. W. Loser

Distribution:

R. R. Gunning
Attn. R. L. Tibbals
S. E. Hammond
R. W. Loser
L. M. Steward
G. J. Werkema
J. F. Willging
IRF (Record)
Thru: M. A. Thompson

Key Words:
Soil Sampling
Loser, R.W.
Pu in Soil
PHP RS Rept 317-72-186

INTERNAL REPORT - ~~NOT CLEARED FOR DISTRIBUTION~~

DOES NOT CONTAIN
OFFICIAL USE ONLY INFORMATION
Name/Org: J A Nesheim EMCBC Classifier Date 10-15-08

INTRODUCTION

Plutonium contamination in soil east of Indiana Avenue may be less than what has been projected for the area. This is substantiated by the fact that only 36% of the soil samples taken from the area actually give the expected plutonium concentrations. Therefore, in order to better determine the extent of plutonium contamination east of Indiana Avenue, a request was made for additional soil sampling and analysis.

On November 17, 1972, 20 samples of soil were taken. This report identifies the test area, shows where the samples were taken, and describes the integrity of the soil sampling.

The Test Area

The area begins about 800 feet north of the entrance to the plant, extends south along Indiana Avenue about 4400 feet, and reaches east into farm land about 2000 feet. The area is hilly and consists of undeveloped grassland and plowed, fertile soil. Plutonium contamination in the area is estimated to be between 50 mCi/km^2 and 100 mCi/km^2.

From May of 1969 through January of 1972, the area was sampled 14 times. Of the 14 samples, only 5 samples gave the expected plutonium concentrations. Six samples gave plutonium concentrations less than 50 mCi/km^2 and three samples gave analyses greater than 100 mCi/km^2. The analytical results are given in Table I.

TABLE I

Available Soil Sample Analyses from the Test Area East of Indiana Avenue

Sample Number	Concentration* of Pu-239 in mCi/km²	Sample Date	Property**
2-108	2.7	January 1972	Marcus F. Church
B-53	6.3	May 1969-July 1970	"
B-52	17.6	"	Butler Invest. Ltd. W. C. Ackard
2-90	22.5	January 1972	"
230	35.1	July 1971	"
239	41.8	"	"
241	59.8	"	"
242	73.8	"	"
226	76.0	"	"
240	78.8	"	"
228	83.2	"	"
225	140	"	"
227	159	"	"
229	594	"	"

* For a density of soil 1 g/cm³ and a soil sample depth of 1 cm.

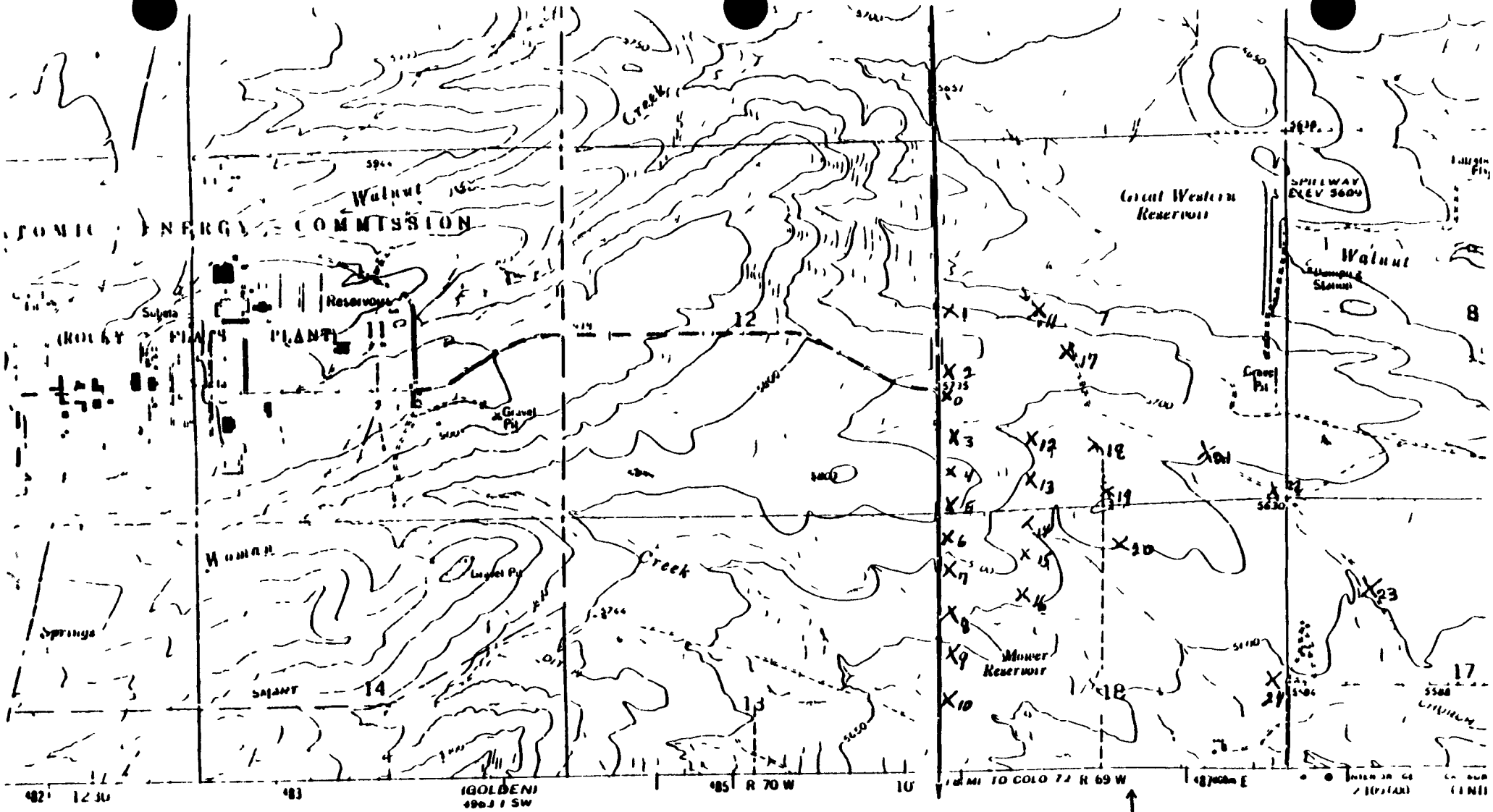
** On file November 28, 1972, at the Jefferson County Courthouse.

Additional Soil Sampling

The latest soil sampling consists of 20 new samples. The map of Rocky Flats (page 5) marked with X's shows the approximate soil sample locations. Five samples along the high tension wires or along the straight dashed line on the map will be taken at a later date. Some of the soil samples, such as the four samples east of the high tension wires, are actually outside the test area.

Each sample consisted of about 150 in^3 of soil and small rocks. Ten samples were taken from unplowed, hard, grass-covered ground which should give good results. The other ten samples were taken from plowed fields. Depending on when the fields were last plowed, the amount of plutonium in the samples should be negligible. These results, of course, will not support the projected plutonium concentrations. Analytical results will be available in December.

Table II lists the condition of soil sampled, i.e., whether plowed or undeveloped, and the property from which the sample was taken.



SCALE 1:24000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

ROAD CL

Heavy duty

Medium duty

QUADRANGLE LOCATION

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U S GEOLOGICAL SURVEY DENVER COLORADO 80225 OR WASHINGTON D C 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

TABLE II

Additional Soil Samples East of Indiana Avenue

Sample Number	Condition of the Soil	Property**
0	hard, grass-covered	Butler Invest. Ltd., W. C. Ackard
1	"	City of Broomfield
2	"	Butler Invest. Ltd., W. C. Ackard
3	Plowed	"
4	"	"
5	"	"
6	"	Marcus F. Church
7	"	"
8	hard, grass-covered	"
9	"	"
10	"	"
12	Plowed	Butler Invest. Ltd., W. C. Ackard
13	"	"
14	"	Marcus F. Church
15	"	"
16	"	"
21	hard, grass-covered	Butler Invest. Ltd., W. C. Ackard
22	"	"
23	"	E. Kippur, I. Kippur, and L. Gordon
24	"	Standley Lake Land Company
11*		City of Broomfield
17*		Butler Invest. Ltd., W. C. Ackard
18*		"
19*		"
20*		Karl P. Brauch

* To be taken.

** On file November 28, 1972, at the Jefferson County Courthouse.

DOCUMENT D-4

"Results of Special Soil Samples Collected
Adjacent to the Rocky Flats Plant Site"
(1977, rev 1979)

by

C T Illsley
Rockwell International

12 pgs

RESULTS OF ANALYSES FOR SPECIAL SOIL SAMPLES COLLECTED ADJACENT TO THE ROCKY FLATS PLANT SITE

ES-376-77-201

C. T. Illsley
Environmental Analysis and Control

September 7, 1977
rev. November 30, 1979

Rockwell International
Rocky Flats Plant
Golden, Colorado

[illegible]
This [illegible]
[illegible]
[illegible], or higher
authority.

Patent Review
4-22-85
[illegible]

PROCEDURES

Twenty-five soil samples collected in August, 1976, by Eberline Instrument Corporation personnel using the Rockwell International soil sampling technique were selected for special analyses. Selection was made on a random basis from each of the six land parcels.

Two of the five sites in Section 6 (Great Western Ventures Property) were selected. Two of the four sites in Section 9 (Church Property), two of the six sites in Sections 21 and 22 (Church Property), five of the 20 sites in Section 23 (Church Property), and four of the 16 sites in Section 24 (Church Property) were selected. Five of the 22 sites in Section 7 and 16 (Good and Associates Property) were selected. These selections provided a minimum of 23% of the sites in each land parcel.

Samples were also included from the background sites at Limon, Livermore, Crook, Penrose, and Lathrop State Park.

All samples had received preanalysis treatment in the Eberline Laboratory in Albuquerque. This treatment included drying at 110°C, screening through a 10 mesh sieve, homogenizing, splitting into two fractions and ball milling one fraction. One hundred gram portions of the ball milled material were placed in 16 ounce plastic bottles for analysis.

Five samples were selected on a random basis for analysis by the Health Services Laboratory, Energy Research and Development Administration, Idaho Falls, Idaho. Cesium-137 was determined with a gamma spectrometric system utilizing a lithium drifted germanium detector and pulse height analyzer. Various isotopes of uranium, thorium, and plutonium were determined by alpha spectroscopy after radiochemical separations. Separations involving uranium and plutonium required the use of isotopic tracers to correct for less than 100 percent recoveries in the chemical procedure.

The entire group of 25 samples was analyzed by two laboratories at Rocky Flats. Gamma spectroscopy, utilizing a lithium drifted germanium detector and Ortec 6240 multichannel pulse height analyzer, was performed in the Environmental Science Laboratory. Each gamma spectrum was interpreted by means of the Ortec gamma analysis computer programs on a PDP-11/05 computer. The following nuclides were conclusively identified in the samples: ^{232}Th, ^{228}Th, ^{226}Ra, ^{137}Cs, and ^{40}K. These radionuclides are all naturally occurring except ^{137}Cs, which is a worldwide fallout product of atmospheric nuclear weapons testing.

Samples were analyzed for isotopes of uranium, thorium, neptunium, and curium by alpha spectroscopy, following radiochemical separations and purifications in the General Service Laboratory. Less than complete recoveries were corrected for by the use of uranium-232 for uranium-238 and 234. Other recoveries were checked by the method of additions in which a known amount of the isotope being sought is added to the sample.

Strontium was determined by beta counting after sample solutions were treated to separate and purify strontium-89, strontium-90, and yttrium-90.

RESULTS

The results of analyses performed at Rocky Flats are presented in Table I. These results represent data for the following radionuclides: ^{137}Cs, ^{238}U, ^{234}U, ^{232}Th, ^{230}Th, ^{229}Th, ^{228}Th, ^{237}Np. ^{244}Cm, ^{89}Sr, ^{90}Sr, ^{226}Ra, and ^{40}K. Isotopic ratios were calculated for various pairs and these values are shown in Table I.

The data on plutonium concentrations shown in Table I are from analyses performed by Eberline Instrument Corporation.

The results of analyses performed at the ERDA Health Services Laboratory in Idaho are presented in Table II. Data from Rocky Flats and Eberline analyses are repeated in Table II for comparative purpo.es.

Table 1. Special Soil Sample Analyses

Site	^{230}Pu*	^{137}Cs	Cs/Pu	^{238}U	^{234}U	234/238	^{230}Th	230/238	^{232}Th	^{228}Th	22[illegible]
Elmon	.04	1.3	32	2.6	2.4	0.9	1.7	0.6	1.9	2.4	
Livermore	.06	2.0	33	3.8	4.3	1.1	2.3	0.6	3.2	4.0	
Creek	.01	1.3	130	3.4	4.0	1.2	1.6	0.5	2.4	2.4	
Pearose	.06	2.0	33	3.8	4.9	1.3	1.6	0.4	1.5	1.8	
L.S.P.**	.05	2.7	54	2.3	2.4	1.0	3.6	1.6	3.3	4.1	
1	.70	3.1	4	2.6	2.5	1.0	2.1	0.8	2.9	3.4	
7	1.06	2.9	3	4.8	5.9	1.2	2.0	0.4	2.7	3.2	
15	.44	0.7	2	3.8	4.1	1.1	2.3	0.6	3.9	3.6	
16	.58	1.1	2	4.3	5.0	1.2	2.1	0.5	3.1	3.2	
19	1.78	4.7	3	2.6	2.3	0.9	4.5	1.7	7.1	8.3	
25	.10	1.1	11	4.7	4.4	0.9	3.3	0.7	3.4	3.9	
28	3.29	0.9	<1	2.7	2.4	0.9	1.2	0.4	1.7	1.8	
32	.03	0.4	15	2.3	2.4	1.0	2.5	1.1	2.4	2.9	
35	.02	0.9	44	2.6	2.5	1.0	4.2	1.6	5.0	5.4	
36	.04	0.9	22	3.8	4.5	1.2	1.1	0.3	1.3	1.2	
40	.08	3.6	44	3.1	2.6	0.8	1.9	0.6	2.6	3.2	
48	.04	0.4	11	3.4	3.5	1.0	1.3	0.4	2.7	3.7	
54	.09	4.2	47	3.9	4.5	1.2	1.7	0.4	2.8	2.9	
60	.11	4.7	42	2.6	2.7	1.0	2.2	0.8	2.9	3.1	
62	.14	2.0	14	4.9	5.3	1.1	1.7	0.3	3.0	3.5	
65	.10	2.9	29	2.8	3.8	1.4	2.9	1.0	4.4	4.5	
67	.28	9.8	35	3.0	2.9	1.0	4.9	1.6	9.6	11.0	
68	.10	5.3	53	3.2	3.3	1.0	0.9	0.3	1.7	2.6	
71	>12	5.1	42	3.2	3.2	1.0	1.1	0.3	1.3	1.2	
72	.10	6.4	64	3.2	3.3	1.0	1.0	0.3	1.7	1.8	
[illegible]	-	2.8	31	3.4	3.6	1.1	2.2	0.6	3.1	3.5	

* Units of activity are d/m/g
Lathrop State Park

Table II. Comparative Analyses of Special Soil Samples
(Disintegrations Per Minute Per Gram)

Radioisotope	Sample No. 8367 (Site No. 7) RF	Sample No. 8367 (Site No. 7) IDO	Sample No. 2495 (Site No. 16) RF	Sample No. 2495 (Site No. 16) IDO	Sample No. 8424 (Site No. 36) RF	Sample No. 8424 (Site No. 36) IDO	Sample No. 5341 (Site No. 65) RF	Sample No. 5341 (Site No. 65) IDO	Sample No. 7699 (Site No. 72) RF	Sample No. 7699 (Site No. 72) IDO
^{137}Cs	2.9	2.5	1.1	0.9	0.9	0.9	2.9	2.4	6.4	6.0
^{238}U	4.8	3.0	4.3	2.4	3.8	2.8	2.8	2.5	3.2	2.3
^{235}U	0.22	0.12	0.20	0.13	0.17	0.13	0.13	0.09	0.15	0.10
^{234}U	5.9	3.0	5.0	2.4	4.5	2.6	3.8	2.3	3.3	2.0
^{230}Th	2.0	3.4	2.1	3.7	1.1	4.6	2.9	3.2	1.0	2.5
^{232}Th	5.3	5.2	6.6	5.0	5.6	4.5	2.5	4.0	3.7	4.4
^{228}Th	7.3	5.0	7.3	4.9	5.0	4.3	4.4	4.0	7.0	4.5
^{238}Pu	0.02[2]	0.03	0.01[2]	<0.01	<0.01[2]	<0.01	<0.01[2]	<0.01	<0.01[2]	<0.01
^{239}Pu	1.06[2]	1.66	0.58[2]	0.37	0.04[2]	0.01	0.10[2]	0.07	0.10[2]	0.13

Notes:
1. Calculated value from ^{238}U value

2. Analysis by Eberline

DISCUSSION

The results show anticipated concentrations for all radionuclides measured in this series of special analyses. Ratios of various pairs of radionuclides also illustrate the normalcy of data. The cesium-to-plutonium ratio yields a mean of 31 over the range <1 to 130 for all samples. The extreme value represents the soil from Crook, Colorado, when the plutonium concentration was measured at only 0.01 disintegration per minute per gram (d/m/g). The mean of 31 should be compared to the value of 48 calculated by Michels and Miller for the Denver area.[1]

The results for ^{238}U fall into the range from 2.3 to 4.9 d/m/g with a mean value of 3.4 d/m/g. This is equivalent to 4.6 parts per million (ppm), by weight, which is to be expected in soils derived from bedrock in the Front Range. These rocks typically contain from 1.8 to 7.6 ppm uranium[2] and there are ore concentrations at locations, such as the Schwartzwalder uranium mine. The mean ratio of ^{234}U to ^{238}U is 1.1 which indicates equilibrium between parent and descendant. The mean ratio of ^{230}Th to ^{238}U is only 0.6, however, indicating separation of the two radionuclides. It appears that the more mobile uranium has become separated during weathering processes from the less mobile thorium daughters. This conclusion is not borne out by the mean ratio of ^{226}Ra to ^{238}U which is 1.2. Radium-226 is a descendant of ^{230}Th.

Similar data were determined for natural thorium. The activity of ^{232}Th was found to be within the range from 1.3 to 9.6 d/m/g/ with a mean of 3.1 d/m/g. This value is equivalent to 12.6 ppm, by weight of thorium. The reported concentrations of thorium in Front Range rocks are in the range between 9 and 36 ppm, with a mean of 22.7 ppm.[2] The mean ratio of ^{228}Th to ^{232}Th was found to be 1.1, which indicates near equilibrium in the thorium decay series.

The results for ^{237}Np do not indicate the presence of this radionuclide in soils surrounding Rocky Flats. The minimum detectable amount by the procedure used was 0.2 d/m/g. The highest values measured were 0.3 d/m/g for sample sites 28 and 68 with standard deviations of 0.4 and 0.2 d/m/g, respectively.

The results for ^{244}Cm are similar to those for neptunium. Most of the data are not significantly greater than the minimum detectable amount of 0.5 d/m/g. One value, 1.6 d/m/g, for site 40 cannot be explained except on the basis of possible contamination in the analytical laboratory.

The sensitivity of the radiochemical procedure for strontium allowed only general screening analyses. The isotope ^{89}Sr was not detected in amounts greater than the minimum detectable. The isotope ^{90}Sr was detected in only two of the 25 samples. The sample from Limon, Colorado showed 13 d/m/g and the sample from site 72 showed 16 d/m/g, compared to minimum detectable of 10 d/m/g.

The range of activity for the naturally occurring radioisotope of potassium, ^{40}K, was from 20.2 to 50.6 d/m/g, with a mean of 36.2 d/m/g. These values are normal for soils derived from rocks containing potassium in the range between two and six percent by weight.

REFERENCES

1. L. G. Miller and D. E. Michels, "Cesium-to-Plutonium Ratio in Fallout on the U.S. Great Plains," HPR 317390-15, Dow Chemical, Rocky Flats Division, October 12, 1972.

2. G. Phair and D. Gottfried, "The Colorado Front Range, Colorado, U.S.A., as a Uranium and Thorium Province," p.30 in The Natural Radiation Environment. University of Chicago Press (1964).

FIGURE 1 – SOIL SAMPLE SITE NUMBERS

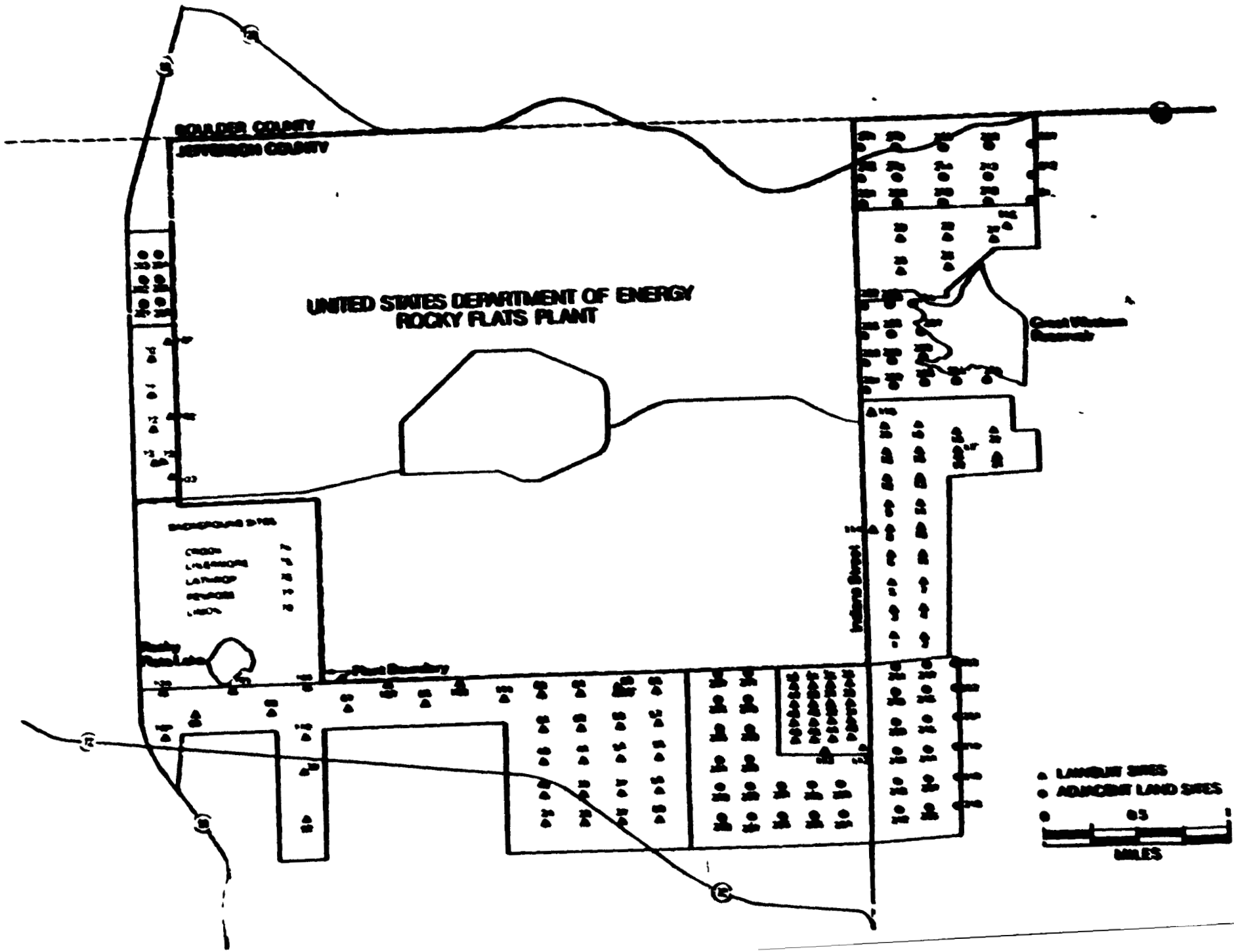


FIGURE PLUTONIUM CONCENTRATIONS IN SOIL
(d/m/g)

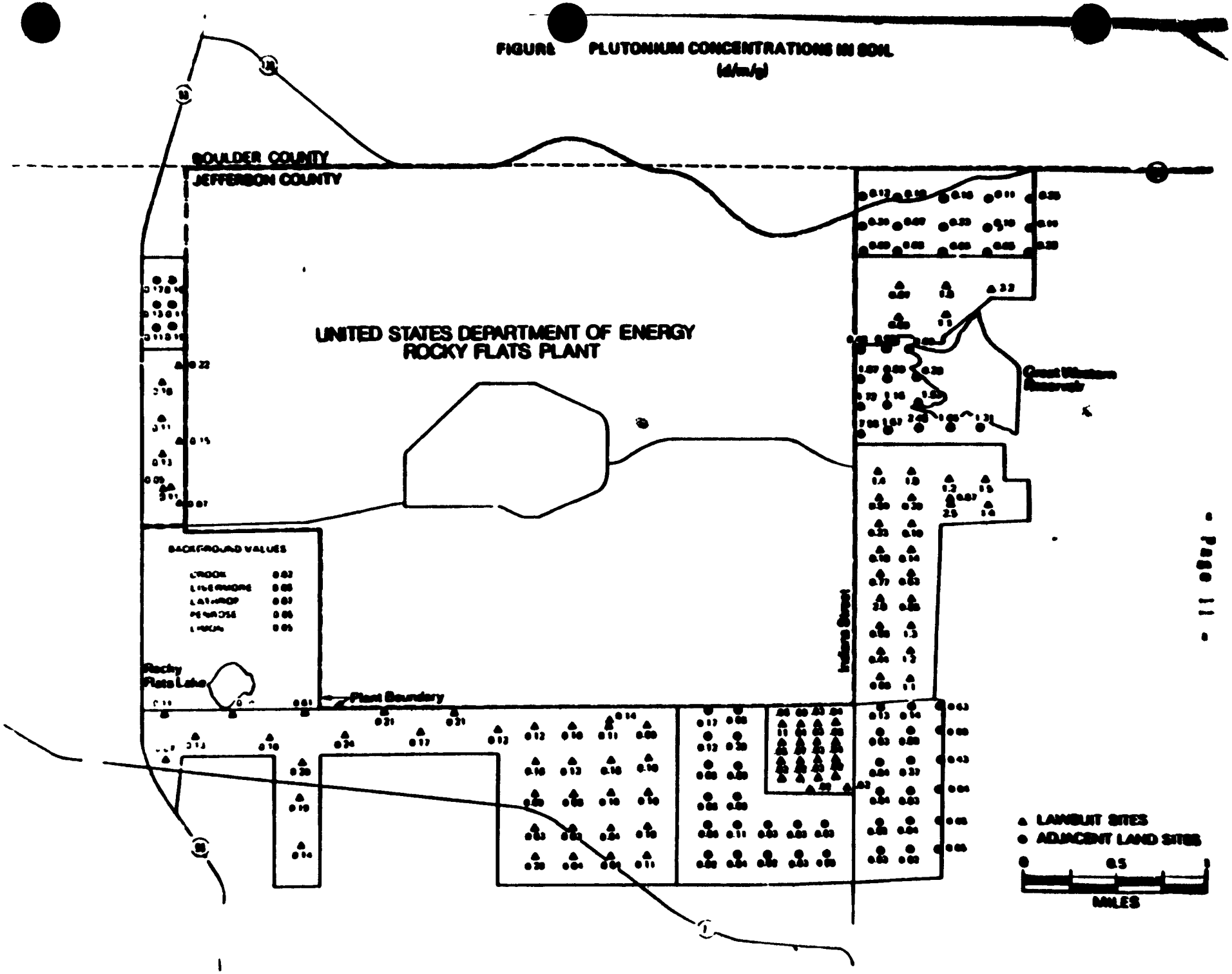
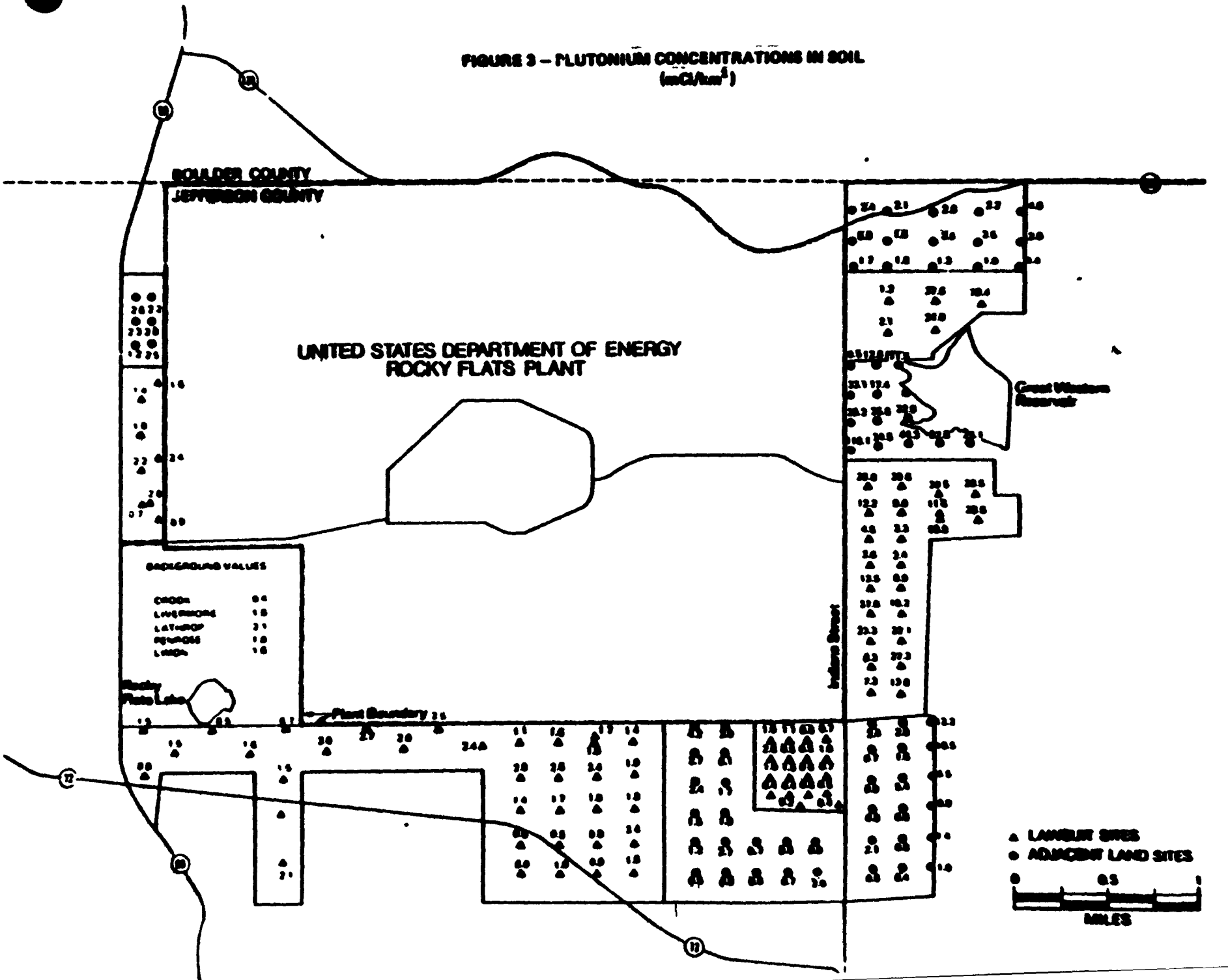


FIGURE 3 – PLUTONIUM CONCENTRATIONS IN SOIL
(mCi/km²)



DOCUMENT D-5

"Radioactive Soil Contamination (Cesium-137 and Plutonium) in the Environment Near the Rocky Flats Nuclear Weapons Plant" (1977)

by

Colorado Department of Health

SEP 26 1977

RADIOACTIVE SOIL CONTAMINATION

(Cesium-137 and Plutonium)

in the environment near the

ROCKY FLATS NUCLEAR WEAPONS PLANT

COLORADO DEPARTMENT OF HEALTH

September 1977

ABSTRACT

The Colorado Department of Health has evaluated levels of radioactive plutonium and cesium in surface soil around the Rocky Flats Nuclear Weapons Plant. Plutonium contamination levels found are essentially the same as reported in previous years. While it is not possible to state conclusively that industrial operations or accidents at Rocky Flats have not contributed any cesium-137 to the environment, all radioactive cesium levels determined are within the range of values attributable to world-wide fallout

Also presented in this report is a very brief evaluation of the soil collection and separation procedure used by Dr. Carl Johnson, Jefferson County Health Department. While not complete enough to fully explain the high values which were reported by Dr Johnson, it appears that the separation procedure alters the plutonium and cesium concentrations and the ratio of the two.

INTRODUCTION AND HISTORY

Atmospheric testing of nuclear weapons by several nations has resulted in the world-wide distribution of measurable quantities of man-made radioactive materials to the environment since the early 1950's Over the earth's land masses most of this material settles on the soil and then is transported through the environment depending on its physical and chemical form, the type of soil, amount of moisture, type of vegetation, and use of the land. Of primary long term concern to health are the long half-life materials Plutonium-239 (a component of the weapons), Cesium-137 and Strontium-90 (which are products of the fission process). These materials, if incorporated into the human body, present a potential long term radiation hazard.

Plutonium as released from weapons and deposited on the earth is primarily in its oxide form (PuO_2) which is a highly insoluble material and, hence, is relatively immobile in the environment as far as chemical processes are concerned In addition, uptake of plutonium in the digestive system is very low. Consequently, the major pathway for exposure of populations to plutonium is resuspension from the soil, inhalation, deposition in the lung, and subsequent translocation to the bone and other organs.

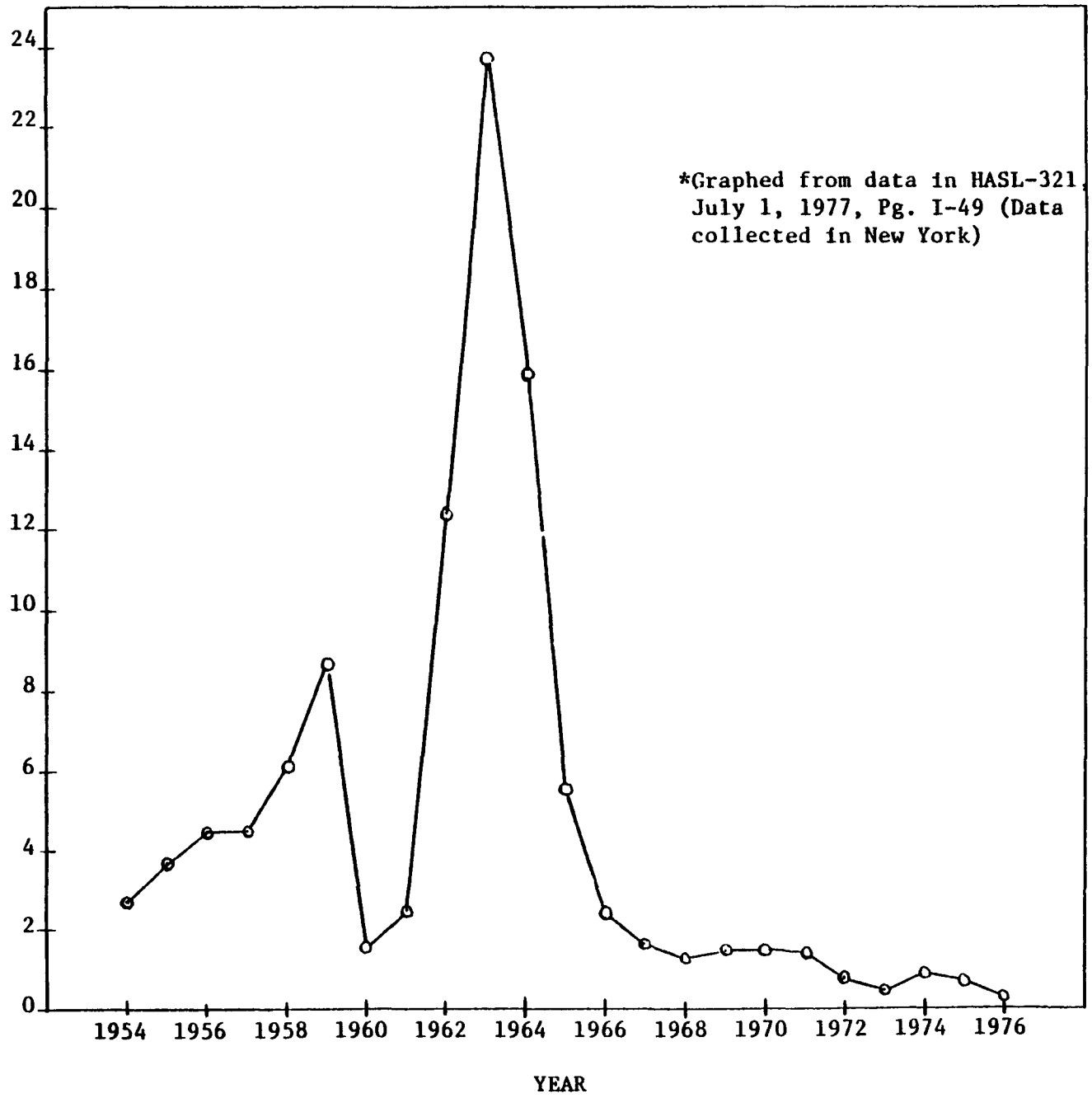
Cesium and strontium, on the other hand, are chemically similar to materials such as sodium, potassium and calcium which form soluble salts and are readily available (at least initially) for chemical transport in the environment. Radioactive cesium and strontium deposited on plants may be eaten and absorbed in the bodies of humans or animals or the materials may be taken through the roots of the plants and reach man in that manner. Inhalation, while it will contribute slightly to human exposure, is generally considered to be an insignificant means compared to the ingestion pathway for these elements.

While world-wide fallout of these materials has been measurable since at least 1954, it reached a peak during the years 1963-1964 and has dropped off rapidly since (See Figure 1). This is explained by the extensive nuclear testing conducted by the U.S and the U.S.S R immediately proceeding the nuclear test ban treaty of 1962. Atmospheric testing conducted by France and China in the years since 1968, has not had a significant impact on total deposition though it has undoubtedly influenced the rate of decrease in fallout levels. Considerable data on world-wide fallout has been generated by the Health and Safety Laboratory of the US ERDA and is available in their quarterly reports. Additional information may be found in the PHS and EPA Radiological Health Data and Reports.

In 1970, following the discovery by Martell of plutonium contamination in the vicinity of Rocky Flats Nuclear Weapons Plant northwest of Denver, considerable soil analysis was performed in this area. The extent of this plutonium contamination was reported by Krey and Hardy (HASL-235, US AEC, Health and Safety Laboratory, August 1, 1970) and by Poet and Martell (Health Physics, Vol. 23, pp 537-548, 1972).

FIG 1

STRONTIUM-90 DEPOSITION RESULTING FROM WORLD-WIDE FALLOUT*



Although the original suspicion was that this plutonium was released during one of the major fires at the plant (1957 or 1969), both of the above referenced articles conclude that a majority of the elevated plutonium levels are due to leakage of plutonium contaminated cutting oil from drums stored in the southeast corner of the plant from 1958 until 1968 The contamination was then spread in an east - southeasterly direction (Figure 2) by the prevailing winds The highest levels of contaminated soil on the plant site have since been covered by a layer of asphalt to decrease additional dispersion.

In addition to reporting concentrations of plutonium-239 in soil samples collected in the area around Rocky Flats and other areas of the state, Poet and Martell analyzed most of their soil samples for strontium-90. These values are reported and the $^{239}Pu/^{90}Sr$ ratio used to determine the extent of plutonium contamination due to industrial operations at the Rocky Flats Plant as opposed to world-wide fallout There is no indication from this data that strontium-90 soil contamination originating from plant operations existed at the time of sample collection (1969-1970)

As a result of the 1969 fire at Rocky Flats and the discovery of off-site plutonium contamination due to plant operations, the Colorado Department of Health initiated an extensive environmental monitoring program This monitoring has included the sampling of air particulates on a continuous 24 hour per day basis since May, 1970, water in the drainage basins crossing the plant on a grab sample basis since 1969, and surface soil on an annual grab sample basis since 1970.

Air and water samples have been analyzed for the presence of beta emitting isotopes (which include most of the fission products of interest) as well as composited for plutonium analysis. Surface soil samples have been analyzed for plutonium, uranium and beryllium

In recognition of potential inhalation hazards due to the off-site plutonium contamination in soil and the increased use of land in the vicinity of the Rocky Flats Plant, the Colorado Board of Health adopted in 1973 an interim standard for plutonium levels in surface soil Land areas exceeding this level of 2 dpm/gm of surface soil are required to receive remedial treatment to lower the concentration prior to their release for residential use. The health risk due to inhalation of resuspended surface soil contaminated with plutonium at this level based on measurements of whole soil and associated time averaged total airborne concentrations has been evaluated previously by this Department ("A Risk Evaluation for the Colorado Plutonium-in-Soil Standard", January, 1976).

In 1975, Dr Carl Johnson (Director, Jefferson County Health Department) presented a report to the Board of County Commissioners of Jefferson County which contained a proposal of a "new standard to define a potential airborne - plutonium particle hazard in terms of the concentration of plutonium in respirable dust". His theory and the results of analyses performed on a number of samples were subsequently published (Johnson, Tidball, Severson, "Plutonium Hazard in Respirable Dust on the Surface of Soil', Science, Vol. 193, pp 488-490). This procedure includes

FIGURE 2

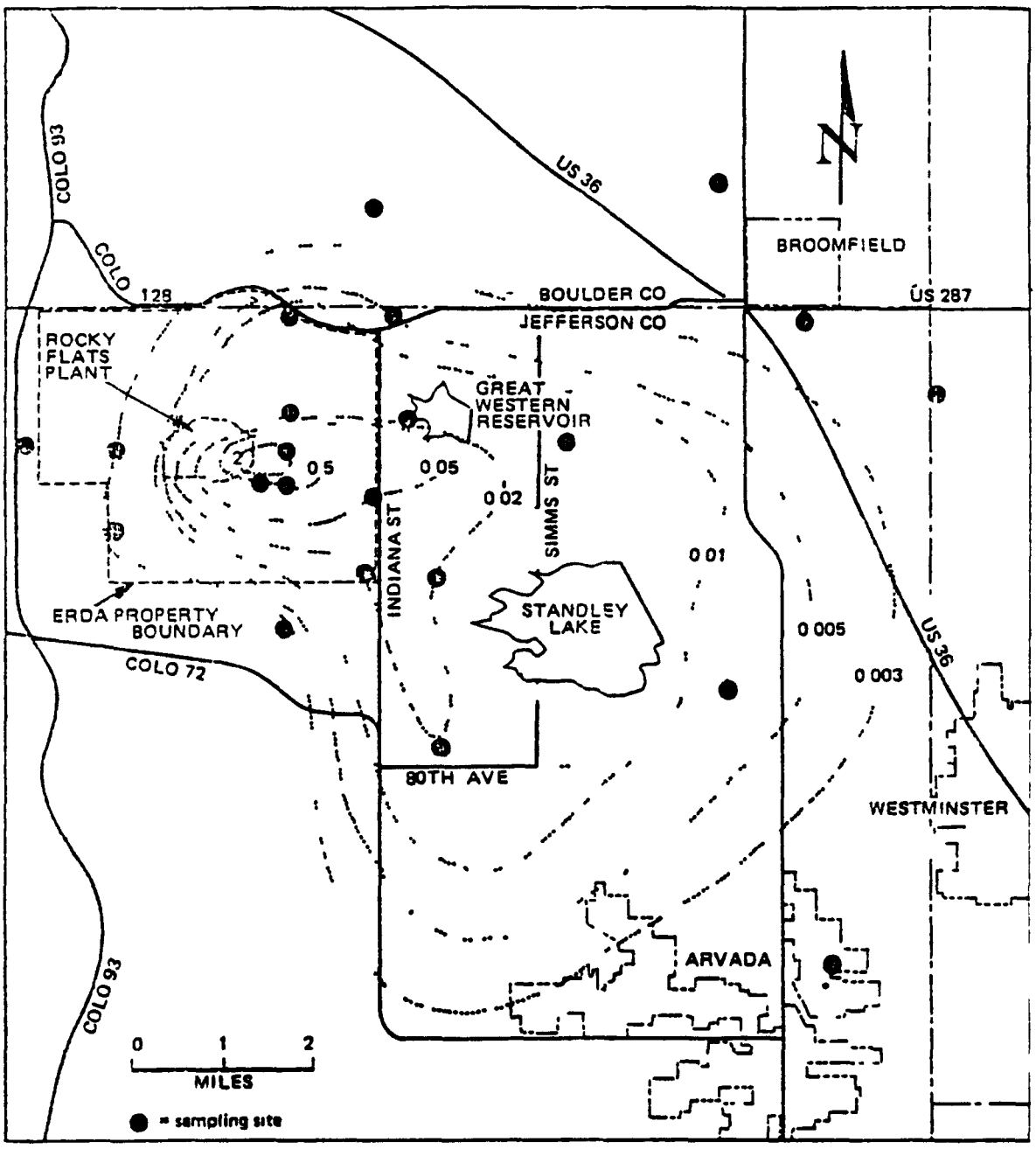


Figure 2 4-24 Plutonium-239 Contours Around Rocky Flats ($\mu Ci/m^2$)
(adapted from Krey, 1970)

NOTE This map was taken from the Draft Environmental Impact Statement, Rocky Flats Plant Site, Golden, Colorado, Vol 1, September 1977 The values on the isopleth curves are total inventory deposition values as calculated by Krey and Hardy, HASL-235, 1970.

sweeping the surface of the soil with a clean brush or wisk broom to obtain a potentially resuspendable soil fraction, dry sieving of the soil collected to obtain a <2 mm fraction, followed by an aqueous hydrogen peroxide digestion to remove soluble salts and organic materials, treatment with an ultrasonic probe to destroy soil aggregates, and aqueous sedimentation to obtain a fraction of soil which is defined by Dr Johnson as respirable. It is this fraction of soil which is then analyzed for plutonium.

A report prepared by R.L. Murri entitled "Gamma Analysis of Plutonium Contaminated Soil at Rocky Flats" (Murri, ES-376-77-197, Rocky Flats Plant, January 10, 1977) concluded that·

> " . The following nuclides were identified in all the samples ^{228}Th, ^{232}Th, ^{226}Ra, ^{137}Cs, and ^{40}K. Only ^{137}Cs was present in generally larger amounts in the six test samples than the background samples Also, ^{241}Am was found exclusively in the six test samples, as was expected. ..The ^{137}Cs results should be further studied to establish its significance."

This study consisted of six surface soil samples collected in a small area east of the asphalt pad known to be contaminated with plutonium, and six background samples (3 near the west plant boundary and 3 along Ralston Creek to the west of the plant site).

As a result of this report and a subsequent report by Dr Carl Johnson (Report to the Jefferson County Board of Health, March 31, 1977) that analysis of four of his "respirable dust" samples yielded significant non-homogeneity of results and one sample with a "large amount" of ^{137}Cs, the Colorado Department of Health undertook an evaluation of cesium-137 in the surface soil samples collected as part of the 1977 Rocky Flats Surveillance Effort.

This paper is presented as a report on that evaluation and includes both the plutonium and cesium-137 results obtained In addition, this Department has reviewed data from other sources relative to this subject, and has evaluated (though not completely) the procedure used by Dr. Carl Johnson to determine what effect, if any, it might have had on the plutonium and cesium concentrations.

PROCEDURES

Sample Collection·

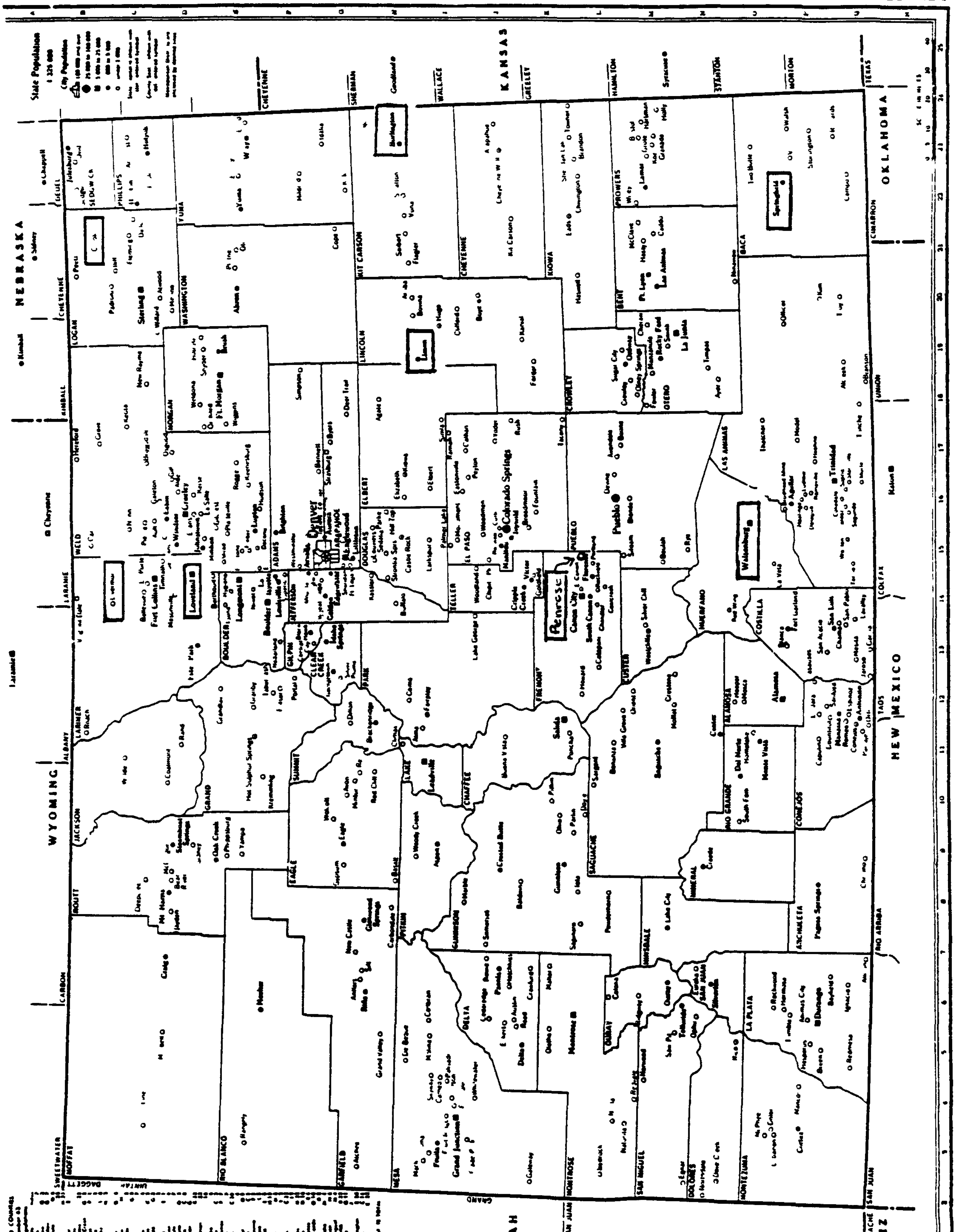
Surface soil samples were collected by three different procedures as part of the 1977 soil survey The collection methods used were the "Colorado Department of Health method", the old "CDH spoon method", and the "Dr Johnson sweeping method" These methods are detailed as follows

The "Colorado Department of Health method", which has been used for the last two years, utilizes a template which outlines a 2 cm x 3 cm area and collects the top 0 3 cm (1/8") of soil within that area. Twenty-five individual samples are collected and composited into one sample that is analyzed for the area. An attempt is made to collect undisturbed soil, however, no information on soil history is obtained The remote area samples (Burlington, Crooke, Limon, Livermore, Loveland, Penrose, Springfield and Walsenburg, See Figure 3) are collected along roads and highways leading to or from the given communities, with individual samples taken at approximately one mile intervals Side roads are utilized where necessary to locate undisturbed sites Samples within the thirteen Rocky Flats Sectors are collected more or less at random and composited (Figures 4-7).

The "Colorado Department of Health spoon method" of collection consists of scooping surface soil to a depth of approximately 1/8" with a spoon Sampling by this method was conducted in Sectors 1, 2, 6 and 7 at the same individual sites (dots in Figure 3) as the CDH method.

The "Dr Johnson method", which was described in Science, Vol 193, consists of sweeping the surface of the soil with a brush or broom and collecting soil from within a 4 square meter area. For the remote locations, one site was selected near each community. In the thirteen sectors this procedure of Johnson, et. al , was modified slightly in that collections from more than one site were composited for the sector sample, the area of each collection being adjusted such that the total was 4 square meters. Sectors 1, 2, 3, 4, 6 and 7 consisted of eight individual samples while Sectors 5, 8, 9, 10, 11, 12 and 13 consisted of four each (See Figures 5-7, "J" indicates site sampled by this method).

Remote sites were collected April 11-15, 1977 (except Walsenburg, February 18). The sector samples were collected during May.


NEBRASKA
KANSAS
OKLAHOMA
NEW MEXICO
ARIZ
UTAH
WYOMING
Denver
Colorado Springs
Pueblo
State Population

FI 3

FIGURE 4
CDH SOIL SURVEYS - SECTOR LOCATIONS

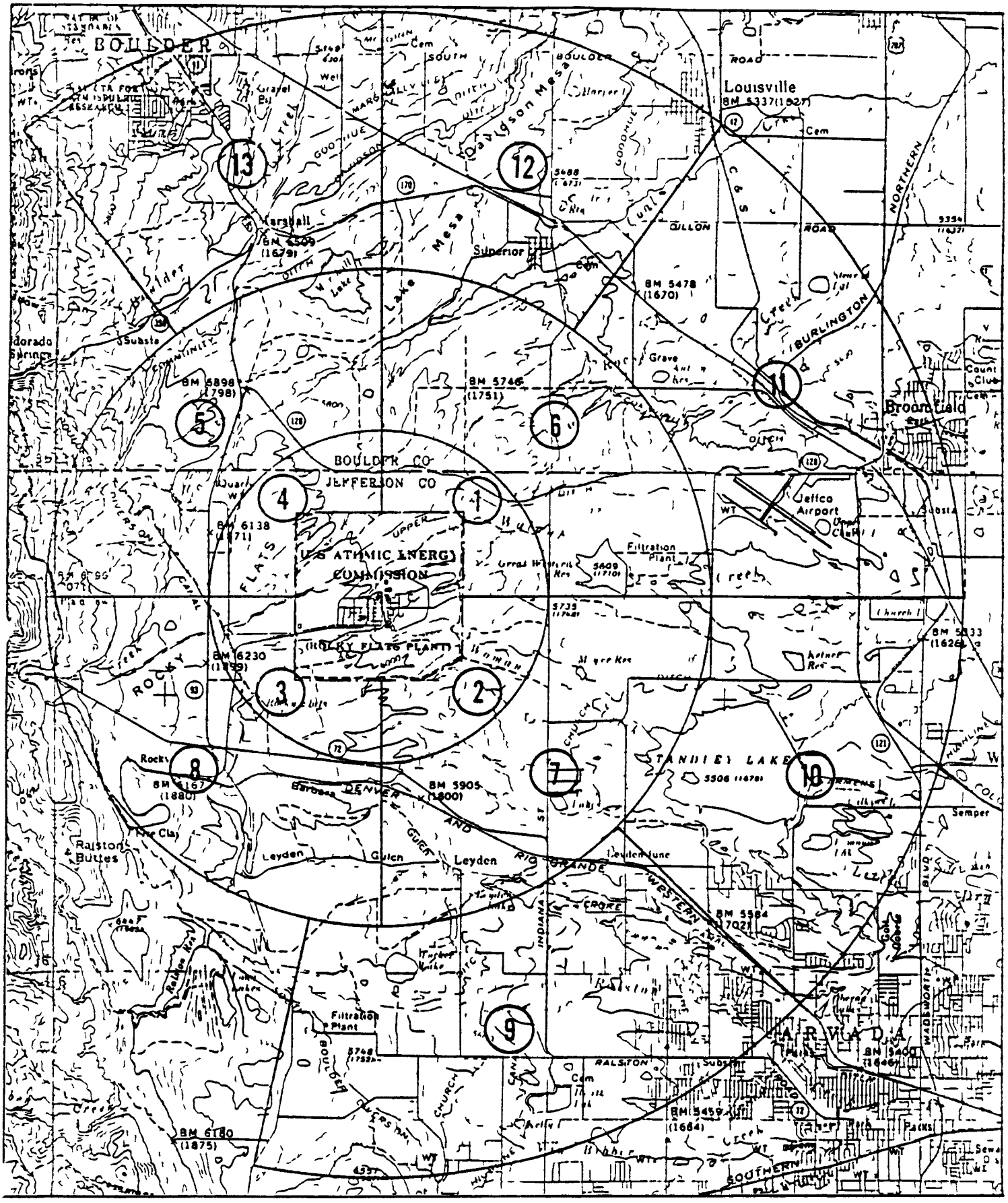


FIGURE 5

1977 SOIL SURVEY - SAMPLING LOCATIONS

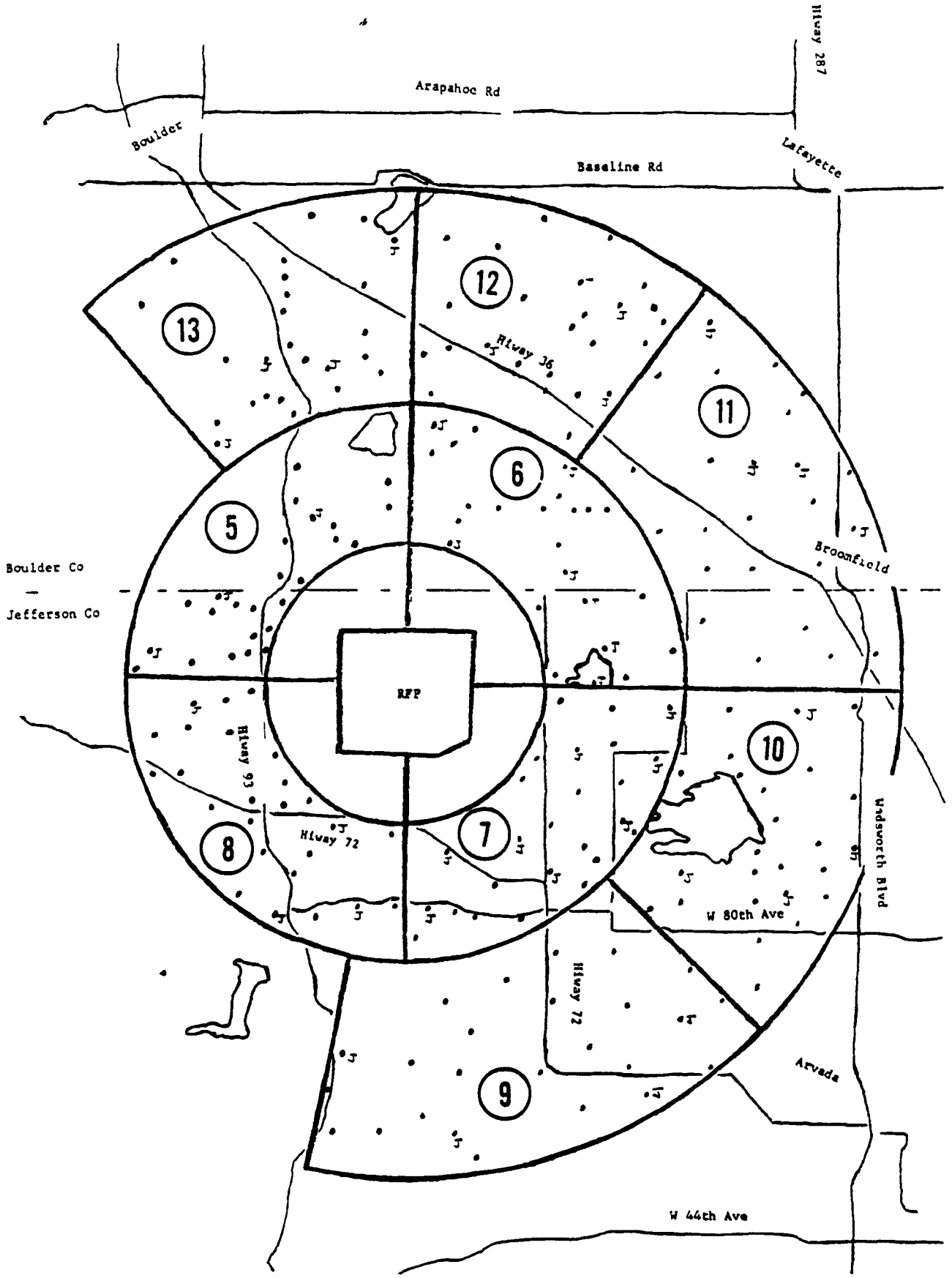
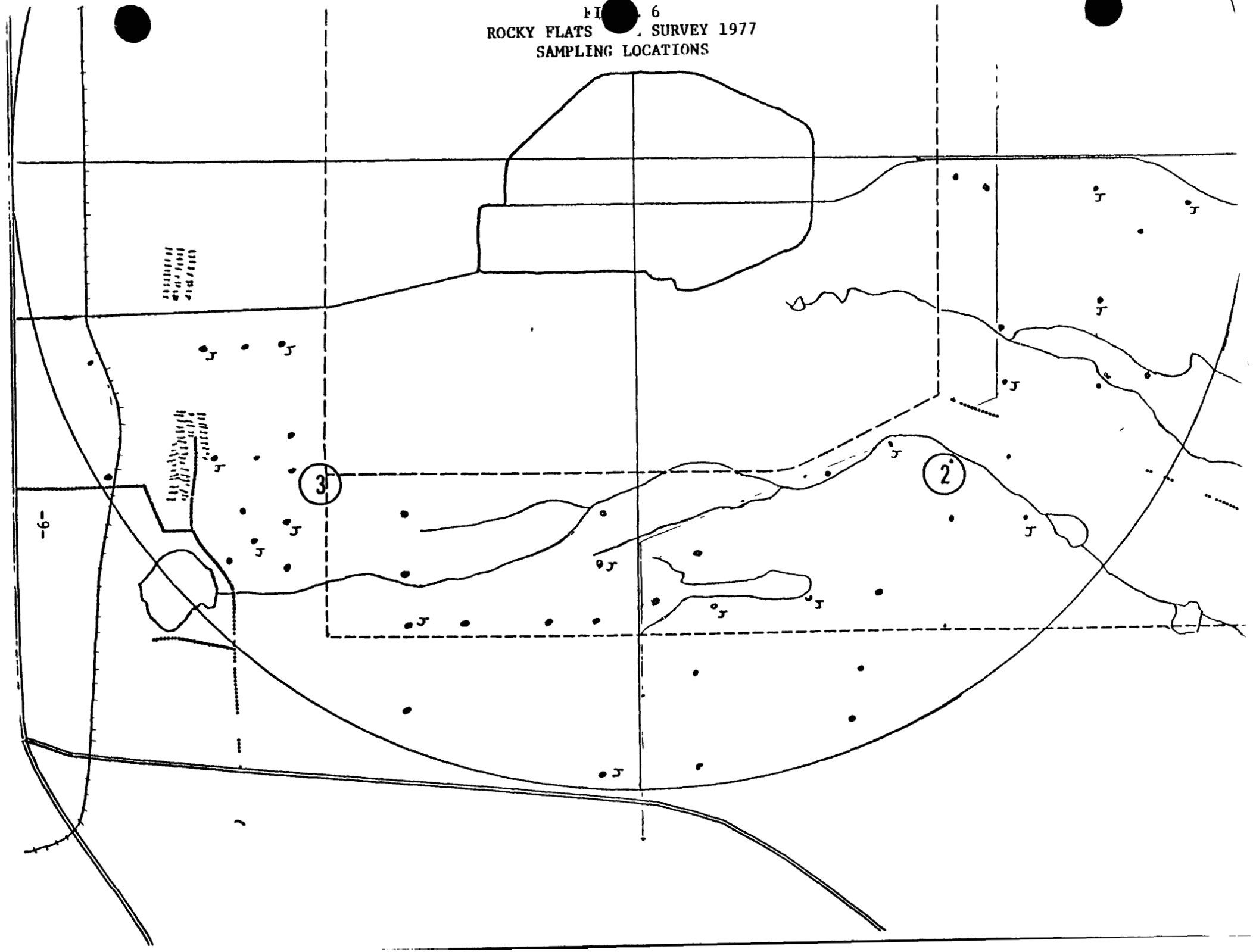


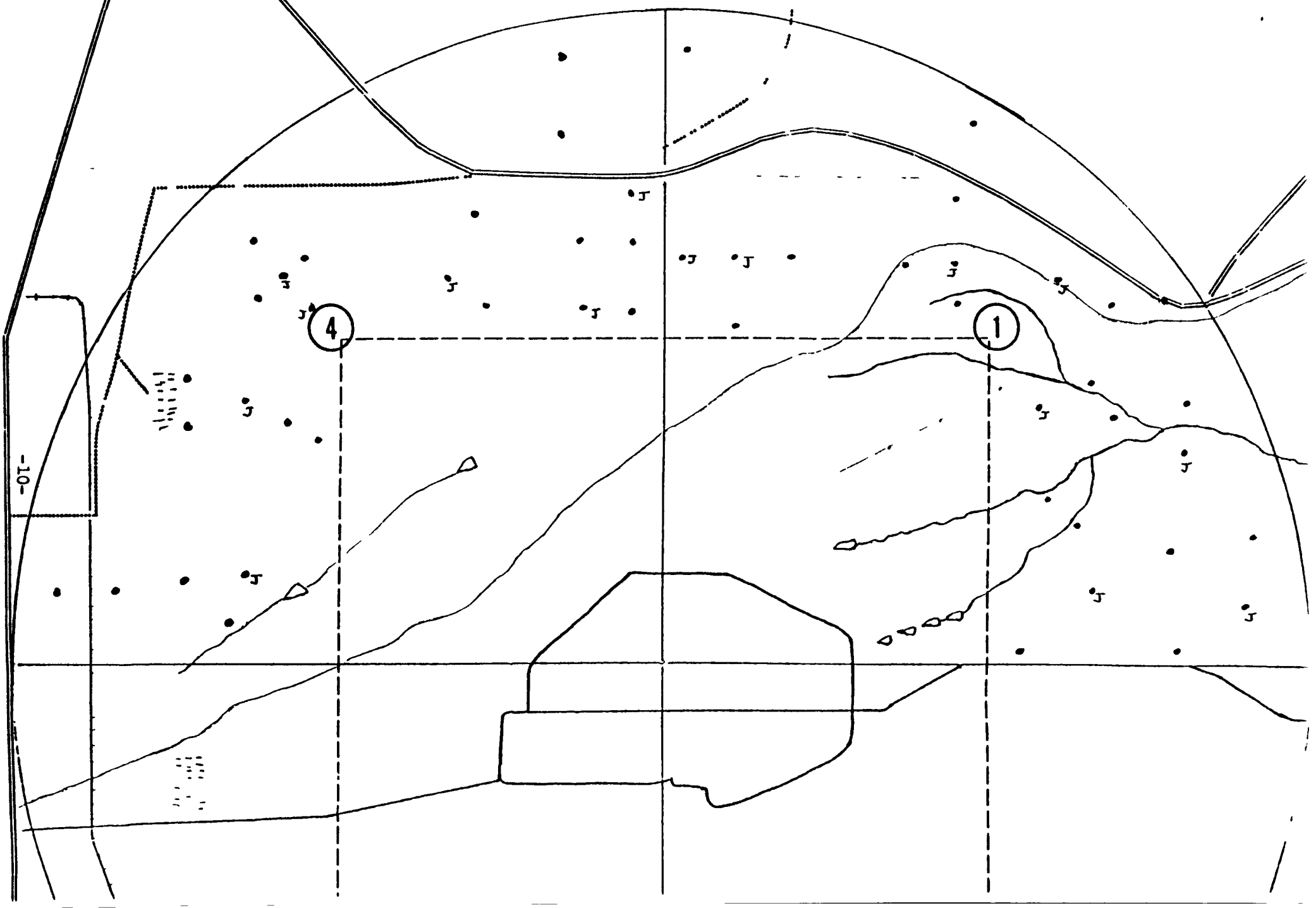
FIGURE 6
ROCKY FLATS SURVEY 1977
SAMPLING LOCATIONS



FIGUR

ROCKY FLATS SOIL SURVEY

1977



Sample Preparation

Following collection, all samples were weighed, then oven dried overnight (103°C) and dry sieved Any material (including rocks and sticks) which failed to pass a 2mm screen was discarded The remaining material was mixed and divided by coning and quartering to yield a sample of approximately 20-30 grams to be ground for plutonium analysis Grinding was performed in an automatic mortar and pestle with approximately 2 grams used for each plutonium analysis One hundred grams of the unground, less than 2mm soil was taken for cesium analysis Replicate cesium analyses were performed on a different aliquot of the less than 2mm soil

Particle Sizing

Representative samples of soil (approximately 80-100 grams each), collected by the CDH method in Sectors 2 and 3, Limon and Loveland were taken for collection of the "less than 5μm" fraction used by Dr Johnson This separation was performed by CDH in cooperation with the Jefferson County Health Department, and in the facilities of the U S Geological Survey following the procedure used by the Jefferson County Health Department This procedure involves a peroxide-heat digestion followed by ultrasonic vibration, sedimentation and freeze drying as described in detail in Appendix II Additional samples could not be run due to the necessity to return essential borrowed equipment.

Plutonium Analysis

All soil samples were analyzed for plutonium by alpha spectroscopy following a procedure (See Appendix III) based on that of Talvitie (Anal Chem 43 1827-1830, 1971). The minimum detectable activity for plutonium-239 is 0 02 dpm/gm.

Cesium Analysis

Cesium analysis was performed using a high resolution (3 KeV FWHM at 662 KeV) Ge(Li) gamma spectroscopy system calibrated using NBS Standard Reference Material 4350 - River Sediment. Samples were counted in 100 ml bottles in a standard geometry for a minimum of 500 minutes. The minimum detectable activity, assuming a one hundred gram sample, 500 minute count, is estimated to be 0.30 dpm/gm for cesium. The spectra obtained were visually examined for other gamma emitting fission products.

RESULTS

Soil Sampling 1976

Composite samples of surface soil collected during 1976 according to the "CDH method" described in the previous section were available for analysis They had already been sieved and split prior to commencement of this study, hence, only portions of the less than 2 mm (dry sieved) fraction were available for cesium analysis. These results (in dpm/gm), along with the results of the plutonium analysis, appear in Table I. Where two separate results appear, they represent analyses on separate aliquots of the same sample Error terms are the 2 sigma counting errors for individual determinations

Soil Sampling 1977

Table II presents data on the mass of the composite soils collected during the annual 1977 soil survey All samples were composited in the field with large rocks and sticks rejected Although several days elapsed between collection and drying, the difference between wet and dry weights provides some indication of conditions at collection The difference between the dry and sieved weights is an indication of the amount of non-soil material (i e. rocks and sticks) collected with the sample. The value for Kg/m^2 calculated for the "CDH sampling method" is used as a density conversion term in subsequent tables. This has been done rather than adopting an arbitrary density as others have done in an attempt to compensate for surface density differences. It is noted that one sample (Walsenburg) has a density of less than 1 gm/cm^3 (3 0 kg/m^2 to a depth of 0 3 cm equals 1 gm/cm^3) which may be due to winter freezing and thawing near the time of collection or a problem with the sample collection. The samples labeled as "Johnson method" were collected by the sweeping technique No attempt has been made to convert the results obtained by this technique to area concentrations due to the imprecision inherent in the collection procedure.

Presented in Table III are the results (again in dpm/gm) for the samples collected in 1977. All results in this table are for the whole (i e. <2 mm fraction) soil. Analyses were also performed on "gross" samples including rocks and sticks, however, the inability to select a representative sample of such material precludes meaningful interpretation of results and these are not reported.

In addition to the analyses performed on whole (<2 mm) soil and reported up to this point, four composite samples were separated according to the procedure used by Dr. Carl Johnson and both plutonium and cesium analysis were performed on the "respirable dust" fraction collected. The results are presented in Table IV. It was hoped originally that it would be possible to run a complete materials balance on these samples, however, this was precluded by the available equipment and the short length of time that vital equipment was available on loan to us which precluded our modifying it. Gamma analysis performed on a composite sample,of the liquid removed from samples during the initial digestion indicated the presence of a trace of Cs-137 which could not be validly quantitated.

TABLE I
PLUTONIUM AND CESIUM-137 CONCENTRATIONS
IN WHOLE (<2mm) SOIL - 1976

	Pu-239 (dpm/gm)	Cs-137 (dpm/gm)
Sector 1	1.51 ± 0.16	7.10 ± 0.43
2	7.77 ± 0.42	5.28 ± 0.36
3	0.36 ± 0.02	14.2 ± 0.53 13.9 ± 0.63
4	0.27 ± 0.04	10.0 ± 0.52
5	0.09 ± 0.02 0.07 ± 0 02	4.34 ± 0.31
6	0.27 ± 0.07 0.20 ± 0 04	2 68 ± 0 25
7	0.27 ± 0 04	2.91 ± 0.28
8	0.13 ± 0.02	4.60 ± 0.31
9	0.16 ± 0 02	3.09 ± 0.26
10	0.16 ± 0 09	2.04 ± 0 22
11	0.04 ± 0.02	1.62 ± 0.18
12	0.07 ± 0.02	2.57 ± 0.26
13	0.09 ± 0.02	1.85 ± 0.18
Burlington	0.02 ± 0.02	1.70 ± 0.20
Crooke	0.09 ± 0.02 0.07 ± 0.02	3.89 ± 0.34
Limon	0.04 ± 0.02	2.79 ± 0.26
Livermore	0.02 ± 0 02	2.04 ± 0.18
Loveland	--	1.96 ± 0.22
Penrose	0.09 ± 0.04	3.43 ± 0.27
Springfield	0.02 ± 0.02	1.77 ± 0.26
Walsenburg	--	2.76 ± 0.25

-- No analysis on these samples

TABLE II
SOIL SAMPLING - 1977
MASS OF SAMPLES COLLECTED

	CDH COLLECTION METHOD					JOHNSON COLLECTION METHOD		
	Wet (gms)	Dry (gms)	Sieved (gms)	Kg/m^2*	% Less*** than 5 µm	Wet (gms)	Dry (gms)	Sieved (gms)
Sector 1	338 1	328 3	278.2	3 71	---	3858 3	3735 3	3016 3
2	275.4	266.5	255.3	3.40	40 23	5468 6	5310.6	4414 8
3	306.6	300.3	265.1	3.53	28.80	4871 2	4768.0	3318.2
4	332.6	323.9	279.2	3.72	---	3680.1	3623.0	2208.2
5	383.1	374.0	275.2	3.67	---	3068.4	3016.4	2033.5
6	335 9	326.8	301.5	4.02	---	3611.0	3504.0	3019 2
7	247.6	240.0	225.9	3.01	---	6819.4	6731.4	5502.8
8	342 0	335 6	311.4	4 15	---	3284.8	3195.8	2399 8
9	315.3	303.9	275.8	3.68	---	3259.9	3144 9	2658 9
10	340 0	325.9	321.4	4 29	---	4515.1	4445 1	4042 1
11	393 9	369.5	386.6	5.15	---	6175.0	5975.0	5592.0
12	371 8	355.7	341.2	4.55	---	2873.7	2827.7	2408 2
13	400.1	385.8	341.1	4.54	---	1960.2	1912.2	1518.6
Burlington	380.3	365 2	361.6	4.81	---	**	**	108 7
Crooke	348 5	325.0	313.0	4.17	---	335.0	**	315 0
Limon	416.5	401 9	319.2	4.26	38.63	[illegible]	**	2074 1
Livermore	373 7	367.1	322.2	4.30	---	3477.3	**	3035.3
Loveland	391.8	379.8	378.5	5.05	37.92	282.5	**	2212 5
Penrose	416.7	406.6	392.3	5.23	---	3466.8	**	3228 8
Springfield	334.3	322.8	315.2	4.20	---	1623.0	**	1396 0
Walsenburg	205.3	**	158.8	2.12	---	346.5	209.6	207.9

* Based on dry weight, less than 2 mm diameter.
** Not determined
*** See separation procedure for details
--- Less than 5µm % was not determined on these samples

TABLE III
PLUTONIUM AND CESIUM-137 CONCENTRATIONS IN WHOLE (<2mm) SOIL - 1977
COMPARISON OF COLLECTION METHODS

	CDH COLLECTION METHOD		OLD CDH (SPOON) METHOD		JOHNSON COLLECTION METHOD	
	Pu-239 (dpm/gm)	Cs-137 (dpm/gm)	Pu-239 (dpm/gm)	Cs-137 (dpm/gm)	Pu-239 (dpm/gm)	Cs-137 (dpm/gm)
Sector 1	2 28 ± 0 51	7 80 ± 0 44	1 42 ± 0 11 1 42 ± 0 13	9 77 ± 0 51	0 29 ± 0 04	8 23 ± 0 53
2	9 41 ± 1 09 9 32 ± 0 69	9 40 ± 0 42 9 40 ± 0 43	8 75 ± 1 18 8 99 ± 0 56	8 15 ± 0 45	5 71 ± 0 29	5 77 ± 0 45
3	0 20 ± 0 04 0 20 ± 0 04 0 24 ± 0 04 0 24 ± 0 04	10 60 ± 0 57 10 22 ± 0 47			0 16 ± 0 04	7 93 ± 0 41
4	0 20 ± 0 04 0 18 ± 0 04 0 22 ± 0 04	10 45 ± 0 58 11 36 ± 0 53			0 29 ± 0 07	10 98 ± 0 48
5	0 13 ± 0 04	6 53 ± 0 42			0 16 ± 0 02	8 08 ± 0 43
6	0 60 ± 0 07 0 71 ± 0 09	5 96 ± 0 38	1 75 ± 0 16	5 47 ± 0 33	0 49 ± 0 07 0 42 ± 0 04	3 47 ± 0 26
7	0 64 ± 0 09	4 15 ± 0 31	1 47 ± 0 11	4 76 ± 0 33	0 07 ± 0 02 0 04 ± 0 02 0 07 ± 0 02	2 76 ± 0 25
8	0 16 ± 0 04	7 17 ± 0 39			0 29 ± 0.07	11 6 ± 0 48
9	0 09 ± 0 02 0 16 ± 0 04	3 96 ± 0 30 3 55 ± 0.28			0 13 ± 0 04	6 68 ± 0 41
10	0 22 ± 0 04	1 96 ± 0 20			0 16 ± 0 04 0 13 ± 0 04 0 20 ± 0 02	3 59 ± 0 36
11	0 07 ± 0 02	2 04 ± 0 22			0 09 ± 0 07	2 79 ± 0 34
12	0 04 ± 0 02 0 07 ± 0.02	2.98 ± 0.25 3.31 ± 0.23			0 07 ± 0 02	4 08 ± 0 36
13	0 07 ± 0 02	3.51 ± 0.27 3.09 ± 0 24			0 11 ± 0 04 0 07 ± 0 04	5 70 ± 0 41
Burlington	0 07 ± 0 02	3 13 ± 0.27				2.26 ± 0 24
Crooke	0 04 ± 0 02	3 09 ± 0 26				5 74 ± 0 33
Limon	0 04 ± 0 02	1 89 ± 0 22 2 11 ± 0 22				4 76 ± 0 24
Livermore	<0 02	3 17 ± 0 19 3 40 ± 0 30				0 91 ± 0 13
Loveland	0 02 ± 0.02	1 51 ± 0 19 1 89 ± 0 20				2 83 ± 0 27
Penrose	0.04 ± 0 02	2 64 ± 0 24				1 85 ± 0 20
Springfield	0.02 ± 0.02	2 08 ± 0 22				0 26 ± 0 08
Walsenburg	0 04 ± 0.04	0 45 ± 0 10				<0 30

TABLE IV
PLUTONIUM AND CESIUM CONCENTRATIONS
CHANGES RESULTING FROM PARTICLE SIZING

		<2mm		<5μm				
		dpm/gm	Cs/Pu (Activity Ratio)	dpm/gm	Cs/Pu (Activity Ratio)	Change in Cs	Change in Pu	Change in Cs/Pu Ratio
Limon	Cs	2.0	*	5.18	*	X 2 6	*	*
	Pu	0 04 ± 0 02		0.09 ± 0.04				
Loveland	Cs	1.70	*	4.47	*	X 2 6	*	*
	Pu	0.02 ± 0 02		0.09 ± 0.04				
Sector 2	Cs	9.40	1 0	31.0	2 15	X 3 3	X 1 5	X 2 2
	Pu	9 37		14 4				
Sector 3	Cs	10.60	48	60.6	114	X 5 7	X 2 4	X 2 4
	Pu	0.22		0.53				

* - No reasonable value may be assigned to these ratios due to the magnitude of the plutonium error term

DISCUSSION

Plutonium

The procedure of sampling surface soil for plutonium analysis, which was selected several years ago by the Colorado Department of Health, is designed specifically for the purpose of indicating whether or not there is a potential inhalation hazard from resuspended plutonium. Compositing of samples is appropriately used to estimate the total affect on an individual subjected to resuspension from several different directions This is done with the full realization that there are individual sites where the concentration is higher than the composite would indicate, and sites where it is lower Sampling techniques which do not composite will, by definition, result in larger variability in concentrations

A second item which must be considered is the effect of collecting disturbed soil Although we have made an attempt to collect "undisturbed soil" in our surveillance of the Rocky Flats area, this has been done only to avoid the possibility of underestimating potential hazards, and is not strictly valid from the standpoint of determining actual health impacts In areas which are remote from Rocky Flats, it is extremely difficult (and becoming more so every year) to locate soil which is truly undisturbed. If one remembers that the fallout plutonium (which is the background against which Rocky Flats contamination must be compared) was deposited primarily in the late 50's and early 60's, the problem is to find soil which has not been disturbed in 15-20 years Natural events including wind and water erosion as well as plowing, road construction, fence maintenance and other activities of man will affect the surface soil composition, in most cases lowering the concentration of deposited contaminants. It should be noted that Sectors 1-4 consist primarily of land currently under the jurisdiction of ERDA and undisturbed (except for grazing animals) by man since the plant was constructed. In the outlying sectors and remote sites, no history of the soil is available. Examination of the plutonium data collected since 1970 (Table V) shows that there has been a significant decrease in surface soil concentrations in remote site samples. While a part of this decrease is certainly due to the downward movement of the plutonium (to a depth below 0.3 cm) as a result of diffusion or burying by soil movement, it is believed that a significant part is due to the difficulty in locating truly undisturbed soil sampling sites.

Results of analyses from Sectors 1-13 indicate values which are generally similar in 1977 to other years. The rapid drop in plutonium concentrations in Sector 2 from 1971-1975 appears to have leveled off, although the significance of this is unclear. Interpretation is complicated by the fact that, this sector, more than any other, will be affected by compositing

TABLE V

ROCKY FLATS PLANT SURVEILLANCE

Plutonium-239 Concentrations in Soil (dpm/gm)

Immediate Vicinity Sector	1977	1976	1975	1974	1973	1972	1971	1970
1	2.28	1 51	--	3 18	--	2 66	3 15	5 55
2	9.37	7 77	9 44	28.19	--	55 75	66 84	24 40
3	0.22	0 36	0 49	0 36	--	0 17	0 07	0 29
4	0.20	0 27	0 22	0.45	--	0 22	0 29	0 31
5	0 13	0 08	0 13	0 70	--	0 33	0 37	0 24
6	0.66	0 24	<0 02	0 48	0 15	0 71	0 63	1 00
7	0 64	0 27	0 29	0 80	0 83	0 57	0 79	1 02
8	0.16	0 13	0.16	0.29	--	0 24	0.60	0 04
9	0 13	0 16	0 09	0 04	0 07	0 31	0 29	0 02
10	0 22	0 16	--	0 17	0 11	0 20	0 12	0 38
11	0 07	0.04		0.23	0 14	0 18	0 12	0 07
12	0.06	0 07	0 07	0 19	--	0 15	0 06	0 02
13	0 07	0.09	0.07	0.13	--	<0.04	0.12	0 04
Remote Sites								
Loveland	0.02	--	--	--	0 12	--	0 10	0 11
Livermore	<0 02	0 02	--	--	0 04	0 07	<0 04	0 04
Crooke	0 04	0.08	--	--	0 05	0 11	0 13	0 04
Burlington	0.07	0.02	--	--	0.05	0 07	0 11	0 09
Limon	0 04	0.04	--	--	0 06	0 07	0.06	0 13
Springfield	0 02	0 02	0 04	--	<0 04	0 12	0 09	0 04
Walsenburg	0 04	--	0.02	--	0 05	0.11	0 07	0 11
Penrose	0 04	0.09	--	--	0 06	0 11	0 08	0 11

-- indicates that no analysis results were available on this sample

relatively high concentration individual samples from the northern portion with low concentration samples from the south, therefore, individual sampling sites are critical This may also help explain the extremely low values in Sector 6 (1973 and 1975) as there is a narrow band of relatively high concentration soil on the extreme southern edge of this sector that could easily have been missed in some years

Direct comparisons (such as ratios) between plutonium concentrations in remote sites and sector samples are not considered valid due to the size of the error terms (refer to Tables I and III) of the analyses as well as problems in obtaining truly comparable "undisturbed" soil samples

Examination of the results of replicate analyses indicate generally excellent analytical reproducibility. Comparisons of results obtained by different sampling techniques reveal only fair to good agreement. It is obvious from all the data available that sampling (techniques, locations, compositing, etc) are the greatest source of variability in soil analysis and will require additional refinements in the future.

Cesium

In order to provide an accurate interpretation of any environmental monitoring program and to avoid misinterpretation, it is essential to examine the analysis process from its inception at sampling through to the calculation of the results This is especially important in the current study since the samples analyzed were collected for one purpose (i.e determination of a potential inhalation hazard from plutonium) and are being examined for another (i.e. Did Rocky Flats release any Cs-137 to the environment?). Consider initially the differences between plutonium and cesium in the environment -

Plutonium (whether produced in a nuclear detonation or released from Rocky Flats) exists in the environment predominantly in its oxide form (PuO_2). This matter has a very low solubility in water and as a result, its movement in the environment is governed primarily by physical processes Principal among these are horizontal dispersion by the wind and vertical migration into the soil by diffusion. Both of these will be affected to a large extent by the moisture content of the soil but not much by the soil type or other constituents present in the soil.

Cesium on the other hand is an element which exists in the environment predominantly in ionic form (similar to sodium, potassium and calcium) and as a result its movement through the environment will be governed primarily by chemical processes As a result, its mobility is a complex function of, not only moisture content, but also, soil type, pH, and ionic balance.

Excellent reviews of this situation are available (ref J.W Stannard, "Plutonium in the Environment", in Uranium, Plutonium, Transplutonic Elements, H C Hodge, et al , ed., 1973) Even though there may be a constant ratio between these two materials in the fallout from nuclear testing, this does not necessarily mean that an environmental sample which contains only a portion of the deposited material (such as surface soil or "respirable dust") will contain the same ratio There is, however, evidence that the depth profiles for Pu and Cs-137 are similar (Hardy, HASL 306, 1976) and since the ratios of fallout products, in surface soil have been used successfully in the past to identify plutonium contamination at Rocky Flats (ref. Poet and Martell, Health Physics, Vol 23, pp 537-548, 1972) they are presented in Table VI

The data in this table was obtained from Table III (adjusting for the soil density and converting units) but is presented as areal distributions to allow comparisons with other sampling methods. The range of Cs/Pu ratios in samples from remote sites (omitting the questionable sample from Walsenburg) is 45-98 with an average of 68.5. This value agrees extremely well with published values (ref Hardy, ibid, 1976 - ratio 62 5), especially considering the size of the error terms associated with the plutonium determinations Ratios for samples collected in the thirteen sectors show values which are universally lower than this. Sectors 3, 4, 5, 8, 12 and 13, which lie west and north of the plant site all fall in the low end of the range of background values. Sectors 1, 2, 6, 7, 9, 10 and 11 which all lie south and east of the plant, and are known to contain areas of plutonium contamination, display Cs/Pu ratios smaller than the backgrounds - exactly as would be expected.

Another method of evaluating the data is to compare the areal distribution of Cs-137 with published values Some of these values are as follows

Range of values nCi/m^2	Comments	Source
49 - 147	Sampled to 10 cm depth in agricultural watersheds.	Ritchie & McHenry (Health Physics, Vol 32, Feb. 1977
15.3 - 244	Depth samples on Great Plans	Miller & Michels (HPR 317390-105, Rocky Flats Report, 1973)
13.7 - 144	Depth Samples	CSU, "Environmental Radiation Surveillance Program - Ft. St. Vrain - Summary Report, Third and Fourth Quarters 1976"

TABLE VI
ROCKY FLATS PLANT SURVEILLANCE - 1977
AREAL DISTRIBUTION OF Pu-239 and Cs-137 (nCi/m^2)

	Pu-239	Cs-137	(Cs/Pu) (Activity Ratio)
Sector 1	3 81	13.0	3 4
2	14.3	14.4	1 0
3	0 35	16.5	47
4	0 33	18.2	55
5	0 21	10 8	51
6	1.20	10 8	9 0
7	0 87	5 6	6 4
8	0 30	13.4	45
9	0.22	6 2	28
10	0.42	3.8	9 0
11	0 16	4.7	30
12	0 12	6.4	53
13	0 14	6.7	48
Burlington	0.15	6 8	45
Crooke	0.08	5.8	73
Limon	0.08	3.8	48
Livermore	<0.04	6.4	--
Loveland	0.05	3.9	78
Penrose	0.09	6.2	69
Springfield	0.04	3.9	98
Walsenburg	0.04	0.4	*
		Remote Locations· Average	68 5
		Range	45 - 98

* This value has been omitted due to large uncertainties associated with both results and the original questions about the validity of the sample

In this case, the values determined from the present study are all lower than published values This is an obvious and expected result considering the fact that the sampling technique only collects surface soil and much of the cesium (and plutonium) is known to have migrated to a depth below 0 3 cm

A third way to evaluate the data is to compare the results from background samples to the results for sectors near the plant As mentioned in the plutonium review, the remote site samples contain soil on which no history is available and some of the individual samples are undoubtedly not representative of fallout products in undisturbed soil While results of those samples may be valid for determining relative airborne hazards from resuspended plutonium, they are <u>not valid</u> for determining amounts of any pollutants originally deposited on the surface of the soil' The highest levels of cesium-137 found were in Sectors 3 and 4 to the west (upwind side) of the plant site

The conclusion which logically follows from these results is that

1 All of the results are consistant with world-wide fallout being the primary, if not, the sole source of the detected Cs-137

2 If any of the radioactive cesium in the soil did originate with industrial operations or accidents at the plant, its contribution is insignificant.

3 Further investigation of this matter would require extensive <u>inventory</u> (not surface) sampling far beyond the scope of the present study and is not warranted based on the results obtained.

Other Investigations

The final items for discussion are the results reported by R J. Murri (Rocky Flats) and Dr Carl Johnson (Jefferson County Health Department)

MURRI

The report by Murri ("Gamma Analysis of Plutonium Contaminated Soil at Rocky Flats," ES-376-77-197, January 10, 1977) included the results of twelve samples, collected by the sampling procedures of the Colorado Department of Health. They are reported in dpm/gm and are directly comparable to samples reported in Table III of this report. The range of values (1.83 - 16.47 dpm/gm, average 8 28 dpm/gm) are not inconsistent with the range of values presented in this report (1.96 - 11.36 dpm/gm) with the effects of compositing are considered.

DR. JOHNSON

The results presented by Dr. Carl Johnson to the Jefferson County Board of Health, March 31, 1977, were based on samples collected by the sweeping technique and separated to yield a "respirable dust" fraction.

Table III presented the results of plutonium and cesium-137 analyses performed on whole (<2mm) soil collected by this technique, as well as the routine CDH method. Comparison of the Cs-137 results indicates little, if any, difference between the techniques. The mathematical average for the 13 sector samples are as follows

Johnson	6.28 dpm/gm
CDH	5 88 dpm/gm

Differences in the plutonium results are most dramatic in sectors 1, 2 6, and 7 which contain sharp concentrations gradients and are, therefore, believed to be the results of individual sample site selection In other sectors, where the plutonium distribution is known to be more uniform the plutonium results are essentially identical

Following collection, the samples were subjected to the particle sizing procedure described in Appendix II of this report Application of this procedure to the evaluation of environmental plutonium as performed by Johnson, Tidball and Severson (Science, Vol 193, pp 488-490) is a unique and experimental procedure which has not been widely accepted by the scientific community. While it is not the intent of this report to review all of the criticisms which have been leveled at the procedure, there are a couple of items which must be discussed in order to determine whether or not Dr Johnson has, in fact, located samples with elevated levels of cesium-137.

This soil separation procedure is a vital step in analysis process and, as such, must be subjected to the same testing and review as the other analytical procedures This includes, at least, tests of its reproducibility and a materials balance to determine the ultimate fate of the materials of interest through the procedure. Although Dr. Johnson has sent his final product to numerous laboratories for analysis, there is no indication that replicate separations have been performed on any samples. The materials balance is necessary in order to shed some light on exactly what is happening through the procedure to yield the large concentrations reported and whether or not this effect is truly representative of potential environmental occurrances. Until these tests are performed, the results obtained by the use of these procedures can not be validly interpreted and therefore, speculation and criticism will continue

It had been hoped that a materials balance evaluation of the separation procedure could be performed as part of this review As explained previously, however, vital equipment on loan for our use had to be returned before this could be accomplished. As a result, we are left to speculate on only the four samples presented in Table IV

As can be seen in this Table, there is an obvious increase in both the plutonium and cesium concentrations in all four samples. This is not at all unexpected for the following reasons. Plutonium in the environment is known to exist in small, finely divided particles which are associated to some degree with larger soil aggregates. The separation procedure is extremely harsh and intentionally destroys soil aggregates to release the plutonium. Collection of the small particles then would tend to concentrate the plutonium.

Cesium-137, as was mentioned earlier, exists in the environment in ionic form It is well known, however, that cesium binds tightly to ion exchange sites on the clay in soils Since the particle sizing technique used by Dr Johnson, et al , was originally designed for the specific purpose of characterizing the clay content of soils and the clays are the smallest fraction it follows directly that much, if not all of the cesium-137 is collected in the "respirable fraction".

Since the ratio of cesium to plutonium is also apparently altered by the separation procedure, it leaves at least questionable, if not invalid, any statements about concentrations or ratios of these materials in the environment.

CONCLUSIONS

1 No significant changes in the levels or distribution of plutonium in the surface soil around Rocky Flats have occurred in the last three years

2 While it is not possible to state conclusively that there has never been environmental contamination by Cs-137 due to industrial operations or accidents at the Rocky Flats Plant, there is nothing available from this investigation or any other evidence of which we are aware to conclude that there has been It is clear that a cesium-137 release, if such did occur, did not contribute significantly to the levels existing as a result of cummulative worldwide fallout

3 The soil sampling procedure of Dr Carl Johnson, which consists of sweeping the surface of the soil, does not provide a sample which is significantly different from the method currently used by the Colorado Department of Health

4 The soil separation procedure of Dr Carl Johnson, et al., alters the plutonium and cesium concentrations in the soil and the ratio of the two! This procedure has not been evaluated, either by its originators, the current study, or any other of which we are aware, to allow the interpretation of its results, comparison to other analytical techniques, or its use in evaluating health impacts due to environmental pollutants

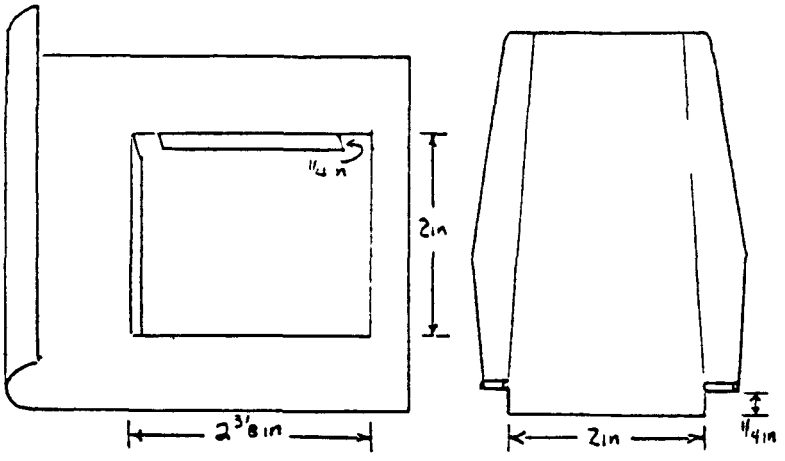
5 The State Health Department also cautioned that surface soil sampling techniques should be used only to indicate the presence of a potential inhalation hazard from resuspended pollutants (This may still be most closely related to health effects of these materials). The method cannot be used as a determination of the total inventory of the pollutants.

APPENDIX I

Sample Collection - Plutonium-in-soil.

Soil samples are collected annually (usually in April or May) from an area, surrounding the Rocky Flats Plant, that is enclosed within a circle 7 miles in radius from the center of the plant site. See Figure 1. Individual samples are collected from the surface soils with the actual sample collection site selected on the basis that the soil appears to be undisturbed (by anything other than natural causes) The general area is selected randomly (but convenient as far as transportation to the location is concerned) within a sector. The individual samples are collected using a locally manufactured soil sampling device or other scoop-typed device. The individual samples are placed in a container with the other samples from the sector. Twenty-five samples are collected into a composite sample from each sector The composite sample is dried and sieved through a 10 mesh screen. The remaining material is then coned and quartered to about a 30 gram fraction. This 30 gram fraction is then finely ground and mixed in a mortar and pestle A 2 gram fraction of this portion of the sample is then digested for plutonium analysis

Note In using the sampling device, only the top 1/8 inch of soil is collected The angle of the scoop is adjusted to accomplish this depth



Soil Sampling Device,
Critical dimensions

MH/bw
1/19/76

Revised 6/1/76

APPENDIX II

SOIL SEPARATION PROCEDURE

The following procedure was used to obtain a "less than 5μm" soil fraction for analysis. It is condensed from the lab notebook used by the Jefferson County Health Department but maintains all of the essential items used by them in their separations.

1. Digestion· Approximately 80 gm of <2mm soil is digested by heating in 30% hydrogen peroxide until no additional foaming is noted. Alcohol is added occasionally to avoid boil over. Digestion takes 1-2 working days with frequent addition of peroxide. (The use of a steam bath has been determined to be too slow and has been replaced by a "hot" plate with the samples removed before they boil over)

2. Dehydration Deionized water is added to the sample to bring the volume to approximately 400 mls. Fine porosity filter cylinders, attached to a vacuum line, are used for removal of the liquid and any dissolved organic or inorganic materials Periodically, the candles are cleaned by backflushing with air.

3. Dispersion Approximately 25 ml of a 50 gm/l sodium metaphosphate solution is added to the dehydrated sample The solution is then subjected to a 5 minute treatment with a 300 W ultrasonic probe.

4. Sedimentation. The entire sample is then transferred to a 1 liter sedimentation vessel with deionized water to a volume of 1 liter, shaken several times to suspend all particles, and then allowed to settle. A settling time for a 20 cm depth is chosen according to Stokes Law for 5 micron particles with a density of 11.46 gm/cm^3, and all liquid and suspended solids collected with a suction tube to that depth The remaining solution in the cylinder is brought again to 1 liter with deionized water and the settling repeated. Five sedimentations on each sample are composited for analysis.

5. Dehydration: Filter cylinders are again used to remove a majority of the water. The remaining water is removed by freeze-drying under vacuum (lyophilization) leaving a fluffy, powder like material of low density for analysis.

6. Determination of $\leq$ 5 μm percent: A second fraction of the same <2 mm soil is taken (about 20 gms) and digested with peroxide as above. Excess water with dissolved organic material and inorganic salts is removed with filter candles. The soil is then transferred to a tared beaker, oven dried

and carefully weighed to determine whole soil mass A precise amount of sodium metaphosphate solution and water is added, allowed to set overnight and then dispersed for 5 minutes with the ultrasonic probe as above The sample is transferred to a 1 liter sedimentation column, shaken and allowed to settle for a period of time, determined by Stokes Law, such that a 5 micron particle of density 11 46 gm/cm^3 reaches a depth of 10 cm. A pipet is lowered into the column to a depth of 10 cm and exactly 25 ml (1/40 of the total) is withdrawn, transferred to a tared collection vessle, oven dried and weighed to determine the less than 5 micron fraction.

Preparation of Soil, Hi-Vol Air Filters,
and Water for Plutonium Analysis

1) Preparation of Soil Samples.

   a) Weigh sample. Oven dry entire sample at 103°C overnight. Weigh dry sample. Record wet and dry weights of sample.

   b) Screen sample through 10 mesh standard screen

   c) Grind the fraction of soil which will not pass screen to break up any lumps of clay or aggregates. Grind small enough to pass through screen.

   d) Discard any pebbles or sticks too large to pass through screen. Weigh the fraction of the sample that passed through the screen, record weight.

   e) Split sample by coning and quartering enough times to obtain a 15-25 gm sample.

   f) Take 15-25 gm sample to counting facility to be ground.

   g) Weigh 2 gm of the ground sample into a platinum crucible. Every fifth sample, do a duplicate. Weigh the sample to the nearest 0.1 mg.

   h) Ignite the sample in the muffle furnace set at 550°C for 1 hr. 15 min. Remove and cool.

   i) Transfer sample from crucible to teflon beaker containing standard aliquot of ^{236}Pu. Rinse crucible with water and add rinse to beaker.

2) Preparation of Hi-Vol air filters.

   a) Sample is received from counting facility in small envelope containing ^1in. squares of filter.

   b) Transfer entire sample to platinum crucible, using forceps. Tap any dust in envelope into crucible as well. Save envelope.

   c) Ignite in muffle furnace at 550°C for 1 hr. 15 min. Remove and cool.

   d) Transfer sample from crucible to teflon beaker containing standard aliquot of ^{236}Pu. Rinse crucible with water and add rinse to beaker.

3) Preparation of water samples.

   a) For composite samples, see separate procedure.

   b) For single water samples, shake sample well. Measure out 1 L or less, if sample is not large enough to use 1 L, using a graduated cylinder. Record volume if not 1 L.

c) Pour sample into 1500 ml beaker. Label with sample number and volume.

d) Add standard aliquot of ^{236}Pu tracer to sample. Add a few ml of 30% H_2O_2 to sample to effect isotopic exchange.

e) Evaporate on hot plate at low heat to near dryness.

f) Transfer concentrated sample to a 250 ml teflon beaker using 6M HCl and 30% H_2O_2 to loosen the residue and rinse the beaker. Police off the sides and bottom of the beaker, rinse thoroughly with 6M HCl. Add all rinses to teflon beaker.

4) Dissolution of sample solids.

a) Add 2 spatulafuls of purified silica sand to each teflon beaker If there is 50-100 ml or more of liquid in beaker, evaporate to dryness.

b) Add 10 ml of conc HNO_3 and 10 ml of 47% HF to each beaker. Wear rubber gloves to prevent contact with HF fumes. Swirl to mix contents of beaker. Evaporate to dryness, slowly enough to prevent spattering.

c) Repeat step b) three times. Be sure residue is thoroughly dry after each step of digestion.

d) Add 6M HCl to residue in beaker to wet residue well (10-20 ml). Wash down sides of beaker when adding HCl. Evaporate to dryness.

e) Repeat step d) twice.

f) Add 20-30 ml 6M HCl to residue in beaker, washing down the sides. Add 1 ml 30% H_2O_2. Cover beaker with watch glass and bring liquid to a boil to dissolve residue. Remove from heat and cool. There should be no residual H_2O_2 remaining.

g) Transfer sample quantitatively to 150 ml glass beaker using 6M HCl. Try to use no more HCl than to give a total volume of 50 ml. It may be necessary to boil the rinse HCl in the beaker with a little H_2O_2 to dissolve the last traces of insoluble residue. There will be residual silica sand.

h) If ion exchange separation is not to take place within 24 hours, cover beaker tightly with parafilm for storage.

1) Preparation of ion exchange resin.

   a) Empty a one-pound bottle of Bio-Rad AG1-X2 (50-100 mesh, Chloride form) ion exchange resin into a 1500 ml beaker.

   b) Slurry resin with deionized water. Stir vigorously.

   c) Decant water and any fines which rise to top after allowing bulk of resin to settle.

   d) Repeat water wash until no more fines rise to the top. Decant as much water as possible after allowing resin to settle thoroughly.

   e) Add conc HCl in the amount of 10% of the volume of the slurry and stir.

   f) If the slurry is too thick, dilute with 1.2 M HCl.

   g) Always keep a liquid layer over the resin.

2) Preparation of the ion exchange columns.

   a) Prepare a plug of glass wool for the bottom of the column.

   b) Insert glass wool plug in glass chromatographic column which has a 250 ml reservoir. Pack into the bottom of the column using a long piece of glass rod or glass tubing. Place a 600 ml beaker under the column.

   c) Using a wash bottle, wash down the sides of the column with 1.2 M HCl. Close stopcock after stem of column fills. Add enough acid to give about 1" of liquid above glass wool.

   d) Pack glass wool with glass rod to expel any air bubbles which might be trapped in the glass wool. Drain liquid to just above glass wool plug.

   e) Add about 30 ml of resin slurry to each column using a large bore pipet. Be careful not to get resin on walls of reservoir, as it will all have to be washed down into the column proper.

   f) Fill the pipet with resin slurry. Open the stopcock on the column and let liquid start to drain. Resin will pack down. The resin level should be even with or a little above the line marked on the columns. (Resin column should be about 20 ml). If it is too low, let some of the resin slurry in the pipet drain slowly onto the resin bed as the liquid drains until the resin bed is at the proper level. Do not allow liquid to drain below top of resin bed - some liquid should always be above it.

   g) Wash down the inside of the reservoir and column with 1.2 M HCl to remove any resin which may adhere. Drain liquid in column to the top of the resin bed to remove any resin which may be adhering to

the column walls. Then add 1 2 M HCl, very carefully to avoid disturbing the resin, to a depth of about 1". Let resin settle, then add 1.2 M HCl to within 1" of top of column below reservoir Allow resin to settle completely.

h) Using funnel whose stem does not reach the bottom of the reservoir, add a 5 ml beakerful of 60-100 mesh purified spherical grained silica sand. Add the sand in a small stream so as not to disturb the resin bed. If the sand and resin layers become mixed, discard contents of column and start over.

i) Drain liquid completely from column. Sand will maintain sufficient capillarity to prevent liquid level from going below top of resin bed.

j) Wash inside of reservoir and column with 20-30 ml conc HCl. Drain column at maximum flow, drain column completely.

k) Add 100 ml 1 2 M HCl column. Let drain at a flow rate of 3 ml/min. (1 drop every 2 sec). Drain completely.

3) Ion exchange separation.

a) Dilute the sample solution in the pyrex beaker to 50 ml with 6 M HCl.

b) Add volume of conc HCl to the sample equal to the sample volume.

c) Add 1 drop 30% H_2O_2 per 10 ml of sample solution.

d) Cover with a watch glass and heat below boiling for 1 hour. (May also heat to below boiling and then allow to sit at ambient temperature overnight.) Remove from heat and cool to room temperature.

e) Meanwhile, add 200 ml 9 M HCl to the prepared resin column. Allow to drain at a rate of 3 ml/min (1 drop/2 sec).

f) Quantitatively transfer the sample from the pyrex beaker to the column using 9 M HCl to rinse the beaker. Allow the column to drain at the same rate as in e) above.

g) Using 9 M HCl rinse the inside of the reservoir and column with about 15 ml of acid. Allow to drain. Repeat twice more.

h) Remove 600 ml beaker, replace with pyrex beaker which held the sample.

i) Add 15 ml 7.2 M HNO_3, rinsing sides of reservoir. Allow to drain at a rate of 1.5 ml/min (1 drop/4 sec). Repeat with a second aliquot of 15 ml of 7.2 M HNO_3. Do not allow column to remain dry for any extended period, since air bubbles may form in column as resin shrinks if it is left dry.

j) Add 45 ml 7.2 M HNO_3 to column. Check flow rate to be sure it is maintained at 1.5 ml/min. Readjust flow rate if necessary.

k) After HNO_3 has drained, rinse column with 5-10 ml 1.2 M HCl (do not exceed 10 ml) and rinse outside of stem of column with 1 2 M HCl. Drain at same rate as HNO_3.

l) Place clean 50 ml beaker labelled with sample number under column

m) Elute plutonium with 50 ml 1 2 M HCl containing 1 ml 30% H_2O_2. Eluent flow rate should be 3 ml/min (1 drop/2 sec). Prepare eluent freshly before use.

n) Flow rate may decrease due to expansion of the resin. It need not be readjusted unless it stops altogether.

Purification of Plutonium-236 Standard

1. Prepare a solution of the plutonium-236 in 50-ml of 6M hydrochloric acid. If the plutonium is initially in 6M hydrochloric acid and has a greater volume, evaporate to 50-ml.

2 Add an equal volume of concentrated hydrochloric acid to adjust the solution to a 9M acid concentration. Add 10 drops of 30% hydrogen peroxide, cover the beaker with a watch glass and heat between 80 and 90°C for 1 hour. Allow to cool.

3. Prepare an ion exchange column as described in Ion Exchange Separation of Plutonium Equilibrate with 9M HCl.

4. Pour the plutonium solution into the reservoir and rinse the beaker with 9M hydrochloric acid. Adjust the flow rate to 1 drop/2 seconds (3-ml/min).

5. When the solution has passed through the column, rinse down the sides of the reservoir with about 15-ml of 9M hydrochloric acid and allow to drain. Repeat the rinse two times with 15-ml portions of 9M hydrochloric acid.

6. Add 75-ml of 9M hydrochloric acid and allow this to drain at the same rate to assure the removal of thorium from the resin.

7. Mix 15-ml of freshly prepared 1M ammonium iodide with 45-ml of concentrated hydrochloric acid and use this to elute the plutonium at a flow rate of 3-ml/min. Collect the plutonium-containing eluate in a 150-ml beaker.

8. Add 15-ml of concentrated nitric acid to the eluate and evaporate to dryness.

9. Dissolve the residue in 6M hydrochloric acid and dilute the solution to approximately 200 pCi/ml with 6M hydrochloric acid.

10. The uranium-232 may be recovered from the resin for use as a tracer standard by washing the resin with 50-ml of 9M hydrochloric acid and then eluting with 100-ml of 1.2M hydrochloric acid.

Standardization of Plutonium-236 Tracer

1) Make a dilution of the 200 pCi/ml stock ^{236}Pu solution in 6M HCl to yield an activity of approximately 5 pCi/100 ul.

2) In each of four clean glass weighing bottles, weigh a 100 ul aliquot of the standard ^{239}Pu solution.

3) Add a 100 ul aliquot of the diluted ^{236}Pu solution to each bottle.

4) Wash down the walls of the weighing bottles with 1.2M HCl. Add 1 ml 30% H_2O_2 to each bottle. Let sit at least 30 min.

5) Quantitatively transfer the contents of the weighing bottles to four 50 ml beakers with 1 2M HCl.

6) Add 20 drops conc H_2SO_4 to each beaker, evaporate to fumes of SO_3, plate as usual.

7) Information to be supplied to counting facility date of purification of ^{236}Pu tracer, date of dilution, aliquot of ^{236}Pu solution, weight of ^{239}Pu solution, specific activity of ^{239}Pu solution, date plated

Polishing Planchets for Plutonium

1) 3/4" diameter stainless steel flat planchets are used for the electrodeposition of plutonium.

2) Preliminary polishing.

   a) Because of the stamping process by which they are manufactured, the circular planchets have a rough burr on the outside rim on one side. Sort the planchets to be polished so that the rough side is up.

   b) The planchets will be polished in two stages· first with lavigated alumina, second with Beuhler AB polishing alumina.

   c) Put the canvas lap on the polishing wheel which has been used for lavigated alumina. Be sure that it is stretched tightly over the surface of the wheel and that the retaining ring does not protrude above the edge of the wheel.

   d) Use a 5% slurry of lavigated alumina in deionized water in a wash bottle.

   e) Turn the wheel on to high speed Be sure the drain is over the sink. Wet the wheel thoroughly with deionized water. Then add a 5-10 ml portion of the well mixed polishing slurry to the center of the wheel.

   f) Using a #2 rubber stopper and masking tape, affix the back of an unpolished planchet (the side without the burr) to the rubber stopper.

   g) Using a circular motion, apply the burred edge of the planchet to the outer 1/3 of the wheel. Rotate the planchet around the wheel in the direction opposite the direction of rotation of the wheel. At the same time rotate the wrist so that all of the planchet rim comes in contact with the wheel during the rotation of the planchet around the wheel. Grind the burr off the edge completely by this process.

   h) Then polish the flat surface of the planchet. Rotate the planchet in the direction opposite the wheel's rotation with the flat surface in contact with the wheel. Use the inner third of the wheel surface. The planchet will not have a mirror finish after this preliminary polishing step.

   i) Remove planchet from stopper. Wash thoroughly with water containing detergent to remove polishing compound. Dry on paper towels.

3) Final polishing.

   a) After all planchets have been through preliminary polishing, remove lap from wheel, and replace with lap used with AB alumina.

   b) Attach planchet to stopper as before. Turn on wheel, wet lap thoroughly with water and add diluted AB alumina slurry to center of wheel.

c) Polish flat surface of planchet as before, but continue polishing until a mirror finish is obtained.

4) Cleaning planchets.

a) Wash planchets thoroughly with detergent. Be sure to remove all polishing compound and adhesive from masking tape.

b) Rinse well with deionized water.

c) Wash with acetone, decant; rinse with deionized water.

d) Cover planchets with 25% v/v HNO_3. Cover beaker with a watch glass. Bring acid to a boil and boil planchets 5 min. Remove from heat. Cool to room temperature.

e) Rinse planchets thoroughly with deionized water to remove all acid. Store planchets under deionized water and covered with a watch glass.

Electrodeposition of Plutonium

1) Preparation of sample.

   a) To eluate from ion exchange column, cautiously add 20 drops of conc H_2SO_4.

   b) Evaporate to SO_3 fumes over low heat Remove from heat and cool.

   c) Add 3ml water to beaker, cover with a watch glass.

   d) Heat until water refluxes off watch glass. Avoid boiling. Remove from heat and cool.

2) Construction of electrodeposition cell.

   a) Punch a hole 3/4" dia in the bottom of a plastic scintillation vial, using a cork borer.

   b) Soak vials in strong chromic acid cleaning solution 3 hours or longer.

   c) Rinse with water, soak vials in 25% v/v HNO_3 for 1 hour or longer.

   d) Rinse vial with water.

   e) With forceps remove a polished 3/4" planchet from the water in which the planchets are stored. Place the planchet, polished side up, on the fingers of the left hand.

   f) Hold the clean vial, threaded end down, above the planchet. Lower the vial over the planchet and apply a vacuum to the end of the vial with the hole.* Center the planchet over the mouth of the vial. Screw on a perforated cap fitted with a rivet while maintaining the planchet in position by the application of vacuum. Screw the cap on tightly.

   g) Add water to the vial until it is 1/3 full. Apply vacuum again. If no large bubbles rise, there is no leak. If there is a leak, empty the water from the vial and reconstruct the cell.

   h) Fill cell with water.

3) Electrodeposition using Eberbach plater.

   a) Add 3-5 drops thymol blue indicator to sample solution.

   b) Neutralize solution to yellow endpoint by dropwise addition of conc NH_4OH.

   c) Empty cell, place rivet of cell in cell holder so cell is standing upright.

* The apparatus for applying the vacuum consists of a side-arm flask equipped with one-hole stopper, to which is attached a two-hole stopper by means of a length of tubing. The vacuum can be applied and released simply by covering the second hole in the rubber stopper when the stopper is placed over the hole in the vial.

d) Quantitatively transfer sample solution to cell, use a total of 6 ml 0.18 M H_2SO_4 to rinse the beaker three times, using 2 ml each time. Add rinses to cell.

e) Neutralize solution in cell to true orange endpoint by blowing gaseous NH_3 over the solution and swirling (solution should have a slight pink color when viewed through the side of the cell).*

f) Set cell in cell holder, tighten shaft lock to hold rivet tightly.

g) Rinse platinum-iridium electrodes with water, dry upper ends. Insert in positive electrode holders.

h) Insert cathode in cell and swing support shelf out so that it is under cell holder. Push cell assembly back so that bottom of cathode can be viewed through cell wall.

i) Position cathode so perforated bottom plate is about 3/16" above shoulder of cell. Then position cell so that cathode is centered laterally. Repeat steps a) through i) for second sample.

j) Turn on power switch. Initially current should read about 0.8 amp and DC power should read no more than 8-8.5V. Current will increase as electrolyte warms during plating. After about 30 min the current should level off at 1.2 amp.

k) Continue electroplating for a total of 1 hour 15 min.

l) Neutralize plating solution with 10 ml 1 9 NH_4OH. Continue plating for 30-60 sec.

m) Without turning power off, remove cathode from cell, remove cell from cell holder. Discard electrolyte. Rinse cell three times with cell rinse solution, then three times with ethanol. Discard washes.

n) Disassemble cell. Discard vial. Remove planchet with forceps and dry by letting liquid drain on a paper towel. Place planchet in cupped planchet marked with sample number. Place cupped planchet in disposable plastic petri dish marked with all sample information. Discard rivet.

o) Repeat steps l) through n) with second cell. Turn off power after removing second cathode from cell.

p) Heat cupped planchets containing flat planchets on hot plate for 2-5 min. Let cool and place back in petri dishes.

q) Deliver to counting facility.

* If orange endpoint is passed, add 1.8 M H_2SO_4 dropwise to return the solution to the proper pH.

Internal Letter

Rockwell International

Date November 22, 1978

TO C. T. Illsley
Address

FROM M. W. Hume
Address Statistics Laboratory
Building 881
Phone 4701

Subject COMPARISON OF AIR SAMPLER STATIONS

Statistical analyses were performed on monthly plutonium in air concentration data collected from 27 different air sampler stations. The data were collected from November 1976 through July 1978. The air sampler stations were located on or outside but within two miles of the perimeter of the Rocky Flats Plant buffer zone. These stations are denoted as S-31 through S-47, S-52, S-57, S-58, S-59, and S-63 through S-68. The nine stations denoted S-45, S-46, S-47, and S-63 through S-68 were installed to collect data for pending litigation. Two of these stations are analyzed by an independent laboratory. The remaining eighteen stations are part of the continuing Rocky Flats Plant monitoring program.

The data indicate no significant differences between the twenty-seven stations as a group. Likewise, there is no significant difference between the nine litigation stations as compared to the remaining eighteen. The two litigation stations analyzed by the independent laboratory do not differ from the other stations.

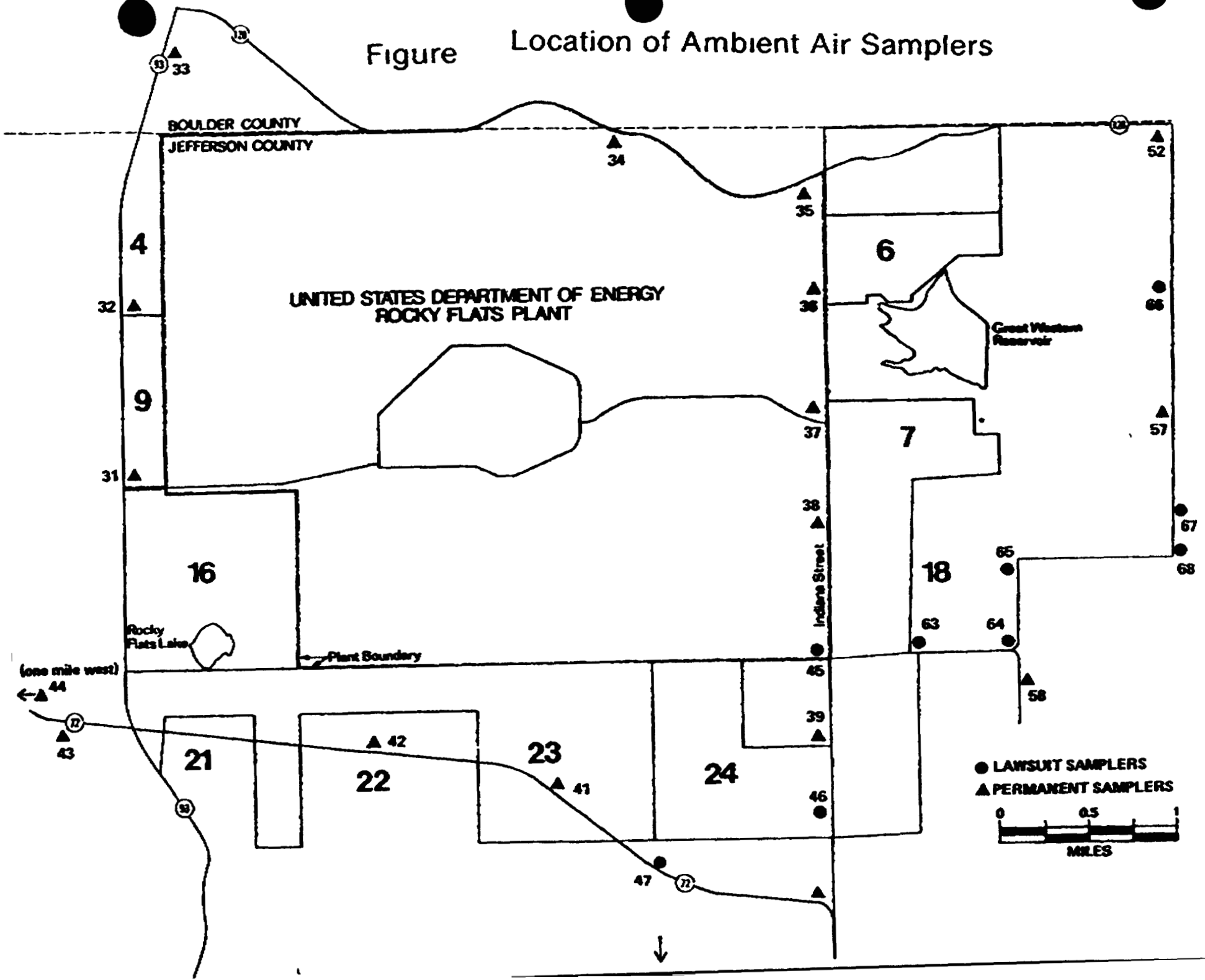
It is concluded that the nine sampler stations installed for litigation do not yield information not provided by the routine Rocky Flats monitoring stations and hence should be discontinued. Moreover, the need for all of the stations included in the routine monitoring program should be investigated.

M. W. Hume

MWH:sas

cc:
R. N. Chanda

Figure Location of Ambient Air Samplers



AIR SAMPLE STATIONS (Pu CONC. IN μCi/mlx10^{-15} #36

Date	S-35	S-36	S-37	S-38	S-39	S-40	#38
NOV 76	0.037	0.051	0.049	0.036	0.025	0.034	#39
DEC 76	0.006	0.008	0.022	0.006	0.005	0.010	#40
JAN 77	0.007	0.014	0.024	0.008	0.010	0.025	#41
FEB 77	0.008	0.009	0.012	0.007	0.007	0.012	#42
MAR 77	0.015	0.020	0.017	0.015	0.014	0.020	#43
APR 77	0.017	0.025	0.023	0.015	0.023	0.023	#44
MAY 77	0.055	0.061	0.049	0.056	0.069	0.060	#45
JUN 77	0.045	0.056	0.063	0.051	0.058	0.055	#46
JUL 77	0.04	0.05	0.05	0.04	0.07	0.04	#47
AUG 77	0.05	0.05	0.06	0.04	0.04	0.04	#48
SEP 77	0.03	0.07	0.04	0.03	0.04	0.04	#49
OCT 77	0.07	0.05	0.09	0.06	0.07	0.07	#50
NOV 77	0.03	0.03	0.04	0.03	0.03	0.03	#51
DEC 77	0.03	0.04	0.06	0.03	0.03	0.04	#52
JAN 78	0.03	0.04	0.04	0.03	0.04	0.04	#53
FEB 78	0.05	0.06	0.05	0.04	0.06	0.06	#54
MAR 78	0.18	0.23	0.15	0.15	0.19	0.28	#55
APR 78	0.14	0.17	0.21	0.08	0.17	0.14	#56
MAY 78	0.07	0.08	0.08	0.06	0.06	0.08	#57
JUN 78	0.05	0.06	0.04	0.07	0.04	0.07	#58
JUL 78	0.05	0.03	0.05	0.04	0.05	0.06	#59

AIR SAMPLE STATIONS (Pu CONC. IN μCi/mlx10^{-15} #62

Date	S-41	S-42	S-43	S-66	S-67	S-68	#64
NOV 76	0.027	0.028	0.020	0.02	0.04	0.03	#65
DEC 76	0.005	0.005	0.009	0.02	0.01	.01	#66
JAN 77	0.004	0.008	0.008	0.01	0.02	0.02	#67
FEB 77	0.007	0.009	0.010	0.03	0.01	0.04	#68
MAR 77	0.016	0.015	0.020	0.02	0.02	0.02	#69
APR 77	0.022	0.024	0.025	0.02	0.02	0.02	#70
MAY 77	0.069	0.211	0.067	0.06	0.05	0.06	#71
JUN 77	0.055	0.050	0.054	0.05	0.05	0.04	#72
JUL 77	0.04	0.05	0.04	0.05	0.04	0.05	#73
AUG 77	0.05	0.05	0.03	0.04	0.04	0.04	#74
SEP 77	0.04	0.05	0.06	0.08	0.06	0.04	#75
OCT 77	0.06	0.09	0.05	0.04	0.04	0.04	#76
NOV 77	0.04	0.04	0.03	0.04	0.05	0.04	#77
DEC 77	0.03	0.03	0.04	0.04	0.04	0.04	#78
JAN 78	0.04	0.05	0.04	0.04	0.02	0.11	#79
FEB 78	0.06	0.04	0.05	0.05	0.07	0.06	#80
MAR 78	0.26	0.17	0.23	0.34	0.29	0.28	#81
APR 78	0.22	0.15	0.09	0.16	0.13	0.04	#82
MAY 78	0.09	0.12	0.11	0.11	0.09	0.12	#83
JUN 78	0.08	0.06	0.07	0.07	0.09	0.06	#84
JUL 78	0.07	0.09	0.05	0.05	0.12	0.09	#85
AUG 78				0.05	0.06	0.06	#86

AIR SAMPLE STATIONS (Pu CONC. IN μCi/mlx10^{-15} #89

Date	S-34	S-49	S-52 JEFFCO	S-57 WALNUT	S-58 WAGNER	S-59 LEYDEN	#91 #92
NOV 76	0.028	0.037	0.019	0.017	0.017	0.022	#94
DEC 76	0.005	0.007	0.011	0.008	0.010	0.007	#95
JAN 77	0.010	0.006	0.005	0.005	0.009	0.004	#96
FEB 77	0.008	0.009	0.007	0.006	0.011	0.009	#97
MAR 77	0.017	0.016	0.016	0.017	0.019	0.010	#98
APR 77	0.022	0.027	0.023	0.024	0.020	0.021	#99
MAY 77	0.060	0.063	0.053	0.064	0.067	0.044	#100
JUN 77	0.043	0.058	0.059	0.055	0.055	0.037	#101
JUL 77	0.04	0.04	0.05	0.02	0.04	0.03	#102
AUG 77	0.05	0.01	0.05	0.04	0;04	0.03	#103
SEP 77	0.04	0.05	0.07	0.03	0.07	0.06	#104
OCT 77	0.09	0.05	0.04	0.07	0.07	0.05	#105
NOV 77	0.03	0.02	0.06	0.05	0.06	0.05	#106
DEC 77	0.04	0.03	0.03	0.03	0.04	0.03	#107
JAN 78	0.04	0.04	0.03	0.04	0.06	0.04	#108
FEB 78	0.05	0.05	0.05	0.03	0.05	0.05	#109
MAR 78	0.19	0.21	0.25	0.15	0.17	0.14	#110
APR 78	0.24	0.11	0.12	0.43	0.09	0.11	#111
MAY 78	0.08	0.08	0.05	0.06	0.12	0.07	#112
JUN 78	0.07	0.05	0.12	0.07	0.06	0.05	#113
JUL 78	0.06	0.09	0.06	0.06	0.06	0.10	#114

AIR SAMPLE STATIONS (Pu CONC. IN $\mu Ci/ml \times 10^{-15}$ #119

Date	S-31	S-32	S-33	
				#121
NOV 76	0.017	0.112	0.031	#122
DEC 76	0.008	0.006	0.003	#123
JAN 77	0.006	0.005	0.006	#124
FEB 77	0.010	0.005	0.008	#125
MAR 77	0.016	0.015	0.014	#126
APR 77	0.020	0.019	0.021	#127
MAY 77	0.059	0.050	0.059	#128
JUN 77	0.206	0.053	0.048	#129
JUL 77	0.06	0.06	0.04	#130
AUG 77	0.05	0.04	0.04	#131
SEP 77	0.06	0.05	0.04	#132
OCT 77	0.09	0.06	0.07	#133
NOV 77	0.03	0.03	0.04	#134
DEC 77	0.04	0.03	0.04	#135
JAN 78	0.07	0.03	0.03	#136
FEB 78	0.07	0.04	0.04	#137
MAR 78	0.08	0.16	0.17	#138
APR 78	0.19	0.11	0.16	#139
MAY 78	0.12	0.09	0.07	#140
JUN 78	0.06	0.09	0.16	#141
JUL 78	0.05	0.04	0.07	#142

DOCUMENT D-7

"Plutonium Concentrations in Soil on Lands
Adjacent to the Rocky Flats Plant"
(1979)

by

C T Illsley and M W Hume
Rockwell International

PLUTONIUM CONCENTRATIONS IN SOIL ON LANDS ADJACENT TO THE ROCKY FLATS PLANT

LPR - 1

C. T. ILLSLEY AND M. W HUME

MARCH 16, 1979

ROCKWELL INTERNATIONAL
ENERGY SYSTEMS GROUP
ROCKY FLATS PLANT

PLUTONIUM CONCENTRATIONS IN SOIL ON LANDS ADJACENT TO THE ROCKY FLATS PLANT

Introduction

Litigation proceedings were initiated against the Rocky Flats Plant claiming radionuclide depositions from the Plant on lands adjacent to the Plant caused the lands to be unfit for human habitation and use. To answer these claims, extensive soil and air sampling projects were conducted in 1976 and 1977. The procedures used in these projects and the results obtained were presented to the U S District Court, Denver, Colorado. Summary soil sample results are included in this document Complete details concerning the litigation program are available At the request of local landowners, a supplemental soil sample program was initiated in the summer of 1978 to characterize plutonium concentrations on other lands adjacent to the Rocky Flats Plant.

The number of sample sites per parcel of land was determined from a statistical evaluation of existing plutonium in soil data. A complete description of the procedures used is recorded in the transcript of "Hearings on Soil Sampling" held in U S District Court, Denver, Colorado, 1977 (Civil Action Numbers 75-M-1111, 75-M-1162, and 75-M-1296)

The locations of seventy-one (71) soil sample sites were surveyed by a professional surveyor, marked on the ground and plotted on a topographic quadrangle map showing the land parcels. Soil samples were collected by Eberline Instrument Corporation by an approved collection technique. Five sub-samples were composited into one sample at each site. Eberline made preliminary sample preparation and delivered the samples to an independent escrow agent.

Sample batches were prepared by an independent escrow agent. Each batch contained blanks, synthetic standards, consensus standards, field samples and replicate field samples. The escrow agent provided a coded numbering system which made the various sample types indistinguishable from one another. The escrow agent submitted sample batches to Eberline, LFE and LASL laboratories for analysis.

The radiochemical procedure used for the determination of plutonium is a modification of the U.S. Nuclear Regulatory Commission Regulatory Guide 4 5 "Measurements Of Radionuclides In The Environment—Sampling and Analysis Of Plutonium In The Soil." The modified version of this procedure is part of the record in the hearings mentioned above

The analytical data were reported to the escrow agent who decoded the sample numbers. After all analyses were completed, the analytical data were forwarded to the project management.

SAMPLE COLLECTION

Sample Site Locations

The 71 sample sites, shown on Figure 1, were located, staked, and marked on the ground by a professional licensed surveyor and crew from Drexel, Barrell and Company, Boulder, Colorado. It was necessary to deviate slightly from the indicated map sites because of the location of roads, fences and bodies of water. Each actual site, however, was accurately plotted on a map and the coordinates recorded by the surveyor. These alternate sites were selected by the project manager and the sampling crew chief.

Sample sites were marked on the ground by procedures to be described later The sample sites were marked with a red capped stake showing map location and site number. These sites were considered as the centers of 10 meter diameter areas for sample collection. The site markers were all removed at the conclusion of sampling

Color photographs were obtained at each sampl site to verify the site number and to depict general topography, surface conditions and type and condition of vegetation.

SURVEYING PROCEDURES

Using the section lines of the respective sections, reference points were staked 50 feet due west of sample sites. Two reference points per sample site were used when possible livestock or farming activities might disturb the reference point. Numerical identification of reference points was used, inclusive for each section. Care was taken to insure that each test site remained undisturbed by vehicular or pedestrian traffic. Surveying and sampling were coordinated so that no more actual sites were located and surveyed than were to be sampled on that particular day

GENERAL SAMPLING PROCEDURES

Soil samples were collected at each site by a technician under direct professional supervision. The technician had received prior training in the soil collection technique utilized A description of this technique, which utilizes a 10 X 10 X 5 cm jig, is given in the Court record of Soil Hearings and also in the Rocky Flats Annual Environmental Monitoring Reports

The plan of operation at each soil sample site was identical and details were recorded in a log book Samples were collected 0.3 meters north of the site marker and at a distance of 5 meters from the site center at the four cardinal points. These 5 samples were composited in one new one gallon paint can

The sample collection log book contains the following information:

(a) Sample number

(b) Sample location

(c) Date of collection

(d) Name of collector

(e) Weather conditions

(f) Soil type

(g) Vegetation

(h) Degree and direction of slope

(i) Soil moisture

(j) Any special conditions

SOIL COLLECTION PROCEDURE

Field Procedure

One composite soil sample was collected at each site. This composite consisted of five samples 5 centimeters deep. Each sub-sample was taken using a sample jig which outlines an area 10 by 10 centimeters square. The jig was driven into the ground to a depth of 5 centimeters and a scoop was used to remove the soil from inside the jig cavity

The five surface samples were composited in a new one gallon metal paint can and the lid was sealed with melted sealing wax The sample container was labeled with sample number, sample location, date and signature of collector

Laboratory Procedure

Prior to radiochemical analysis, each soil sample was placed in a clean metal pan and oven dried at 110°C. After drying, the samples were weighed The sample was then sieved through a 10 mesh screen Oversize material was weighed and discarded The fine material was weighed and returned to the original sample can The can was rotated on a ball mill (without balls) at 120 rpm for 30 minutes. The sample was then coned and quartered and split into two equal fractions. One fraction was transferred to a new can and labelled with the sample number This material is held as reserve sample. The other soil fraction was returned to the original sample can.

Ten 1-inch steel grinding balls were placed in each sample can and the can was rotated on a ball mill at 120 rpm for at least 4 hours One hundred gram aliquots of the homogeneous fine powder were transferred to plastic bottles and labelled.

All sample aliquots were delivered to the independent escrow agent who prepared ten gram aliquots for radiochemical analysis The escrow agent submitted batches of 23 "unknowns" to the laboratories. Each batch included field samples, replicate field samples, synthetic standards, consensus standards and blanks.

ANALYSIS OF SOIL FOR PLUTONIUM

All soil samples were analyzed for plutonium 239 plus 240 and plutonium 238 by a radiochemical procedure using alpha particle counting The method of analysis was that specified in NRC Regulatory Guide 4 5 as modified. An isotopic tracer (plutonium 236) was added to each sample before dissolution to determine chemical recovery in the separation procedure. Recoveries determined as less than 50% required sample re-analysis. Plutonium was isolated, purified, electrodeposited onto a metal planchet and analyzed by alpha spectrometry Results were reported as disintegrations per minute 239-240 Pu and 238 Pu per gram of soil

QUALITY CONTROL

The goal of the quality plan was to assure that data having the highest attainable precision and accuracy was obtained in the investigation. This goal required planned control of all project elements having impact on the integrity of the data

It was the responsibility of the Rockwell sub-contractors to prepare and utilize complete quality assurance and quality control programs. These programs were reviewed and approved by the Rockwell project manager.

All activities at the sample sites were conducted in a manner to prevent damage to the land and to protect the integrity of the samples Procedures were prepared and followed for maintaining chain of custody of samples from collection, through analysis and finally storage.

Sample identification was required to permit traceability of each sample and its related data from the map site through sample collection, analysis, and reporting. The quality plan included procedures for sample identification and certification. In order to further blind all samples, an independent escrow agent re-numbered all samples from a list of computer derived random numbers.

The integrity of all samples was maintained during sample collection, packaging, shipping, storage, preparation and laboratory processing. Samples were protected to avoid alteration of the chemical composition or other characteristics through contamination or alteration of the sample.

All equipment used for sample site location, sample collection and sample analysis was checked out and calibrated and maintained with records of all such activities kept in permanent log books. Certified standards were used for all calibrations.

The 236 Pu isotopic tracer used for recovery determinations was standardized against a National Bureau of Standards standard source. The tracer had a 238 Pu impurity less than 0.5% alpha activity and a 239 Pu impurity less than 0 1% alpha activity.

All standards used in the radiochemical procedures are traceable to National Bureau of Standards standards. Radiometric standards were used to determine alpha counter geometry factors.

Primary analyses were performed by the Eberline Instrument Corporation (EIC), Albuquerque, New Mexico Quality control analyses were performed by LFE Environmental Analysis Laboratories (LFE), Richmond, California and Los Alamos Scientific Laboratory (LASL), New Mexico.

All three laboratories routinely participate in inter-laboratory cross-check programs conducted by EPA and DOE organizations The results of these inter-laboratory collaborative programs are published by the sponsoring agency.

ANALYTICAL RESULTS

The results of analyses for plutonium in the 71 soil samples collected in September, 1978 on lands adjacent to the Rocky Flats Plant are presented in Tables I and II and are shown at the actual sample sites on Figures 2 and 3. Summaries of the soil data are given in Tables III and IV. It should be noted that Figures 2 and 3 also include data obtained for the Rocky Flats land litigation. Concentrations of americium in these soil samples have been determined and are available upon special request.

Figure 2 gives the plutonium 239 and 240 concentrations in units of disintegrations per minute per gram of soil (size fraction less than 10 mesh). Figure 3 gives the same data converted to units of millicuries per square kilometer. This conversion was performed by multiplying d/m/g by gram weight of fines (<10 mesh) and dividing by the sample area (500 cm^2). Changing units also required an ~~additional divisor of 111~~. multiplier of 4.5.

Table I presents all the analytical data as reported, including all replicate analyses. The data are segregated into the various land parcels, i.e., sections 4, 6, 7, 19 and 24. In column 3 of Tables I and II, an assigned value is given for each sample site. This value was determined by taking the average of all the reported analyses for each sample. The plutonium concentrations in units of millicuries per square kilometer (m Ci/km^2) are given in column 4 of Tables I and II.

Table II presents the same data as Table I, except they are listed by landowner.

Tables III and IV present listings of the data arranged by land sections. Included in the tables are number of sites per section, the two highest values, the two lowest values and the median for each section or portion of a section.

RESULTS OF LABORATORY QUALITY CONTROL

Samples arrived at each laboratory in groups of approximately twenty which constituted a batch to be processed as a unit The primary laboratory received five batches and the quality control laboratories one apiece. Each batch consisted of field samples, replicate field samples, blanks consensus standards, and synthetic standards. All samples were indistinguishable but for their numeric code known only by the escrow agent. Each batch contained six quality control samples, two each randomly selected from blanks, synthetic standards, and consensus standards The analytical results for these are given in Table V. More than six such samples appear in Eberline batches due to subsequent reruns of field samples necessitated primarily by low tracer recoveries. These quality control efforts were tailored after the quality control program used in the aforementioned litigation.

The quality control sample results of Table V demonstrate agreement within and between the primary and control laboratories The relative few discrepancies do not warrant the cost of resolution. The results for the two synthetic standards compare with their fabricated values of 4 2 and 12 2. The results from the three consensus standards compare with the results 1.2, 5.2, and 0.5 which were established with extensive analyses in the sister litigation program.

All analyses of field samples including replicates are given in Table I. These results also demonstrate agreement within and between the primary and control laboratories. Moreover, these results are consistent with the results for adjacent land parcels studied in the sister litigation program. These combined results are depicted in Figures 2 and 3. Due to the complexities of sampling and analytical procedures, any single result may not be entirely indicative of actual plutonium deposition. A good estimate which does indeed characterize a land parcel is obtained by assessing numerous adjacent sites Such values are the medians presented in Tables III & IV.

EVALUATION OF RESULTS

The analytical results for samples of soil from lands west and south of the Rocky Flats Plant indicate low concentrations of plutonium. In Section 4 the range is from 0.11 to 0.19 d/m/g (1-3 mCi/km^2) with a median of 0.13 d/m/g (2 mCi/km^2). The soil in Section 9 contains plutonium in the range between 0.05 and 0.22 d/m/g (1-2 mCi/km^2) and the median is 0.12 d/m/g (2 mCi/km^2). In Sections 21 and 22 the plutonium varies from 0.05 to 0.61 d/m/g (1-3 mCi/km^2), with a median of 0.15 d/m/g (2 mCi/km^2). Section 23 includes soils containing plutonium in the range from 0.03 to 0.28 d/m/g (1-6 mCi/km^2) and the median is 0.10 d/m/g (2 mCi/km^2). Section 24 viewed as whole shows plutonium levels between 0.02 and 0.39 d/m/g (0-6 mCi/km^2) with a median of 0.04 d/m/g (1 mCi/km^2). This section was also subdivided into two parcels, the northeast quarter section and the remainder of the section. The plutonium values for the quarter section fall in the range from 0.02 to 0.11 d/m/g (0-3 mCi/km^2), with a median of 0.04 d/m/g (1 mCi/km^2). The remainder of the section shows levels from 0.02 to 0.39 d/m/g (0-6 mCi/km^2) and the median value is 0.07 d/m/g (2 mCi/km^2). It should be recognized from Table IV that the values in millicuries per square kilometer were rounded to the nearest whole number. Values less than 0.5 are indicated as 0 mCi/km^2.

In summary, there are no plutonium concentrations in soil from Sections 4, 9, 21, 22, 23 and 24 greater than the Colorado Guideline of 2 d/m/g. Likewise, the analytical results show that there are no levels in these sections greater than the EPA Proposed Guideline of 200 mCi/km^2.

Samples of soil from Section 18 contain plutonium in the range between 0.14 and 2.0 d/m/g (2-38 mCi/km^2) with a median of 0.7 d/m/g (10 mCi/km^2). One sample with a concentration of 2.0 d/m/g is thus equal to the State Guideline but does not exceed it or the EPA Guideline.

Section 7 was sampled at 23 sites. The results show plutonium levels from 0.28 to 7.6 d/m/g (6-118 mCi/km^2) with a median of 1.4 d/m/g (29 mCi/km^2). Considering the south half of the section, the range of values is 0.39 to 2.5 d/m/g (9-60 mCi/km^2) with the median value at 1.4 d/m/g (29 mCi/km^2). There is therefore one sample in this half section with a plutonium concentration of 2.5 d/m/g (60 mCi/km^2) which exceeds the Colorado Guideline but not that of the EPA. Since the median characterizes the parcel more completely than an individual sample, it is proposed that the half section should be evaluated on the basis of the median value of 1.4 d/m/g (29 mCi/km^2).

The north half of Section 7 shows plutonium concentrations between 0.28 and 7.6 d/m/g (6-118 mCi/km^2) with a median of 1.4 d/m/g (23 mCi/km^2). Two samples produced results greater than the Colorado Guideline, but less than the EPA Proposed Guidance. The same argument for considering the median of 1.4 d/m/g (29 mCi/km^2) should be applicable in this land parcel.

Soil samples were collected at 20 locations in Section 6. The results as summarized in Table IV, show plutonium concentrations in the range between 0.05 and 3.2 d/m/g (1-79 mCi/km^2) with a median of 0.11 d/m/g (2 mCi/km^2). The north half section had 15 samples and the plutonium concentrations fell in the range from

0 05 and 0 34 d/m/g (1-6 mCi/km^2) with a median of 0 11 d/m/g (2 mCi/km^2) These values are below both the Colorado Guideline and the EPA Guidance The south half section produced plutonium concentrations in the range from 0 07 to 3 2 d/m/g (1-79 mCi/km^2) and the median is 1 1 d/m/g (24 mCi/km^2) One sample contained a level of plutonium greater than the Colorado Guideline but less than the EPA Guideline The median value which characterizes the half section is only 1 4 d/m/g and is less than the guideline

The data on plutonium concentrations in soil and air samples collected from lands involved in litigation have been evaluated by the Inhalation Toxicology Research Institute in Albuquerque, New Mexico A report entitled "Defendant's Analysis Of Health Risks" has been submitted as an exhibit to U S. District Court in Denver, Colorado. The conclusion of this report is as follows·

> Potential radiation doses to people having unrestricted use of lands near the Rocky Flats boundary line have been estimated using different exposure models and different sets of environmental measurements. All of the approaches described above yielded similar results in estimating the radiation doses and in projecting the probabilities for human health injury. The most important risks to people from exposures to plutonium and americium are potential increases in their incidences of lung, bone and liver related cancers The probabilities for deaths due to cancers ranged between 1 and 3 per hundred million persons per year. This level of risk was shown to be small in comparison to the risks from exposures to naturally-occurring radionuclides and other natural background radiations

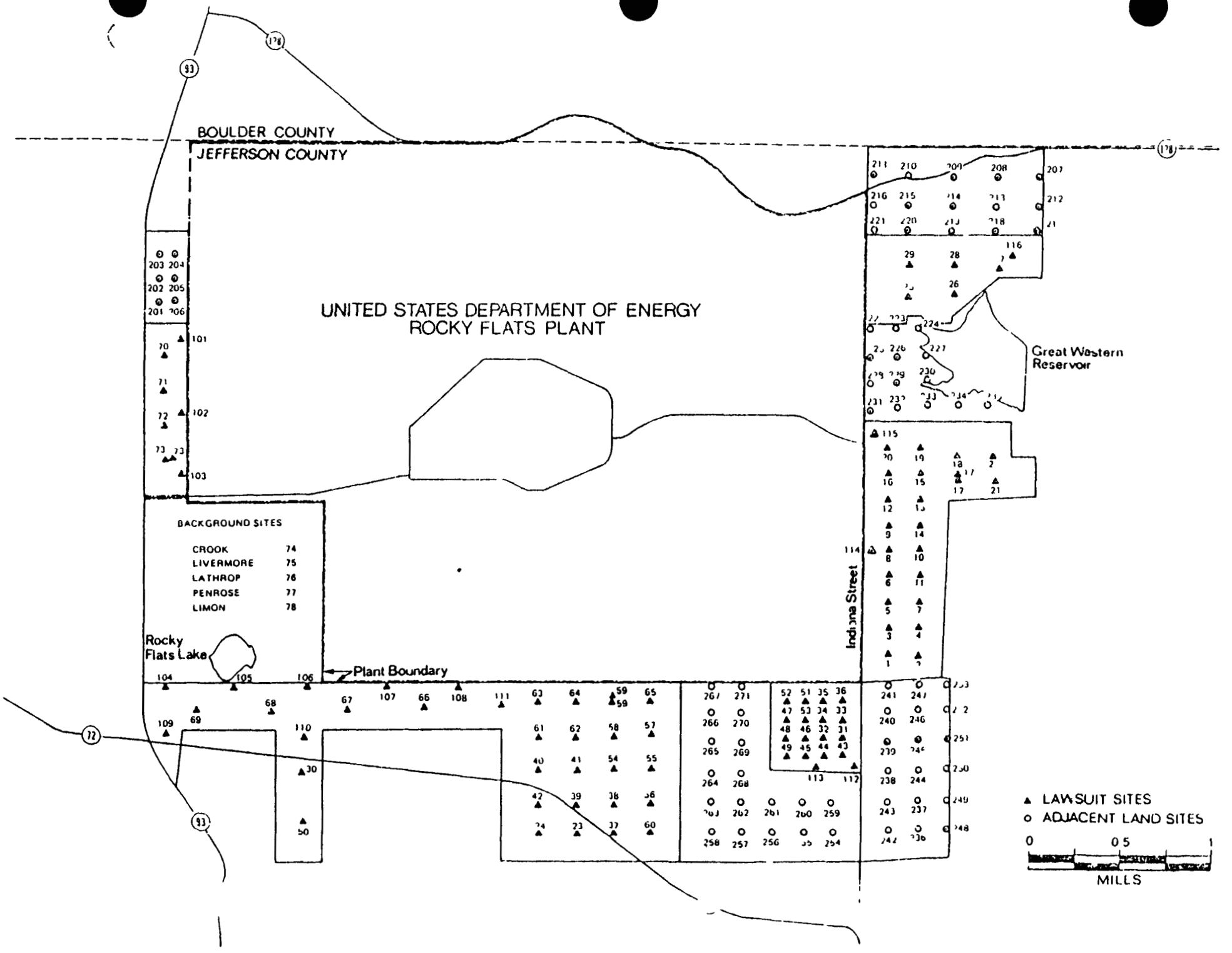

BOULDER COUNTY
JEFFERSON COUNTY
UNITED STATES DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
Great Western Reservoir
Indiana Street
Rocky Flats Lake
Plant Boundary
BACKGROUND SITES
CROOK 74
LIVERMORE 75
LATHROP 76
PENROSE 77
LIMON 78
LAWSUIT SITES
ADJACENT LAND SITES
0 0.5 1
MILES

FIGURE 2 - PLU JIUM CONCENTRATIONS IN SOIL
(d/m/g)

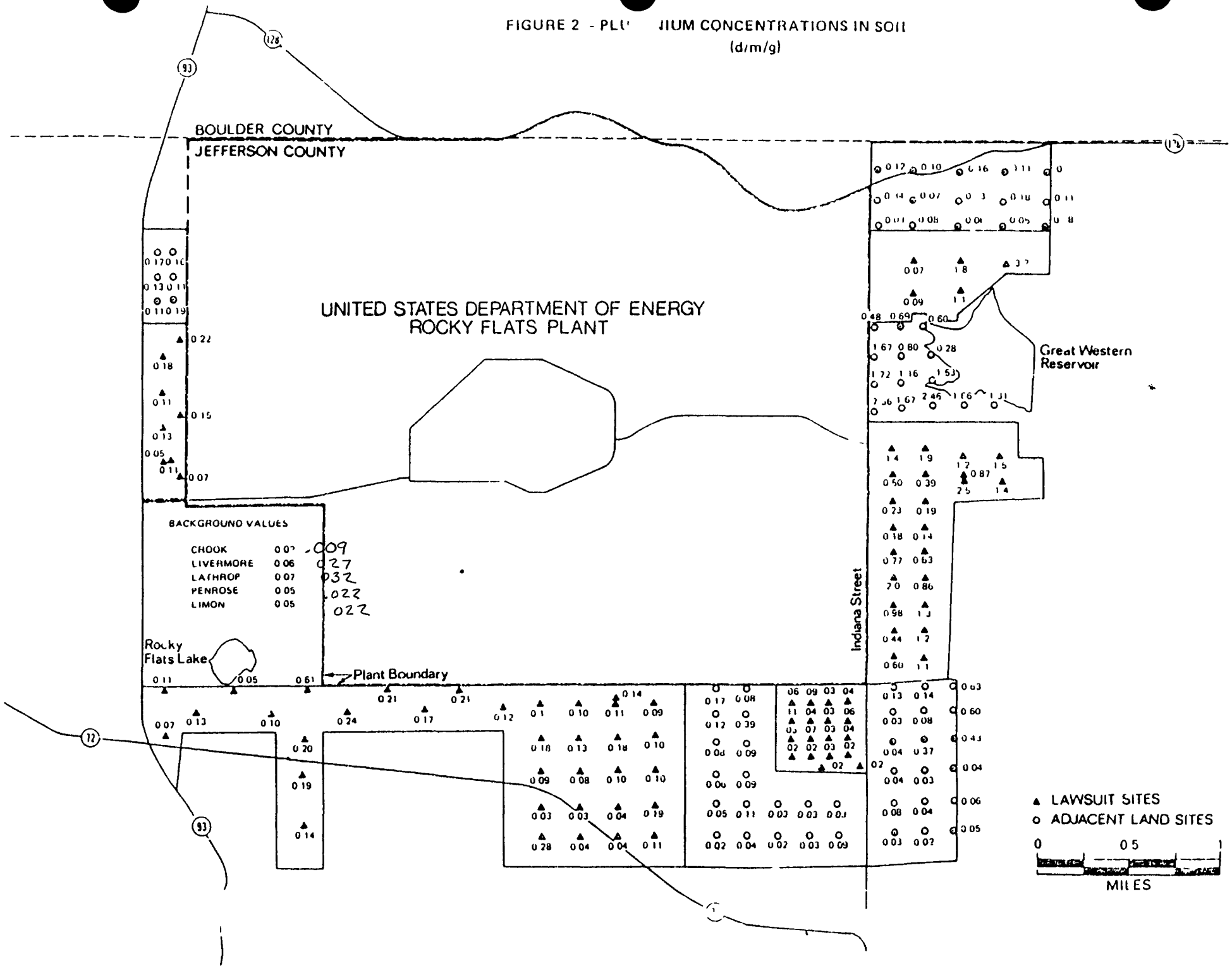


FIGURE 3 – PLUTONIUM CONCENTRATIONS IN SOIL
(mCi/km²)

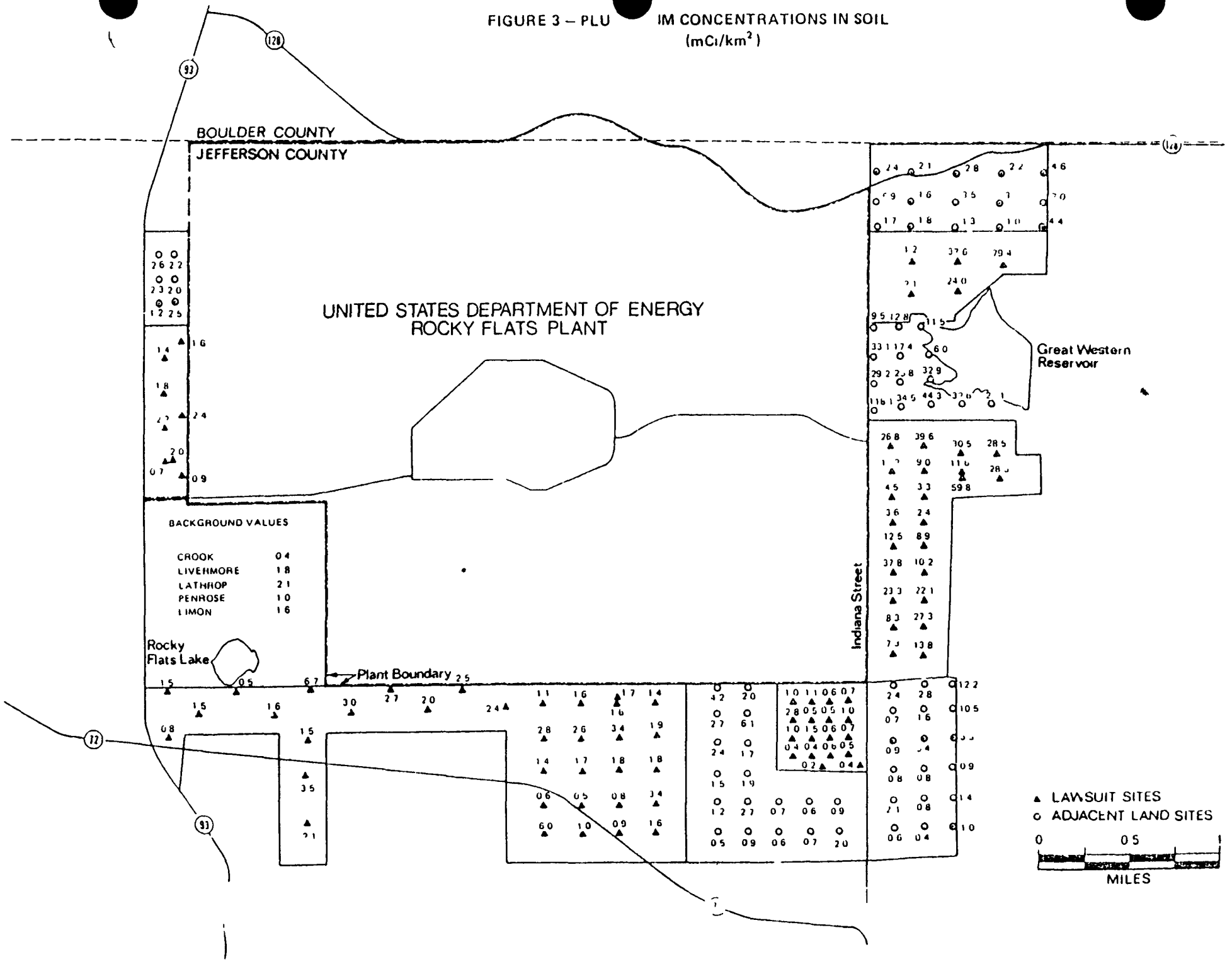


TABLE I

RESULTS OF TESTING FOR

PLUTONIUM CONCENTRATION

IN NEIGHBORING LANDOWNERS' SOIL

LISTED BY SECTION NUMBER

* Designates LASL Results (in d/m/g ± d/m/g error)

** Designates LFE Results (in d/m/g ± % error)

All Others are Eberline Results (in d/m/g ± d/m/g error)

Field Number	Pu-239 Analysis	Site Values d/m/g	mCi/km^2
SECTION 4			
201	0.08 ± 0 02	0 11	1 18
	0 13 + 0 01		
202	0 13 ± 0 02	0 13	2 28
203	0.17 ± 0 02	0.17	2 55
	0 17 ± 0 03		
204	0.14 ± 0 02	0 16	2 24
	0.15 ± 0.01		
	0 24 ± 0.02		
	*0 162 ± 0 02		
	**0.11 ± 37		
205	0.10 ± 0 01	0 11	2 01
	0.12 ± 0.02		
	*0.102 ± 0 01		
	**0.12 ± 8		
206	0.19 ± 0 01	0.19	2 54
SECTION 6			
207	0.20 ± 0.02	0.25	4.58
	0.30 ± 0.02		
208	0.11 ± 0.01	0 11	2.21
209	0.16 ± 0.01	0.16	2.76
210	0.10 ± 0 01	0.10	2.08
	0.09 ± 0.01		
	*0 091 ± 0 01		
	**0 10 ± 9		

211	0 12 ± 0 02	0 12	2 14
212	0 0o ± 0 02	0 11	1 97
	0 16 ± 0 02		
213	0.18 ± 0 02	0.18	3 54
214	0.23 ± 0.02	0.23	3 46
215	0.07 ± 0 01	0 07	1.55
216	0.05 ± 0 04	0 34	5 89
	0.12 ± 0.01		
	0.11 ± 0.02		
	*1 33 ± 0 07		
	**0.10 ± 9		
217	0.35 ± 0.07	0 28	4.45
	0.25 ± 0.02		
	0.25 ± 0.02		
	*0.308 ± 0.02		
	**0.220 ± 6		
218	0.06 ± 0.01	0 05	1.05
	0.04 ± 0.01		
219	0.02 ± 0.01	0.06	1 31
	0.10 ± 0.01		
220	0.08 ± 0.02	0.08	1.76
221	0.09 ± 0.01	0.09	1 71

SECTION 7

222	0.48 ± 0.04	0 48	9.54
223	0 61 ± 0 06	0 69	12 85
	0 76 ± 0.03		

224	0 64 ± 0 07	0 60	11 48
	0.55 ± 0.02		
225	1 54 ± 0.14	1 67	33 06
	1.77 ± 0.08		
	1 89 ± 0.06		
	*1.71 ± 0.07		
	**1.44 ± 5		
226	0.80 ± 0.04	0 80	17 45
227	0.28 ± 0.02	0 28	5 96
228	1 72 ± 0.08	1 72	29 22
229	1.16 ± 0 06	1 16	25.80
230	1 34 ± 0.08	1 53	32.92
	1.58 ± 0.20		
	1.29 ± 0.05		
	*1.53 ± 0.04		
	**1.93 ± 5		
231	10.7 ± 0.5	7.56	118 12
	4.4 ± 0.2		
232	1 67 ± 0.06	1.67	34.51
233	1.86 ± 0.10	2.46	44.28
	2.16 ± 0.12		
	*3.13 ± 0.11		
	**2.67 ± 5		
234	1 66 ± 0.09	1.66	32.59
235	1.31 ± 0.10	1.31	25.13

SECTION 19

236	0.02 ± 0.01	0 02	0.42

237	0 10 ± 0.02	0 04	0 82
	0.03 ± 0.01		
	0 04 ± 0 01		
	*0.016 ± 0.004		
	**0 034 ± 13		
238	0 04 ± 0 02	0 04	0 77
	0 04 ± 0.01		
239	0 04 ± 0 01	0 04	0 92
240	0 01 ± 0 01	0 03	0.73
	0 05 ± 0 01		
241	0.07 ± 0.02	0 13	2 42
	0.18 ± 0 01		
242	0 05 ± 0.02	0.03	0 63
	0.01 ± 0.01		
	0.03 ± 0.01		
	0.02 ± 0 01		
	*0.029 ± 0.007		
	**0.029 ± 18		
243	0 08 ± 0.01	0.08	2.06
244	0.03 ± 0.01	0 03	0.75
245	0.40 ± 0.05	0.37	5.41
	0.33 ± 0.02		
246	0.08 ± 0.02	0.08	1.63
	0 07 ± 0.01		
247	0.14 ± 0.01	0 14	2.84

248	0 05 ± 0.03	0 05	1 00
	0 03 ± 0.01		
	0 06 ± 0 01		
	*0 047 ± 0 007		
	**0 056 ± 13		
249	0 05 ± 0.01	0 06	1 40
	0.06 ± 0.01		
250	0 04 ± 0 01	0.04	0 91
251	0.42 ± 0.04	0.43	5 54
	0.44 ± 0 03		
252	0 45 ± 0 06	0.60	10 49
	0.74 ± 0.07		
253	0.63 ± 0.04	0.63	12.19

SECTION 24

254	0.06 ± 0.02	0.09	2.03
	0.11 ± 0.01		
255	0.03 ± 0.01	0.03	0 74
	0.05 ± 0.01		
	0.03 ± 0.01		
	*0.033 ± 0.007		
	**0.026 ± 17		
256	0.02 ± 0.01	0.02	0.59
257	0.04 ± 0.01	0.04	0.90
258	0.03 ± 0.01	0.02	0.46
	<0 01		
259	0 03 ± 0.01	0 03	0 87

260	0 03 ± 0 01	0 03	0 59
261	0 03 ± 0 01	0 03	0 71
262	0.10 ± 0 02	0 11	2 74
	0.11 ± 0.01		
263	0 05 ± 0.01	0 05	1 18
264	0.07 ± 0.01	0 06	1.46
	0 04 ± 0 01		
265	0.06 ± 0.02	0 08	2.41
	0.08 ± 0.01		
	0.11 ± 0.01		
	*0.078 ± 0.007		
	**0 06 ± 10		
266	0.12 ± 0.02	0.12	2.71
267	0.16 ± 0.02	0.17	4.22
	0.17 ± 0.02		
268	0.10 ± 0.04	0 09	1 89
	0.12 ± 0.02		
	0.07 ± 0.01		
	0.10 ± 0.01		
	*0.082 ± 0.01		
	**0.09 ± 10		
269	0.09 ± 0.01	0.09	1.73
270	0.43 ± 0.06	0.39	6.12
	0.34 ± 0.03		
271	0.07 ± 0.02	0.08	1.96
	0.08 ± 0.01		

TABLE II

RESULTS OF TESTING FOR

PLUTONIUM CONCENTRATION

IN NEIGHBORING LANDOWNERS' SOIL

LISTED BY LANDOWNER

* Designates LASL Results (in d/m/g ± d/m/g error)

** Designates LFE Results (in d/m/g ± % error)

All Others Are Eberline Results (in d/m/g ± d/m/g error)

Field Number	Pu-239 Analysis	Site Values d/m/g	Site Values mCi/km^2
JEFFCO AIR PARK ASSOCIATES, SECTION 6			
207	0.20 ± 0.02	0.25	4.58
	0.30 ± 0.02		
208	0.11 ± 0.01	0.11	2.21
212	0.06 ± 0.02	0.11	1.97
	0.15 ± 0.02		
213	0.13 ± 0.02	0.18	3.54
217	0.35 ± 0.07	0.28	4.45
	0.25 ± 0.02		
	0.25 ± 0.02		
	*0.308 ± 0.02		
	**0.220 ± 6		
218	0.06 ± 0.01	0.05	1.05
	0.04 ± 0.01		
MARGARET I. SANDERS, EXECUTRIX, SECTION 6			
209	0.16 ± 0.01	0.16	2.76
214	0.23 ± 0.02	0.23	3.46
219	0.02 ± 0.01	0.06	1.31
	0.10 ± 0.01		
JOHN H. SHUTTLEWORTH, JR., SECTION 6			
210	0.10 ± 0.01	0.10	2.08
	0.09 ± 0.01		
	*0.001 ± 0.01		
	**0.10 ± 9		

211	0 12 ± 0 02	0 12	2 44
215	0 07 ± 0 01	0 07	1 55
216	0 05 ± 0.04	0 34	5.89
	0.12 ± 0 01		
	0 11 ± 0.02		
	*1 33 ± 0.07		
	**0 10 ± 9		

STEPHEN P & CHERYL A. KAATZ, SECTION 6

220	0 08 ± 0 02	0 08	1 76
221	0.09 ± 0 01	0 09	1.71

CITY OF BROOMFIELD, SECTION 7

222	0 48 ± 0.04	0.48	9.54
223	0.61 ± 0.06	0 69	12.85
	0.76 ± 0.03		
224	0.64 ± 0 07	0.60	11 48
	0.55 ± 0 03		
225	1.54 ± 0.14	1.67	33.06
	1.77 ± 0.08		
	1 89 ± 0.06		
	*1.71 ± 0 07		
	**1.44 ± 5		
226	0.80 ± 0.04	0 80	17.45
227	0 28 ± 0.02	0 28	5 96
228	1 72 ± 0.08	1.72	29 22
229	1 16 ± 0.0o	1.16	25.80

230	1 34 ± 0 08	1 53	32 92
	1 58 ± 0 20		
	1 29 ± 0.05		
	*1 53 ± 0 04		
	**1 93 ± 5		
231	10 7 ± 0 5	7.56	118 12
	4.4 ± 0 2		
232	1.67 ± 0 06	1 67	34.51
233	1.86 ± 0 10	2 46	44.28
	2.16 ± 0 12		
	*3 13 ± 0 11		
	**2 67 ± 5		
234	1.66 ± 0 09	1.66	32.59
235	1.31 ± 0.10	1.31	25.13

AUBREY E. & CORA E. LADWIG, SECTION 19

239	0.04 ± 0.01	0.04	0.92
240	0.01 ± 0.01	0.03	0.73
	0.05 ± 0 01		
241	0.07 ± 0.02	0.13	2.42
	0 18 ± 0 01		
245	0.40 ± 0.05	0.37	5.41
	0.33 ± 0.02		
246	0.08 ± 0.02	0.08	1.63
	0.07 ± 0 01		
247	0.14 ± 0.01	0.14	2 84
	0.42 ± 0 04	0.43	5.54
	0 44 ± 0 03		

232	0 45 ± 0 06	0 60	10 49
	0 74 ± 0 07		
253	0 63 ± 0 04	0.63	12.19

TWIN LAKES JOINT VENTURE, SECTION 19

233	0 04 ± 0.02	0.04	0.77
	0 04 ± 0 01		
243	0 08 ± 0 01	0 08	2.06
242	0 05 ± 0.02	0.03	0 33
	0.01 ± 0.01		
	0 03 ± 0.01		
	0.02 ± 0.01		
	*0.029 ± 0.007		
	**0.029 ± 18		
236	0.02 ± 0.01	0.02	0.42
237	0.10 ± 0.02	0.04	0 82
	0.03 ± 0.01		
	0.04 ± 0.01		
	*0.016 ± 0.004		
	**0.034 ± 13		
244	0.03 ± 0.01	0.03	0 75

ALKIRE INVESTMENT COMPANY, SECTION 19

248	0.05 ± 0.03	0.05	1.00
	0.03 ± 0.01		
	0 06 ± 0.01		
	*0.047 ± 0.007		
	**0.053 ± 13		

249	0 05 ± 0 01	0 06	1 40
	0.03 ± 0 01		
250	0 01 ± 0 01	0.04	0.91

WILLIAM J. FORTUNE & JOHN A FORTUNE, TRUSTEE, SECTION 24

254	0 06 ± 0 02	0 09	2 03
	0.11 ± 0.01		
255	0 03 ± 0.01	0 03	0.74
	0.05 ± 0 01		
	0 03 ± 0 01		
	*0 033 ± 0 007		
	**0 026 ± 17		
256	0.02 ± 0.01	0.02	0.59
257	0.04 ± 0.01	0.04	0.90
258	0.03 ± 0.01	0.02	0.46
	<0.01		
263	0.05 ± 0.01	0.05	1.18
264	0.07 ± 0.01	0.06	1.46
	0.04 ± 0.01		

GLENN YOUNG & COMPANY, SECTION 24

259	0.03 ± 0.01	0 03	0.87
260	0.03 ± 0.01	0.03	0.59
261	0.03 ± 0.01	0.03	0.71
262	0.10 ± 0.02	0.11	2.74
	0.11 ± 0.01		

265	0 05 ± 0 02	0 03	2.41
	0 08 ± 0 01		
	0 11 ± 0 01		
	*0 078 ± 0 007		
	**0.06 ± 10		
266	0 12 ± 0 02	0 12	2 71
267	0 16 ± 0.02	0 17	4 22
	0 17 ± 0 02		
268	0.10 ± 0.04	0.09	1 89
	0 12 ± 0.02		
	0 07 ± 0 01		
	0 10 ± 0.01		
	*0.082 ± 0.01		
	**0.09 ± 10		
269	0.09 ± 0.01	0.09	1.73
270	0.43 ± 0.06	0.39	6.12
	0 34 ± 0.03		
271	0.07 ± 0.02	0.08	1 96
	0.08 ± 0.01		

EDWARD J. & MARGARET MARY HOGAN, SECTION 4

201	0.08 ± 0.02	0 11	1.18
	0.13 ± 0.01		
202	0.13 ± 0.02	0.13	2.28
203	0.17 ± 0.02	0.17	2 55
	0.17 ± 0.03		
204	0 14 ± 0 02	0 16	2 24

TABLE III

Plutonium Summaries

(d/m/g)

Location	No of Sites	High Values	Low Values	Median
Section 6	20	3.2, 1.8	0 05, 0.06	0.11
North half	15	0.34, 0.28	0.05, 0.06	0 11
South half	5	3 2, 1.8	0 07, 0.09	1.1
Section 7	23	7.6, 2.5	0.28, 0.39	1 4
North half	14	7.6, 2.5	0.28, 0.48	1 4
South half	9	2.5, 1 9	0.39, 0.87	1.4
Section 18	14	2.0, 1 3	0 14, 0.18	0.7
Section 19	18	0.63, 0.60	0.02, 0.03	0.07
Section 24	36	0.39, 0.17	0.02, 0.02	0.04
Northeast Quarter	18	0.11, 0.09	0.02, 0.02	0.04
Remainder	18	0.39, 0.17	0.02, 0.02	0.07
Section 23	21	0.28, 0.18	0.03, 0.03	0.10
Section 21 and 22	14	0.61, 0.24	0.05, 0.07	0.15
Section 9	8	0.22, 0.18	0.05, 0.07	0.12
Section 4	6	0.11, 0.17	0.11, 0.11	0.18
Background	5	0.07, 0.06	0.02, 0.05	0.06

TABLE IV

Plutonium Summaries

(mCi/km^2)

Location	No. of Sites	High Values	Low Values	Median
Section 6	20	79, 38	1, 1	2
North half	15	6, 5	1, 1	2
South half	5	79, 38	1, 2	24
Section 7	23	118, 60	6, 9	29
North half	14	118, 44	6, 10	28
South half	9	60, 40	9, 12	29
Section 18	14	38, 27	2, 3	10
Section 19	18	12, 10	0, 1	2
Section 24	36	6, 4	0, 0	1
Northeast Quarter	18	3, 2	0, 0	1
Remainder	18	6, 4	0, 1	1
Section 23	21	6, 3	1, 1	2
Section 21 and 22	14	6, 4	1, 1	2
Section 9	8	2, 2	1, 1	2
Section 4	6	3, 3	1, 2	2
Background	5	2, 2	0, 1	2

TABLE V

QUALITY CONTROL RESULTS PLUTONIUM 239 in d/m/g

	Eberline 1	2	3	4	5	LASL	LFE
Blanks	0.05	0 03	0 06	0.03	0 02	0.024	0.022
	0 05	0 05	0 03	0 06	0.03	0.018	0.037
	0.05	0.04	0 02	0 01			
	0.03	0.03	0.01				
Synthetic Standard	4 23 3.72		4.29 4.27	4.34 3.71	3.88 4.20	7.44	3.70
Synthetic Standard	12.1 12.0	9.09 11.0 12.15 12.0	11.5	12.3 12.14		10.9	10.5
Consensus Standard	2.64 1.56			1.12 2.46	1.17 1.34	0.135	
Consensus Standard	8.35 5.36	4.94 3.92	5.24 9.59	6.21 6.13			23.4
Consensus Standard		0.59 0.54	0.89 0.45		0.39 0.50	0.497	0.48

R J Illsley

DISCLOSURE TO THE CITY OF BROOMFIELD

JANUARY 22, 1985

INTRODUCTION

This Disclosure is made to the City of Broomfield ("City") pursuant to paragraph 3.d of the Settlement Agreement entered into on December 14, 1984, and approved by the United States District Court for the District of Colorado on December 17, 1984, in Civil Action Nos. 75-M-1162 and 75-M-1296. The City is a third-party beneficiary to the Settlement Agreement. This Disclosure also satisfies the requirements of paragraph 1.d of the proposed Agreement between the City, the Department of Energy ("Department") and Rockwell International Corporation ("Rockwell").

The purpose of this Disclosure is to set forth material facts necessary to fully inform the City about the amounts of radioactive materials (specifically plutonium and americium) released from the Rocky Flats Plant ("Plant") and present on the lands to be transferred to the City at Closing of the Settlement Agreement. The lands to be transferred to the City at closing of the Settlement Agreement lie immediately east of the Plant and consist of two parcels referred to herein as (1) the Great Western Venture parcel which lies immediately north of the City's reservoir property and (2) the northern portion of the Ackard-Butler property which lies immediately south of the City's reservoir property.

The Disclosure addresses federal and state plutonium-in-soil guidance and standards; analyses of soils on the lands to be transferred to the City; the health risks associated with the presence of plutonium and americium on those lands; and epidemiologic studies relating to releases of plutonium and americium from the Plant. Also included in this disclosure is a bibliography of publications and documents that address these matters in more detailed and technical terms.

It is required under the terms of the Settlement Agreement that the lands to be transferred to the City shall be used for open space or reservoir expansion purposes only. For this reason, it is expected that few persons would occupy these lands for any significant period of time. Thus, while this disclosure addresses the health risks resulting from the presence of plutonium and americium to "putative" populations occupying such lands, it is not suggested that concerns over exposures of large populations to these materials should be the focus of the City's deliberations on this matter. Rather, the discussion herein on risks to large populations should be viewed as a statement that when the maximum effects that can be reasonably postulated as a result of the presence of these materials in the measured quantities are considered, the effects are so small that they cannot be scientifically measured. It follows that in the context of the use to which the City will put these lands, the risks to the small number of persons who may occupy the lands for short periods of time are so small that they can be disregarded.

Expansion of the reservoir using some of the transferred lands likewise should not be viewed as a basis for increases in radiation exposures to users of the City's water supply because such exposures have already been shown to be insignificant, and expansion of the reservoir can only reduce exposures. It is most important to consider the fact that with respect to exposures of persons to environmental plutonium and americium from the Plant through any pathway (whether directly from soils or through the water systems), these exposures are only a small fraction of the exposures resulting from naturally occurring radionuclides such as radium and its daughter products. See Bibliography No. 1.

I. Plutonium in Soil Guidance and Standards

Currently applicable federal regulations for off-site concentrations of materials such as plutonium are found in the Code of Federal Regulations at 10 C.F.R. Part 20. However, these regulations specify radiation dose limits and air concentration limits that can be related to soil concentrations only indirectly. The United States Environmental Protection Agency ("EPA") has proposed guidance on dose limitations for persons exposed to transuranium elements, including plutonium and americium, in the general environment. The EPA's proposed guidance does not specify limits on soil concentrations of these elements, but does establish "screening levels" for these materials in soils.

The State of Colorado has adopted a "plutonium-in-soil" standard that limits conentrations of this material in soils and

requires that, at levels beyond the limit, special procedures be employed if construction activities are undertaken. The Colorado standard was promulgated under the authority of the Colorado State Health Department, which, under Colorado law, has exclusive authority to deal with matters of radiation protection and to advise local governmental entities with regard to such matters.

A. EPA Guidance.

Recommendations on limiting dose rates to persons in the general population exposed to transuranium elements were developed by the Environmental Protection Agency (EPA) under authority of the former Federal Radiation Council, which was established by Executive Order 10831 and Public Law 86-373 (42 U.S.C. 2021(h)), and transferred to the Environmental Protection Agency by Reorganization Plan No. 3 of 1970. These require that the Administrator of the Environmental Protection Agency ". . . advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards, and in the establishment and execution of programs of cooperation with States." These recommendations and proposed guidance were published in the Federal Register on November 30, 1977, and revised in accordance with comments received in response to the notice. The EPA has not yet formally promulgated the proposed guidance.

The text of the Proposed Guidance (Bibliography No. 2) states that in order to assure the protection of persons in the

general population by limiting the radiation doses that an individual in a critical segment of the population may receive from concentrations of transuranium elements present above average background levels in the general environment, the following recommendations shall apply for the guidance of Federal Agencies:

1. The annual alpha radiation dose rate to members of the critical segment of the exposed population as the result of exposure to transuranium elements in the general environment should not exceed either:

a. 1 millirad per year to the pulmonary lung,

or

b. 3 millirad per year to the bone.

These dose rates are based upon further projections which evaluate the probability that the exposed population will develop such health effects as cancer and genetic defects. At or below these dose rates, the EPA concluded that the risks of such effects in exposed population would be no greater than one in one million per person per year.

Appended to the Proposed Guidance in Annex V are the methods by which the Proposed Guidance may be implemented. Soil screening is one method. Inherent in its application is the assumption that soil contamination by transuranium elements will cause radiation exposure through pathways such as inhalation of resuspended soil, ingestion of food grown on the land, and ingestion of drinking water contaminated by soil runoff. The soil screening levels are

based upon mathematical models which project the relationship between soil contaminations of transuranium elements and human exposures. The screening level is the total transuranium element concentration in the top 1 cm of soil. Levels of contamination below soil screening levels are considered unlikely to lead to dose rates in excess of those recommended by the Proposed Guidance. Thus, lands with contamination levels less than the soil screening level of 200 mCi/km^2 (millicuries per square kilometer) are considered suitable for normal human activities, including residential and agricultural use. None of the lands to be transferred to the City has contamination levels approaching the screening level.

The EPA has assessed the presence of plutonium and americium on lands adjacent to the Plant. Bibliography No. 3. This assessment was conducted by the EPA at the request of various Colorado officials during the promulgation of the Proposed Guidance specifically to address the question of whether there are significant health hazards as a result of the presence of plutonium and americium on lands adjacent to the Plant. Based upon data obtained from federal agencies and the State of Colorado, the EPA concluded that the dose limitations in the Proposed Guidance had not been exceeded on any off-site lands and that the lands off-site of the Plant were suitable for all normal uses, including agricultural and residential use.

B. Colorado Soil Standard -- Construction Activities.

The Colorado Department of Health has promulgated a standard for protection against exposure to radiation during construction activities. (Standards for Protection Against Radiation, 6 C.C.R. 1007-1, pp. 1-9, 160 (1978)). Bibliography No. 4. This standard establishes a soil contamination level for plutonium at 2.0 d/m/g (disintegrations per minute of plutonium per gram of dry soil) or 0.01 microcuries per square meter. 0.01 microcuries per square meter is equivalent to 10 millicuries per square kilometer. However, because the EPA and Colorado use different sampling dimensions, it is not possible to directly compare the EPA guidance and the Colorado standard.) The regulation is intended to protect persons, primarily construction personnel, exposed to plutonium-contaminated soil during construction. The plutonium soil standard is implemented through the "suggested interim guidance for evaluation" provided by the Colorado Department of Health to local governments in the exercise of their land use powers under C.R.S. 1973, 30-28-133. If soil sampling indicates that concentrations in excess of the standard exist, a special review mechanism is triggered to ensure that construction on the parcel takes account of the plutonium concentration present and utilizes special techniques (e.g., dust reduction, thorough wetting down of the construction site). The regulation therefore requires only special construction techniques and does not prohibit development of the lands.

Of the lands to be transferred to the City, only the northern portion of the Ackard-Butler parcel contains concentrations of plutonium in excess of the Colorado standard. However, with completion of the remedial action program, concentrations on this parcel will be reduced to levels at or below the state standard.

II. Analysis of Soils on Plaintiffs' Lands

The soil testing program conducted by Rockwell on Great Western Venture and Ackard-Butler lands in 1977 revealed that the amounts of plutonium and americium concentrations on those lands ranged from levels below background to as much as two orders of magnitude above background. "Background" levels were established from samples taken at locations remote from the Plant. These locations were selected by the State of Colorado for this purpose. Bibliography No. 5.

From the data, it is seen that the Church, Ackard-Butler, and Great Western properties on the east boundary of the Plant have the highest concentrations. The Church property at the southeast corner of the plant boundary has levels below background. This parcel of land has continuously been plowed for wheat crops by Church, and it is believed that plowing has mixed the surface soil and that concentrations of transuranium elements from the plant have been significantly diluted.

With respect to the lands being transferred to the City, the following summary is provided based on the soil sampling method established by the Colorado Department of Health:

a. Great Western Venture Parcel

low value--0.06 d/m/g

high value--0.44 d/m/g

median value--0.23 d/m/g

b. Ackard-Butler Parcel

low value--0.13 d/m/g

high value--17.1 d/m/g

median value--2.4 d/m/g

c. Background Locations

low value--0.03 d/m/g
high value 0.18 d/m/g } ave = .08

The number of samples taken within each of the parcels of land was established by statistical methods with the objective of estimating the median value for each parcel. Thus, with respect to the portion of Ackard-Butler parcel to be transferred to the City, the values listed above are based on all the samples taken on the Ackard-Butler and Church properties east of the Plant combined. These properties were treated as one parcel in the statistical analysis. No median value is specified for the background locations because these sites were specified independently by the Colorado Department of Health prior to the testing program conducted by Rockwell.

Analysis of 25 samples from plaintiffs' lands and samples from each of the five background locations used in the testing program show that with respect to radionuclides other than plutonium

and americium, the levels of these radionuclides on plaintiffs' lands are consistent with background levels. Thus, the only materials from the Plant that have been measured above background levels off-site from the Plant are plutonium and americium. Bibliography No. 6.

III. Analysis of Health Risks

The risk associated with the presence of radioactive materials in the environment is almost exclusively the induction of cancer in various organs of the body. There has been concern for genetic effects resulting from irradiation of the organs involved in reproduction. However, no genetic effects have been observed in any of the irradiated human populations that have been studied to date.

The risks posed by plutonium and americium in soils arise only if those materials enter the body through ingestion or inhalation. The magnitude of the risks of adverse health effects posed by such materials depends on the quantities of the materials that are deposited in various organs of the body.

The organs in which plutonium and americium concentrate in the body after inhalation are the lung, liver and bone. (These materials are not readily absorbed by the body through ingestion because of the chemical nature of the compounds they form in the environment.) The United States Environmental Protection Agency has identified the lung and bone as the organs of concern with respect to plutonium and americium.

To place the risks associated with the levels of plutonium and americium on lands adjacent to the Plant in perspective, it is

appropriate to make a comparison between radiation doses to critical organs resulting from these materials and radiation doses to the same organs resulting from natural sources of radiation occurring in the Rocky Flats environs. Table 1, taken from Government Defendants' Analysis of Health Risks, Bibliography No. 7, shows such a comparison.

Table 1
Estimated Annual Radiation Doses
for Residents in the Denver, Colorado Area (mrem/yr)[1]

Radiation Source	Whole-Body	Lung	Bone[2]
Cosmic Rays[3]	50	50	50
External Irradiation by Terrestrial Radionuclides[4]	72	72	57
Lung Irradiation by Inhaled Naturally Occurring Radionuclides		100	
Internal Radiation by Naturally Occurring Radionuclides in the Body	27	24	60
Total Natural Background	149	246	167
210Po in Cigarettes (2 packs/day)[5]		10	

1. Values from Natural Background Radiation in the United States NCRP Report No. 45, 1975.
2. The dose to the bone is the dose to the endosteal cells of the bone which are considered to be the critical cells for transuranium elements.
3. Value for the Denver area taking into account a 10% building shielding factor.
4. Value for the Denver area taking into account a 20% building shield factor for the whole body and lung and an additional 20% body shielding factor for bone.
5. Value from Little et al. (Distribution of Polonium in Pulmonary Tissues of Cigarette Smokers, New England J. Med. 273, 1965).

Internal Irradiation from Radionuclides Released from the Rocky Flats Facility and Fallout[6]	0.3	5

From Table 1 it is seen that the radiation doses resulting from plutonium and americium released from the Plant (including plutonium and americium deposited from nuclear weapons tests in the atmosphere) are a very small fraction of the doses resulting from natural sources. The values given in the table are based on actual measurements in the environment. The risks of bone cancer associated with a dose of 167 millirems per year to the bone resulting from the total natural background sources are approximately 32 times (160 divided by 5) greater than the risks associated with a dose of 5 millirem to the bone resulting from Rocky Flats releases of plutonium and americium.

Estimates of the risk of lung cancer associated with materials on lands adjacent to the Plant are shown in Table 2.

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6. Total dose from plutonium and americium in Plant soil. No attempt has been made to subtract out the contribution from fallout, and it was assumed that all of the food consumed was raised on the land around the Plant.

Table 2

Summary of Health Risk Projections at Rocky Flats Boundary for Potential Exposures of the Pulmonary Lung to Plutonium and Americium

	Annual Risk[7]
EPA Model	one chance in forty milli
Fallout Analogy	one chance in thirty-thr million
Environmental Dispersion Model	one chance in one hundr million
EPA Guidance	one chance in one million

The risks shown in Table 2 were calculated by three different methods. See Bibliography No. 7. The risks for bone cancers fall below the values shown in Table 2.

The EPA, in its proposed guidance on environmental releases of radioactive materials, such as plutonium, suggests that risks associated with environmental levels of these materials be limited to a risk of one in one million per year for lung cancer. (The EPA concludes that doses of 1 millirad to the lung or 3 millirad to bone per year correspond to risks of one in one million per year of contracting cancer.) Below this level, the EPA implicitly suggests that

7. Individual risk for cancer.

the risks should be disregarded in considering what use should be made of lands upon which these materials have been deposited.

The risks associated with plutonium and americium from the Plant are (1/33 to 1/100) of the EPA suggested limit. Moreover, from Table 1, the risk of lung cancer from naturally occurring radioactivity must be taken to be 9,840 times greater (246 per million per year divided by 1 per 40 million per year) than the risk of lung cancer from plutonium and americium.

From this analysis it is seen that for persons who would continually inhabit or occupy lands adjacent to the Plant, the annual risks of lung cancer are increased very little by the presence of plutonium and americium in soils. For example, assuming that as many as 100,000 persons lived on these lands continuously for 70 years, the number of extra lung cancers that might occur as a result of Plant activities would be 0.17, or less than one lung cancer.

At the same time, the dose to the lung of these same persons resulting from natural radiation sources would be 246 millirem per year, as noted in Table 1. This corresponds to an annual risk (calculated on the same basis as the risk from Plant plutonium) of 246 x 1/1,000,000. Thus, for a population of 100,000 persons living plaintiffs' lands for 70 years, the number of lung cancers resulting from natural radiation would be 86 cancers. An increase of 86 lung cancers in a population of 100,000 persons would not be detectable because of about 20,000 total cancers, 4,000 lung cancers are

expected to occur in such a population, and the variability in the 4,000 lung cancer statistics is ± 160.

Table 3, see page 15A, taken from Defendants' Analysis of Health Risks provides data on Pu concentration based on the EPA model for all lands sampled by Defendants. See Bibliography No. 7

Table 3

Relationship of ^{239}Pu Air Concentrations and Soil Concentration levels Near the Rocky Flats Facility

Air Concentrations (fCi/m^3) from Samplers located on Different Properties[a]

	Great Western Section 6		Good Section 7		Good Section 18	Church Section 24		Church Section 23		Church Sections 21,22	
ar	S-36	S-35	S-37	HASL#2	S-38	S-45	S-39	S-41	S-47	S-42	S-43
75	.012	.027	056	039	027		026	033		037	056
76	017	.013	.024	019	.015		.013	012		013	014
77	040	033	044		.032	048	039	037	044	050	037
78	096	.081	089		.067	066	087	117	116	097	091

Soil Concentrations (fCi/m^2) for Different Properties[b]

27.4×10^6	49×10^6	20×10^6	1.6×10^6	3.4×10^6	4.4×10^6

Resuspension Factor (fCi/m^3 of air)/(fCi/m^2 of soil) for Different Properties[c]

1.5×10^{-9}	1.0×10^{-9}	1.8×10^{-9}	30×10^{-9}	18×10^{-9}	11×10^{-9}

Air concentration data taken from RFP-ENV-75 through RFP-ENV-78.

Soil concentration data are the sums of the median values for the Type C and Type D soil samples taken from Summary III of Exhibit A

Air concentrations of plutonium were averages of all values listed for each Section of land.

IV. Epidemiologic Studies

Two reports appeared in 1981 that indicated a statistical relationship exists between cancer incidence patterns in the Denver Standard Metropolitan Statistical Area (SMSA) for 1969 to 1971 and soil concentrations of plutonium released from the Plant (Johnson Bibliography Nos. 8 and 9; Chinn Bibliography Nos. 10 and 11). Using cancer incidence statistics for individual census tracts taken from the Third National Cancer Survey and plutonium soil concentration contours derived from measurements reported by Krey (1976) and Frey and Hardy (1970), Johnson and Chinn concluded that radioactivity released from the Plant was a likely cause of the observed high cancer incidences in populations living near the plant. This relationship is doubtful because (a) analyses of tissues obtained from autopsies of Denver area residents did not show plutonium concentrations higher than those found in people living in other areas of the United States (Cobb et al., 1982, EPA Tissue Study Bibliography No. 14), (b) sufficient time had not elapsed for plutonium released from the Plant to cause the observed increases in cancer incidences during 1969 to 1971; (c) the cancers reported to be in excess included many types that are not likely to result from internally deposited plutonium; and (d) cancer incidence patterns for men and women observed in this study are not typical of those that would be expected if they were caused by a single environmental factor. However, because of public concern for radiation exposures, the Department undertook a study to further explore cancer patterns in

relation to the Plant. (Crump Report, Bibliography No. 12). In addition to the cancer incidence data used by Johnson and Chinn for 1969 to 1971, the Department analyzed data for 1979 to 1981. Cancer incidences for the later period would be more likely to show an effect of exposure to Plant plutonium if such a relationship actually exists. This is due to the long periods of time necessary for a radiation exposure to result in the development of a cancer.

The primary conclusions derived from the Department's study are:

1. The most significant statistical correlation identified in this study is between census tract cancer incidence and distance from the State Capitol Building located near the geographic center of Denver.

2. For both 1969 to 1971 and 1979 to 1981, cancer incidences in Area I (within 10 miles of the Plant) were no greater than those in the Denver SMSA in general.

3. When analyses were restricted to census tracts with low population mobility, trends toward higher cancer incidences in areas nearer to the Plant were strengthened during 1969 to 1971 and weakened during 1979 to 1981. However, because of the long latency period for most environmental cancers, the later period should be more indicative of any association between the Plant and cancer incidences in the Denver SMSA.

4. Between 1979 and 1981, cancer incidences in Area I (nearest to the Plant) were generally lower than those in Area II, which is further from the Plant.

5. Statistical correlations between census tract cancer incidence data and Johnson's exposure areas or other Plant-related variables largely disappear when the analyses are controlled for demographic and socio-economic confounding factors.

6. In total, these statistical analyses do not support a relationship between the Plant and cancer incidence. Excess cancers reported by Johnson in Area I for 1969 to 1971 are not likely to have been related to the Plant.

CONCLUSION

The risks associated with the amounts of radioactive materials released from the Plant and present on Plaintiffs' lands to be transferred to the City upon closing of the Settlement Agreement are small in comparison to the risks from exposure to naturally occurring radionuclides and other natural background radiations and are sufficiently small that they can be disregarded in any consideration relating to the use of the lands.

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DOCUMENT D-9

"Soil Sample Collection and Analysis for Plutonium
on Lands Adjacent to Great Western Reservoir for the City of Broomfield"
(1985)

by

C T Illsley
Rockwell International

SOIL SAMPLE COLLECTION AND ANALYSIS FOR PLUTONIUM ON LANDS ADJACENT TO GREAT WESTERN RESERVOIR FOR THE CITY OF BROOMFIELD

EAC-417-85-1

CONFUSING ON ACREAGE REQ. REMED. 60-100 acres

April 10, 1985

Prepared by: C. T. Illsley
Rockwell International
Rocky Flats Plant
P. O. Box 464
Golden, Colorado 80401

Site 200

INTRODUCTION

Regulations promulgated by the Colorado Department of Health (CDH) under Colorado Statutes require that land in an "area of concern" in the vicinity of the Rocky Flats Plant be sampled and analyzed for plutonium before construction activities may proceed. Furthermore, as part of the recent Federal Court settlement agreement for the Rocky Flats Plant land litigation, it was agreed that certain lands adjacent to the Plant would be evaluated for plutonium contamination. If it is determined that soil on these lands contains plutonium at concentrations greater than the CDH guideline, remedial actions will be initiated. The permissible level of radioactive material in uncontrolled areas as specified in RH4.27 of the Rules and Regulations Pertaining to Radiation Control, circulated by CDH in 1978 is 2 disintegrations per minute per gram (2 d/m/g) of dry soil.

The sample collection, analytical data and evaluation of results are described to fulfill the requirements of the State of Colorado.

SITE LOCATION

The sampled site is owned by the City of Broomfield and lies within the "area of concern" as outlined by CDH. The land is located in the northern half of Section 7, T2SR69W. The area sampled is immediately adjacent to Great Western Reservoir on the west and south.

LAND USE

The land was originally utilized as pasture for grazing livestock. This use was discontinued after Broomfield acquired the land. There are no disturbed areas on this parcel of ground. Walnut Creek flows eastward across the northeast corner of the area and a network of small tributaries drains the southwest corner into Great Western Reservoir.

SAMPLE COLLECTION PROCEDURES

The boundaries of the area are well defined by fences on the west, north and south and by the shoreline of Great Western Reservoir on the east. The site included about 150 acres and the CDH guideline of one composite sample per each 10 acres was followed. The site was divided into four sectors which were labeled A, B, C and D.

Sector A was subdivided into 2 ten acre sample sites. Sector B was subdivided into 2 ten acre sample sites and 1 seven acre sample site. Sector C was subdivided into 3 ten acre sample sites and 1 five acre sample site. Sector D was subdivided into 3 ten acre sample sites and 3 five acre sample sites. The total number of samples was 15 prepared from 355 sub-samples. The site and sectors are shown on the attached map.

Each sample site was divided into a sampling grid on a spacing of 132 feet. Sector and site boundaries were located using a "Rolalape". The locations for each subsample were made by pacing.

Soil samples were collected at each location using the CDH prescribed template and scoop. The 5 x 6 cm template was forced into the ground surface and the scoop was used to remove the top 1/8 inch (0.32 cm) of soil. It was attempted to collect only the fine fraction of the topsoil. Most of the grass, sticks, seeds and rocks were removed from the sample before it was placed in a new one gallon paint can.

ANALYTICAL PROCEDURES

Sample preparation and analysis was performed according to published procedures. The entire sample was dried at 100°C, sieved through a 10 mesh sieve, weighed and the fine portion was ball milled. The milled portion was sieved through a 35 mesh sieve and stored in plastic screw cap bottles. Ten gram aliquots of each sample were analyzed for plutonium. Blank soil and synthetic standard soils were blindly batched with the field samples in a random manner as quality controls in the radiochemical laboratory.

Plutonium analyses were performed by Accu-Labs Research, Inc., 11485 W. 48th Avenue, Wheat Ridge, Colorado.

The soil samples were totally dissolved using a 40 percent solution of hydrofluoric acid. A plutonium-236 tracer was added to the soil before dissolution. After fuming with HF, the sample was brought to volume with nitric acid (HNO_3). Plutonium was separated from the solution with an anion exchange column.

The purified material was then eluted from the column and electroplated on a polished steel disc. The radioactivity on the disc was measured in a solid state alpha spectrometer and the recovery was determined from the tracer peak.

QUALITY CONTROL

During sample analysis, quality control consisted of blank soil analysis, standard soil analysis, reagent blank analysis and selective duplicate sample analysis. All samples were submitted to the analytial laboratory in a random and blind manner.

Accu-Labs Research, Inc. (ALR) operates under a rigorous Quality Assurance (QA) Program designed to comply with the Criteria for Nuclear Power Plants set forth in Title 10, Code of Federal Regulations, Part 50, Appendix B (10CFR50). This program also complies with the U.S. Nuclear Regulatory Commission (NRC) Quality Asssurance specifications described in Regulatory Guide 4.15. The stringent system of controls and checks inherent in ALR's QA program ensures analytical results of the highest caliber.

ALR employs a number of procedures to monitor instrument efficiency, technician performance, method performance and overall accuracy and precision. Utilizing their QA program, ALR has been successful in becoming certified for radiochemical analyses by the Environmental Protection Agency (EPA) and other regulatory authorities.

RESULTS OF ANALYSES

The letter report from ALR and Table I present the results of the radiochemical analyses. Deviations reported are for the variability of the radioactive disintegration process (counting error) at the 95 percent confidence level (1.96 sigma).

CONCLUSIONS

The results of the radiochemical analyses show that the value for the standard (2.2 ± 0.06 d/m/g) agreed with the analytical value (2.7 ± 0.7 d/m/g). The blank value of 0.07 ± 0.13 d/m/g is typical of many replicate analyses of the same soil sample.

The sample results are within the range from 0.8 to 8.4 d/m/g of plutonium-239. Based on these results, it is concluded that only 3 ten acre plots, D-1, D-2 and D-3 contain plutonium at concentrations significantly higher than the CDH guideline of 2 d/m/g. These 60 acres of

land will require remedial action such as plowing, disking and reseeding. P[redacted]ions in four other sectors, [redacted] greater th[redacted].2, 2.2 and 2.2 d/m/g) are not high enough to present a health hazard. (The maximum value is only 6 percent of the EPA proposed screening level of 40 d/m/g). These 90 acres of land should not be disturbed at this time.

Accu-Labs Research, Inc.
11485 W 48th Avenue Wheat Ridge, Colorado 80033
(303) 423-2766

April 3, 1985

Mr. Chuck Illsley
Rockwell International
Rocky Flats Plant
P.O. Box 464
Golden, CO 80402-0464

RE: 8890-19611-17
Date Samples Rec'd 3-25-85
Purchase Document No. 12715PB

REPORT OF ANALYSIS

ALR Designation	Sponsor Designation	Plutonium-239, total ± counting error* pCi/g (dry)	Air Dry Loss, %
8890-19611-17-1	85-A-1	0.64 ± 0.23	9.3
-2	85-A-2	0.39 ± 0.15	7.2
-3	85-B-1	0.73 ± 0.19	8.0
-4	85-B-2	1.1 ± 0.2	6.4
-5	85-B-3	1.0 ± 0.2	9.2
-6	85-C-1	0.81 ± 0.19	5.5
-7	85-C-2	0.97 ± 0.24	4.1
-8	85-C-3	0.74 ± 0.20	2.3
-9	85-C-4	0.48 ± 0.13	4.4
-10	85-D-1	3.8 ± 0.5	15.3
-11	85-D-2	3.5 ± 0.4	16.7
-12	85-D-3	1.9 ± 0.5	7.9
-13	85-D-4	0.82 ± 0.24	5.3
-14	85-D-5	1.0 ± 0.2	8.1
-15	85-D-6	0.36 ± 0.13	3.0
-16	STD. No. 60/242	1.2 ± 0.3	--
-17	Blank	0.03 ± 0.06	--

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.
These samples are scheduled to be disposed of 45 days after the date of this report.

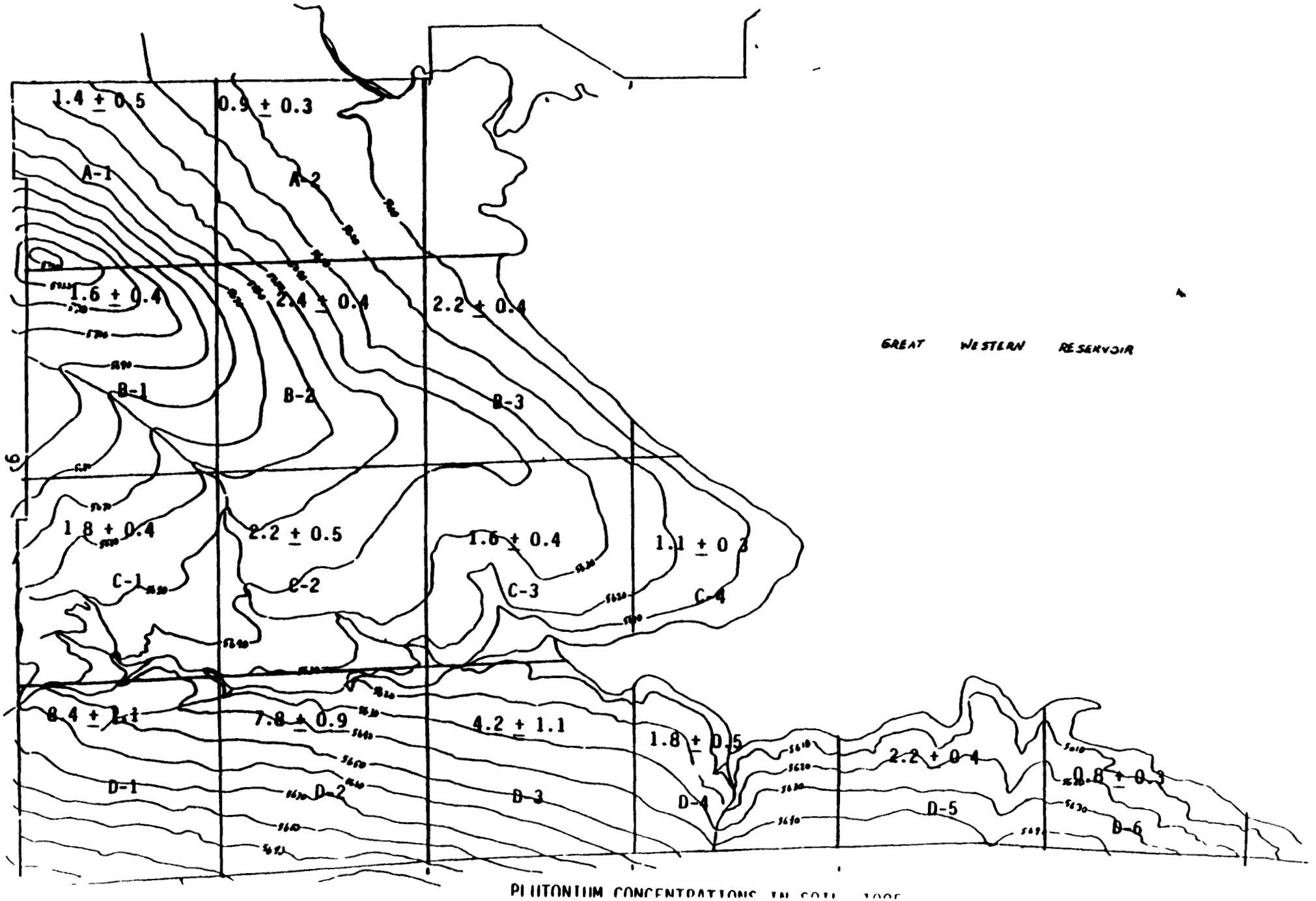
Bud Summers
Radiochemistry
Supervisor

BS/dh

TABLE I. GREAT WESTERN RESERVOIR
SOIL SAMPLE ANALYSES 1985

(PLUTONIUM CONCENTRATIONS IN D/M/G)

LOCATION	PLUTONIUM-239
A-1	1.4 ± 0.5
A-2	0.9 ± 0.3
B-1	1.6 ± 0.4
B-2	2.4 ± 0.4
B-3	2.2 ± 0.4
C-1	1.8 ± 0.4
C-2	2.2 ± 0.5
C-3	1.6 ± 0.4
C-4	1.1 ± 0.3
D-1	8.4 ± 1.1
D-2	7.8 ± 0.9
D-3	4.2 ± 1.1
D-4	1.8 ± 0.5
D-5	2.2 ± 0.4
D-6	0.8 ± 0.3



PLUTONIUM CONCENTRATIONS IN SOIL, 1985

DOCUMENT D-10

"Remedial Action Program on Jefferson County Open Space Land in Section 7, T2S, R69W, South of Great Western Reservoir"
(1987)

by

C T Illsley
Rockwell International

REMEDIAL ACTION PROGRAM ON JEFFERSON COUNTY OPEN SPACE

LAND IN SECTION 7, T2S, R69W,

SOUTH OF GREAT WESTERN RESERVOIR

EAC-420-87-1

January 15, 1987

Prepared by C. T. Illsley
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P. O. Box 464
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REVIEWED FOR CLASSIFICATION
BY S L CUNNINGHAM
Date 2/12/87 (U)

INTRODUCTION

Regulations promulgated by the Colorado Department of Health (CDH) under Colorado Statutes require that land in an "area of concern" in the vicinity of the Rocky Flats Plant be sampled and analyzed for plutonium before construction activities may proceed. Furthermore, as part of the recent Federal Court Settlement Agreement for the Rocky Flats Plant land litigation, it was agreed that certain lands adjacent to the Plant would be evaluated for plutonium contamination. If it was determined that soil on these lands contains plutonium at concentrations greater than the CDH guideline, remedial actions would be initiated. The permissible level of radioactive material in uncontrolled areas as specified in RH4.27 of the Rules and Regulations Pertaining to Radiation Control, circulated by CDH in 1978 is 2 disintegrations per minute per gram (2 d/m/g) of dry soil or 0.90 pCi/g.

This report describes the sample collection, analytical data, evaluation of results for a parcel of land located immediately east of Rocky Flats. Remedial actions taken to fulfill the requirements of the State of Colorado on this land are also summarized.

SITE LOCATION

The sampled site is owned by the City of Broomfield and Jefferson County and lies within the "area of concern" as outlined by CDH. The land is located in the southern half of Section 7 and western half of Section 18, T2S, R69W. The area sampled is south of Great Western Reservoir, east of Indiana Street and north of West 96th Avenue (see Figure 1).

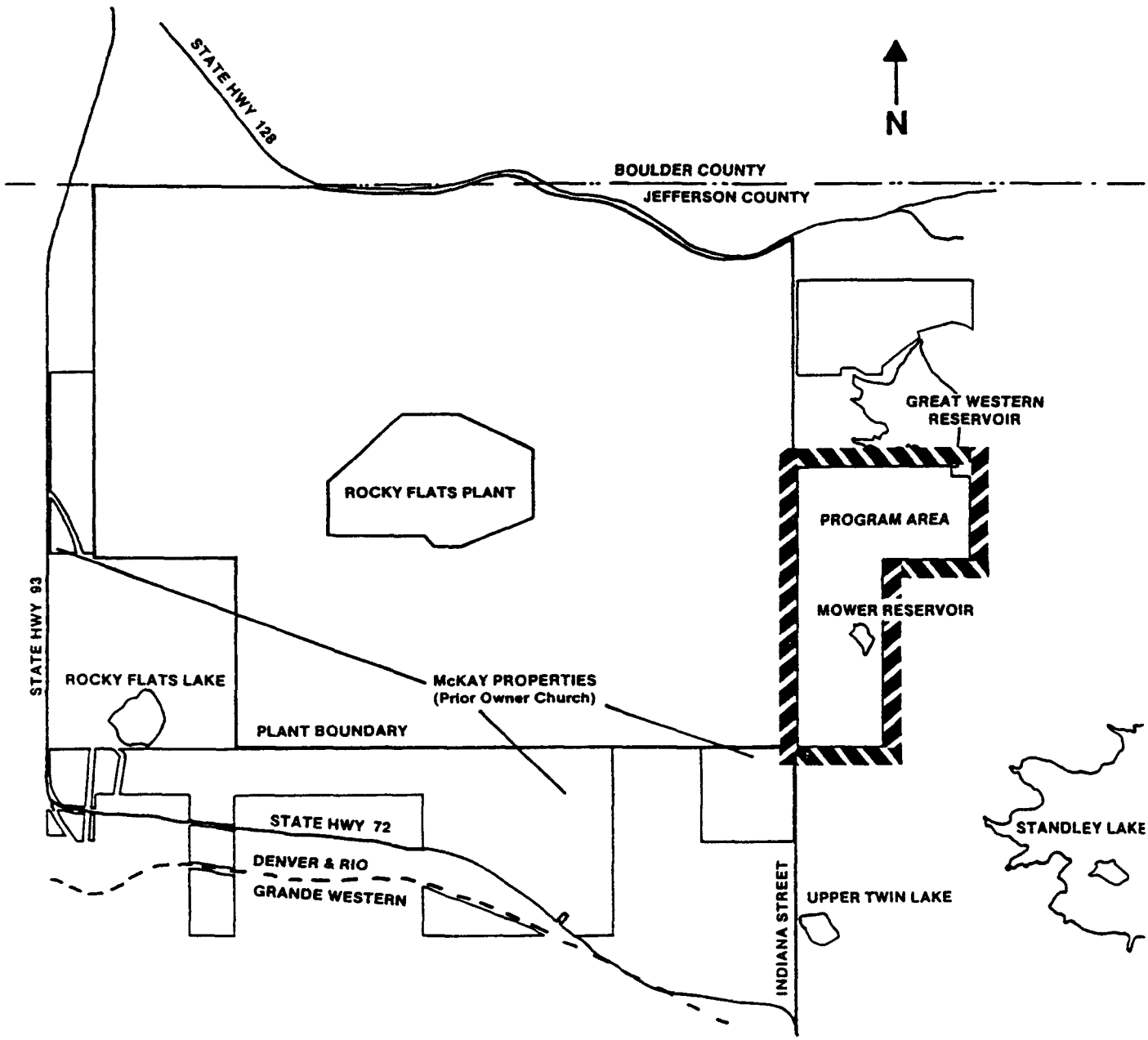

FIGURE 1 INDEX MAP SHOWING LOCATION OF PROGRAM AREA

LAND USE

The land was originally utilized as pasture for grazing livestock and as cropland for growing winter wheat. The cropland has been tilled for 25 years or more. Woman Creek flows eastward across the southern portion of the area into Standley Lake. A small irrigation ditch delivers water from Woman Creek to Mower Reservoir. The vegetation in the area consists of native grasses, various shrubs and small trees along Woman Creek and wheat stubble and weeds in wheat fields abandoned since 1980.

SAMPLE COLLECTION PROCEDURES

The boundaries of the area are well defined by barbed wire fences on all four sides. These boundaries were checked by professional surveyors from C. R. Moore and Associates (Rockwell contractor) and ADG Engineering Inc. (Jefferson County contractor). The site includes about 640 acres and the CDH guideline of one composite sample per each 10 acres was followed with minor modifications. The City of Broomfield land was divided into 10 - ten acre plots in order to include the entire triangular shaped area. This resulted in some overlap with two 10 acre plots in the recently acquired Jefferson County Open Space land. Fourteen 10 acre plots were established on the latter. The centers of each of these plots were located by professional surveyors from Drexel, Barrell and Company. These sites were selected from those utilized in the original soil sample testing program conducted by Rockwell and DOE in 1977.[1] The identities of these sites were agreed upon by CDH and Rockwell, based on the Rocky Flats Settlement Agreement. Each sample site was

divided into a sampling grid on a spacing of 165 feet. Sector and site boundaries were located using a Rolatape[R] (Model 400). The locations for all subsamples were made by pacing. Soil samples were collected at each location using the CDH prescribed template and scoop. The 5 x 6 cm template was forced into the ground surface and the scoop was used to remove the top 1/8 inch (0.32 cm) of soil. The intent was to collect only the fine fraction of the topsoil. Most of the grass, sticks, seeds and rocks were removed from each sample before it was placed in a new one gallon paint can.

ANALYTICAL PROCEDURES

Sample preparation and analysis were performed according to standard procedures, approved by the Colorado Department of Health.[2,3,4] The entire sample was dried at 100°C, sieved through a 10 mesh sieve, weighed and the fine portion was ball milled. The milled portion was sieved through a 35 mesh sieve and stored in plastic screw cap bottles. Ten gram aliquots of each sample were analyzed for plutonium. Blank soil and synthetic standard soils were blindly batched with every group of seven field samples in a random manner as quality controls in the radio-chemical laboratory.

Plutonium analyses were performed by Accu-Labs Research, Inc., 11485 W. 48th Avenue, Wheat Ridge, Colorado.

The soil samples were totally dissolved using a 40 percent solution of hydrofluoric acid. A plutonium-236 tracer was added to the soil before dissolution in order to determine chemical yield. After fuming with HF, the sample was brought to volume with nitric acid (HNO_3). Plutonium was separated from the solution with an anion exchange column.

The purified material was then eluted from the column and electroplated onto a polished steel disc. The radioactivity on the disc was measured in a solid state alpha spectrometer and recovery was determined from the tracer peak.

QUALITY CONTROL

During sample analysis, quality control consisted of blank soil analysis, standard soil analysis, reagent blank analysis and duplicate sample analysis. All samples were submitted to the analytical laboratory in a random and blind manner.

Accu-Labs Research, Inc. (ALR) operates under a rigorous Quality Assurance (QA) Program designed to comply with the Criteria for Nuclear Power Plants set forth in Title 10, Code of Federal Regulations, Part 50, Appendix B (10CFR50). This program also complies with the U.S. Nuclear Regulatory Commission (NRC) Quality Assurance specifications described in Regulatory Guide 4.15. The stringent system of controls and checks inherent in ALR's QA program ensures analytical results of the highest caliber.

ALR employs a number of procedures to monitor instrument efficiency, technician performance, method performance and overall accuracy and precision Utilizing their QA program, ALR has been successful in becoming certified for radiochemical analyses by the Environmental Protection Agency (EPA) and other regulatory authorities.

RESULTS OF INITIAL ANALYSES

Table I summarizes the results of the initial radiochemical analyses of soil samples collected in 1985 before remedial action. Deviations reported are for the variability of the radioactive disintegration process (counting error) at the 95 percent confidence level (1.96 sigma). The data are also depicted on Figure 2 along with historical data from 1977.

CONCLUSIONS FROM INITIAL TESTING

The results of the radiochemical analyses show that three averaged analysis values for the soil standard (1.12, 1.02 and 1.01) agreed well with the standard value of 1.0 pCi/g. The average blank values (0.10, 0.01 and 0.005 pCi/g) are typical of many replicate analyses of the same soil sample.

The sample results are within the range from 0.46 to 5.6 pCi of plutonium per gram of dry soil. Fifteen values are greater than the Colorado Department of Health plutonium-in-soil standard of 0.90 pCi/g. It should also be noted that the maximum value of 5.6 pCi/g is about 30% of the EPA proposed screening level.[5]

It can be seen from Figure 2 that a comparison of the 1985 and 1977 results shows, with a few exceptions, that the more recent plutonium in soil concentrations are significantly less than the prior data at the same locations. These reductions are probably due to the eight year time

TABLE I

ANALYSES OF SOIL SAMPLES FROM SECTION 7 AND 18,
T2S,R69W.
(Plutonium Concentrations in pCi/g)

Sample No.	Site No.	Plutonium 239 ± Counting Error
GWS 85-1	1	5.6 ± 0.5
GWS 85-2	2	5.0 ± 0.5
GWS 85-3	3	2.9 ± 0.4
GWS 85-4	4	2.2 ± 0.4
GWS 85-5	5	2.5 ± 0.4
GWS 85-6	6	0.86 ± 0.3
GWS 85-7	7	1.0 ± 0.2
GWS 85-8	8	0.74 ± 0.2
GWS 85-9	9	3.6 ± 0.4
GWS 85-10	10	2.2 ± 0.4
I 85-2	9	0.46 ± 0.2
I 85-4	10	0.61 ± 0.2
I 85-5	3	0.96 ± 0.2
I 85-6	4	1.0 ± 0.3
I 85-7	11	0.52 ± 0.2
I 85-11	12	0.81 ± 0.3
I 85-12	7	0.03 ± 0.1
I 85-16	8	0.12 ± 0.1
I 85-17	18	0.82 ± 0.2
I 85-18	19	1.8 ± 0.2
I 85-19	22	3.0 ± 0.5
I 85-20	21	2.1 ± 0.4
I 85-21	17	1.0 ± 0.2
I 85-22	20	1.4 ± 0.2

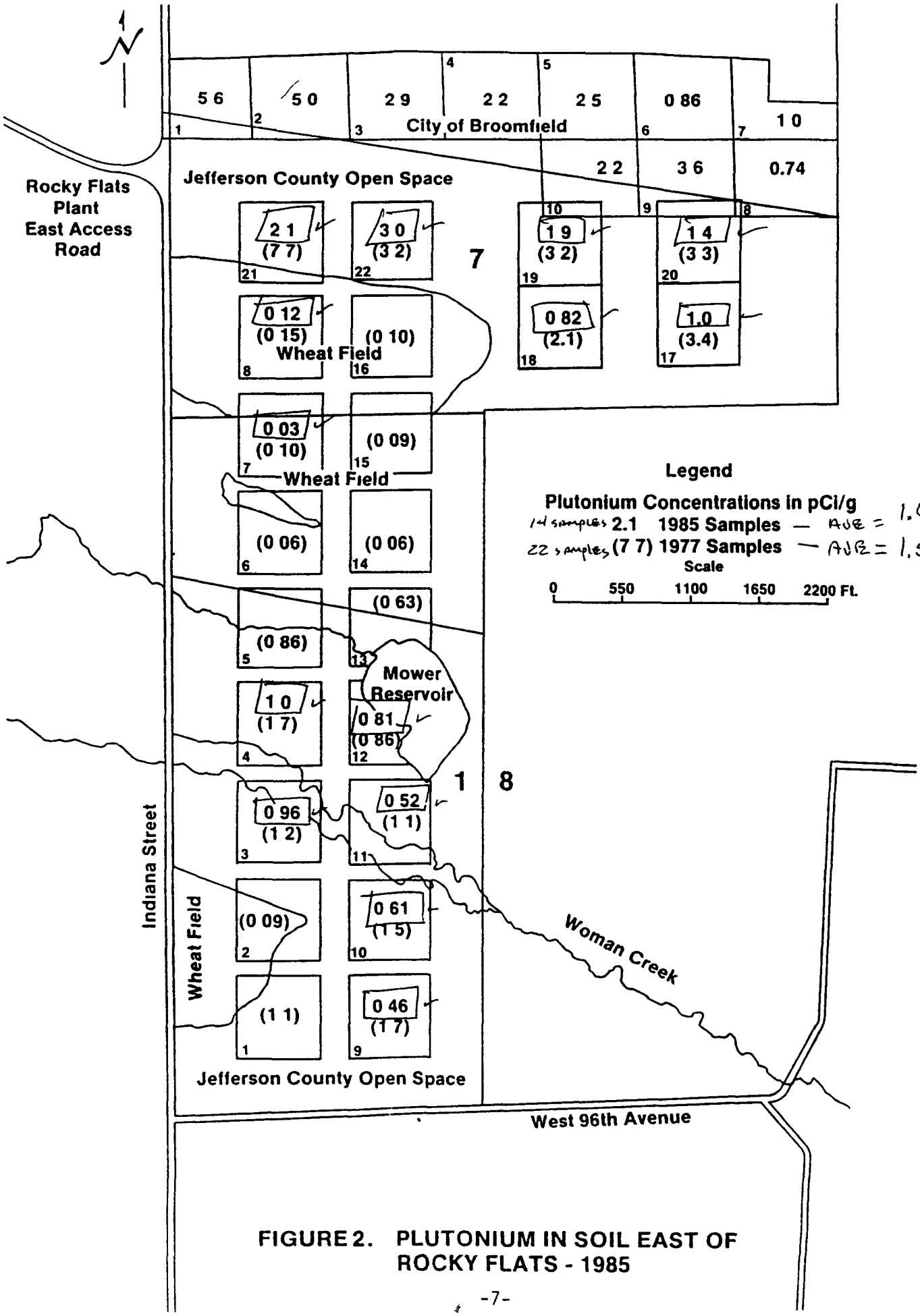

FIGURE 2. PLUTONIUM IN SOIL EAST OF ROCKY FLATS - 1985

difference which could have allowed for plutonium weathering and migration, the larger surface area represented by the 1985 samples [10 acres per sample as compared to the 1977 samples (0.2 acre per sample)], and the fact that a different laboratory utilizing a slightly different radiochemical procedure performed the analyses.

Figure 2 also shows the locations of the three abandoned wheat fields, one in Section 7 and two in Section 18. The 1985 data substantiate the earlier conclusion that the plutonium concentrations in the soil in the previously tilled plots are about 4% of the CDH standard. It is therefore reasonable to conclude that ripping, plowing and disking will reduce the plutonium concentrations in the other areas to levels below the state standard.

Based on the 1985 data, about 75 acres of the newly acquired City of Broomfield land will require remedial action. Most of the remainder of Section 7, purchased by Jefferson County, but excluding the abandoned wheat fields, will require remedial action. The Jefferson County land in Section 18 will require remedial action on about 40 acres. This is the area along Woman Creek between Indiana Street and Mower Reservoir.

REMEDIAL ACTION PROGRAM PLAN

Remedial action recommendations were prepared by Gary Finstad of the US Soil Conservation Service.[6] These recommendations included tillage on alternating strips (standard strip farming techniques) laid out along the contour to minimize wind and water erosion. Remedial action should not be undertaken on the unbroken strips until the first set is re-established in protective grass. Strips with a width of 120 to 150 feet were recommended.

Following tillage a cover crop of sorghum was suggested to control erosion until native grasses could be planted in the fall. The sorghum could be cut if necessary, to provide an improved seed bed for the grass seeding.

Prior to initiation of the ground preparation activities, a Fugitive Dust Permit (No. 85JE052L) was obtained from the Colorado Department of Health (CDH). This permit requires constant monitoring of wind speed and soil density during soil disturbance activities to control blowing dust. If the wind speed exceeds 15 mph or if the soil moisture falls below 15%, all activities on the soil will cease. Vehicle speeds on all disturbed areas must not exceed 15 mph. All disturbed surface areas must be revegetated and snow fences must be installed if found necessary by CDH.

Air samplers must be operated during the soil tillage activities and samples will be analyzed for alpha radioactivity and plutonium concentrations. If the alpha activity exceeds 0.06 pCi/m^3, all soil disturbance actions will be stopped.

REMEDIAL ACTION PLAN IMPLEMENTATION

Eleven strips of land were surveyed and staked at an approximate spacing of 140 feet. The strips ran almost exactly east-west, except where slight variations in topography caused shifts to northwest or northeast. The longest strip was about 3000 feet long and the shortest was about 750 feet long.

Rocky Flats type air samplers were set up at the north edge and at the mid south edge of the work area. The samplers received electrical power from portable 1600 watt gas powered generators. Operation was continuous from June 12 through July 28, 1986 and samples were collected and analyzed once every 24 hours.

Soil moisture test holes were drilled at three locations, one at the north edge, one in the center and one at the south edge of the work area. Aluminum tubes were inserted in each test hole and the locations were marked with flagged stakes. Soil moisture measurements were taken each day that soil disturbance activities were underway. Measurements were made with a Troxler Electronic Laboratories neutron moisture gauge Model 3321. Instrument readings were verified by soil samples analyzed gravimetrically in the Rockwell Rocky Flats General Laboratory.

Tilling the soil on the Jefferson County Open Space lands began on June 11, 1986. The first operation consisted of ripping the soil with an agricultural implement having point chisel rippers, spaced 12 inches apart in three rows. Power was supplied by a four wheel drive 350 horsepower farm tractor. The ripping procedure was applied four times.

The second operation consisted of three passes with an implement having chisel plow curved rippers. The rippers were spaced 12 inches apart in three rows. The third and finish process was performed by one pass with a vibrashank ripper. These smaller rippers were spaced 6 inches apart in 3 rows.

Seed bed preparation in the cultivated area also required removal of thousands of yucca plants because they would interfere with proper operation of the seeder. The many ripping operations dislodged the plants by uprooting or breaking off the roots. It was then necessary to manually collect the plants. A crew of "yucca pickers" placed the plants on a tractor mounted hay fork rack and the tractor operator made piles of yucca plants throughout the worked fields. The piles were later removed using a front-end loader and 10 ton dump truck. 300 loads of yucca were hauled to the Rocky Flats Plant sanitary landfill for final disposal.

Soil samples were then collected from the ten strips to determine the effectiveness of tilling in reducing plutonium concentrations. Samples were collected according to CDH prescribed procedures as previously described. Samples were taken at the edges and center of each strip at a spacing of 150 feet. Strip number one (the westernmost) yielded 24 subsamples which were composited into one sample for analysis. The next strip, number two, was separated into two sections and 24 subsamples were composited from each section labeled "east" and "west." Strips three and four were sampled in a like manner. The remaining seven strips were shorter and were sampled by compositing 14 subsamples for each strip.

The results of soil analyses for plutonium in nine of the eleven strips were all less than the CDH guideline of 0.90 pCi/g (2 d/m/g). The plutonium concentrations in strip #1 and the west half of strip #2 were still greater than 0.90 pCi/g. Approximately 20 acres in these two strips were then tilled three more times with the chisel plow rippers and two more composite samples were collected. The results of analyses for these samples were still greater than 0.90 pCi/g plutonium.

The next attempt at tilling included the use of a three bottom moldboard plow. The 20 acres was plowed three times to a depth of 12 inches and finished with one application with the vibrashank ripper. Ten soil samples were collected from these 20 acres and analyzed individually for plutonium. The average of the four values from strip #1 was 0.83 pCi/g and the average of the six values from strip #2 (west) was 0.63 pCi/g plutonium. The final results of soil analyses on all eleven strips are shown on Figure 3.

The final results of soil analyses from the area showed that the concentrations of plutonium were less than 0.90 pCi/g (2 d/m/g) and ready for seeding as agreed to by CDH. Application of sorghum seed at the rate of 10 pounds per acre was initiated on July 24, 1986. The first sprouts of sorghum appeared on August 4, 1986. The final 20 acres of ground that required deep plowing and ripping was planted with sorghum on August 2, 1986.

The sorghum plants grew to a maximum height of 12 inches and did not generate any seeds. The plants stopped growing in early October and wilted back after the first local frost. The application of wild grass seed began on October 29, 1986 and was completed on November 17, 1986. This long time period was

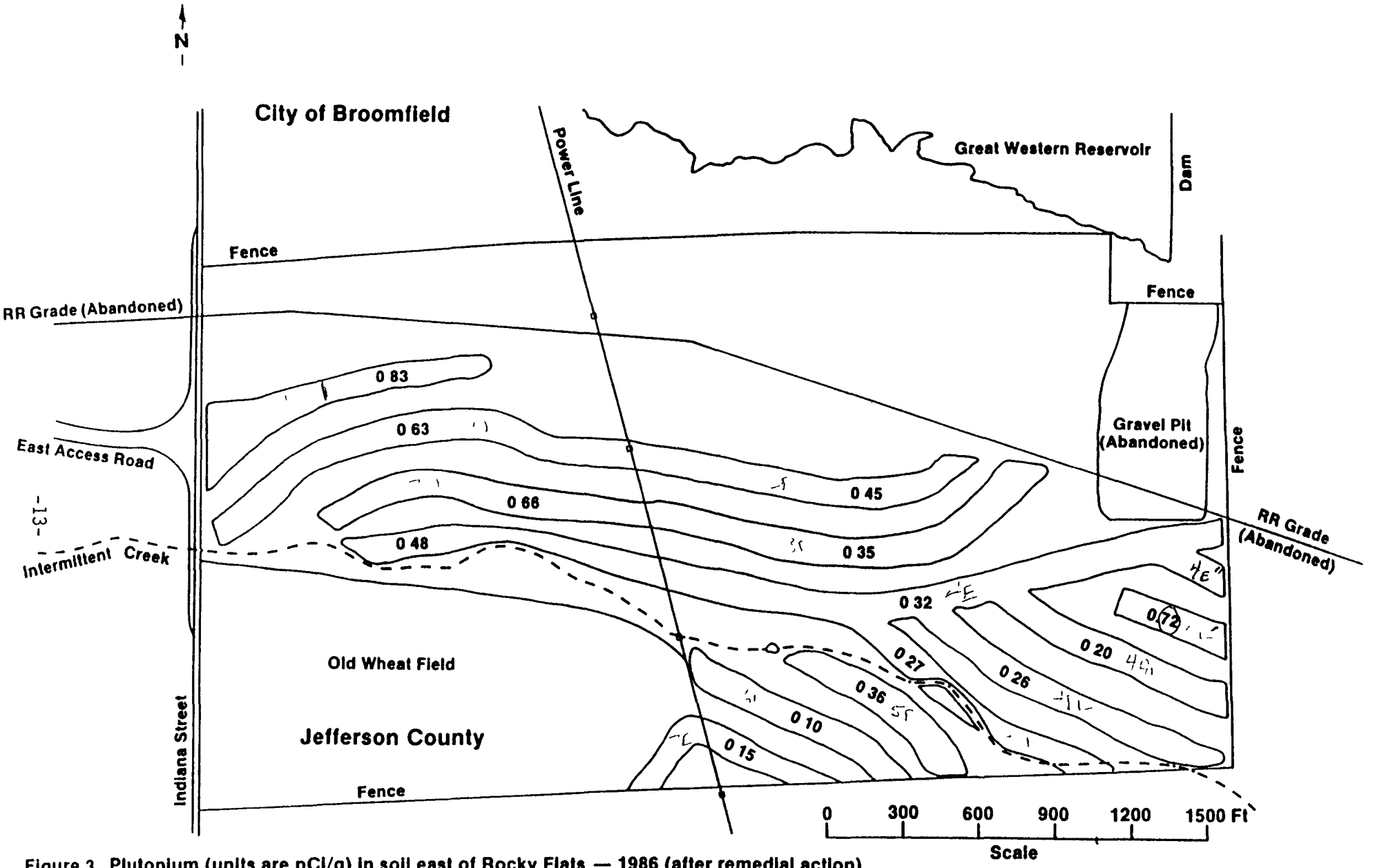

Figure 3 Plutonium (units are pCi/g) in soil east of Rocky Flats — 1986 (after remedial action)

required because of several small snowstorms, winds in excess of the control speed of 15 mph, and below freezing temperatures. The grass seed was applied at a rate of 15 pounds of pure live seed (PLS) per acre and contained a mixture of varieties as indicated below

Special Grass Seed Mixture

Species	Variety	Purity	Germination	Pure Live Seed
Western Wheatgrass	Arriba	36.03%	84%	30.26%
Sideoats Grama	Vaugh	34.36%	88%	30.24%
Smooth Brome	Lincoln	10.39%	73%	7.58%
Pubescent Wheatgrass	Luna	8.29%	91%	7.54%
Other	----	10.93%	---	------
TOTAL		100 %		75.62%

$$\text{Planting Rate} = \frac{15 \text{ lb PLS/acre}}{0.7562} = 19.84 \text{ lb/acre}$$

Since the cover crop of sorghum was not as heavy as desired, supplemental mulching was provided by the addition of long stemmed, weed-free native grass hay. This hay was applied at the rate of 4000 pounds per acre and forced into the soil with a tractor drawn crimper. Mulching began on November 24, 1986 and was completed on January 15, 1987. Once again delays in mulch application were caused by freezing temperatures and snowfall.

REFERENCES

1. Hume, M.W., and Illsley, C.T., "Plutonium Concentrations In Soil on Lands Adjacent To The Rocky Flats Plant," LPR-1, March 1979, Rockwell International.

2. ASTM C998-83 "Standard Method for Sampling Surface Soil for Radionuclides," Annual Book of ASTM Standards, Vol. 12.01., 1983.

3. ASTM C999-83 "Standard Method for Soil Sample Preparation for the Determination of Radionuclides," Annual Book of ASTM Standards, Vol. 12.01, 1983.

4. ASTM C1001-83 "Standard Method for Radiochemical Determination of Plutonium in Soil by Alpha Spectrometry," Vol. 12.01, 1983.

5. EPA "Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment," EPA 520/4-77-016, September 1977, US Environmental Protection Agency.

6. Finstad, G. D., "Erosion Control and Revegetation Recommendations for Proposed Remedial Action Projects," April 1985, US Soil Conservation Service.

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(303) 423-2766

November 27, 1985

Mr. Chuck Illsley
Rockwell International
Rocky Flats Plant
P.O. Box 464
Golden, CO 80402-0464

RE: 8890-20831-12
Date Samples Rec'd 10-17-85
P.O. No. 48464

REPORT OF ANALYSIS

ALR Designation	Sponsor Designation	Plutonium-239, ± counting error* pCi/g (dry)	Duplicate Result	Air Dry Loss, %
8890-20831-12-1	GWS-85-1	5.9 ± 0.5	5.2 ± 0.5	4.3
-2	GWS-85-2	4.9 ± 0.5	5.0 ± 0.5	4.6
-3	GWS-85-3	2.5 ± 0.4	3.3 ± 0.4	4.2
-4	GWS-85-4	2.1 ± 0.4	2.2 ± 0.3	4.7
-5	GWS-85-5	2.6 ± 0.4	2.4 ± 0.3	7.3
-6	GWS-85-6	1.0 ± 0.3	0.72 ± 0.19	7.5
-7	GWS-85-7	0.84 ± 0.21	1.2 ± 0.2	4.9
-8	GWS-85-8	0.58 ± 0.20	0.89 ± 0.21	3.0
-9	GWS-85-9	4.2 ± 0.4	2.9 ± 0.4	4.9
-10	GWS-85-10	2.3 ± 0.3	2.0 ± 0.4	7.7
-11	Blank	0.13 ± 0.12	0.07 ± 0.12	--
-12	Standard	0.93 ± 0.19	1.3 ± 0.3	--

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.
These samples are scheduled to be disposed of 45 days after the date of this report.

Bud Summers
Radiochemistry
Supervisor

BS/dh dh

Accu-Labs Research, Inc.
11485 W 48th Avenue Wheat Ridge Colorado 80033
(303) 423-2766

December 26, 1985

Mr. Chuck Illsley
Rockwell International
Rocky Flats Plant
P.O. Box 464
Golden, CO 80402-0464

RE: 8890-20915-9
Date Samples Rec'd 11-1-85
P.O. No. 48464PB

REPORT OF ANALYSIS

ALR Designation	Sponsor Designation	Plutonium-239, ± counting error* pCi/g	Plutonium-239, duplicate, ± counting error* pCi/g
8890-20915-9-1	I-85-2	0.38 ± 0.19	0.53 ± 0.24
-2	I-85-4	0.53 ± 0.22	0.69 ± 0.21
-3	I-85-5	0.83 ± 0.30	1.1 ± 0.2
-4	I-85-6	1.1 ± 0.3	0.89 ± 0.29
-5	I-85-7	0.62 ± 0.22	0.43 ± 0.18
-6	I-85-11	0.74 ± 0.28	0.88 ± 0.36
-7	I-85-12	0.10 ± 0.14	-0.04 ± 0.12
-8	Blank	-0.03 ± 0.08	0.05 ± 0.10
-9	Standard	1.2 ± 0.3	0.84 ± 0.24

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.
These samples are scheduled to be disposed of 45 days after the date of this report.

Bud Summers
Radiochemistry
Supervisor

BS/dh

Accu-Labs Research, Inc.
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(303) 423 2766

December 12, 1985

Mr. Chuck Illsley
Rockwell International
Rocky Flats Plant
P.O. Box 464
Golden, CO 80402-0464

RE: 8890-20877-9
Date Samples Rec'd 10-25-85
P.O. No. 48464PB

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	8890-20877-9-1 I85-16	8890-20877-9-2 I85-17	8890-20877-9-3 I85-18	8890-20877-9-4 I85-19	8890-20877-9-5 I85-20
Determination· pCi/g					
Plutonium-239, ± counting error*	0.11 ± 0.13	0.70 ± 0.19	1.6 ± 0.2	2.9 ± 0.4	2.3 ± 0.3
Plutonium-239, duplicate, ± counting error*	0.13 ± 0.16	0.93 ± 0.21	2.1 ± 0.3	3.2 ± 0.6	1.9 ± 0.6
Air Dry Loss, %	2.1	1.8	1.1	1.8	1.8

Mr. Chuck Illsley
Rockwell International

RE· 8890-20877-9
Date Samples Rec'd 10-25-85
P.O. No. 48464PB

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	8890-20877-9-6 I85-21	8890-20877-9-7 I85-22	8890-20877-9-8 Blank	8890-20877-9-9 Standard
Determination· pCi/g				
Plutonium-239, ± counting error*	0.75 ± 0.17	1.7 ± 0.3	0.03 ± 0.12	1.1 ± 0.2
Plutonium-239, duplicate, ± counting error*	1.3 ± 0.3	1.2 ± 0.2	-0.02 ± 0.11	0.92 ± 0.29
Air Dry Loss, %	1.3	1.5	--	--

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.
These samples are scheduled to be disposed of 45 days after the date of this report.

Bud Summers
Radiochemistry
Supervisor

BS/dh

NATIVE VEGETATION | REMEDIATED VEGETATION

Figure 1 Photograph taken October 1990 comparing native vegetation on the left with remediated vegetation on the right

Figure 2 Photograph taken spring 1986 showing [redacted] rocks brought to the surface during initial tilling operations

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(303) 423-2766

SAMPLES TAKEN AFTER 1ST TILLING OPERATION ON SEC 7 STRIPS
SOIL SUBSAMPLES TAKEN TO MAKE 1 OR 2 SAMPLES/STRIP - 14 SAMPLES TOTAL

Mr. Chuck Illsley
Rockwell International
Rocky Flats Plant
P.O. Box 464
Golden, CO 80402-0464

RE: 8890-22225-16
Date Samples Rec'd 6-26-86
P.O. No. 65746 and 78499DR

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	8890-22225-16-1 STP-1-W	8890-22225-16-2 STP-2-W	8890-22225-16-3 STP-2-E	8890-22225-16-4 STP-3-W	8890-22225-16-5 STP-3-E
Determination: pCi/g (dry)					
Plutonium-239, ± counting error*	1.8 ± 0.3	1.1 ± 0.3	0.44 ± 0.22	0.85 ± 0.22	0.42 ± 0.19
Plutonium-239, duplicate, ± counting error*	1.3 ± 0.3	3.7 ± 0.4	0.46 ± 0.21	0.47 ± 0.20	0.28 ± 0.19
Plutonium-239, ± counting error*	1.8 ± 0.3	1.2 ± 0.2	--	--	--
Plutonium-239, ± counting error*	2.0 ± 0.3	0.88 ± 0.27	--	--	--
Air Dry Loss, %	<0.1	<0.1	<0.1	<0.1	0.6

Mr. Chuck Illsley
Rockwell International

RE: 8890-22225-16
Date Samples Rec'd 6-26-86
P.O. No. 65746 and 78499DR

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	8890-22225-16-6 STP-4-W	8890-22225-16-7 STP-4-E	8890-22225-16-8 STP-4-'E	8890-22225-16-9 STP-4A-E	8890-22225-16-10 STP-4B-F
Determination: pCi/g (dry)					
Plutonium-239, ± counting error*	0.25 ± 0.18	0.35 ± 0.20	0.47 ± 0.21	0.12 ± 0.16	0.32 ± 0.19
Plutonium-239, duplicate, ± counting error*	0.71 ± 0.23	0.29 ± 0.20	3.1 ± 0.3	0.29 ± 0.20	0.20 ± 0.19
Plutonium-239, ± counting error*	--	--	0.84 ± 0.17	--	--
Plutonium-239, ± counting error*	--	--	0.86 ± 0.17	--	--
Air Dry Loss, %	0.5	0.2	0.3	0.2	0.1

Mr. Chuck Illsley
Rockwell International

RE: 8890-22225-16
Date Samples Rec'd 6-26-86
P.O. No. 65746 and 78499DR

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	8890-22225-16-11 STP-4C-E	8890-22225-16-12 STP-5-E	8890-22225-16-13 STP-6-E	8890-22225-16-14 STP-7-E	8890-22225-16-15 Standard
Determination: pCi/g (dry)					
Plutonium-239, ± counting error*	0.36 ± 0.20	0.93 ± 0.22	0.14 ± 0.17	0.20 ± 0.21	1.0 ± 0.2
Plutonium-239, duplicate, ± counting error*	0.18 ± 0.18	0.18 ± 0.18	0.05 ± 0.16	0.09 ± 0.16	1.2 ± 0.3
Plutonium-239, ± counting error*	--	0.13 ± 0.16	--	0.11 ± 0.15	--
Plutonium-239, ± counting error*	--	0.18 ± 0.16	--	--	--
Air Dry Loss, %	0.2	0.1	0.1	0.4	--

Mr. Chuck Illsley
Rockwell International

RE: 8890-22225-16
Date Samples Rec'd 6-26-86
P.O. No. 65746 and 78499DR

REPORT OF ANALYSIS

ALR Designation	8890-22225-16-16
Sponsor Designation	Blank
Determination: pCi/g (dry)	
Plutonium-239, ± counting error*	0.03 ± 0.15
Plutonium-239, duplicate, ± counting error*	-0.11 ± 0.22
Plutonium-239, ± counting error*	0.05 ± 0.16
Air Dry Loss, %	--

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.
These samples are scheduled to be disposed of 45 days after the date of this report.

Bud Summers
Radiochemistry
Supervisor

BS/dh

Accu-Labs Research, Inc.
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RESULTS AFTER 2nd TILLING OF WEST END STRIPS 1+2 IN SEC 7

2 samples

July 24, 1986

Mr. Chuck Illsley
Rockwell International
Rocky Flats Plant
P.O. Box 464
Golden, CO 80402-0464

RE: 8890-22307-4
Date Samples Rec'd 7-14-86

REPORT OF ANALYSIS

ALR Designation Sponsor Designation	8890-22307-4-1 STP 1W2	8890-22307-4-2 STP 2W2	8890-22307-4-3 Blank	8890-22307-4-4 Standard
Determination: pCi/g				
Plutonium-239, ± counting error*	2.4 ± 0.3	0.86 ± 0.25	0.05 ± 0.06	1.0 ± 0.4
Plutonium-239, duplicate, ± counting error*	2.4 ± 0.3	0.98 ± 0.20	0.08 ± 0.07	0.90 ± 0.21
Air Dry Loss, %	1.2	2.0	--	--

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.
These samples are scheduled to be disposed of 45 days after the date of this report.

Bud Summers
Radiochemistry
Supervisor

BS/dh
dh

Accu-Labs Research, Inc.
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RESULTS AFTER 3rd TILLING OPERATION ON SBC & strips

August 1, 1986

Mr. Chuck Illsley
Rockwell International
Rocky Flats Plant
P.O. Box 464
Golden, CO 80402-0464

RE: 8890-22394-12
Date Samples Rec'd 7-28-86
P.O. No. 65746DD

REPORT OF ANALYSIS

ALR Designation	Sponsor Designation	Plutonium-239, ± counting error*, pCi/g	Plutonium-239, duplicate, ± counting error*, pCi/g
8890-22394-12-1	STP 1W3 A	0.96 ± 0.19	1.7 ± 0.3
-2	STP 1W3 B	0.46 ± 0.13	0.34 ± 0.13
-3	STP 1W3 C	0.51 ± 0.17	1.0 ± 0.2
-4	STP 1W3 D	0.78 ± 0.20	0.85 ± 0.17
-5	STP 2W3 A	0.56 ± 0.15	1.3 ± 0.2
-6	STP 2W3 B	0.54 ± 0.15	0.52 ± 0.15
-7	STP 2W3 C	0.46 ± 0.14	1.1 ± 0.2
-8	STP 2W3 D	0.32 ± 0.13	0.48 ± 0.14
-9	STP 2W3 E	0.60 ± 0.16	0.42 ± 0.15
-10	STP 2W3 F	0.65 ± 0.15	--
-11	Blank	0.00 ± 0.07	--
-12	Standard	1.1 ± 0.2	--

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.
These samples are scheduled to be disposed of 45 days after the date of this report.

Bud Summers
Radiochemistry
Supervisor

BS/dh

DOCUMENT D-11

"Remedial Action Program on Jefferson County Open Space Land
Status Report for Period January 15, 1987 to October 15, 1987"
(1987)

by

Rockwell International

REMEDIAL ACTION PROGRAM ON JEFFERSON COUNTY OPEN SPACE LAND

STATUS REPORT FOR

PERIOD JANUARY 15, 1987 TO OCTOBER 15, 1987

EAC-420-87-3

October 15, 1987

REMEDIAL ACTION PROGRAM ON JEFFERSON COUNTY OPEN SPACE LAND
STATUS REPORT FOR PERIOD
JANUARY 15, 1987 TO OCTOBER 15, 1987

Introduction

Figure 1 shows the location of lands designated for remedial action as part of the 1984 settlement agreement. The settlement agreement ended litigation with landowners involving the Rocky Flats Plant and alleged impacts on land values proximate to the plant.

Since the Colorado Department of Health (CDH) was a party to the lawsuit, the CDH soil plutonium standard for construction activities is the standard used in the mitigation. Figure 2 shows the results of sampling in the area for the years 1977 and 1985. Note the areas that were above the CDH construction limit of 0.9 pCi/g consistently through both sampling programs. One area is west of Mower Reservoir (Area A) and another is from Indiana and the RFP East Access Road east 1 mile to the Section 7 boundary (Area B). Sampling in both years was conducted according to the Colorado Department of Health (CDH) protocol and analyzed by independent laboratories. These are the two areas of interest for the remedial action in Jefferson County.

Historical Summary of Actions Through September 1, 1987. Area A - Four strips approximately 1500 feet x 150 feet were ripped and plowed in June and July of 1987. The strips were separated by undisturbed strips of ground approximately 150 feet wide (Figure 3). The total plowed area is approximately 20 acres. The plowed strips have not yet been planted Sampling was conducted after the plowing and the results are shown in pCi/g on Figure 3. The west end of strip number one still showed values higher than the CDH construction standard. It was plowed a second time in July of 1987. It will be re-sampled in October of 1987. If the area fails to meet the CDH construction standard, it will again be re-plowed

(Name) (Title)

Area B - Approximately 100 acres were ripped and plowed in June and July of 1986. Figure 4 shows the configuration of the plowed and unplowed strips. Also shown on Figure 4 are the results of sampling conducted after the plowing was completed. All areas that were plowed now meet the CDH construction standard. In late Fall of 1986, native grasses were seeded into the area. In the Spring of 1987, it was apparent that the vegetation had failed. In June of 1987, the 100 acres were ripped again and sorghum was planted. The sorghum is tall and thickly growning.

Proposed Actions

Area A - There is no vegetation on the plowed strips other than a healthy weed crop of cheat grass. Cheat grass or downey brome is an aggressive annual grass that invades disturbed areas and competes with desirable species for water and nutrients. January and February are the driest months of the year and two of the most windy. A good vegetation cover is needed to prevent wind erosion. Winter wheat is the only vegetation that can be planted now that could provide cover in those months. Winter wheat must be planted as soon as possible. The area will be disked twice to control the cheatgrass and winter wheat planted the week of October 12. Mulch will be applied at a rate of 2 tons per acre and crimped into the soil. In late March or early April of 1988 the strips will be mechanically turned over or chemically treated to stop the wheat growth and to control weeds, and native grasses will be drilled The wheat growth must be stopped to prevent it from competing for water and nutrients with the desired permanent vegetation. A mid-summer 1988 weed control treatment may be necessary. The intermediate strips will be plowed in the spring of 1989, at the earliest. The process of planting will be repeated with a completion date of Summer 1990.

Area B - The sorghum cover is doing very well, even on the rocky areas The week of October 12 will be used to spray Roundup to kill the cheatgrass. The week of October 26 will then be used to plant native grasses through the sorghum cover. The sorghum will protect the ground, but will weather through the winter enough so that it will not shade the grass seedlings in the spring. Some weed control may be necessary in mid-summer of 1988. The intermediate strips will be plowed in the spring of 1989 and the whole process repeated

The Soil Conservation Service has been consulted and concurs with the details of the plan.

Departures from Historical Plans

Due to changing conditions caused by the difficulty in plowing the small rocky areas and the native grass seeding failure, some changes are warranted that require discussion with the Jefferson County Open Space and Administrative staffs. These are listed below:

1. Chemical weed control of cheatgrass will be necessary. Roundup will be sprayed under the sorghum cover or directly to weedy unseeded ground. This will reduce the tremendous cheatgrass cover and allow the perennial native to take hold. Roundup (isopropylamine salt of glyphosate) is an effective non-specific weed control agent which degrades quickly in the soil. It will be applied under strictly controlled situations by a licensed applicator with guidance from the manufacturer. The Rockwell project manager will discontinue operations if winds exceed 10 mph and if soil moisture is less than 15%.

2. An experimental use of a rock rake will be attempted prior to seeding this fall. Rocks will be windrowed to one side of a plowed strip in a long fence-like pile. It is possible that other measures may be needed such as borrowing a suitable cover, screening rocks out, etc. A small area with a large rock content will also be experimentally hydroseeded to determine the capabilities of hydroseeding and hydromulching.

3 The Soil Conservation Service originally recommended that the present seed mix be used to reclaim these lands. The mix consists of 40% western wheatgrass, 40% sideoats grama, 10% pubescent wheatgrass and 10% smooth brome. This recommendation was made to bring the land back

to native grassland, which is the designated goal and use in the SCS management plans for the area. These grasses can be very difficult to grow and require several years before an effective cover can be established.

Sideoats grama may take years to grow into a major community component. It makes up 40% of the seed mix. That leaves a large hole to fill in the community that will be left to bare soil and weeds in the meantime.

It is now recommended that the seed mix be altered to 40% Western wheatgrass, 40% smooth brome, 10% pubescent wheatgrass and 10% sideoats grama. This will establish a quick cover that protects the soil. Smooth brome planted on the Coors gasline on the RFP site has done very well and has stabilized the soil.

The Soil Conservation Service has been consulted and concurs with the herbicide spraying recommendation. The SCS has also agreed to reconsider the seed mix composition with either agreement of Jefferson County or with a land use goal stated by Jefferson County that will be compatible with a revised seed mix.

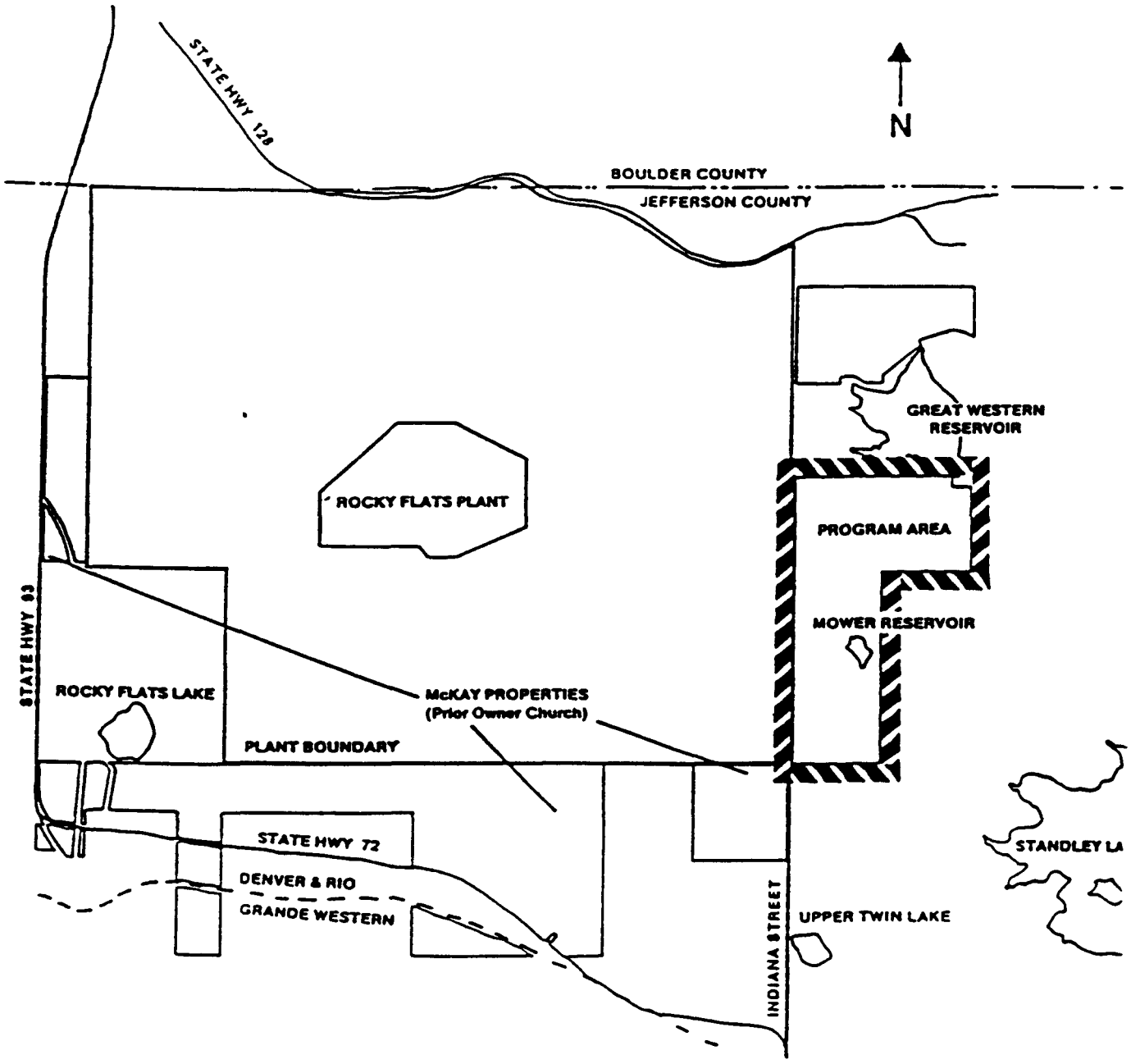


FIGURE 1. INDEX MAP SHOWING LOCATION OF PROGRAM AREA

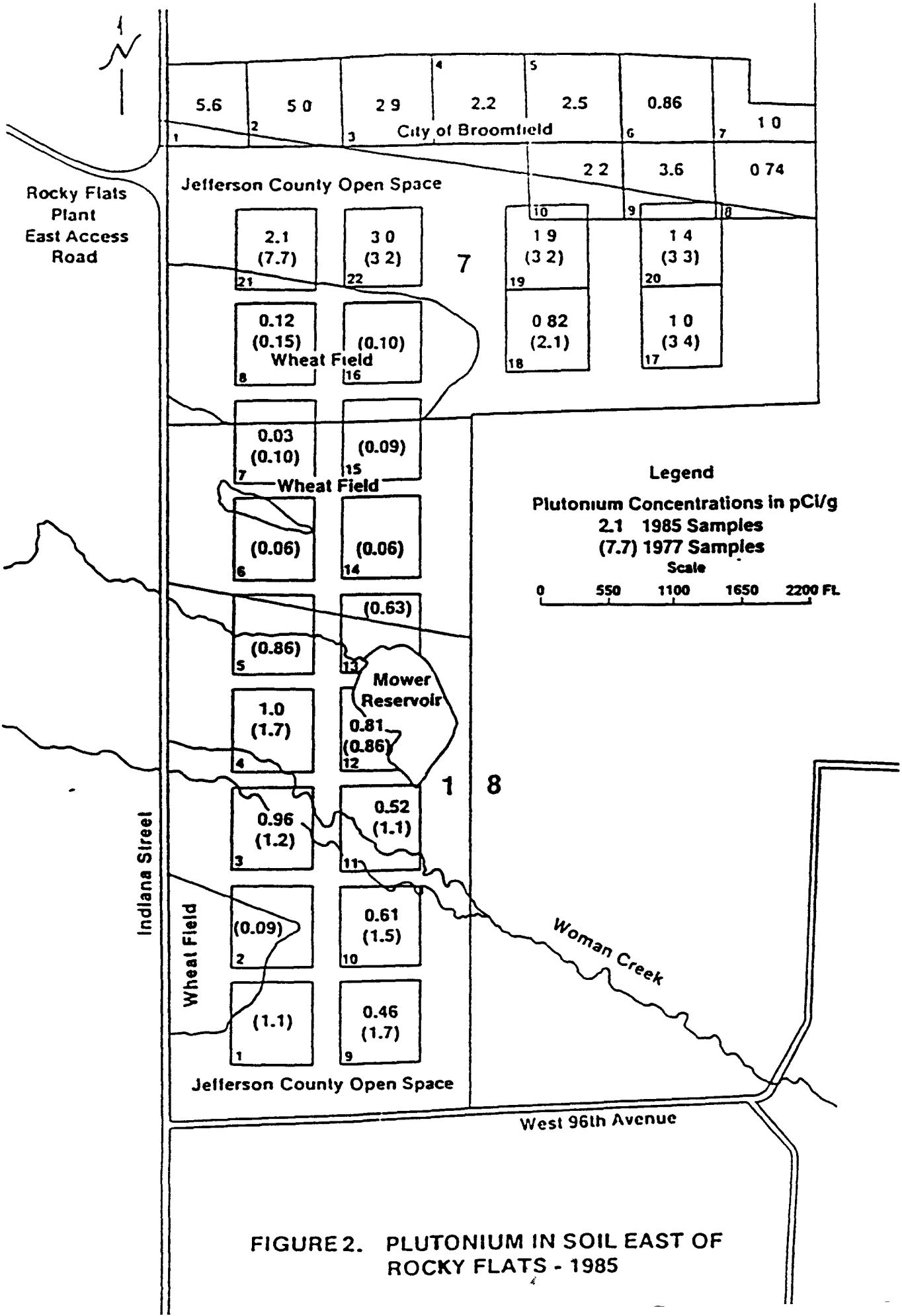
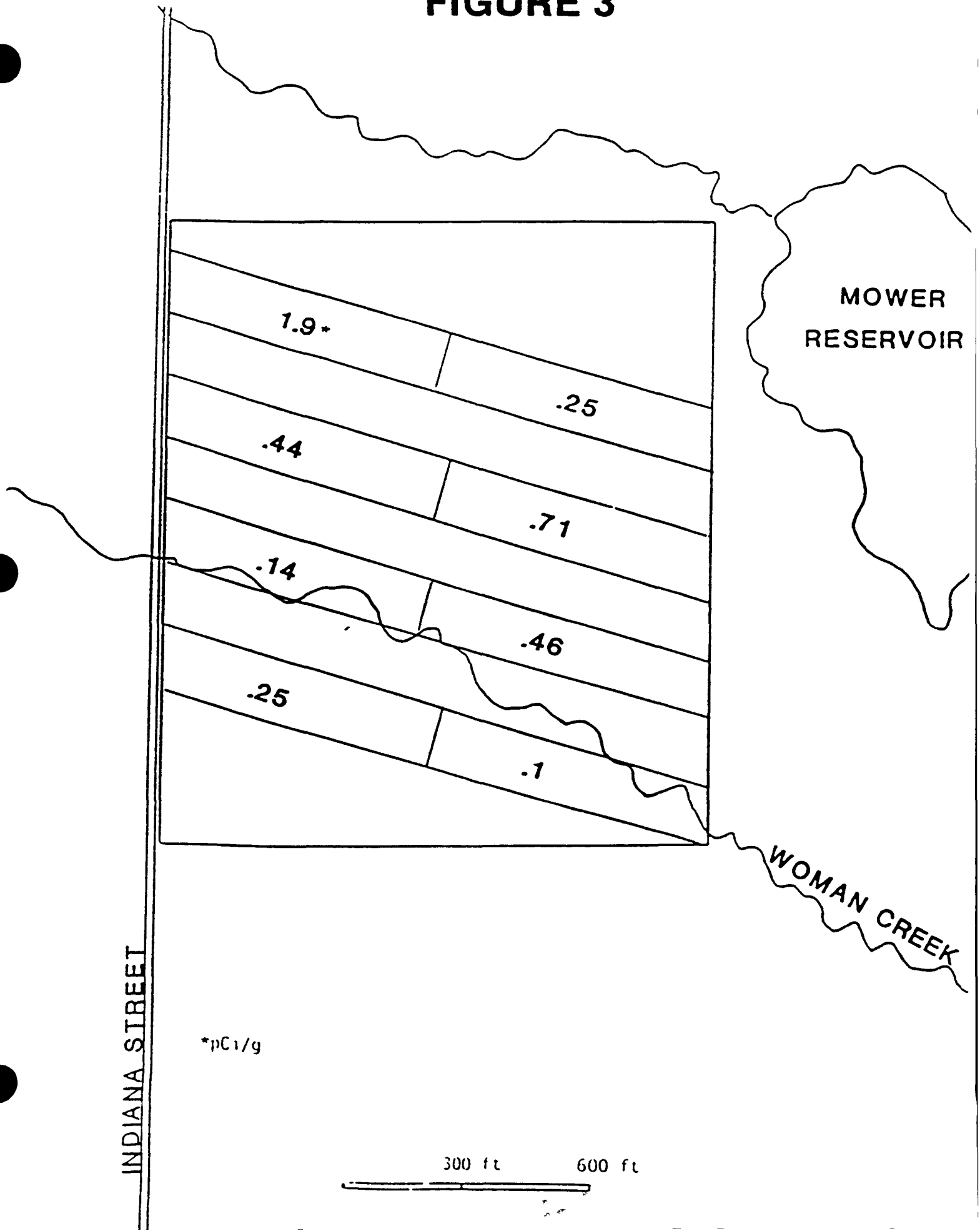


FIGURE 2. PLUTONIUM IN SOIL EAST OF ROCKY FLATS - 1985

FIGURE 3


1.9*
.25
.44
.71
.14
.46
.25
.1
MOWER
RESERVOIR
WOMAN CREEK
INDIANA STREET
*pCi/g
300 ft
600 ft

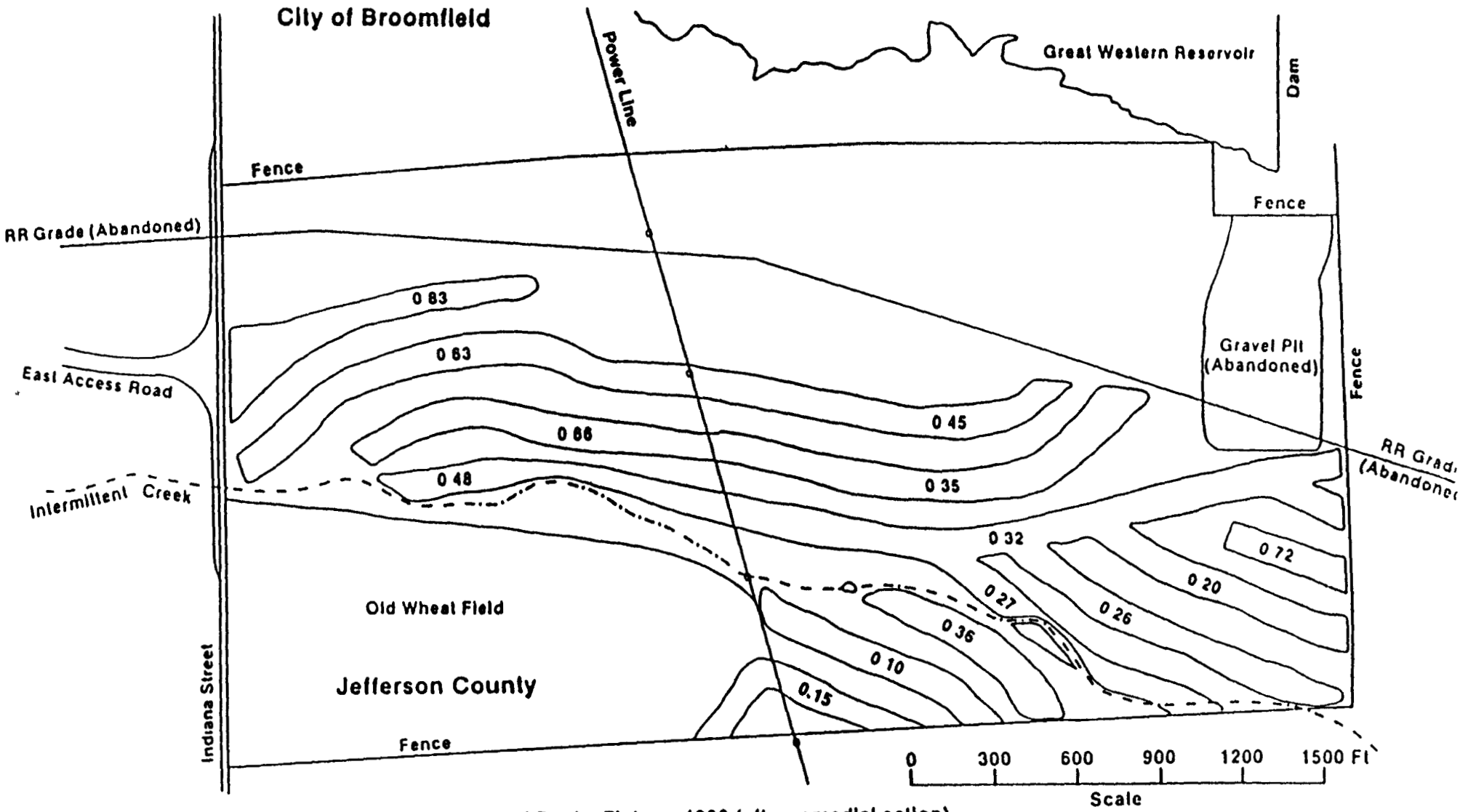


Figure 4 Plutonium (units are pCi/g) in soil east of Rocky Flats — 1986 (after remedial action)

REMEDIAL ACTION PROGRAM ON JEFFERSON COUNTY OPEN SPACE LAND
UPDATE FOR PERIOD JANUARY 1987 TO OCTOBER 1987

I. Section 18, west and southwest of Mower Reservoir - 20 acres.

A. June 22 to July 31, 1987. Plowing and ripping operations conducted on 20 acres. Four strips 150 feet wide and 1500 feet long were plowed After initial activities, sampling showed that the west end of the northern strip remained above the CDH standard. The northern-most strip was plowed again.

B. Week of October 12, 1987. The strips will be disked to destroy cheat grass growth and planted with winter wheat. Mulch will be added and crimped at a rate of 2 tons/acre. This will stabilize the areas over the winter.

C. Late March or April, 1988. Strips will be mechanically turned over or chemically treated to stop wheat growth and seeded with native grasses.

D. Mid-summer, 1988, chemical weed control will be investigated.

E. If stand of grass is offering adequate site stabilization, the unplowed areas will be plowed, tested and planted with winter wheat. Fall 1988.

II. Section 7, south and southwest of Great Western Reservoir - 100 acres.

A. June 12 to July 28, 1986. Ripping operations conducted.

B. June 11, 1987. Areas re-ripped. Vegetation had failed. Sorghum was replanted and came up well.

C. Week of October 19, 1987. Cheat grass will be controlled with Roundup application.

D. Week of October 26, 1987. Native grasses will be seeded through the sorghum cover. Alternative seeding practices will be investigated such as broadcast seeding, hydroseeding and alternatives such as borrowing a suitable 6 inch cover soil to place on the rocks will be evaluated. These alternatives will be investigated to determine the best way to reclaim the small areas of rocky, difficult lands and prevent erosion.

E. Spring 1988, early April. An evaluation of probable seeding success will be made based on available moisture and indications of sprouting. If necessary, a second spring seeding will be conducted.

F. Mid-summer 1988 weed control may be necessary. Seeding success will be evaluated. If revegetation is successful, the intervening strips will be plowed.

REMEDIAL ACTION AIR SAMPLING RESULTS - 1987

DATE	DATE OFF	SAMPLER	VOLUME m3	POINT EST. pCi/m3	+/- ERROR pCi/m3
22-JUN-87	23-JUN-87	A	1627	0.000088	0.000042
22-JUN-87	23-JUN-87	B	1627	0.000197	0.000057
23-JUN-87	24-JUN-87	A	1605	0.000028	0.000039
23-JUN-87	24-JUN-87	B	1622	0.000038	0.000038
24-JUN-87	25-JUN-87	A	1528	0.000001	0.000040
24-JUN-87	25-JUN-87	B	1593	0.000161	0.000049
25-JUN-87	26-JUN-87	A	1721	0.000073	0.000039
25-JUN-87	26-JUN-87	B	1712	0.000044	0.000039
26-JUN-87	27-JUN-87	A	1825	0.000003	0.000033
26-JUN-87	27-JUN-87	B	1825	0.000006	0.000040
30-JUN-87	01-JUL-87	A	1627	0.000009	0.000038
30-JUN-87	01-JUL-87	B	1644	0.000038	0.000076
01-JUL-87	02-JUL-87	B	1627	0.000000	0.000038
02-JUL-87	03-JUL-87	A	1579	-0.000006	0.000039
02-JUL-87	03-JUL-87	B	1627	0.000011	0.000038
06-JUL-87	07-JUL-87	A	1729	-0.000002	0.000032
06-JUL-87	07-JUL-87	B	1735	-0.000019	0.000034
07-JUL-87	08-JUL-87	A	1559	0.000062	0.000043
07-JUL-87	08-JUL-87	B	1559	-0.000025	0.000039
08-JUL-87	09-JUL-87	A	1672	0.000057	0.000039
08-JUL-87	09-JUL-87	B	1683	0.000198	0.000053
09-JUL-87	10-JUL-87	A	1644	0.000001	0.000037
09-JUL-87	10-JUL-87	B	1616	0.000074	0.000041
13-JUL-87	14-JUL-87	A	1661	0.000063	0.000040
[illegible]UL-87	14-JUL-87	B	1638	0.000031	0.000038
[illegible]JUL-87	15-JUL-87	A	1571	0.000040	0.000041
14-JUL-87	15-JUL-87	B	1582	0.000001	0.000039
15-JUL-87	16-JUL-87	A	1655	0.000014	0.000038
15-JUL-87	16-JUL-87	B	1672	0.000008	0.000037
16-JUL-87	17-JUL-87	A	1526	-0.000010	0.000040
16-JUL-87	17-JUL-87	B	1593	0.000130	0.000045
17-JUL-87	18-JUL-87	A	1509	-0.000005	0.000041
17-JUL-87	18-JUL-87	B	1497	-0.000013	0.000041
20-JUL-87	21-JUL-87	A	1706	0.000003	0.000036
20-JUL-87	21-JUL-87	B	1695	0.000031	0.000038
21-JUL-87	22-JUL-87	A	1548	0.000005	0.000041
21-JUL-87	22-JUL-87	B	1554	0.000021	0.000041
22-JUL-87	23-JUL-87	A	1622	-0.000010	0.000037
22-JUL-87	23-JUL-87	B	1610	-0.000003	0.000038
23-JUL-87	24-JUL-87	B	1723	-0.000003	0.000033
24-JUL-87	25-JUL-87	A	1328	-0.000032	0.000044
24-JUL-87	25-JUL-87	B	1367	0.000015	0.000045
27-JUL-87	28-JUL-87	A	1678	0.000024	0.000038
27-JUL-87	28-JUL-87	B	1635	-0.000013	0.000037
28-JUL-87	29-JUL-87	A	1559	0.000017	0.000040
28-JUL-87	29-JUL-87	B	1633	0.000001	0.000037
29-JUL-87	30-JUL-87	A	1644	-0.000003	0.000037
29-JUL-87	30-JUL-87	B	1650	-0.000005	0.000037
30-JUL-87	31-JUL-87	A	1644	0.000117	0.000044
[illegible]UL-87	31-JUL-87	B	1633	-0.000018	0.000036
[illegible]UL-87	01-AUG-87	A	1559	-0.000028	0.000028
31-JUL-87	01-AUG-87	B	1565	-0.000012	0.000038
03-AUG-87	04-AUG-87	A	1678	0.000013	0.000037
03-AUG-87	04-AUG-87	B	1672	0.000022	0.000038

REMEDIAL ACTION AIR SAMPLING RESULTS - 1987

DATE ON	DATE OFF	SAMPLER	VOLUME m3	POINT EST. pCi/m3	+/- ERROR pCi/m3
04-AUG-87	05-AUG-87	A	1525	0.000011	0.000041
04-AUG-87	05-AUG-87	B	1531	-0.000015	0.000039
05-AUG-87	06-AUG-87	A	1661	-0.000012	0.000037
06-AUG-87	07-AUG-87	A	1729	0.000439	0.000065
06-AUG-87	07-AUG-87	B	1644	0.000030	0.000038
20-AUG-87	21-AUG-87	A	1548	0.000340	0.000064
20-AUG-87	21-AUG-87	B	1571	0.000390	0.000068
21-AUG-87	22-AUG-87	A	1458	0.000009	0.000041
21-AUG-87	22-AUG-87	B	1458	0.009778	0.001607
04-NOV-87	04-NOV-87	A	1639	0.000007	0.000043
04-NOV-87	04-NOV-87	A	1639	0.000007	0.000043
04-NOV-87	04-NOV-87	C	1663	0.000086	0.000044
05-NOV-87	05-NOV-87	A	1644	-0.000003	0.000036
05-NOV-87	05-NOV-87	C	1651	0.000064	0.000044
06-NOV-87	08-NOV-87	A	4891	0.000011	0.000015
06-NOV-87	08-NOV-87	B	4824	0.000000	0.000014
06-NOV-87	08-NOV-87	C	4806	0.000035	0.000016
06-NOV-87	08-NOV-87	D	4827	0.000013	0.000015
06-NOV-87	08-NOV-87	E	4039	-0.000008	0.000016
09-NOV-87	13-NOV-87	A	6404	0.000000	0.000011
09-NOV-87	09-NOV-87	B	1709	0.000007	0.000041
09-NOV-87	14-NOV-87	C	8116	0.000015	0.000009
09-NOV-87	11-NOV-87	D	4936	0.000018	0.000015
09-NOV-87	10-NOV-87	E	3263	0.000008	0.000021
[illegible]-NOV-87	12-NOV-87	D	1584	0.000072	0.000046
[illegible]-NOV-87	13-NOV-87	B	1542	-0.000007	0.000044
13-NOV-87	13-NOV-87	D	1514	0.000105	0.000155
13-NOV-87	13-NOV-87	E	1510	0.000000	0.000046
14-NOV-87	14-NOV-87	A	1752	0.000044	0.000041
14-NOV-87	14-NOV-87	B	3367	-0.000001	0.000020
14-NOV-87	14-NOV-87	C	1758	-0.000010	0.000039
14-NOV-87	14-NOV-87	D	3362	-0.000008	0.000021
14-NOV-87	14-NOV-87	E	3366	-0.000007	0.000020
23-NOV-87	23-NOV-87	A	3581	0.000001	0.000020
23-NOV-87	23-NOV-87	B	1639	-0.000018	0.000042
23-NOV-87	23-NOV-87	C	3576	0.000013	0.000021
23-NOV-87	23-NOV-87	D	1639	-0.000019	0.000042
23-NOV-87	23-NOV-87	E	1639	-0.000015	0.000042
04-DEC-87	04-DEC-87	A	542	-0.000041	0.000127
04-DEC-87	04-DEC-87	C	559	0.000020	0.000125

DOCUMENT D-13

"Status of Remedial Action on Jefferson County Lands
East of Indiana Street, November 1987 to November 1988"
(1988)

by

Rockwell International

STATUS OF REMEDIAL ACTION ON JEFFERSON COUNTY LANDS EAST OF INDIANA STREET NOVEMBER, 1987 TO NOVEMBER, 1988

This report summarizes the actions that have occurred on the remedial action lands east of Indiana Street adjacent to the Rocky Flats Plant. These lands are owned by Jefferson County The last update presented to Jefferson County was in November of 1987

Subsequent to the plowing activity in the area immediately to the west of Mower Reservoir in Section 18, sampling indicated that the plutonium levels in the soil remained above the standard of 0 9 picocuries per gram of soil The area was plowed a second time and sampled again The results were not yet available for the November 1987 update document. The sample results were 0 04 ± 0 13 pCi/g and 0 00 ± 0 13 pCi/g for duplicate analysis This indicates that plowing the second time was successful in reducing the plutonium concentrations below the standard, and revegetation activities could begin.

SOUTH AREA ACTIVITIES (WEST OF MOWER RESERVOIR, SECTION 18)

FALL, 1987

In order to reduce competition from weed species, primarily cheat grass, the plowed strips were disced in early November to kill the weeds. This was in anticipation of a spring seeding of native grasses. Removing the weedy species would give the planted native grasses a better chance of successful growth in the spring. To reduce or eliminate any wind or water erosion from the surface, 1) the surface was left in a roughened state; 2) winter wheat was planted at approximately 20 pounds of seed per acre, and 3) a native grass hay mulch was placed onto the surface at a rate of 2 tons per acre and crimped into the soil with a disc with crimper blades This was all completed in early December

WINTER, 1987-1988

Inspections were conducted during the winter months to detect any erosion early and perform any necessary erosion control work. The inspections revealed that little if any erosion was occurring and the snow downwind of the area was clean, even after heating of the soil had exposed the mulched area

SPRING, 1988

Seeding of the area was begun toward the end of April, and

completed April 25 The native grass seed was planted through the existing cover of weeds without disturbing the surface to any great extent. A significant amount of natural vegetation not killed by the plowing is recovering This will greatly increase the diversity of the revegetated surface

SUMMER, FALL, 1988

The summer and fall months at the project site were extremely dry Normal thunderstorm activity contributed very little precipitation The seeds have not sprouted, for the most part A site visit with Mr Gary Finstad of the U.S Soil Conservation Service on October 17th, 1988 revealed that most of the seed is lying dormant in the soil. A winter of precipitation should produce a good crop of native grass in the spring. Erosion protection is being provided by the winter wheat that did germinate and a continuous cover of annual and perennial weeds

NORTH AREA (SOUTH OF GREAT WESTERN RESERVOIR, SECTION 7)

FALL, 1987

The plowed strips in the north area were sprayed with Roundup herbicide during the first two weeks in November. This was to reduce the competition caused by weeds, primarily cheat grass, with the native grasses. The control was very successful. Roundup was used because it is a safe, easily used herbicide with a very short residence time in the soil. Erosion protection for the winter months was provided by the tough, fairly tall stalks of the sorghum cover that had been planted previously

WINTER, 1987-1988

Periodic inspections during the winter were conducted to find and correct any erosion problems that might be occurring. Erosion was not a problem, although prairie dogs continue to increase in numbers and threaten to compromise revegetation efforts in some areas

SPRING, 1988

Seeding was started during the first part of April and was completed on the 15th. The seeding was done through the remaining standing dead vegetation which had weathered sufficiently during the winter so as not to hinder the seeding equipment.

SUMMER, FALL, 1988

As discussed above for the south area, the summer was very dry and very little of the seed germinated over the summer. It is lying dormant and more success will be seen in the spring of 1989. Erosion protection is being provided by annual and perennial weeds, rock, and the remaining sorghum skeletons.

FUTURE PLANS FOR NORTH AND SOUTH AREAS

Monitoring for both erosion control and vegetation success are planned for the winter of 1988-1989, and spring/summer 1989. Pending the outcome of the spring germination and summer growth of grasses, the next possible time to begin plowing the intermediate strips in the areas will be fall of 1989, although it might be advisable to wait until spring of 1990.

Other activities that will be started will be some experimental work with hydromulching and hydroseeding for the exceptionally rocky areas. Prior to any startup of these activities, Jefferson County will be notified, and asked for approval of any plans for these practices

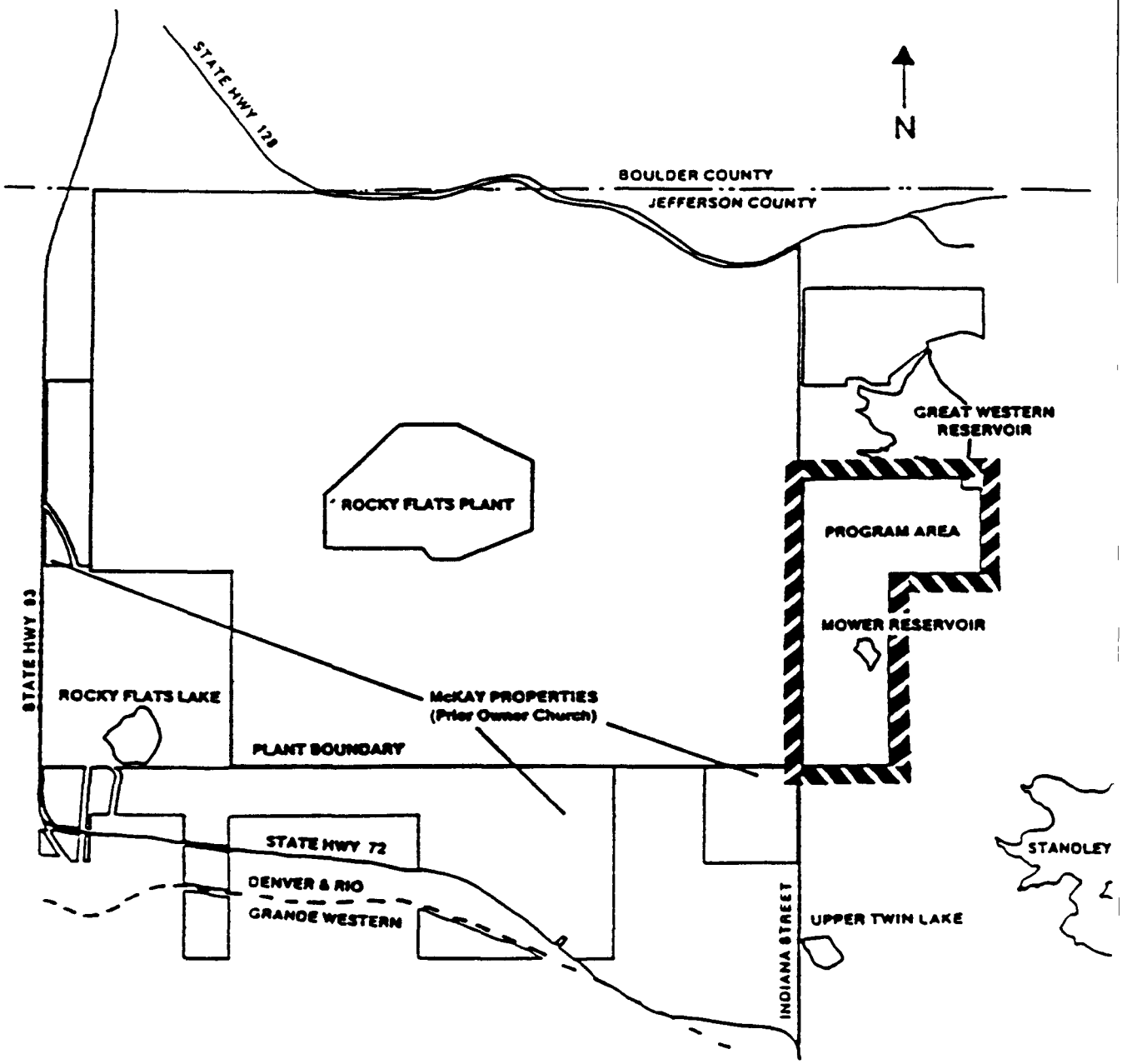


FIGURE 1 INDEX MAP SHOWING LOCATION OF PROGRAM AREA

DOCUMENT D-14

"Status of Remedial Action Program on Jefferson County Open Space Land,
January 1989 to August 1989"
(1989)

by

Rockwell International

STATUS OF REMEDIAL ACTION PROGRAM ON
JEFFERSON COUNTY OPEN SPACE LAND
JANUARY 1989 TO AUGUST 1989

INTRODUCTION

This report summarizes the actions that have occurred on the remedial action lands east of Indiana Street adjacent to the Rocky Flats Plant. These lands are owned by Jefferson County. The last update presented to Jefferson County was in November of 1988.

SOUTH AREA ACTIVITIES - 20 ACRES
WEST OF MOWER RESERVOIR, SECTION 18

SPRING, 1987

Plowing and ripping operations were conducted on 20 acres in June and July Four strips, 150 feet wide and 1500 feet long, were plowed Sampling showed that the west end of the northern strip remained above the CDH standard. The northern strip was plowed a second time in July. This strip was sampled in September and results were below the CDH standard, so revegetation activities could proceed.

FALL, 1987

The plowed strips were disked in early November to kill the competitive weed species, primarily cheatgrass. To reduce or eliminate any wind or water erosion the surface was left in a roughened state, winter wheat was planted at approximately 20 pounds of seed per acre and a native grass hay mulch was crimped into the soil at a rate of 2 tons per acre. This work was completed in early December.

WINTER, 1987

Inspections of the area revealed that little if any erosion was occurring. The snow downwind of the area was clean, even after solar heating of the soil had exposed the mulched area.

SPRING, 1988

The native grass seed was planted in April through the existing cover of weeds without disturbing the surface to any great extent. A significant amount of natural vegetation that was not killed by the plowing was recovering and would increase the diversity of the revegetated surface.

FALL, 1988

The summer and fall months at the project site were extremely dry. A site visit with Mr. Gary Finstad of the U.S. Soil Conservation Service on October 17th, 1988 revealed that most of the seed is

lying dormant in the soil. Winter precipitation was expected to produce a good crop of native grass in the spring. Erosion protection consisted of the winter wheat that did germinate and a continuous cover of annual and perennial weeds.

SUMMER, 1989

A site visit with Mr. Gay Finstad of the U.S. Soil Conservation Service on July 24, 1989 revealed growth varying from good to poor. There is much musk thistle, bindweed and cheatgrass infestation. Recommendations were: 1) Leave areas with good grass establishment alone until next season, then control weeds and encourage vegetative reproduction by mowing. 2) Areas with marginal growth may show improvement in October due to cool season grasses. If growth is good, treat as no 1 above, otherwise treat as no. 3 below. 3) Interseed into existing cover on or about November 1, 1989. Areas with cheatgrass infestation may be treated with herbicide (Roundup), but any herbicide effective on cheatgrass will also kill the desirable grasses. Bindweed can be eliminated with herbicide (Banvel). Timely mowing of musk thistle can be an effective control.

NORTH AREA - 100 ACRES
SOUTH OF GREAT WESTERN RESERVOIR, SECTION 7

SPRING, 1986

Approximately 100 acres were ripped and plowed in June and July . All areas that were plowed were sampled and meet the CDH standard.

FALL, 1986

Native grasses were seeded into the area.

SPRING, 1987

Inspections showed the vegetation had failed. Failure was attributed to the high rock content. In June , the 100 acres were ripped again and sterile sorghum was planted.

FALL, 1987

The sorghum cover was doing very well, even on the rocky areas. The plowed strips were sprayed with Roundup herbicide during the first two weeks in November. This successfully controlled competition from weeds, primarily cheatgrass. Erosion protection for the winter months consisted of the stalks of sorghum.

WINTER, 1987-1988

Inspections showed erosion was not a problem. Prairie dogs were noticed to be increasing in numbers. Prairie dogs can compromise revegetation efforts.

SPRING, 1988

Native grasses were seeded through the sorghum cover in April.

FALL, 1988

The summer was very dry and very little seed germinated over the summer. Winter precipitation was expected to produce more success in 1989. Erosion protection was provided by annual perennial weeds, rocks, and the remaining sorghum skeletons.

SUMMER, 1989

A site visit with Mr. Gary Finstad of the U.S. Soil Conservation Service on July 24, 1989 revealed that the southernmost strips showed good grass establishment. Some areas are very spotty and only marginally successful. The predominately rocky areas are showing few, if any, signs of grass and will need to be reseeded. Erosion control consists of native weed cover and rock. Recommendations were:1) Leave areas with good grass establishment alone until next season, then control weeds and encourage vegetative reproduction by mowing. 2) Areas with marginal growth may show improvement in October due to cool season grasses. If growth is good, treat as no. 1 above, otherwise treat as no. 3 below. 3) Interseed into existing cover on or about November 1, 1989. Areas with cheatgrass infestation may be treated with herbicide (Roundup), but any herbicide effective on cheatgrass will also kill the desirable grasses. Bindweed can be eliminated with herbicide (Banvel).

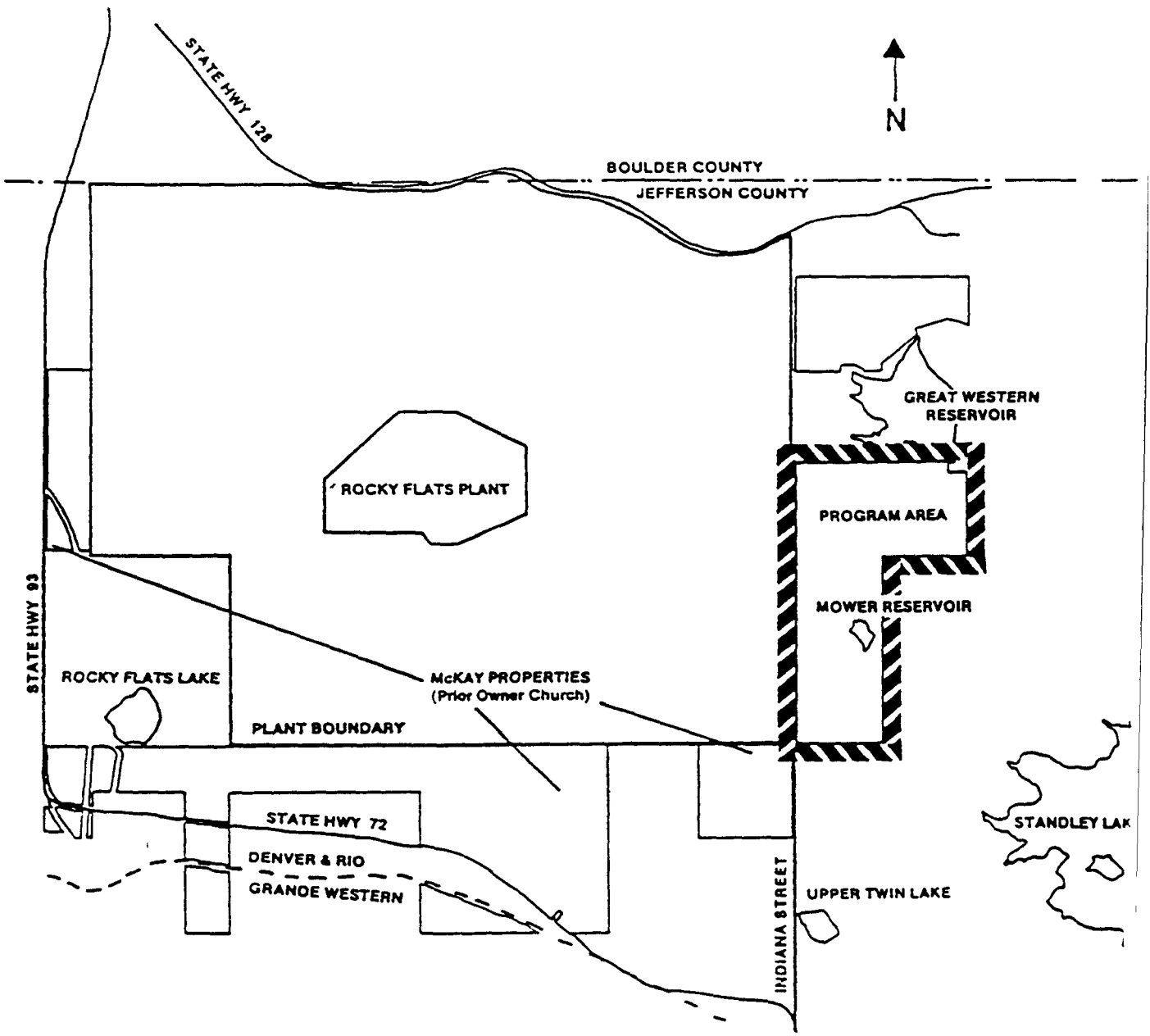


FIGURE 1 INDEX MAP SHOWING LOCATION OF PROGRAM AREA

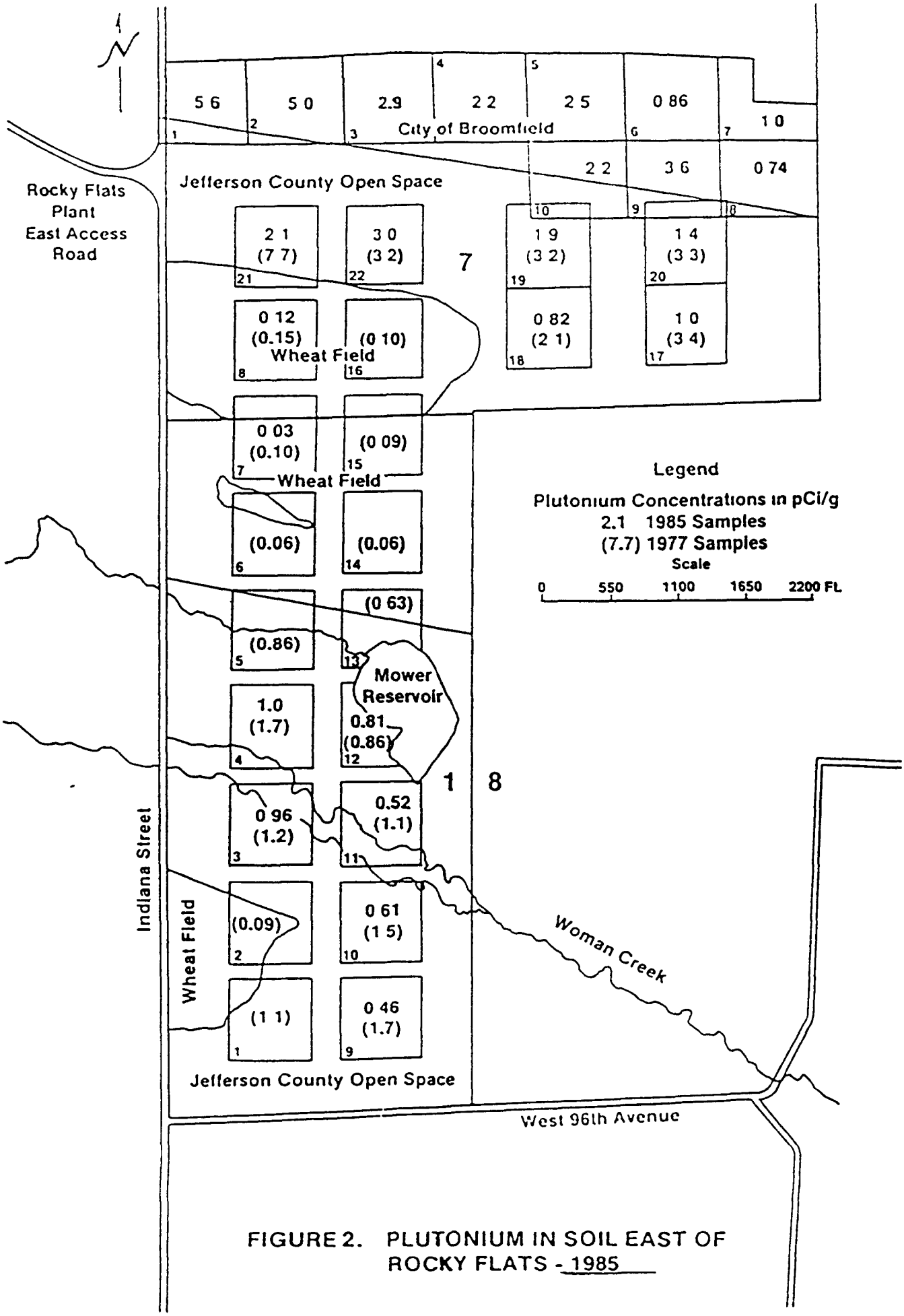


FIGURE 2. PLUTONIUM IN SOIL EAST OF ROCKY FLATS - 1985

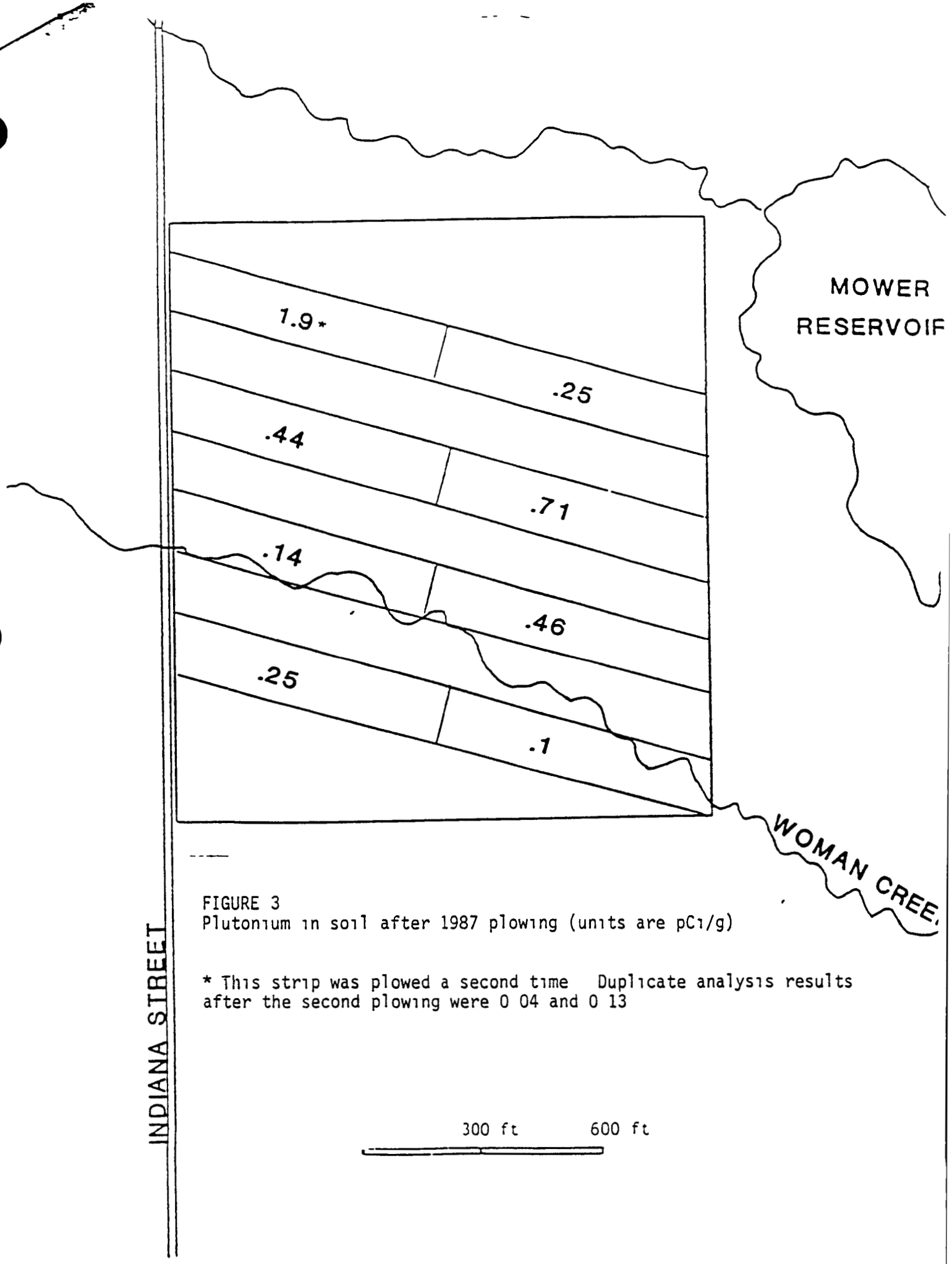


FIGURE 3
Plutonium in soil after 1987 plowing (units are pCi/g)

* This strip was plowed a second time Duplicate analysis results after the second plowing were 0 04 and 0 13

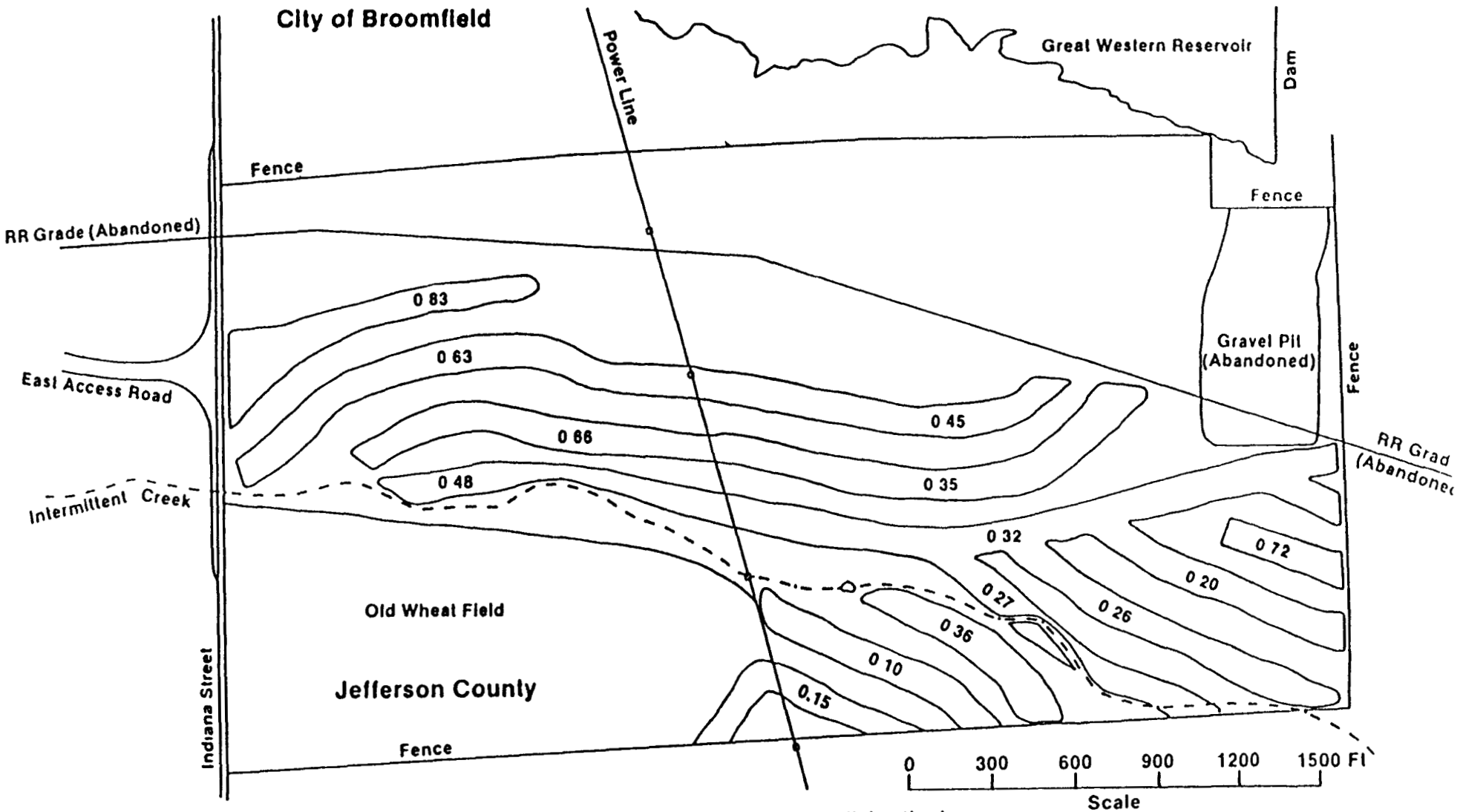


Figure 4 Plutonium (units are pCi/g) in soil east of Rocky Flats — 1986 (after remedial action)

SEEDING RECOMMENDATION

Species	Variety[1/]	Characteristics[2/]	Percent of mix	lb PLS per acre drilled
Western Wheatgrass (*Agropyron smithii*)	Arriba	N,C,S	40	6.4
Sideoats Grama (*Bouteloua curtipendula*)	Vaughn	N,W,B	40	3.6
Pubescent Wheatgrass (*Agropyron trichophorum*)	Luna	I,C,S	10	1.4
Smooth Brome (*Bromus inermis*)	Lincoln	I,C,S	10	1.3
		TOTALS	100%	12.7

[1/] These varieties were developed for conservation uses, they have superior vigor and production potential. They are available locally--ACCEPT NO SUBSTITUTES. We recommend that certified seed be purchased; this is a guarantee of species and varietal purity.

[2/] Characteristics: N = native, I = introduced, not indigenous to this area, C = cool season (begins growth and makes seed in spring to early summer, with some regrowth in the fall), W = warm season (begins growth and makes seed in warm summer months); S = sod former; B = bunch grass.

[3/] PLS = Pure Live Seed. This is viable seed of the right species. To find PLS in a bag or lot of seed, check the seed tag:

$$PLS = \frac{\% \text{ Purity} \times \% \text{ Germination}}{100}$$

If a bag of western wheatgrass has 90% purity and 80% germination, we have

$$\frac{90 \times 80}{100} = 72\% \text{ PLS.}$$

If we want to seed 16 lb PLS/acre, and our PLS is 72%, we need to seed bulk seed at a rate of $\frac{16}{.72} = 22.2$ lb/acre.

JEFFERSON COUNTY REMEDIAL ACTION LANDS

1989 REMEDIATION STATUS
AND
ACTIONS FOR 1990

EXECUTIVE SUMMARY

The fourth growing season of the remediation effort ended this past autumn Weeds dominate the panorama of the remedial action lands Approximately 90% of the plowed-reseeded lands have no seeded grass cover The poor outcome of the reseeding effort appears very related to

1) ineffective amounts and/or seasonal distribution of precipitation,
2) extremely rocky surfaces or clayey soils,
3) an expanding prairie dog population

Most of the successfully seeded and established portions (10%) of the remedial action lands have produced a substantial stand of grasses These areas also bear many weeds but should adequately suppress this weed onslaught

Prairie dogs have devastated much of the vegetal cover of the remediation lands, including both the plowed, seeded strips and the alternating strips of unplowed prairie Prairie dog control must occur in order to stabilize soils

Planned actions include

1) low and no tillage methods of reseeding,
2) irrigation for seedling establishment,
3) enduring weed suppression and control through mowing and herbicidal methods,
4) prairie dog suppression and control with physical and/or toxicogenic methods

INTRODUCTION

This report concludes the fourth growing season since remedial activities were initiated on these lands, it summarizes both the 1989 land status and 1990 planned remedial actions.

The goal of the remediation effort is

1) soil mixing to reduce surface concentrations of plutonium of the subject land to bring them into compliance with CDH guidelines of 2 d/m/g (9 pCi/g) of dry soil, and
2) revegetation to stabilize the soils with a sustainable, reproducing vegetation (one that would evolve towards a native grassland)

No remedial activities occurred on these lands this past growing season due to a temporary void in the RFP position of the soils-range scientist The position was filled in mid-September, after which the evaluation of land status was performed During separate occasions, outside professional critiques were solicited from Gary Finstad of the USDA Soil Conservation Service, Wayne Woods of Vegetation Services and Frank Kunze of Jefferson County Open Space

ECOLOGICAL AND MANAGERIAL STATUS OBSERVATIONS

During 1989, the remedial action lands existed in a state of weed infestation with a fair, but unreliable stabilization of soils Figure 1 illustrates the managerial status of these lands.

Tall weeds such as Canadian, Russian and musk thistles as well as mustards dominate the plowed, reseeded lands The substratum is dominated by shorter weeds such as bindweed and cheatgrass (downy brome) Weeds are the sole vegetal cover of approximately 90% of the reseeded lands.

Only 10% of the reseeded areas have a fair to excellent establishment of grasses. Despite a co-existing weed component in these areas, most of the grasses appear well enough established and to have the competitive advantage over the weeds for control of resources.

Localized surface accumulations of rocks (cobbles) occur over approximately 30% of the reseeded land The majority of these cobbles surfaced during tillage and in some cases impose nearly a 90 percent surface coverage These areas have a vegetal cover of weeds with no apparent seeded grasses

A prairie dog infestation impacts approximately 60% and 30% of the northern and southern remediation lands, respectively These percentages are inclusive of both the plowed,seeded lands and the unplowed lands (alternating strips of land that currently are planned to be plowed) Consequently, some of the unplowed lands exist in a stressed prairie/weed vegetation or pasture/weed vegetation.

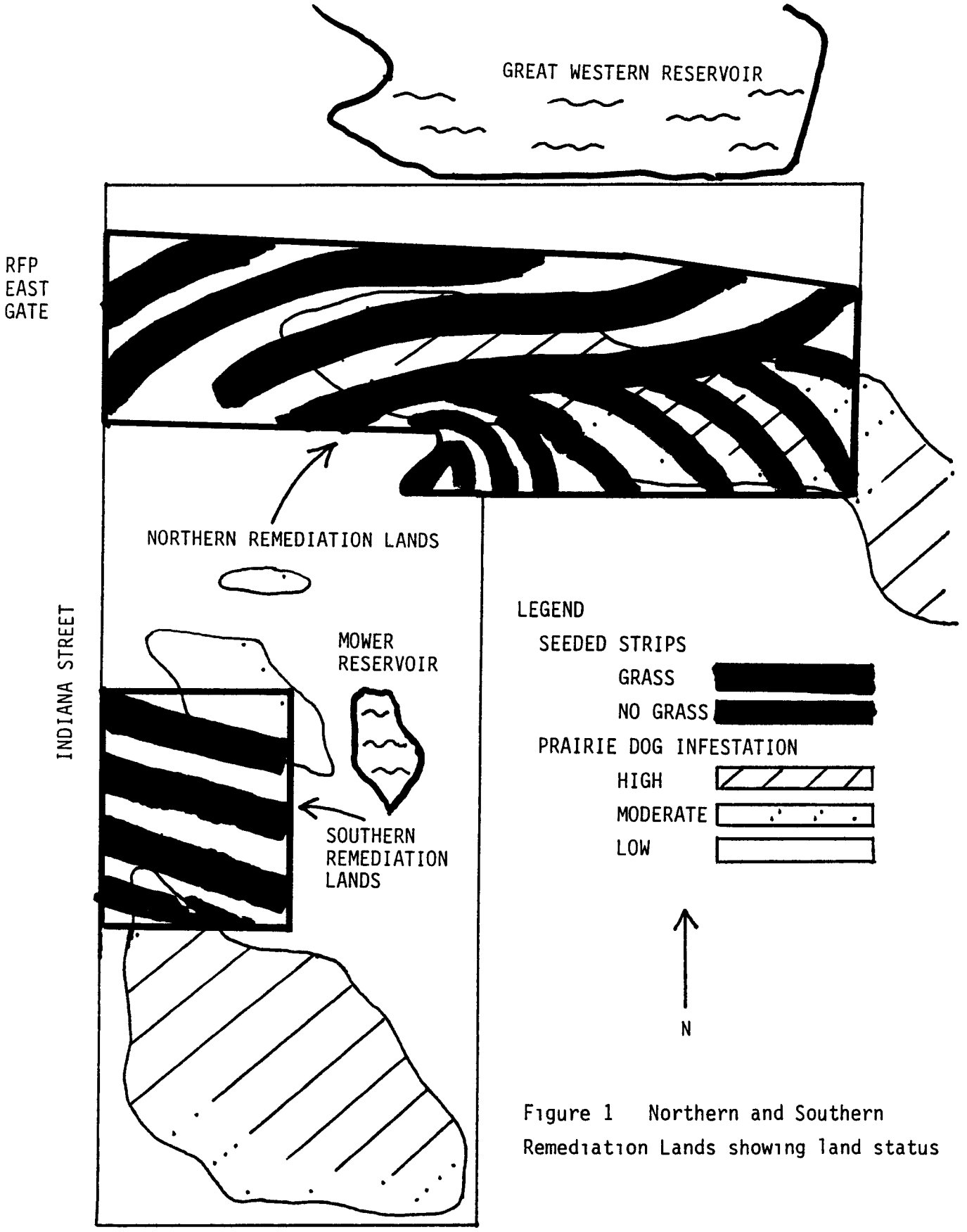


Figure 1 Northern and Southern Remediation Lands showing land status

Where burrow density is greatest (about 20% of reseeded lands), the prairie dog impact to the landscape environment is of particular severity and interest Here, with relatively minimal wind protection, are soil materials that once were purposely plowed under and now have been brought back to the surface around burrows, while between the burrows are vegetationally denuded soils These barren soils are exposed to wind and water erosion

SEEDING RESULTS ANALYSIS

Based on the above observations and precipitation records, the poor seeding and/or plant establishment results apparently can be attributed to at least three factors

1) Lack of effective amounts of precipitation and soil moisture Relative to the clayey and rocky soils, effective amounts of precipitation simply were not distributed over each year's growing season to coincide with timing of seed and/or seedling physiological demand Winter and spring recharge of soil moisture apparently was inadequate some years for either germination or seedling requirements

2) Extremely rocky surface The rocks impeded placement and coverage of the fine seeds during the seeding operations

3) Prairie dog infestation. The demise of any successfully emerged seedling is very predictable due to its palatability to the prairie dogs. In addition to their herbivory and burrowing habits, the rodent keeps a mowed vegetation as its visual defense against ground and aerial predators Their activities promote soil destabilization High activity areas surround individual burrows with barren soils (areas of $25ft^2$ to $200ft^2$ per burrow), while further out persistent and heavy grazing has eliminated grasses to favor a suppressed weed population

The successfully seeded and established areas had little or no prairie dog activity Otherwise, the 10% seeding success in the northern remediation lands appears very related to the factor of topography, which translates into the maintenance of favorable amounts of soil moisture More specifically, the small areas of success occurred only on upland terrain that either was nearly level or sloping to the north (a NW to NE arc). These sites have a diminished evaporation rate of soil moisture relative to the hotter and drier south facing slopes

Factors contributing to the 10% seeding success in the southern remediation lands were not apparent other than the possibility of pockets of deep and/or loamy soils

1990 ACTIONS

In light of the above observations and analyses, management of the remedial action program will be intensified. The following action components will occur during 1990 in order establish and nurture a desired vegetation and stable soil

A Action Components

1) Change of seed mix Through seeding evaluations and discussions with Gary Finstad and others, the following seed mix will be used for seeding operations during 1990 It is not substantially different from the original seed mix As additional information is gleaned from results of remediation methods and procedures, it should be expected that subsequent requests for seed mix changes may be forthcoming.

Species	Variety	Percent of Mix old	new
Western wheatgrass (Agropyron smithii)	arriba	40	40
Sideoats grama (Bouteloua curtipendula)	Vaughn	40	25
Blue grama (Bouteloua gracilis)		0	15
Pubescent wheatgrass (Agropyron trichophorum)	Luna	10	10
Smooth brome (Bromus inermis)	Lincoln	10	10

2) Prairie dog suppression and control Approximately 100 acres are currently impacted by prairie dogs, perhaps 30 acres are critically impacted Without controls or limits, prairie dog acreages tend to expand 20% to 30% per year Thus, 80% of the northern remediation lands likely would be impacted by the end of the next growing season, 1990

An effective control implies eliminating more than 80% of a prairie dog colony, otherwise the first annual reproduction is absorbed by the colony and brings the population back to 100% (Normally when reproduction cannot be absorbed into the colony, pups will migrate to adjacent areas)

Live trapping and transplanting prairie dogs is discouraged by the Colorado Division of Wildlife. It is expensive and inefficient. More than half of transplanted prairie dogs die or are killed by predators during the first week unless expensive set-up efforts are performed Late winter and early spring prior to pups being born is the best time for trapping.

A grain applied toxicant (zinc phosphide) is available and regulated by the EPA However, it is only 85% to 90% effective and a return to 100% of the population can occur in just three years The grain may impart a non-target kill, particularly birds July 15 through November 15 are the effective use dates of this product

An aluminum phosphide fumigation, regulated by the EPA, results in 95% to 98% reduction in prairie dogs Since burrows are sealed, fleas which transmit bubonic plague become entrapped in holes There is no residual poison on soils, vegetation or poisoned rodents (in fact, coyotes and foxes commonly dig out some of the carcasses and consume them) A non-target kill may occur in the burrows April 1 through October 15 are the effective use dates of this product

The most efficient approach to the arrest and control of the prairie dog infestation is fumigation The procedure will be administer by a licensed pest control company The prerequisite of a black-footed ferret reconnaissance or search will be complied with prior to the fumigation action.

3) Weed suppression and control A program of herbicide spraying and mowing will be implemented this spring and summer to control the weed infestation and reduce any fire hazard such as might be created by downy brome (cheat grass) Applied herbicides will include only those approved by RFP, all of which have short term residuals.

4) Seed bed preparation Tillage will not only provide a suitable seed bed in areas of least rockiness, but also may provide some control of certain weed species Other than a possible herbicide treatment, the rocky areas will receive no pre-seeding treatment and seeding should occur with a hydroseeder Any tillage of rocky areas may serve mostly to bring an even greater percentage of rocks to the surface while allowing fine soil materials to settle still further below the surface, thus, reducing both the effective area and already poor quality of seed bed

5) Seeding Two weeks subsequent to herbicide treatment of rocky areas, the seed mix will be hydroseeded (mid May at latest) On areas of least rockiness, a cover crop of forage sorghum will be drill seeded immediately following any tillage during late spring, then during late autumn interseeding of the seed mix will occur within the standing sorghum

6) Mulching· Mulching will include a crimped or tackified straw mulch and a hydromulch, only the one most appropriate for site conditions to be used after each seeding operation

7) Irrigation The potentiality of another partial or season long dry spell must be reckoned with in order to have the greatest probability for success The experiences of the past four seasons have shown moisture to be the most limiting factor of success. Subsequent to a successful seed germination, plant establishment can fail due to lack of effective soil moisture during critical periods A single or dual truck spray irrigation system will be implemented this summer to meet the demands of

the seeded vegetation The tanker truck will have a 4000 gallon capacity with a pump and top-mounted water gun. Source of supplemental water would be Pond C-2 or RFP domestic supply With effective amounts of natural precipitation, supplemental watering would not be required

B ACTION IMPLEMENTATION CHRONOLOGY

1. SPRING 1990

PARTIES	Jefferson County Officials
ACTION 1·	Respond to any proposed action, particularly regarding herbicide spraying, prairie dog suppression and seed mix changes
PARTY·	Remediation Coordinator
ACTION 2.	Evaluate responses and accordingly arrange any contracts for herbicide spraying and prairie dog suppression and order seed mix.
	Arrange contracts for tilling, seeding and mulching and leasing equipment.
DATE	Spring 1990

2 Spring 1990

PARTY	Contractors
ACTION 1·	With appropriate consultations, apply herbicide to suppress cheatgrass and emerging broadleaf plants on lands to be reseeded. If necessary and similarly approved, apply broadleaf herbicide to the 10% successfully seeded and established areas in order to reduce any aggressive weed competition
DATE DUE	Mid to late spring
PARTY	Contractors.
ACTION 2	Depending upon time since herbicide application, hydroseed the rocky areas with seed mix and cover with hydromulch Till and seed forage sorghum on non-rocky areas. Mulch with straw and secure with tackifier or crimper
DUE DATE	Late April through mid-June
PARTY	Remediation Coordinator or contractor
ACTION 3	Irrigate when necessary for appropriate germination if natural precipitation fails to occur
DATES DUE	April through mid-June

3 Summer 1990

PARTY	Remediation Coordinator
ACTION 1	Closely monitor reseeded areas for necessary irrigation, weed control, fertilization and soil erosion Accordingly, activate necessary contractor or personnel
DATES DUE	Duration of summer

4 Autumn 1990

PARTY	Remediation Coordinator
ACTION 1	Closely monitor reseeded areas for necessary irrigation, weed control and soil erosion. Accordingly, activate necessary contractors or personnel
DATE DUE	Early autumn
PARTY	Contractor
ACTION 2.	Interseed forage sorghum areas with the seed mix and follow with mulch that is well secured and able to withstand the winds of winter and early spring
DATE DUE.	Early November

5 1991

PARTY	Remediation Coordinator.
ACTION:	Monitor all aspects and status of remediation lands Accordingly, respond and treat as described above or in another appropriate manner
DATE DUE.	Year round.

JEFFERSON COUNTY REMEDIAL ACTION LANDS

ANNUAL REPORT

JANUARY, 1991

REVIEWED FOR CLASSIFICATION/UCNI
By George H. Setlock
Date 12/13/90

JEFFERSON COUNTY REMEDIAL ACTION LANDS
ANNUAL REPORT JANUARY 1991

INTRODUCTION

This report summarizes the current status and land management activities planned for 1991 on Jefferson County remediation land The March 1990 report proposed a program of remedial actions for the 1990 growing season but those activities were not carried out, for the most part, due to personnel changes at Rocky Flats Plant (RFP) RFP is concerned about this break in activities and has assigned a full time manager to the offsite areas with specific interest in revegetation Michael Guillaume of EG&G is the manager of the offsite areas and can be reached at the plant site at 966-4291 With the specific goal of revegetation, the actions proposed for 1991 are similar to the 1990 proposal except for a change in amount of land area requiring revegetation work Due to the successful growing season in 1990, the area requiring new seeding is 40% smaller

The goals of the remediation program are

1) Reduce the surface plutonium concentrations to below the Colorado Department of Health (CDH) plutonium-in-soil construction standard of 0 9 pCi/g by tilling the soil, and
2) Revegetate the resulting disturbed soil to stabilize with a perennial, self-sustaining grass cover

Soil samples were taken from the tilled and untilled strips in January 1991 The CDH Radiation Control Division was consulted on the soil sampling methodology The soil samples will be analyzed for plutonium and americium The previous soil samples taken in 1986 and 1987 do not follow current quality assurance protocols, thus new samples to confirm the reduction of soil plutonium by tilling are needed A significant change in the analysis results from the earlier data is not expected The lab results will be sent to Jefferson County as soon as they are available

CURRENT LAND STATUS

RFP has monitored the Jefferson County remediation land since the 1988 seeding activity Data from 1989 and 1990 show the remedial action lands were protected from wind and water erosion by a fair-to-good vegetative ground cover Figure 1 presents a photograph taken October 1990 comparing the native vegetation with the remediated vegetation The percentage of grass versus weed cover is highly variable on the site Some areas are completely dominated by seeded grasses and others are completely dominated by weeds The vegetation shown in Figure 1 is representative of the cover The vegetative ground cover is sufficient to stabilize the soil and minimize soil erosion Gary Finstad of the Soil Conservation Service concluded the area of successful revegetation increased significantly during the 1990 growing season The intended result of the 1991 land management program is to increase the area and productivity of perennial grasses and diminish competition from weedy species

The objective of revegetation is to speed natural processes of vegetation establishment by encouraging desirable permanent plant species and discouraging weedy species By the natural

process of revegetation, weedy species are generally the first plants to invade disturbed sites As the weeds modify the immediate environment they allow other more permanent plants to invade and replace the weeds The disturbed site thus evolves over time into a self-sustaining plant community Weeds are not a dependable plant cover as many are annuals and highly dependent on precipitation

The increase in revegetated species may be explained by the above average spring rainfall that was received in 1990 The Boulder station of the National Oceanic and Atmospheric Administration reported 4 4 inches of moisture in March 1990 compared with an average of 1 8 inches during March 1987-89

Along with the overall increase in perennial plant cover, each species in the seed mix is found on the remediation lands Increasing the number of individual species generally enhances the stability of a plant community

The prairie dog population continues to interfere with plant growth on the tilled strips as well as the untilled native grass strips In addition to grazing, the prairie dogs remove standing vegetation from around their burrows for a line-of-site protection from predators The population seems to be increasing on the remediation lands as well as other adjacent areas

A successful revegetation program on the Jefferson County remediation lands must consider the following factors

1) Precipitation during seedling establishment has been sporadic Precipitation records show inconsistent moisture in years prior to 1990 A mature plant community can adjust to periods of low moisture but new seedlings require consistent moisture until they become established
2) Sufficient time to evaluate revegetation success has not been used in the past The growth pattern of many seeded plant species, particularly the native species, does not produce a visibly significant plant growth for several years Plants adapted to dry environments produce extensive below ground plant mass with limited above ground production when very young This growth pattern results in maximum moisture collecting ability through the roots while minimizing moisture loss through leaf surfaces After securing a dependable moisture supply, the plant increases above ground production Measuring revegetation success after only two years may not allow sufficient time for effective evaluation
3) Figure 2 presents a photograph taken during 1986 showing the extent of rocks brought to the surface during the initial tilling operation Tilling brings many rocks to the surface which now interfere with the revegetation effort The seed drill cannot operate properly in rocky soil The intimate contact required between seed and soil cannot be made without the presence of fine soil particles Without contact with the soil, the seeds will not maintain adequate moisture for germination and early growth
4) Prairie dog activities degrade the vegetation on the site The prairie dogs graze the new emerging seedlings and mow surrounding plants to maintain a visual defense against predators Even the tough Spanish Bayonet cactus (Yucca glauca) is not immune to their mowing
5) Revegetation success is often related to topography Topography effects evaporation rates and thus available water for plant growth Warmer south facing slopes tend to have higher evaporation rates which deplete soil water more quickly Successfully revegetated areas at the site more often occur on nearly level to north-facing slopes

while the less successful revegetation areas are more often on south-facing slopes

6) Weeds dominate many areas on the site Weeds are very effective competitors for water and nutrients to the detriment of more desirable species Weed species currently provide much of the ground cover important to soil protection but more desirable grass species are needed for long term soil stability

1991 LAND MANAGEMENT PROGRAM

The overall objective of remediation is to reduce plutonium concentration to below 0 9 pCi/g by mixing the surface soil through tilling The resulting disturbed soil is then revegetated to stabilize the land surface and minimize resuspension Tilling the the alternate strips will not occur until the initial strips are successfully revegetated as directed by the Settlement Agreement

The objective of the 1991 land management plan is to minimize soil resuspension while increasing revegetation success The most plausible health risk from the lands is due to inhalation of resuspended plutonium contaminated soil Therefore reducing soil resuspension minimizes the potential health risk from inhalation This section of the annual report first discusses weed management, prairie dog suppression and changing the grass seed mix, issues that effect all the remediation lands Secondly the management program outlines specific management units requiring more intensive activities

WEED MANAGEMENT PROGRAM An ideal weed management program would utilize both mechanical mowing of weeds and herbicide applications Currently no herbicides are being used at RFP due to the possibility for surface water contamination This policy needs reevaluation considering the requirements of revegetation on the remedial action lands Rocky Flats hopes to resolve this issue and allow herbicide use on the action lands before the 1991 growing season A weed management program that provides for timely weed management will be developed for the entire growing season Mowing operations and perhaps herbicide applications should be conducted at appropriate times during the growing season, based on the growth stages of the target weed species

PRAIRIE DOG SUPPRESSION Prairie dogs currently impact the remedial action lands to the detriment of the revegetation effort Control methods such as chemical annihilation to passively discouraging expansion are technically feasible, the various options are being investigated Jefferson County Open Space manages land areas adjacent to the remedial action lands with large prairie dog populations A prairie dog control policy compatible with Open Space policy should be pursued before the upcoming season

GRASS SEED MIX CHANGE The performance of the grass seed mix used in 1986 and 1988 can be improved with the addition of Blue grama Blue grama makes up a large percentage of the native vegetation and its strong drought resistance provides soil stability during poor moisture years As the revegetation effort is evaluated each year, changes to the seed mix will occur with increased knowledge The following table presents the proposed changes to the seed mix

Grass seed mix proposed for 1991

Species	Variety	Percent of mix old	Percent of mix new
Western wheatgrass (Agropyron smithii)	Arriba	40	40
Sideoats grama (Bouteloua curtipendula)	Vaughn	40	25
Blue grama (Bouteloua gracilis)		0	15
Pubescent wheatgrass (Agropyron trichophorum)	Luna	10	10
Smooth brome (Bromus inermis)	Lincoln	10	10

MANAGEMENT UNITS This management plan divides the lands into management units based upon current revegetation success as reported by Gary Finstad of the Soil Conservation Service (letter 10/15/90) This division considers the similarity of the cultural requirements of seedbed preparation, seeding and mulching

Management Units

#1) 50% of the land considered successfully revegetated

#2) 10-15% of the land considered marginal

#3) Failure areas covered by rocks

#4) Failure areas not covered by rocks

Management Unit #1 These areas contain sufficient ground cover of perennial grasses to insure stability of the soil from wind and water erosion Areas considered successfully revegetated will be managed for weed control and prairie dog suppression Enhancement of existing perennial vegetation will be the goal

Management Unit #2 These areas contain grasses but not in sufficient density to insure soil stabilization A weed management program will be initiated in the spring and continue through the summer and fall During late fall, this area will be seeded with the grass seed mixture using a rangeland drill The rangeland drill will seed through the existing vegetative cover into the soil No seedbed preparation will be needed prior to seeding After seeding, areas requiring additional cover will be mulched with straw The straw will be held in place by crimping or applying a tackifying agent

Management Unit #3 Units 3 and 4 failed to establish any seeded grass species Unit 3 is covered by rocks brought to the surface during the initial tilling operations of 1986 (see Figure 2) The surface rocks prevent the seed drill from placing seed in contact with soil necessary for sustained growth These areas are not subject to wind or water erosion nor likely

to support sizable amounts of vegetative cover A weed management program will be started in the spring and grass seeding will be done in the fall As drill seeding is not practical, hydroseeding techniques will be used followed by a straw or hydroseed mulch

Management Unit #4 Unit 4 contains areas that failed to establish vegetation for reasons other than rocky surface soils (see page 2) These areas are potentially the most difficult to revegetate A weed management program will start in the spring followed by seeding a cover crop of forage sorghum During late fall, interseeding of the grass seed mix will occur within the standing sorghum If the sorghum cover does not supply sufficient protection, a mulch will be applied

1991 CHRONOLOGY

The following sequence of events are planned for the upcoming year

Winter -Determine offsite herbicide policy with CDH
-Meet with Open Space personnel on Prairie dog control
-contract for weed control and revegetation activities

Spring -Implement area wide weed response program and prairie dog controls
-Seed sorghum in Management Unit #4

Summer -Maintain weed response program
-Monitor and evaluate land management plan

Fall -Maintain weed management program
-Drill seed with grass seed mix and mulch in Management Unit #2 and #4
-Hydroseed and mulch in Management Unit #3
-Evaluate overall land management plan

RADIOACTIVE AMBIENT AIR MONITORING DATA
AVERAGE pCi/cubic meter

Table 1

LOCATION	1985	1986	1987	1988
S-37	0 000008	0 000027	0 000007	0 000010
S-38	0 000005	0 000003	0 000005	0.000006
S-52	0.000002	0.000003	0.000003	0.000003
S-57	0 000004	0 000003	0 000002	0 000001
S-58	0 000002	0 000002	0 000003	0.000004

Table 2

1986		pCi/CUBIC METER
JAN	S-37	0 000007
FEB	S-37	0 000002
MAR	S-37	0.000011
APR	S-37	0.000003
MAY	S-37	0.000006
JUN	S-37	0 000031
JUL	S-37	0 000231
AUG	S-37	0.000017
SEP	S-37	0 000003
OCT	S-37	0.000003
NOV	S-37	0.000004
DEC	S-37	0.000001

S-52 JEFFCO Airport
S-57 WALNUT creek
S-58 - Wagner

Data From air monitoring program

Table 1 is yearly averages of monthly data

1985 - year before initial tilling
1986 - year of deep plowing
1987 - } remedy activities
1988 - }

Table 2 - high hit for S-37 in July → during tilling operations
- up wind of site but possible influence

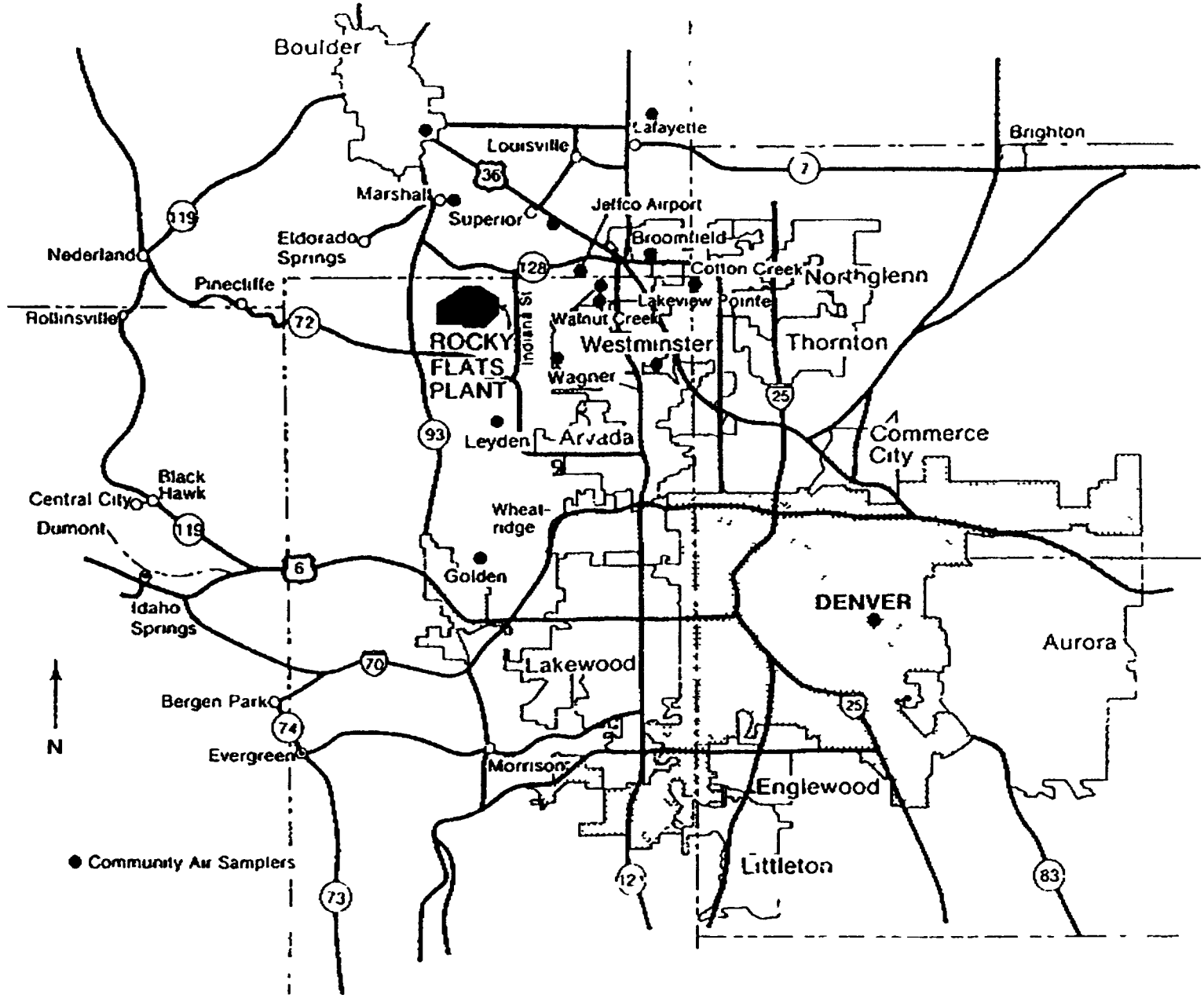
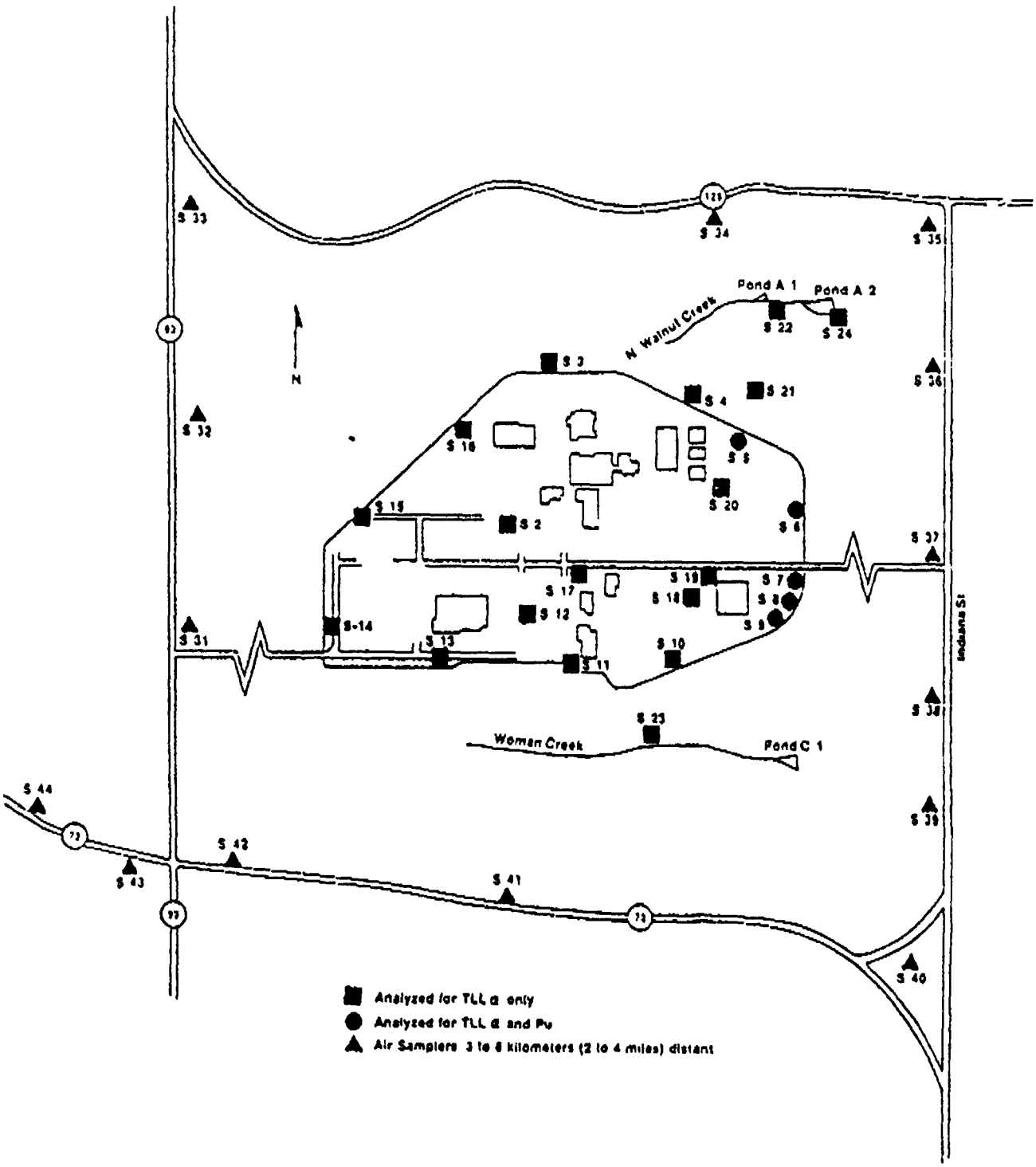


Figure 2. Community Ambient Air Samplers

Figure 1. Locations of Onsite and Perimeter Ambient Air Samplers



Feb. 1990

COLORADO DEPARTMENT OF HEALTH

RADIATION CONTROL DIVISION

ROCKY FLATS SURFACE SOIL SURVEY 1970 - 1989

The Colorado Department of Health has conducted surface soil surveys in the vicinity of the Rocky Flats plant since 1970 Minor modifications were made in the sample collection method each year from 1970 to 1975 These modifications were made to enable reliable comparisons of the information that was collected from one year to the next The sample collection method was standardized in 1975 and remained unchanged until 1989

The attached map shows how the area in the vicinity of Rocky Flats has been divided into sectors for the surface soil survey Twenty-five samples are collected in each sector and combined into a single composite Compositing the sector samples produces an average value for the surface soil plutonium contamination in the sector

Deposition of airborne plutonium contamination on irregular terrain leaves some areas with slighly greater, or less, contamination than would be expected on a smooth surface The average concentrations for each sector that are measured in composite samples are relatively unaffected by the local variations in concentration that are caused by irregular terrain

The data provided by the annual surveys has led to four important conclusions

First, the concentration of plutonium in the surface soil is highest in those sectors that are closest to the Rocky Flats plant, establishing the plant as the source of the plutonium contamination

Second, the surface soil plutonium concentrations are much higher on the east side of the plant than they are on the west side This pattern is consistent with the prevailing wind pattern, in which wind blows generally from west to east

Third, in most cases surface soil contamination is the result of contaminant transport through the air from the point of release to its destination on adjacent land The plutonium contamination in surface soil near the Rocky Flats Plant therefore serves as a good indicator that plutonium is present in the air, or at least that it was present in the air at one time Although the offsite concentration of airborne plutonium is too low to measure the presence of plutonium on the ground downwind from Rocky Flats provides clear evidence that airborne plutonium has been carried offsite from the plant

Fourth the measured concentrations of plutonium in surface soil around Rocky Flats and elsewhere in Colorado have fallen steadily since the survey began in 1970

In the early years of the survey plutonium contamination was found on the ground hundreds of miles away from Rocky Flats The distance from Rocky Flats was so great that the contamination could not possibly have originated from the Rocky Flats plant The plutonium that was found in these remote locations was a

result of worldwide fallout from open-air testing of nuclear devices Similar concentrations of plutonium could be found on the ground at many other locations all around the world Worldwide fallout has contributed only a small fraction of the total plutonium contamination in surface soil near the Rocky Flats plant

Open-air testing was discontinued by all the major military powers of the world after the signing of the Test Ban Treaty of 1964 As a result of that treaty, the quantity of plutonium that was released into the atmosphere, and subsequently the rate of accumulation of plutonium in the environment, was sharply reduced The traces of plutonium that used to be present in surface soil have dissipated in the environment over time By 1986, plutonium concentrations in most parts of Colorado, and elsewhere in the world, had fallen to a point where they were too low to measure by any but the most sophisticated techniques

While the plant continues to release some plutonium into the environment, wind and water erosion have simultaneously dispersed and diluted the plutonium that accumulated on the surface soil in the early days of the plant's operation Releases of plutonium from the plant, based on U S Department of Energy reports, have declined since the plant first began operations in the 1950s The quantities of plutonium that have been released in recent years are no longer large enough to replace the plutonium in the surface soil at a rate equal to the rate that weathering processes dissipate plutonium in the environment In 1986, plutonium concentrations in many areas near Rocky Flats were difficult or impossible to distinguish from the general pattern of worldwide fallout

Since the last surface soil survey in 1986, the Department of Health has acquired new analytical equipment that has enabled a 10-fold improvement in the sensitivity of plutonium measurements Where plutonium concentrations were too low to measure in the 1986 survey, it may be possible to detect plutonium in samples that were collected in 1989 from the same sectors The 1989 survey was further enhanced by additional analysis for beryllium, radioactive fission products, americium-241, and specific uranium isotopes, in addition to plutonium

From 1970 to 1986, field personnel used their best judgment to collect samples in a more or less random pattern within each sector, while at the same time selecting sampling points that would accurately characterize the average plutonium concentration measurement for the sector In 1989, the Department of Health simplified the process of selecting sampling locations by mathematically randomizing the sample collection points within sectors Field personnel went directly to predetermined locations and, once there selected specific places to collect their samples in a manner that would minimize the effect of irregular terrain This modification to the sampling program helps to assure that field personnel do not inadvertently bias the sample collection procedure in a way that would diminish the accuracy of the survey data

In 1989, the Department of Health modified its sampling strategy for the first time since 1975 The 1989 survey will still be comparable to all previous surveys that the Department has conducted, dating back to 1970 The purpose of the new modifications is to obtain more detailed information about the concentration of plutonium in surface soil near the plant Sectors 1 and 2 have now been divided into nine subsectors Five samples are collected into a single

composite from each subsector A 25-sample composite for the entire sector was eliminated from the sample collection plan for sectors 1 and 2 The sample collection plan for all other sectors remains unchanged

The new sampling strategy will provide more detailed information about the direction that plutonium travels after it is released into the air from the Rocky Flats plant It will also provide more detailed information about the concentration of plutonium in surface soil close to the plant and the rate at which the plutonium concentration drops with distance from the plant

ROCKY FLATS PLANT SOIL CONTAMINATION INFORMATION

The first 3 pages is a summary of Colorado Department of Health (CDH) surface soil sampling and plutonium analysis results from 1976 through 1986 Sampling was done on a random basis for 13 sectors of land area near the Rocky Flats Plant (map 1) and 8 locations remote from the Plant (samples containing only world-wide fallout)

The next page contains the State of Colorado's Plutonium-In-Soil Standard (RH 4 35), which was adopted by the State Board of Health in 1973 and re-affirmed in 1976 No other officially promulgated plutonium in soil contamination standard exists nationally or internationally

The second and third maps are those of the DOE's predecessor agencies They identify inventory levels of plutonium based on depth samples Such a methodology identifies levels in excess of the State Plutonium-In-Soil Standard (the Standard) (2 disintegrations per gram of soil or Ø Ø1 microcurie per square meter) much farther to the East of the Plant than by the State soil sampling procedure used in adopting the Standard (the sampling procedure was based on information developed by the Colorado Committee on Environmental Information in 197Ø)

The fourth map is CDH information based on 13 sampling sectors near the Plant from undisturbed surface soil in 1971 (see the CDH historical data summary previously identified)

The fifth and sixth maps are those from the Dow Chemical Company's annual environmental surveillance reports based on all soil data gathered by all investigators and used in 2 computer models (the 1971 map is based on a U S Environmental Protection Agency (EPA) depositional model used at the Nevada Test Site)

The last 3 maps indicate that the area in excess of the Standard is not as extensive as indicated in the DOE inventory maps

The seventh map is from the soil study ordered by U S. District Court Judge Richard Matsch in the lawsuit, brought by land owners against the federal government and its contractors The data presented is based on the State sampling procedure. The locations circled are those that were in excess of the Standard The values to the South of the Plant have been resampled and have been certified, in accord with the lawsuit settlement documents, as meeting the Standard. The State testified at the City of Arvada annexation hearings as to the certifications on these lands

The last (eighth) map is representative of the remedial action done on a portion of the Jefferson County Open Space land having the highest off-site plutonium concentrations (17 disintegrations per gram of soil) Remediation is not complete at this time The preferred grass cover is not up to the expectations of the Plant and the Soil Conservation Service, who designed the remedial plan and which CDH approved

The last page of this soil document contains 2 assessments, 1976 and 1989 The 1976 assessment was made on some guesstimates and the then-current dose and risk models, while the 1989 assessment is made on more definitive data and conversion assumptions

ROCKY FLATS PLANT SURVEILLANCE

Pu 239 + 240 Concentrations in Soil (dpm/gm)

Immediate Vicinity Sector	1986	1985-1982	1981	1980	1979	1978	1977
1	0 57	--	<0 18	0 69	--	--	2 28
2	3 28	--	4 88	6.93	--	--	9 37
3	<0 04	--	0 60	0.24	--	--	0 22
4	0.35	--	0.27	0 18	--	0 20	0 20
5	0 09	--	<0 18	0.09	--	0 11	0 13
6	0.09	--	0.31	0 09	--	--	0.66
7	<0.04	--	0.53	0.73	--	0 56	0 64
8	0 07	--	<0 18	0.09	--	0 13	0 16
9	<0.02	--	0.33	0 29	--	0 07	0.13
10	<0.11	--	1 15	0 04	--	--	0 22
11	<0.15	--	<0.18	0 04	--	--	0 07
12	<0 09	--	<0.18	0 04	--	--	0 06
13	<0.18	--	--	<0.02	--	<0 07	0 07
Remote Samples							
Loveland	<0.04	--	*	--	--	<0 04	0 02
Livermore	<0.04	--	*	--	--	0.04	<0.02
Crooke	<0 02	--	*	--	--	0 07	0 04
Burlington	<0.02	--	*	0.04	--	<0.04	0 07
Limon	<0.07	--	*	0.04	--	<0 04	0 04
Springfield	<0 09	--	*	0.04	--	0 27	0.02
Walsenburg	<0 04	--	*	--	--	<0 04	0.04
Penrose	<0 04	--	*	--	--	0.13	0 04

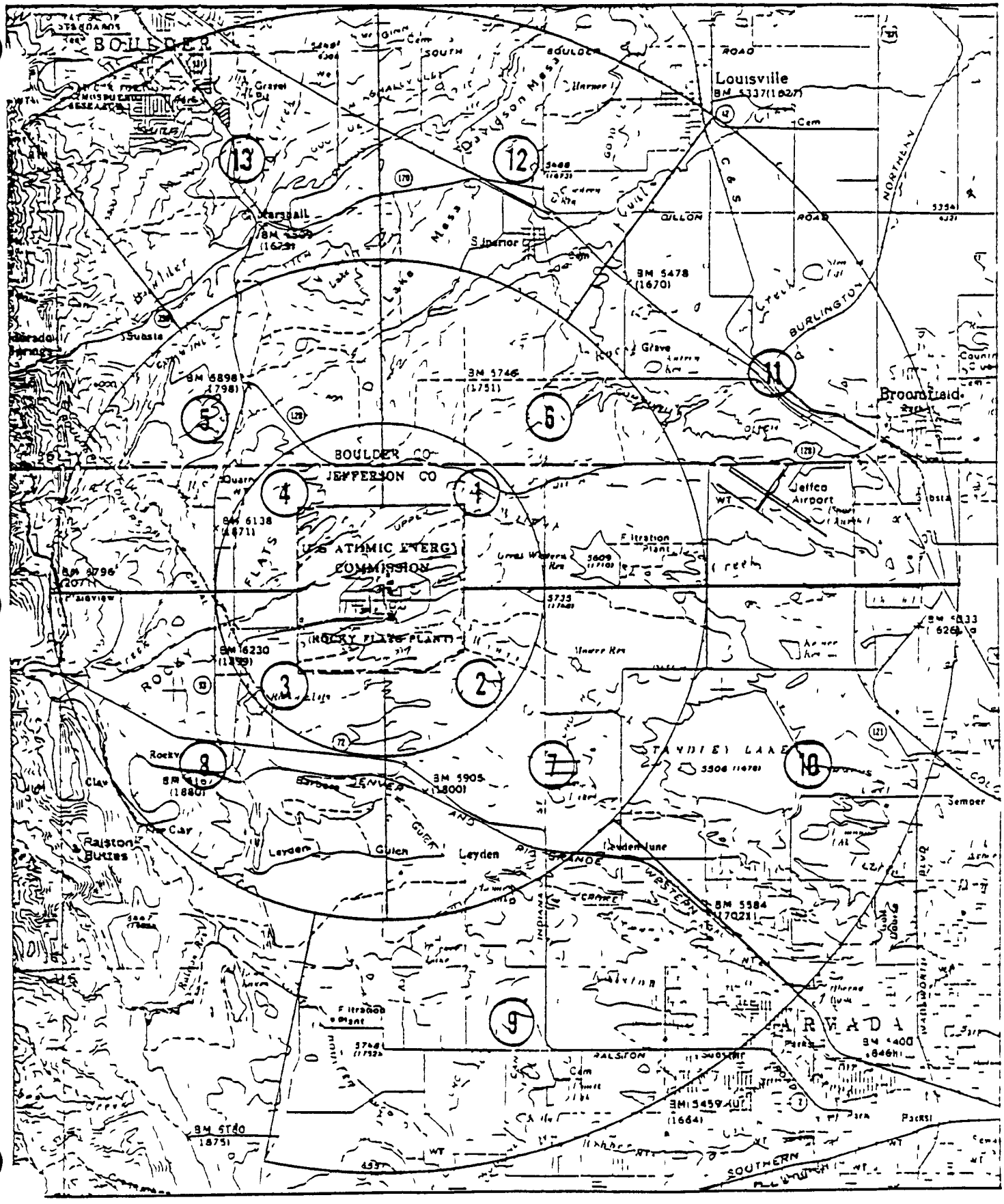
ROCKY FLATS PLANT SURVEILLANCE

$Pu^{239+240}$ Concentrations in Soil (dpm/gm)

Immediate Vicinity Sector	1976	1975	1974	1973	1972	1971	1970
1	1.51	--	3.18	--	2 66	3.15	5 55
2	7.77	9.44	28.19	--	55.75	66.84	24.40
3	0.36	0.49	0 36	--	0 17	0.07	0 29
4	0.27	0.22	0.45	--	0.22	0 29	0.31
5	0.08	0.13	0.70	--	0 33	0 37	0 24
6	0.24	<0.02	0.48	0.15	0.71	0.63	1 00
7	0.27	0.29	0 80	0 83	0.57	0.79	1.02
8	0.13	0.16	0.29	--	0.24	0 60	0 04
9	0.16	0.09	0 04	0.07	0.31	0.29	0 02
10	0.16	--	0 17	0.11	0.20	0.12	0.38
11	0.04	--	0.23	0 14	0.18	0 12	0 07
12	0.07	0.07	0.19	--	0.15	0.06	0 02
13	0.09	0.07	0.13	--	<0 04	0 12	0 04
Remote Samples							
Loveland	--	--	--	0.12	--	0.10	0 11
Livermore	0 02	--	--	0.04	0 07	<0.04	0 04
Crooke	0.08	--	--	0.05	0.011	0.13	0.04
Burlington	0.02	--	--	0.05	0 07	0 11	0.09
Limon	0.04	--	--	0.06	0.07	0 06	0 13
Springfield	0.02	0 04	--	<0.04	0.12	0.09	0 04
Walsenburg	--	0 02	--	0.05	0.11	0.07	0 11
Penrose	0.09	--	--	0.06	0.11	0.08	0.11

-- indicates that no analytical results are available on this sample
* samples not collected

Colorado Department of Health - Radiation Control Division
6/87



RF 0-4(1)
Soil Sampling Area Map

MAP 1

CDH STD

RH 4 34 Notifications and Reports to Individuals

4.34.1 Requirements for notification and reports to individuals of exposure to radiation or radioactive material are specified in RH 10.4 of these regulations

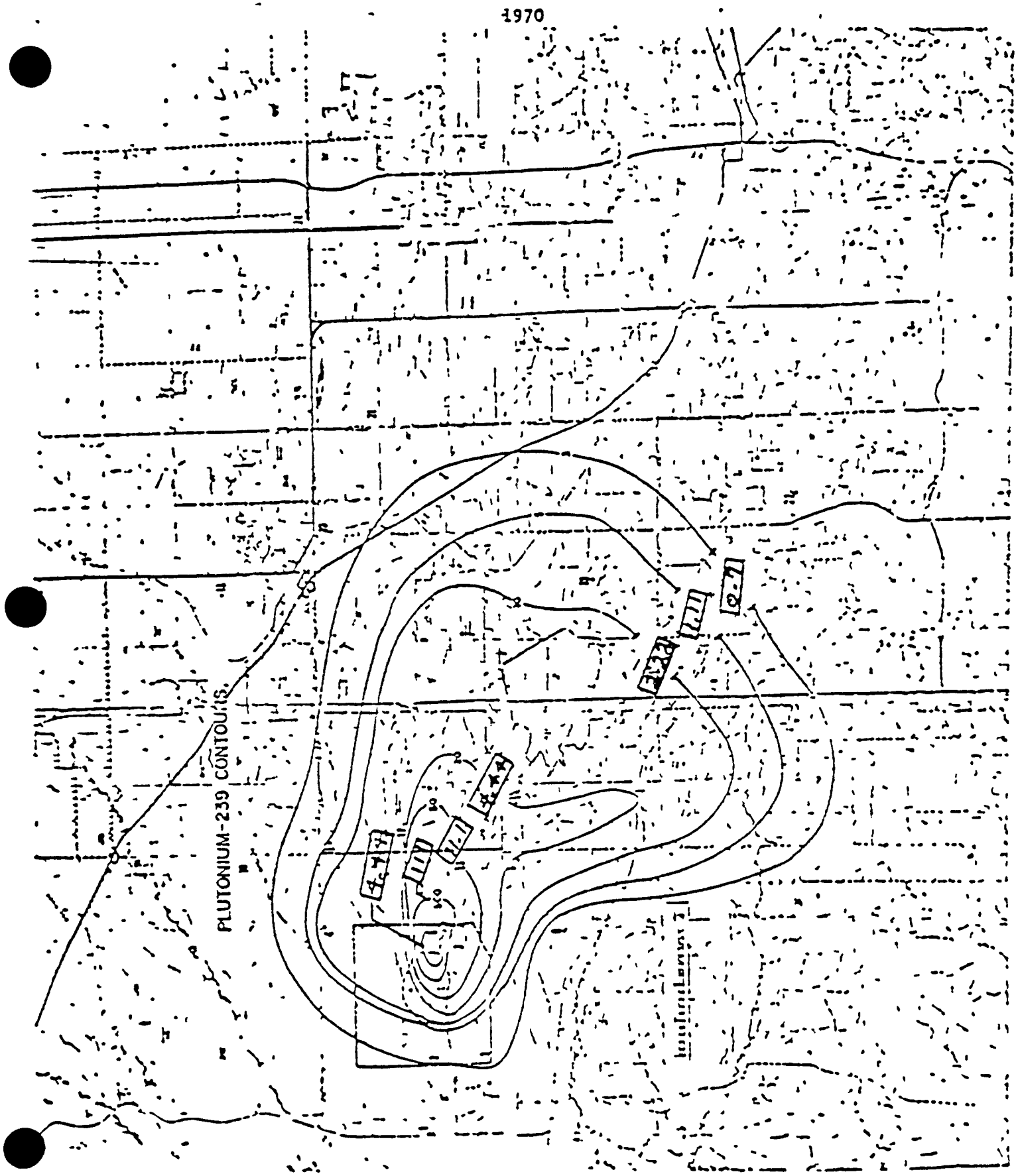
4.34.2 When a licensee or registrant is required pursuant to RH 4.31 to report to the Department any exposure of an individual to radiation or radioactive material, the licensee or registrant shall also notify the individual Such notice shall be transmitted at a time not later than the transmittal to the Department, and shall comply with the provisions of RH 10 4 of these regulations.

RH 4.35 Permissible Levels of Radioactive Material in Uncontrolled Areas

4.35.1 Plutonium. Contamination of the soil in excess of 2.0 disintegrations per minute (Bq) of plutonium per gram of dry soil or square centimeter of surface area (0.01 microcurie plutonium per square meter [370 Bq]) presents a sufficient hazard to the public health to require the utilization of special techniques of construction upon property so contaminated. Evaluation of proposed control techniques shall be available from the Department of Health upon request

★ (APPROXIMATE DISINTEGRATIONS PER MINUTE/GRAM OF DRY SOIL)

1970



*The AEC's plutonium-239 contours are for millicuries per square kilometer. These values have been converted to disintegrations per minute per gram of soil as if all of the plutonium could be found in the top centimeter of soil. This is not what has been observed by the AEC so the values given may be in error on the high side.

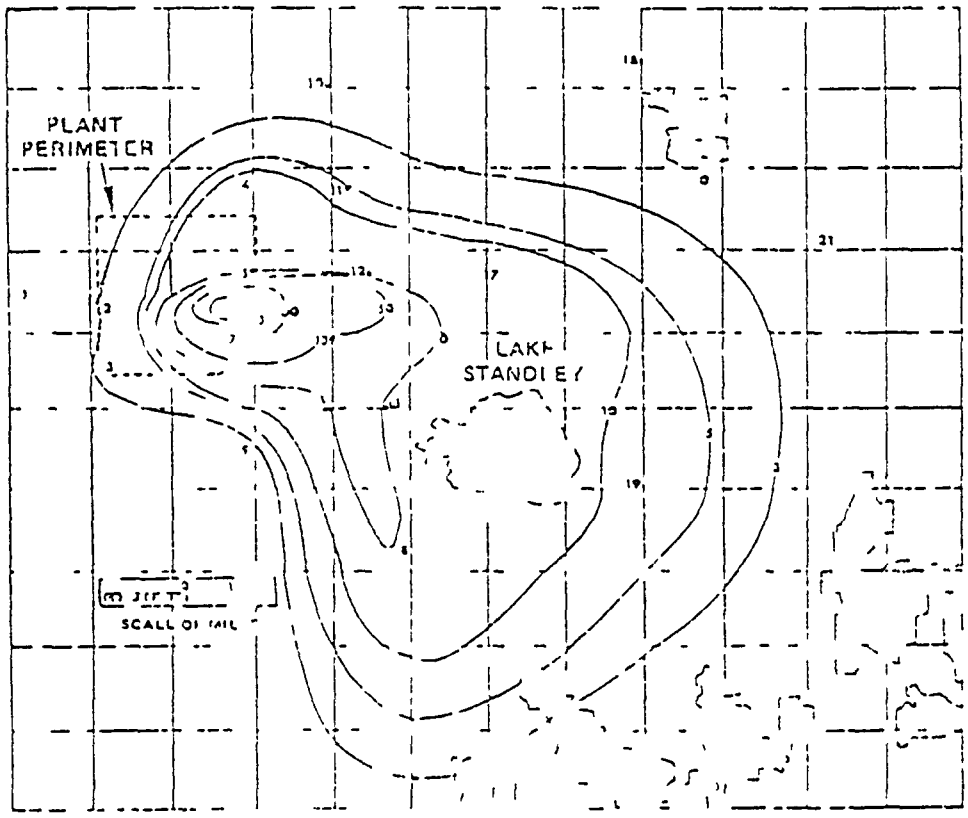
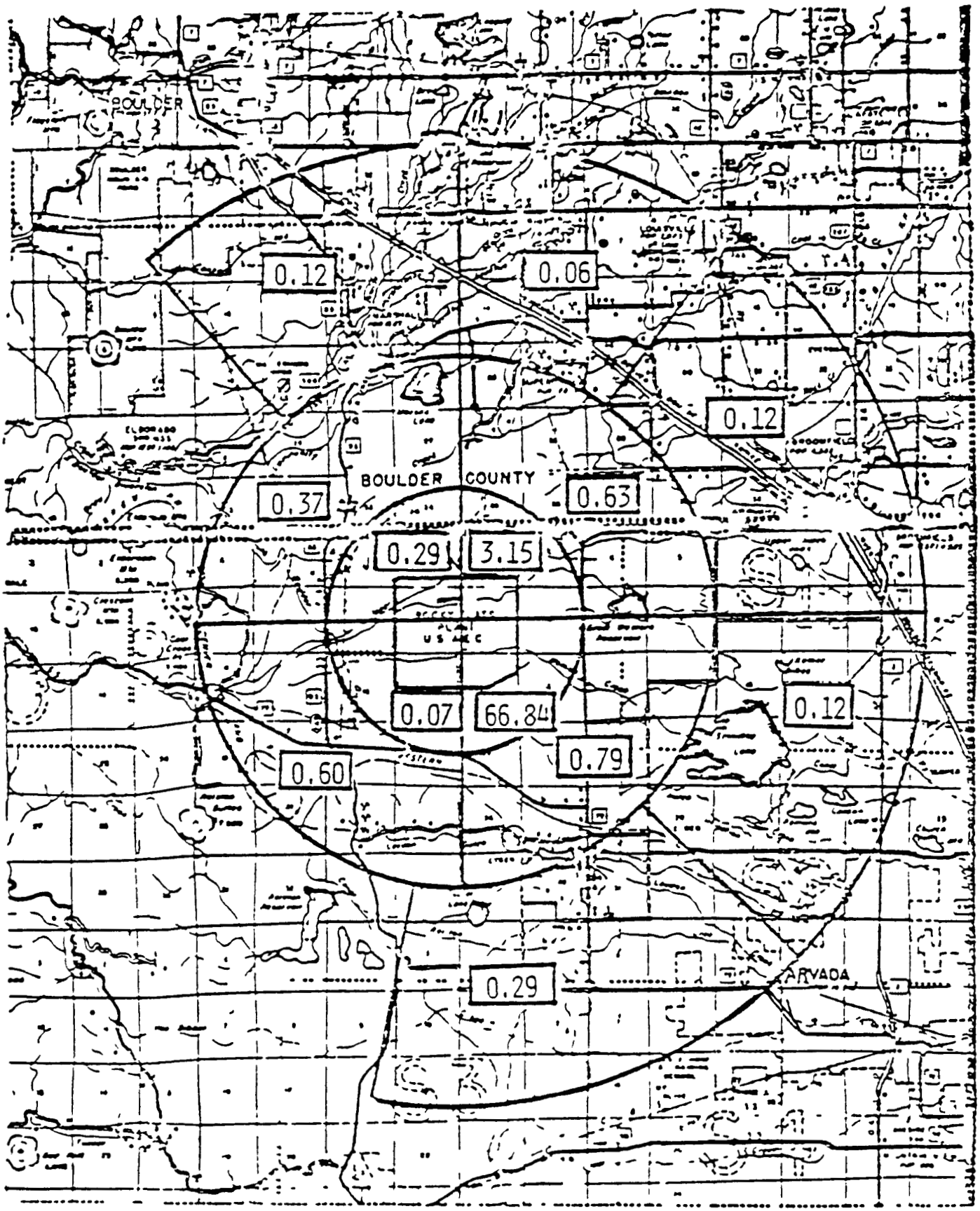


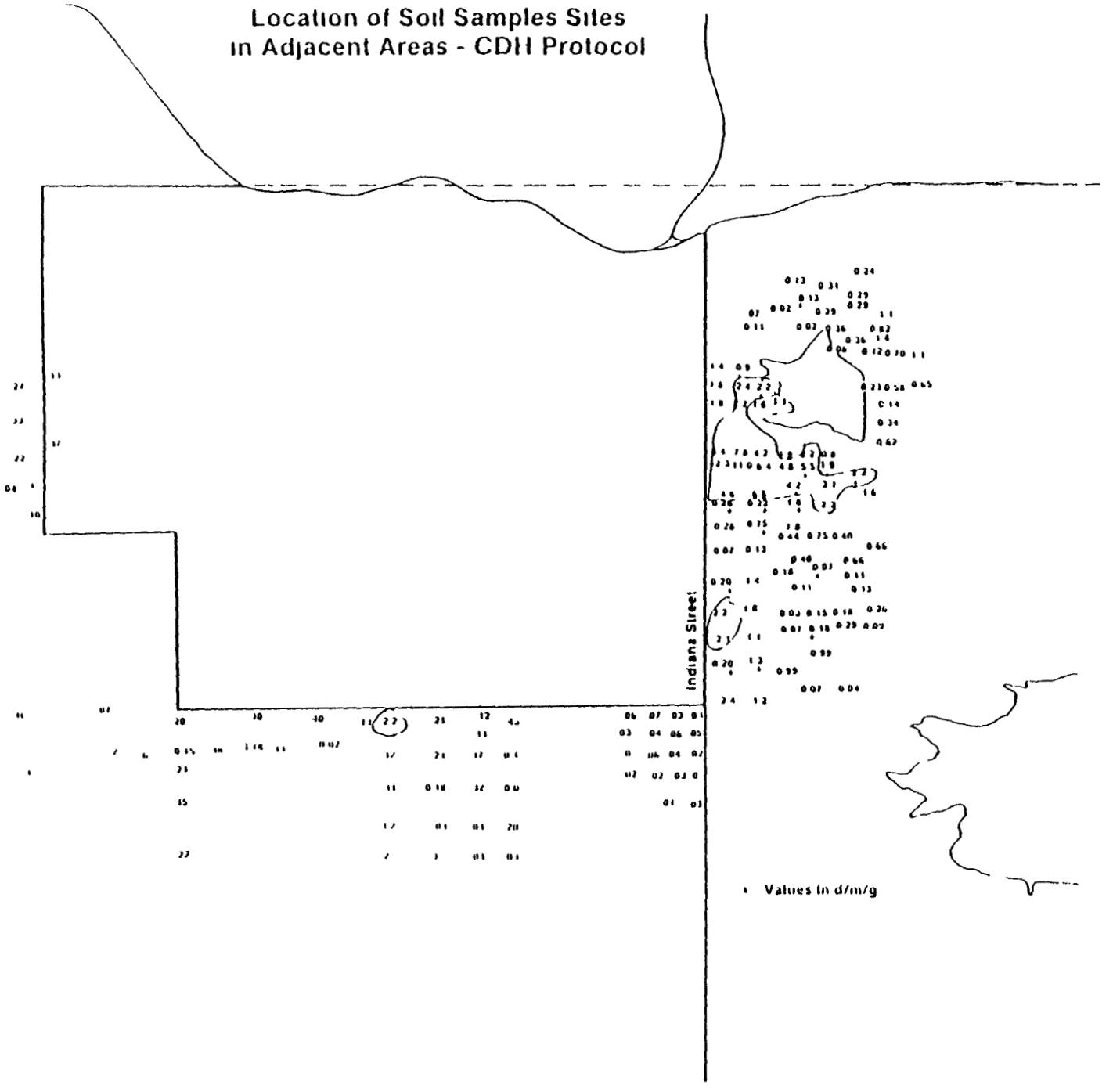
FIGURE A1 7
ROCKY FLATS 1971
PLUTONIUM-239 CONTOURS nCi/km^2 (16)

PLUTONIUM IN SOILS

(DISINTEGRATIONS PER MINUTE/GRAM OF DRY SOIL)



Location of Soil Samples Sites in Adjacent Areas - CDH Protocol



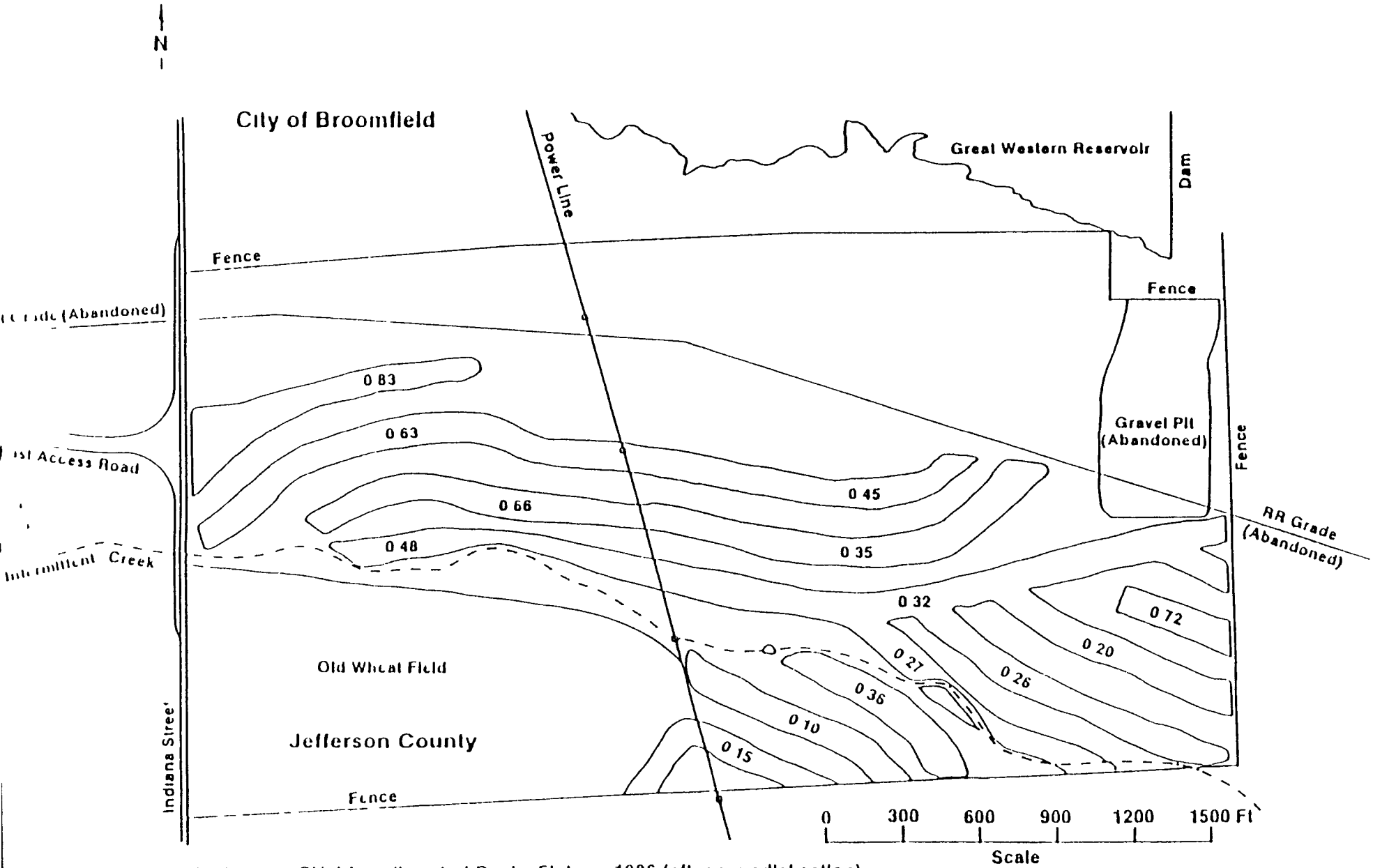


Figure 3 Plutonium (units are pCi/g) in soil east of Rocky Flats — 1986 (after remedial action)

SIMPLIFIED CONVERSION TABLE FOR THE VARIOUS UNITS USED IN THE LITERATURE TO EXPRESS THE ACTIVITY OF PLUTONIUM CONTAMINATION IN SOIL

(1)	(2) mCi/km² *	μCi/m² *	d/m/100 cm² *	d/m/g	pCi/g	μCi/100 cm² *
mCi/km²	1 0	$1\ 0 \times 10^{-3}$	$2\ 22 \times 10^{1}$	$2\ 22 \times 10^{-1}$	$1\ 0 \times 10^{-1}$	$1\ 0 \times 10^{-6}$
μCi/m²	$1\ 0 \times 10^{3}$	1 0	2.22×10^{4}	$2\ 22 \times 10^{2}$	$1\ 0 \times 10^{2}$	$1\ 0 \times 10^{-2}$
d/m/100 cm²	$4\ 5 \times 10^{-2}$	$4\ 5 \times 10^{-6}$	1 0	$1\ 0 \times 10^{-2}$	$4\ 5 \times 10^{-3}$	$4\ 5 \times 10^{-7}$
d/m/g	4 5	$4\ 5 \times 10^{-3}$	$1\ 0 \times 10^{2}$	1 0	$4\ 5 \times 10^{-1}$	4.5×10^{-6}
pCi/g	$1\ 0 \times 10^{1}$	1.0×10^{-2}	$2\ 22 \times 10^{2}$	2 22	1 0	$1\ 0 \times 10^{-4}$
μCi/100 cm²	$1\ 0 \times 10^{6}$	1.0×10^{2}	$2\ 22 \times 10^{6}$	$2\ 22 \times 10^{4}$	1.0×10^{4}	1 0

LEGEND

mCi/km² - Millicuries per square kilometer.

μCi/m² - Microcuries per square meter

d/m/100 cm² - Disintegrations per minute per 100 square centimeters

d/m/g - Disintegration per minute per gram of dry soil (the units in which the results of soil sample analyses are reported).

pCi/g - Picocuries per gram of dry soil

μCi/100 cm² - Microcuries per 100 square centimeters.

*For a density of soil of 1 g/cm³ and a soil sample depth of 1 centimeter

(1) X F = (2), (2) ÷ F = (1)

CDH HEALTH RISK FROM ROCKY FLATS PLANT PLUTONIUM-IN-SOIL CONTAMINATION - 77o ASSESSMENT (OVERESTIMATED)

INHALATION

ORGAN	SOIL CONCENTRATION	RESUSPENSION TERM	BREATHING RATE	EXPOSURE PERIOD	DOSE FACTOR	DOSE
[illegible]	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-9/M X 100 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	1100 rem/uCi RFPu =	32258 rem
[illegible]	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-9/M X 100 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	4200 rem/uCi RFPu =	98182 rem
RD BM:	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-9/M X 100 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	0 rem/uCi RFPu =	0 rem
LIVER	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-9/M X 100 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	1600 rem/uCi RFPu =	37273 rem
GONAD	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-9/M X 100 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	60 rem/uCi RFPu =	3855 rem

INGESTION

ORGAN	SOIL CONCENTRATION	DILUTION FACTOR	SOIL CONCENTRATION	INGESTION RATE	EXPOSURE PERIOD	DOSE FACTOR	DOSE
BONE	(31 uCi RFPu/sq M X	1 Decrease) =	1e-6 uCi per gram X	1 gram/day X	365.25 days/yr X 73 years X	5.41 rem/uCi RFPu =	13332 rem
RD BM:	(31 uCi RFPu/sq M X	1 Decrease) =	1e-6 uCi per gram X	1 gram/day X	365.25 days/yr X 73 years X	0 rem/uCi RFPu =	0 rem
LIVER:	(31 uCi RFPu/sq M X	1 Decrease) =	1e-6 uCi per gram X	1 gram/day X	365.25 days/yr X 73 years X	2.223 rem/uCi RFPu =	25684 rem
GONAD:	(31 uCi RFPu/sq M X	1 Decrease) =	1e-6 uCi per gram X	1 gram/day X	365.25 days/yr X 73 years X	3913 rem/uCi RFPu =	28100 rem

4 7 ~/x

ORGAN	DOSE	RISK FACTOR		RISK
LUNG	2224994 rem X	000004 risk/rem	=	000001 risk of lung cancer
BONE	228136175 rem X	000006 risk/rem	=	000001 risk of bone cancer
RD BM:	0 rem X	0 risk/rem	=	0 risk of leukemia
LIVER:	3895629525 rem X	000002 risk/rem	=	1.77e-7 risk of liver cancer
GONAD:	3815263797 5 rem X	000028 risk/rem	=	3.34e-7 risk of genetic damage

GRAND TOTAL 000003 risk of disease/person

1 CHANCE IN 357945. IN A LIFETIME
FROM DISEASES OF THIS CAUSE

CDH HEALTH RISK FROM ROCKY FLATS PLANT PLUTONIUM-IN-SOIL CONTAMINATION - 1989 RE-EVALUATION (least conservative)

INHALATION

ORGAN	SOIL CONCENTRATION	RESUSPENSION TERM	BREATHING RATE	EXPOSURE PERIOD	DOSE FACTOR	DOSE
LUNG	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-7/M X 1 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	1200 rem/uCi RFPu =	22659 rem
BONE	(31 uCi RFPu/sq M / 25 Reduction) X	1e-7/M X 1 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	5800 rem/uCi RFPu =	110365 rem
RD BM:	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-7/M X 1 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	400 rem/uCi RFPu =	28941 rem
LIVER:	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-7/M X 1 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	1200 rem/uCi RFPu =	22659 rem
GONAD:	(31 uCi RFPu/sq M / 25 Reduction) X	(1e-7/M X 1 Increase) X	23 cu M/day X	365.25 days/yr X 73 years X	23 rem/uCi RFPu =	438025 rem

INGESTION

ORGAN	SOIL CONCENTRATION	DILUTION FACTOR	SOIL CONCENTRATION	INGESTION RATE	EXPOSURE PERIOD	DOSE FACTOR	DOSE
BONE	(31 uCi RFPu/sq M / 10 Decrease) =	1e-7 uCi per gram X	.2 gram/day X	365.25 days/yr X 73 years X	184.3 rem/uCi RFPu =	83333 rem
RD BM:	(31 uCi RFPu/sq M / 10 Decrease) =	1e-7 uCi per gram X	2 gram/day X	365.25 days/yr X 73 years X	7 99 rem/uCi RFPu =	28489 rem
LIVER:	(31 uCi RFPu/sq M / 10 Decrease) =	1e-7 uCi per gram X	2 gram/day X	365.25 days/yr X 73 years X	21 4 rem/uCi RFPu =	31894 rem
GONAD:	(31 uCi RFPu/sq M / 10 Decrease) =	1e-7 uCi per gram X	2 gram/day X	365.25 days/yr X 73 years X	1 29 rem/uCi RFPu =	28828 rem

ORGAN	DOSE	RISK FACTOR		RISK
LUNG	3265782 rem X	000002 risk/rem	=	000001 risk of lung cancer
BONE	171967385 rem X	000005 risk/rem	=	000001 risk of bone cancer
RD BM:	3134945265 rem X	000002 risk/rem	=	2.78e-7 risk of leukemia
LIVER:	83753389 rem X	000005 risk/rem	=	000002 risk of liver cancer
GONAD:	3005281515 rem X	3001 risk/rem	=	5 23e-8 risk of genetic damage

GRAND TOTAL 000004 risk of disease/person

1 CHANCE IN 278474 IN A LIFETIME
FROM DISEASES OF THIS CAUSE

08/30/89 WH

/580

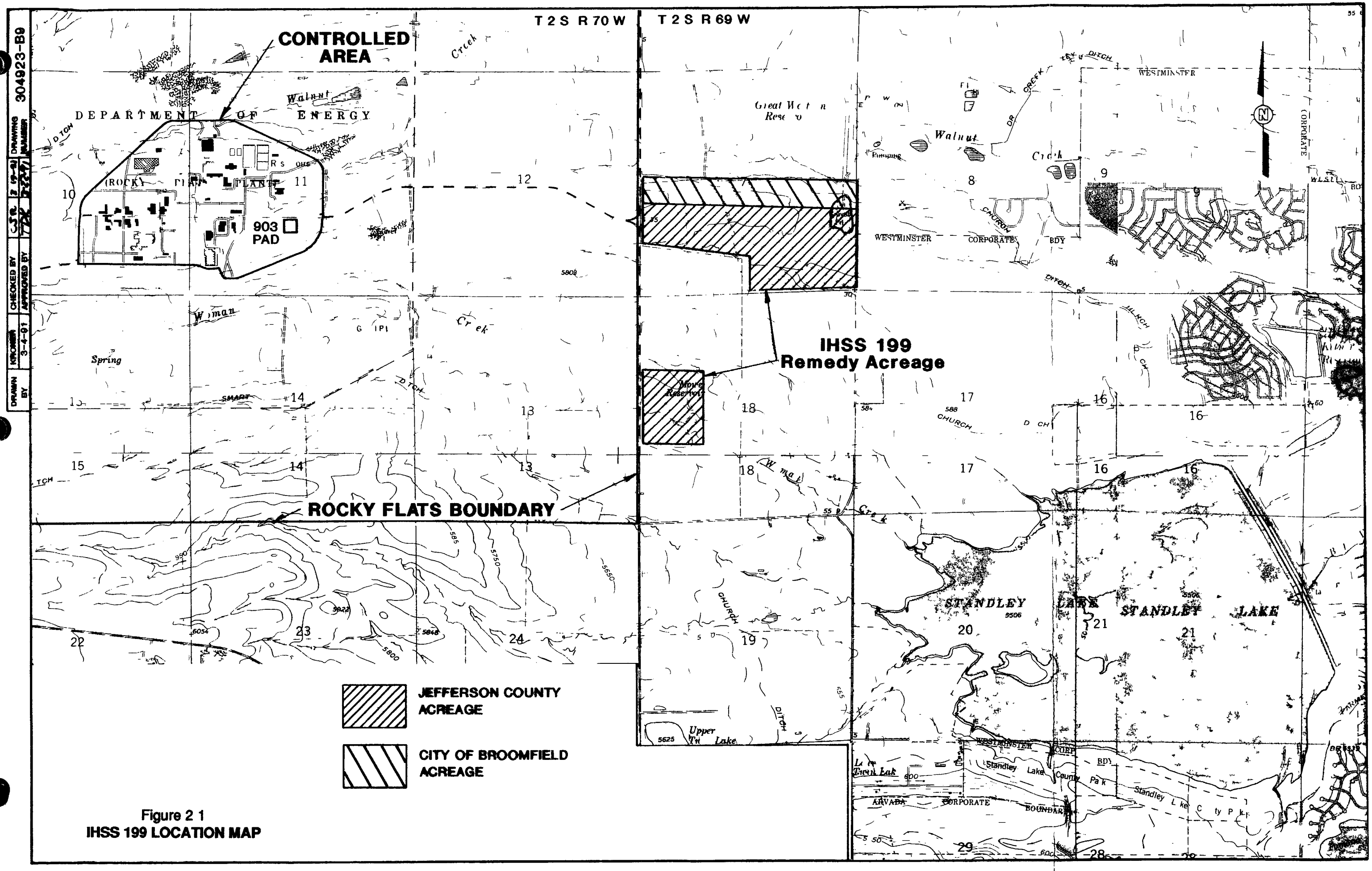


Figure 2 1
IHSS 199 LOCATION MAP

DRAWN BY	CHECKED BY	DRAWING NUMBER
KRONBER 3-4-91	APPROVED BY	304923-B9

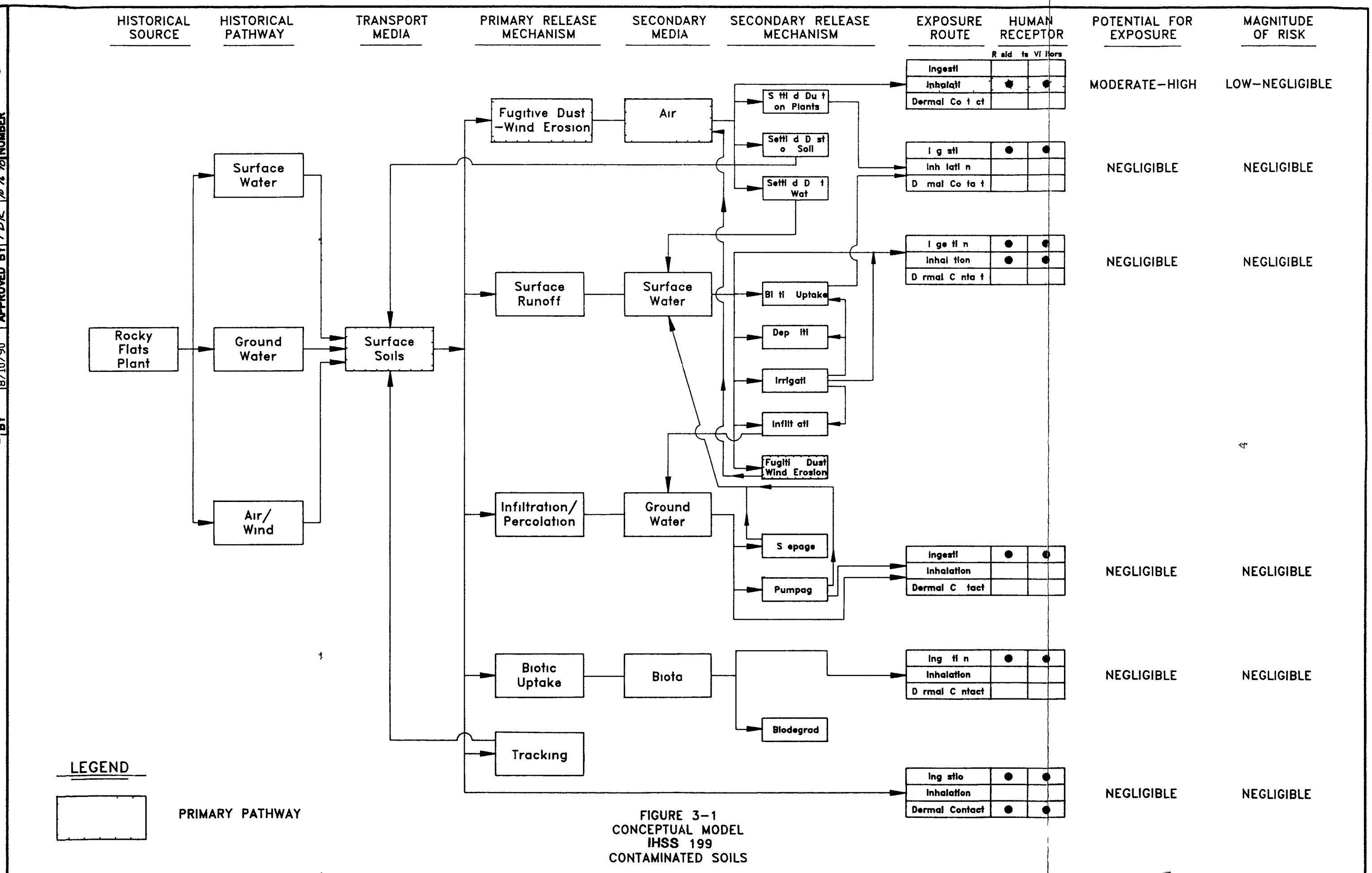


FIGURE 3-1
CONCEPTUAL MODEL
IHSS 199
CONTAMINATED SOILS

DRAWN BY KRONER 8/10/90 | CHECKED BY CJA 10 16 90 | APPROVED BY TDK 10 16 90 | DRAWING NUMBER 30 3-B1

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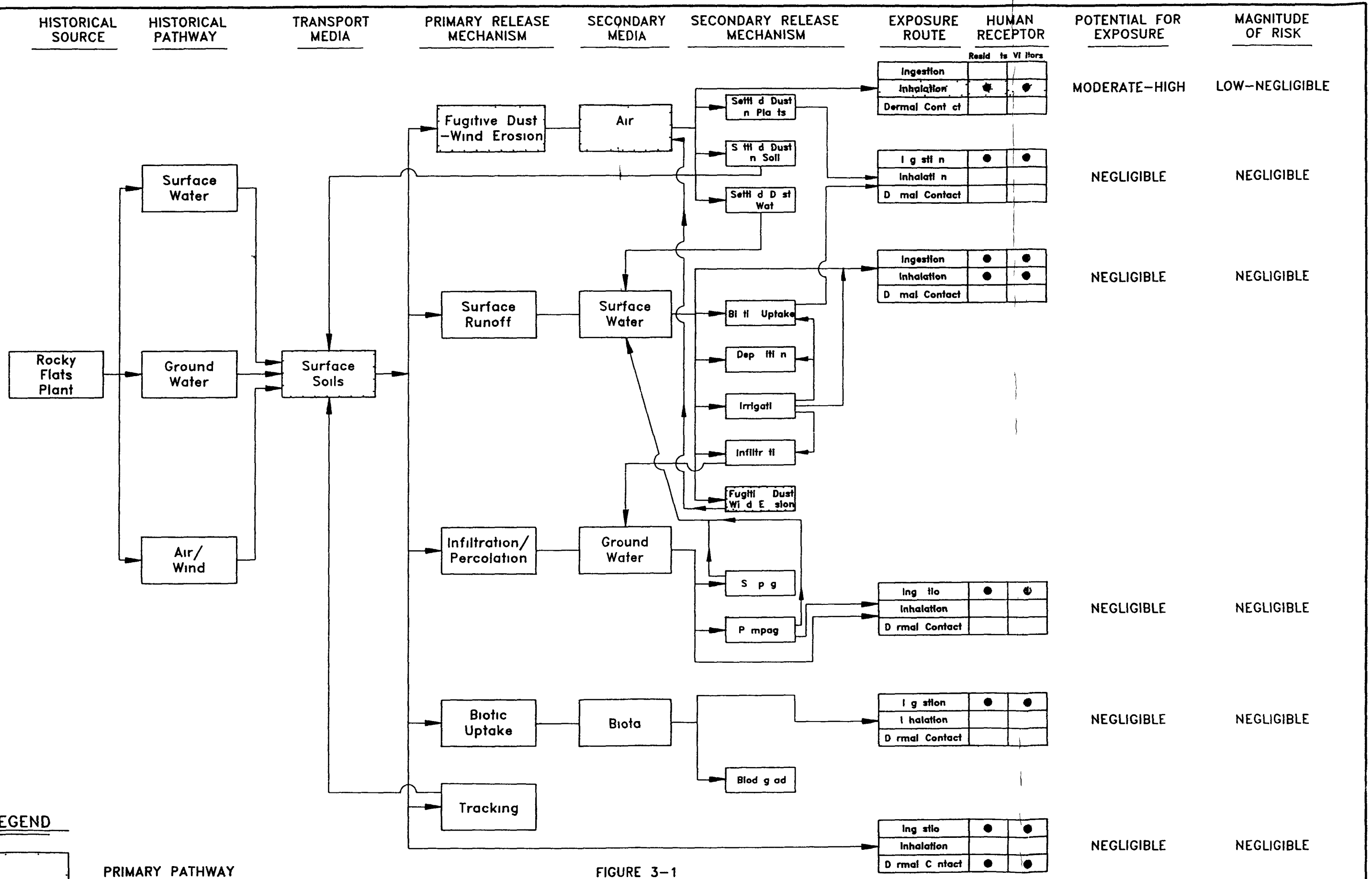

FIGURE 3-1
CONCEPTUAL MODEL
IHSS 199
CONTAMINATED SOILS

DRAWN BY	KRONER 8/10/90	CHECKED BY	CJA	10 16 90	DRAWING NUMBER	30 3-B1
		APPROVED BY	TDK	10-16-90		

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