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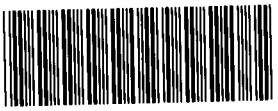

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ANNUAL ENVIRONMENTAL MONITORING REPORT
U S DEPARTMENT OF ENERGY, ROCKY FLATS PLANT

January through December 1978

ENVIRONMENTAL ANALYSIS AND CONTROL

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Air
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ANNUAL ENVIRONMENTAL MONITORING REPORT
U S DEPARTMENT OF ENERGY, ROCKY FLATS PLANT

January through December 1978

Daryl D Hornbacher

INTRODUCTION

The Rocky Flats Plant is a Government-owned and contractor-operated facility It is part of a nationwide nuclear weapons research, development, and production program administered by the Albuquerque Operations Office of the U S Department of Energy (DOE) The prime operating contractor for the Rocky Flats Plant is the Energy Systems Group of Rockwell International

The Rocky Flats Plant is located in northern Jefferson County, Colorado, almost equidistant from the cities of Boulder, Golden, and Arvada (Figure 1) The facility, located at 105° 11′ 30″ west longitude and 30° 53′ 30″ north latitude, is approximately 26 kilometers (16 miles) northwest of downtown Denver The site consists of approximately 2,650 hectares (6,500 acres) of Federally owned land As shown in Figure 2, major Plant structures are located within a security-fenced area of 155 hectares (385 acres)

The Plant is a key DOE facility for producing components for nuclear weapons, thus, its product is directly related to national defense The Plant is involved in fabricating components from plutonium, uranium, beryllium, and stainless steel Production activities include numerous metalworking, fabrication, and assembly shops, chemical recovery and purification of transuranic radionuclides, and quality control functions Research and engineering programs supporting these activities include chemistry, physics, materials technology, ecology, nuclear safety, and mechanical engineering

As part of DOE's energy research programs, a Small Wind Energy Conversion Systems (SWECS) test facility has been constructed in the northwest corner of the Rocky Flats Plant site to test small wind-energy machines This test facility is a national research center in the development and testing of wind energy devices

The more than 100 structures that now constitute the Plant contain about 189,000 square meters (2 1 million square feet) of floor space Of this space, major manufacturing, chemical processing, and waste treatment facilities occupy about 126,000 square meters (1 4 million square feet) About 29,800 square meters (331,000 square feet) of that total is for a new plutonium recovery and waste treatment building now under construction Major laboratory and research buildings occupy about 13,850 square meters (154,000 square feet) The remaining floor space is divided among administrative, utility, security, warehousing, storage, and construction contractor facilities

All of the Plant's heating requirements are supplied by in-plant steam boilers that normally use natural gas but also are capable of using fuel oil During Calendar Year 1978, approximately 21 5 million cubic meters (717 million cubic feet) of natural gas and approximately 1,916 cubic meters (479 thousand gallons) of fuel oil were used Raw water is purchased from the Denver Water Board and is drawn from Ralston Reservoir and the South Boulder Diversion Canal The Rocky Flats Plant used approximately 512,000 cubic meters (128 million gallons) of water during 1978

The piedmont of the Front Range of the Rocky Mountains rises 8 kilometers (5 miles) west of the site and crests at the Continental Divide, which is 32 kilometers (20 miles) beyond The natural environment of the Plant site and vicinity is influenced primarily by (1) the Front Range of the Rocky Mountains and (2) the site elevation, which is approximately 1,829 meters (6,000 feet) above

sea level. The surficial geology of Rocky Flats consists of a thin layer of gravelly topsoil underlain by a 6- to 15-meter-thick layer (20 to 49 feet) of coarser clayey gravel. This, in turn, is underlain by an impermeable bedrock structure upon which most of the Plant's building foundations are supported. Area hydrology is influenced by the topsoil, which consists of gravelly and highly permeable alluvium. Little water is retained in the soil, and vegetation in the area is sparse. Cactus such as Prickly Pear and Spanish Bayonet, plus assorted grasses representative of a mixed short- and mid-grass plain, constitute the main ground cover. Introduced Eurasian weeds also make up a significant percentage of the flora. Cottonwood trees grow adjacent to watercourses. The geographic features of the Plant, in combination with rocky soil, low rainfall, frequent high winds, and solar radiation, produce a harsh semiarid climate.

As shown in Figures 2 and 3, surface water runoff from the Plant is from west to east. Runoff is carried from the Plant by three major drainage basins that are tributary to Walnut Creek on the north and to Woman Creek on the south. The south fork of Walnut Creek is the main effluent watercourse from the Plant. The confluence of the north and south forks of Walnut Creek is 1.1 kilometers (0.7 miles) west of the Plant's eastern perimeter. Great Western Reservoir, a major water supply for the city of Broomfield, is about 1.6 kilometers (1 mile) east of this confluence. Woman Creek flows east from Rocky Flats into Standley Lake, a water supply for the city of Westminster and for portions of the cities of Northglenn and Thornton. Ponds on the north fork of Walnut Creek are designated A-1, A-2, and A-3. Ponds on the south fork are designated B-1 through B-4, and the pond on the Woman Creek watercourse is designated C-1.

Personnel in the Environmental Sciences Department of Rockwell International at Rocky Flats conduct an extensive environmental surveillance program. This program is designed to provide assurance that the many safeguards at the Plant effectively limit the release of radioactive or toxic materials. Environmental Sciences personnel assist various operating groups in adhering to the DOE policy that "... operations shall be conducted in a manner to assure that radiation exposure to individuals and population groups is limited to the lowest levels technically and economically practicable."

The environs are monitored and sampled for radioactivity and for chemical and biological pollutants. Air, water, and soil are sampled on the Plant site and throughout the surrounding region. Several Federal, State, and local governmental agencies independently conduct additional environmental surveys on and off the Plant site. The Colorado Department of Health samples air, soil, and water at the Rocky Flats site. It also operates an on-site, continuous, particulate air sampler for the Jefferson County Health Department. The DOE Environmental Monitoring Laboratory (EML) conducts particulate air sampling in the vicinity of the Rocky Flats Plant and periodically performs special studies, including sediment and soil sampling and analysis. Additional special sampling has been performed by the U.S. Environmental Protection Agency (EPA).

The information contained in this report is a compilation of data provided monthly to the DOE Rocky Flats Area Office, the Radiation and Hazardous Waste Control Division of the Colorado Department of Health, Region VIII of the EPA, the health departments of Boulder and Jefferson Counties, and to interested city officials in communities near the Plant.

SUMMARY

During 1978, the Rocky Flats Plant conducted an environmental monitoring program that included the sampling and analysis of air, water, and soil on and off the Plant site.

Particulate samples were collected from air samplers that operated continuously at the Plant perimeter and in 12 communities located near the Plant. Analysis of these samples indicated that the concentrations of airborne plutonium at perimeter and community locations were identical and were within the range attributed primarily to fallout from atmospheric nuclear weapons testing. Evaluation of these data showed that an above-ground nuclear test conducted by The People's

Republic of China in March 1978 contributed to the 1978 level of plutonium in the Rocky Flats environs and in community sampling locations Even with increases from fallout, the average plutonium concentrations in air at the perimeter and in the communities were less than 0 06 X 10^{-15} μCi/ml This value is less than 0 30% of the applicable DOE Radioactivity Concentration Guides (RCG) and less than 6% of the proposed EPA guidance for plutonium in ambient air

During 1978, water discharge from the Plant site consisted of storm water runoff and treated sanitary water The sanitary water was processed through a tertiary treatment facility before discharge, and the discharges were monitored for compliance with the Plant's National Pollutant Discharge Elimination System (NPDES) permit * Violations of NPDES daily limits occurred on nine occasions and were related to fluoride, pH, suspended solids and biochemical oxygen demand The monthly limit for biochemical oxygen demand was exceeded in February and March In all cases, the causes for these violations were identified and corrective actions taken

The plutonium, uranium, americium, and tritium radioactivity concentrations measured in Great Western Reservoir and Standley Lake during 1978 all were found to be less than 0 07% of the applicable RCG's

Drinking water from nine communities was monitored for plutonium, uranium, and americium The annual average of the 1978 monthly average uranium concentrations was less than 0 06% of the RCG and was in the concentration range expected for the Rocky Mountain Front Range area As for plutonium and americium, 237 out of 240 samples had no measurable radioactivity at a minimum detectable concentration (MDC) of <0 1 X 10^{-9} μCi/ml and/or for some samples, an MDC of <0 02 X 10^{-9} μCi/ml. All plutonium and americium concentrations were less than 0 01% of the applicable RCG The sum of the plutonium and americium alpha radioactivity in community drinking water was less than 1 5% of the State of Colorado regulation for alpha-emitting radionuclides in drinking water and the EPA National Interim Primary Drinking Water Regulations

*An EPA permit identifying permissible discharge levels for various nonradioactive effluents

Soil samples evaluated during 1978 were collected to support special projects On-site samples were collected in preparation for a construction project to control surface water Off-site samples were collected to expand the data base for plutonium in soil in areas within one mile east, west, and south of the Plant boundary On site, the plutonium-in-soil concentrations ranged from 0 06 to 29 4 pCi/g Off site, the values ranged from less than detectable to a maximum of 1 4 pCi/g

An assessment was made of the potential Plant contribution to public radiation dose At the Plant boundary, the maximum probable radiation dose was calculated to be a 70-year dose commitment of <0 02 millirem to the whole body and <2 31 millirem to the bone By comparison, the annual doses to the total body and bone, from radiation background in the Denver area, are stated to be 150 and 168 millirem respectively [1] The radiation doses of <0 02 millirem and <2 31 millirem represent <0 004% and <0 15%, respectively, of the appropriate DOE radiation protection standards

Because of the similarity of all community radionuclide concentrations measured in 1978, no community could be singled out as having received a maximum radiation dose The maximum probable 70-year radiation dose commitment at any of several unspecified communities was calculated to be <0 003 millirem to the total body and <0 83 millirem to the bone These values include some contribution from sources other than Rocky Flats, such as the persistence of pre-1978 fallout These values represent <0 002% and <0 17% of the appropriate DOE dose standard In comparison, annual radiation doses from natural background of 150 millirem to the total body and 168 millirem to the bone have been reported [1]

Total dose to the population living within 80 kilometers (50 miles) was calculated using the community radiation dose values Based on the 70-year total-body dose of <0 003 millirem, the total population dose was estimated to be <5 7 man-rem The corresponding dose from natural radiation background is 287,000 man-rem

SITE METEOROLOGY AND CLIMATOLOGY

During 1978, complete data were not collected from the Plant's 61-meter (200 foot) meteorological

lower because of problems with the magnetic tape and processing units of the data acquisition system Data are being gathered from off-site sources for review A summary of temperature, precipitation, and wind data for the 24-year period, 1953-1976, is given in Table 1 Figure 4 shows the most recent wind rose (1975) that accurately depicts typical wind speed and wind direction for the Rocky Flats Plant

MONITORING, DATA COLLECTION, ANALYSES, AND EVALUATION

Applicable Guides and Standards

The Rocky Flats Plant Environmental Monitoring Program includes evaluating Plant compliance with all appropriate guides, limits and standards These values are numerous and varied Guide values for radionuclides in ambient air and waterborne effluents, for example, have been adopted by the Department of Energy [2] The guides are based on recommendations published by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP) Limits for nonradioactive pollutants in effluent water have been defined by an Environmental Protection Agency NPDES discharge permit,[3] and in 1976, the EPA established standards for radionuclides in drinking water [4] These drinking water standards have been adopted, in turn, by the State of Colorado [5]

The Radioactivity Concentration Guides (RCG)[2] published by DOE [formerly the Energy Research and Development Administration (ERDA)] included permissible concentrations of specific radionuclides and mixtures of radionuclides in air (RCG_a) and water (RCG_w) for controlled areas and uncontrolled areas. These guides are reduced by a factor of three when applied to a suitable sample of the exposed population Numerical values of the guides for specific radionuclides are cited in some of the tables presented in this report The guides additionally restrict the concentration of radionuclides in a mixture such that the sum of the ratios between each radionuclide concentration and the appropriate concentration guide shall not exceed a value of 1 The guides further state that a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture to the concentration guide for that radionuclide does not exceed one-tenth and (b) the sum of such ratios for all radionuclides considered as not present in the mixture does not exceed one-fourth

During 1978, average specific radionuclide concentrations in air and water were all less than one-tenth of the appropriate concentration guides for specific radionuclides The sum of the ratios of these average concentrations to their respective RCG's was less than one-fourth of all air and water sampling locations The measured concentrations in the tables have therefore been compared to the concentration guides for specific radionuclides rather than the guide for mixtures

In the interpretation of concentration data for radionuclides in Plant effluents and environmental samples, the data are treated as if the materials are soluble This assumption serves as an additional safeguard because the RCG's for soluble radionuclides handled at Rocky Flats are more restrictive than those for insoluble radioactive materials Throughout this report, where a radionuclide concentration is expressed as the cumulative measurement of more than one isotope, the stated RCG used for comparison represents the most restrictive RCG for that grouping of isotopes Plutonium concentrations measured at Rocky Flats represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97% of the radioactivity

Uranium concentrations are the cumulative alpha radioactivity from the uranium isotopes 233, 234, and 238 These isotopes have a much higher specific activity than uranium-235, which is the major isotope (93% by weight) in enriched uranium used at Rocky Flats

The alpha radioactivity from these three isotopes represents approximately 97% of the radioactivity from uranium The most restrictive RCG's for air and water for these isotopes are those for uranium-233 and -234, which are identical and are listed as appropriate throughout this report

The applicable EPA standard for beryllium (a nonradioactive material) in airborne effluents from Plant buildings is 10 grams per day per stationary source in a 24-hour time period [6] Currently, there are no DOE or EPA guides or standards for radionuclides in effluent air For ambient air, the applicable DOE RCG's for soluble plutonium-239 and -240 in uncontrolled areas and for the general population are 60×10^{-15} μCi/ml and 20×10^{-15} μCi/ml respectively

The DOE soluble plutonium-239 and -240 RCG in waterborne effluents for the general population is $1,667 \times 10^{-9}$ μCi/ml The comparable RCG for americium-241 in water is $1,330 \times 10^{-9}$ μCi/ml The most restrictive RCG for uranium-233, -234, and -238 in water is $10,000 \times 10^{-9}$ μCi/ml, which is the RCG for either uranium-233 or Uranium-234

In 1976, the Environmental Protection Agency promulgated regulations for radionuclides in drinking water [4] These regulations were effective on June 24, 1977, along with primary drinking water regulations for microbiological, chemical, and physical contaminants The intent of the Safe Drinking Water Act was to ensure that each state has primary enforcement for maintaining drinking water quality To comply with these requirements, the Colorado State Board of Health modified existing State drinking standards to include radionuclides [5] Two of these community drinking water standards are of interest in this report The State standard for gross-alpha particle activity (including radium-226 but excluding radon and uranium) in community water systems is a maximum of 15 picocuries per liter [pCi/l (15×10^{-9} μCi/ml)] Americium and plutonium, which are alpha-emitting radionuclides, are included in this limit The limit for tritium in drinking water is 20,000 pCi/l ($20,000 \times 10^{-9}$ μCi/ml)

The Rocky Flats Plant NPDES permit,[3] issued in 1974 by the EPA, established effluent concentration limitations and limitations for nitrate and pH in the discharge from Holding Pond A-3 in the Walnut Creek drainage

Background Radioactivity

The DOE guide values for radioactive materials in air and water relate to concentrations above background The concentration measurements shown in this report, however, include contributions from fallout deposition and naturally occurring radioactive materials Because of fallout, regional background is variable and not well defined A more detailed discussion of background radioactivity is given in the air and water monitoring and the radiation dose sections of this report

Analytical Procedures

Analyses for plutonium-239 and -240, uranium-233, -234, and -238, and americium-241 are conducted in the following manner Prior to any separation of elements from the sample matrix, a known quantity of nonindigenous radioactive tracer is added to each sample These tracers are used to determine chemical recovery The tracers used for plutonium, uranium, and americium are plutonium-236, uranium-236, and either americium-243 or curium-244, respectively

Separation of the radioisotopes from the environmental and effluent matrices is performed by ion exchange techniques The purified radioisotopes are electrodeposited onto stainless steel disks and are radiometrically determined by alpha pulse height spectrometry [7] The resulting radionuclide concentrations are cumulative radioactivity from the various isotopes for a given element, as measured by the alpha pulse height spectrometry system

Detection Limits

Table 2 shows nominal values for the Minimum Detectable Concentrations (MDC) of materials in various media The values shown are for typical sample volumes analyzed in the Rocky Flats monitoring program For any individual sample, the MDC may be larger or smaller, depending on detector, counting parameters, and the size of the sample collected and analyzed Table 2 also lists specific nonradioactive standards and Radioactivity Concentration Guides (RCG's) applicable to airborne and waterborne effluent

Data Reduction

Average concentration (C_{avg}) represents the calculated arithmetic mean of the set of observed

data Any observed concentration below the MDC was assigned the MDC value for reporting and averaging purposes When one or more MDC values are included in a set of values the computed mean value of that set is preceded by a less-than sign (<)

Standard deviations typically are included in sets of environmental data, however, the use of standard deviations can be misleading and is considered inappropriate for the data in this report

The variability of environmental conditions from one sampling period to another will result in nonrandom variations in the measured concentrations The distribution of measured concentrations therefore would not be normal Under these circumstances, standard deviation values illustrate only the variability of the measured concentrations not the reliability of the data For these reasons standard deviations are not included in this report A tabulation of minimum and maximum concentrations (C_{min} and C_{max}) have been included with each data set for the purpose of defining the range of measured concentrations

Quality Control

An analytical quality control program is conducted by the Rocky Flats Health and Environmental Laboratory (H&EL) to ensure the reliability of environmental data

The program includes the following elements

1 Development, evaluation, improvement, modification, and documentation of analytical procedures

2 Intralaboratory quality control

3 Participation in interlaboratory quality control programs

4 Instrument performance evaluation

The Rocky Flats Chemistry Standards Laboratory prepares "blind" standard samples using calibrated radioisotopes traceable to the National Bureau of Standards These standard samples are prepared to simulate routine environmental samples Statistical analysis of quality control data and an assessment of laboratory performance is conducted by the Chemistry Standards Laboratory on a monthly basis Table 3 shows the measurement statistics for the control program based on a six-month average

The Rocky Flats Health and Environmental Laboratory participates in a laboratory intercomparison study program conducted by the EPA's Environmental Monitoring and Support Laboratory Participation is limited to those programs which are representative of the Rocky Flats Monitoring Program Examples are

- Gross alpha and gross beta activity in water
- Radionuclides on air filters
- Tritium concentration in water
- Gamma activity in water

Data from completed analyses are returned to the EPA Quality Assurance Branch for statistical analysis and for comparison with other participating laboratories Participants are furnished with a computer report and updated performance chart The computer reports list the results for all of the labs submitting results All results are compared against a normalized grand average of all results and against the known value The performance chart is a graph of the laboratories performance over a two-year period A warning level is established at two sigma deviations from expected results and a control level is established at three sigma deviations

The Health and Environmental Laboratory participates in the Environmental Measurements Laboratory's (EML) Quality Assessment Program Soil, water, air filter, animal tissue, and vegetation samples containing radionuclides are submitted by EML on a quarterly basis The results are given to EML who publishes both a quarterly report and an annual summary listing the results reported by all participants

Table 4 shows a comparison of Rocky Flats H&EL with other participating laboratories in the DOE

EML and the EPA Environmental Monitoring and Support Laboratory's cross-check programs The data concerns air, soil, and water for the period from October 1977 to August 1978 Health and Environmental Laboratory results are compared to the grand mean for all laboratories reporting common data The H&EL results are plotted as a function of their normalized deviation from the grand mean Two sigma about the mean is considered a warning level A three-sigma deviation is considered a control level requiring investigation and corrective action During the period under consideration, the majority of the cross-check samples analyzed for this program were within the two-sigma range

Airborne Effluent Monitoring

Particulates in ventilation effluents from production and research facilities are sampled continuously Particulate contaminants are removed from these effluents by means of High Efficiency Particulate Air (HEPA) filters Samples of filterable particulates, indicative of the effluent quality, are collected downstream from the final stage of HEPA filters For detection of abnormal conditions, ventilation systems containing plutonium are equipped with selective alpha monitors that are sensitive to radionuclides such as plutonium-239 and americium-241 These monitors alarm automatically if out-of-tolerance conditions are experienced

Three times each week the filterable particulate samples are removed and radiometrically analyzed for long-lived alpha emitters Concentrations of long-lived alpha emitters are indicative of the effluent quality and HEPA filtration efficiency

At the completion of each month, the samples are composited, by ventilation system, for specific radiochemical separation and alpha pulse height analysis for plutonium and uranium (as described in the Analytical Procedures section of the report) An aliquot of each composite sample is analyzed for beryllium particulates using a flameless atomic absorption spectrophotometer technique [8]

In February 1978, specific analysis for uranium and beryllium was expanded from 12 to 37 effluent locations Effluent air from 15 ventilation systems is sampled continuously for tritium A bubbler with water is used as the collection medium Tritium concentrations in these samples are measured using a liquid scintillation spectrometer

Table 5 presents quantitative data for radioisotopes and beryllium released to the atmosphere in ventilation effluents during 1978 The concentrations and quantities include small background contributions

During 1978, the total amount of plutonium released to the atmosphere was less than 2 76 microcuries Uranium and beryllium releases from the 37 ventilation systems were less than 53 07 microcuries and 17 573 grams respectively Slightly less than one curie of tritium was released During February, less than 15 575 grams of beryllium were released Of this total, approximately 14 56 grams of beryllium was accidentally released as the result of a small welding-related fire on February 23, 1978 This beryllium release was confined to Government-owned property with no spread to any adjacent off-site location, as determined by beryllium measurements in on-site and perimeter ambient air samples

Instrumentation to provide in-stack monitoring for carbon tetrachloride, total hydrocarbons, mass emission rates for particulates, oxides of nitrogen, and sulfur dioxide effluents has been purchased and is being installed in selected exhaust ventilation systems This equipment will provide the data to confirm compliance with appropriate stack emission standards.

Ambient Air Monitoring

High-volume ambient-air samplers are located on the Rocky Flats Plant site, at the Plant perimeter [at a distance of approximately 3 to 6 kilometers (2 to 4 miles) from the Plant center], and in 12 surrounding communities The air samplers are of a Rocky Flats design, which is described in detail in Rockwell Engineering Drawings 27261-1

through 27261-6 The high-volume samplers operate continuously at a volume flow rate of approximately 19 liters per second (40 cubic feet per minute) Particulates are collected on a 20- X 25-centimeter (8- X 10-inch) Delbag Microsorban® filter The effectiveness of the high-volume sampler and the filter media has been evaluated by Dr James B Wedding, Colorado State University, Fort Collins, Colorado The Rocky Flats design compared favorably to the EPA-specified standard Hi-Volume Sampler for a variety of field-realistic conditions The filter media was found to be greater than 99 9 percent efficient for particle sizes and pressure drops typical of ambient air sampling [9]

Airborne particulates in ambient air are sampled continuously at 23 locations within and adjacent to the Rocky Flats exclusion area (Figure 5) The sample filters are collected weekly and analyzed for total long-lived alpha (TLLα) If TLLα activity exceeds 0 01 pCi/m^3, specific plutonium analysis is performed During 1978, all TLLα concentrations were below 0 01 pCi/m^3 On a routine basis, filters from 11 of the 23 samplers are composited and analyzed biweekly for plutonium Table 6 contains the results of average concentrations of plutonium radioactivity in airborne particulates during 1978 The highest percentages of the RCG_a were at Samplers S-8 and S-9 These samplers are located within the security fence directly east (downwind) of an area in which the soil is known to contain plutonium During the summer of 1978, a soil removal operation was conducted in this area The soil removal operation is described elsewhere in this report

The average concentrations of plutonium in ambient air at the 11 on-site stations during 1978 ranged from 0 05 X 10^{-15} μCi/ml to 0 86 X 10^{-15} μCi/ml These concentrations were less than 1 5 percent of the RCG_a for soluble plutonium in ambient air in uncontrolled areas

Samples of airborne particulates are collected on filters by high-volume air samplers at 14 locations along or near the Plant perimeter These perimeter samplers are located between 3 and 6 kilometers (2 and 4 miles) from the Plant center (Figure 6) The samplers are numbered S-31 through S-44. Samples from each location are collected weekly, analyzed for total long-lived alpha activity, composited by location, and analyzed for a four-week period for plutonium Table 7 presents the average concentrations of plutonium radioactivity in airborne particulates at Stations S-31 through S-44 during 1978 The average concentration of plutonium in ambient air at these locations during 1978 was less than 0 06 X 10^{-15} μCi/ml This concentration was less than 0 30% of the soluble plutonium RCG_a for the general population

Samples of airborne particulates also are collected at 12 locations in or near communities in the vicinity of the Rocky Flats Plant These locations, as identified in Figure 6, are Boulder, Broomfield, Denver, Golden, Jeffco Airport, Lafayette, Leyden, Marshall, Superior, Wagner, Walnut Creek, and Westminster Sample filters are collected weekly, analyzed for total long-lived alpha activity, composited by location, and analyzed for a four-week period for plutonium radioactivity

Table 8 presents the average concentrations of plutonium in airborne particulates at the community stations during 1978 The average concentration of plutonium in ambient air at the community stations was less than 0 06 X 10^{-15} μCi/ml That value is less than 0 30% of the soluble plutonium RCG_a for the general population

The 1978 perimeter and community monthly average concentrations of plutonium in airborne particulates are shown graphically in Figure 7 From this figure, two observations can be made First, within experimental error there is no difference in the monthly concentrations at perimeter and community locations Second, in March there was a significant increase in the concentrations at all locations This increase was followed by a steady decrease that lasted until October 1978

The increased plutonium in ambient air during the period from March through October was a result of fallout On March 14, 1978, The People's Republic of China conducted an above-ground test of a nuclear device Radioactive fallout from this test began passing over the continental United States on about March 18, 1978 This was evidenced in Colorado by observing total long-lived beta activity in ambient air Such observations are

conducted routinely by the Colorado Department of Health [10] The data shown in Figure 8 show the passage of fallout during March that persisted throughout the remainder of 1978 Beta-emitting radionuclides in fallout have half-lives that are shorter than alpha-emitting radionuclides such as plutonium, consequently, the plutonium concentrations displayed in Figure 7 did not decrease at the same rate as the total long-lived beta concentrations shown in Figure 8

The People's Republic of China conducted a second above-ground test in December, this also contributed to increased total long-lived beta activity in ambient air However, plutonium concentrations measured at Rocky Flats perimeter and community locations did not vary This is due in part to the fact that the last sampling period for 1978 was a six-week period from November 10 to January 5, 1979 This diluted the effect that might have been observed in the plutonium concentration results Also, there may have been less plutonium in the fallout that passed over Colorado in December

From Figure 7, a reasonable estimate of the nuclear testing fallout contribution to plutonium concentrations in ambient air can be made The January and February 1978 plutonium concentrations at perimeter and community locations averaged $<0\ 04 \times 10^{-15}$ μCi/ml These concentrations reflect some residual fallout from the September 1977 nuclear test The increased concentrations measured from March to October are solely due to fallout. Therefore, the concentrations from October through December of $<0\ 02 \times 10^{-15}$ μCi/ml are concentrations that could have been anticipated had the March 1978 above-ground test not been conducted

In summary, the perimeter and community plutonium concentrations during 1978 both averaged $<0\ 06 \times 10^{-15}$ μCi/ml. This concentration can be subdivided into fallout concentration of $<0\ 04 \times 10^{-15}$ μCi/ml from the March test The remainder, $<0\ 02 \times 10^{-15}$ μCi/ml, is from background due to plutonium from previous above-ground testing with an undefinable part of the $<0\ 02 \times 10^{-15}$ μCi/ml concentration possibly being of Rocky Flats origin. Currently the measurement techniques and sensitivity of measurements at Rocky Flats are not sufficient to determine the Rocky Flats contribution that may be part of the balance concentration of $<0\ 02 \times 10^{-15}$ μCi/ml The significance of these values is discussed in the dose assessment section of this report

Waterborne Effluent Monitoring

North Walnut Creek receives storm-water runoff from the north side of the Plant site (See Figure 3) Holding Pond A-3 on North Walnut Creek is used to impound this runoff for analysis prior to discharge Ponds A-1 and A-2 are isolated from North Walnut Creek and are used for storage and evaporation of water containing less than $1,667 \times 10^{-9}$ μCi/ml of plutonium This water is Rocky Flats laundry wastewater and water from one Plant cooling tower This water is pumped to Pond A-2 from Pond B-2 During the summer months, natural evaporation is enhanced by spraying the water from Pond A-2 through fog nozzles over the surfaces of Ponds A-1 and A-2 These ponds then receive the excess water that does not evaporate during the process Typically, the plutonium content in this water averages less than 5×10^{-9} μCi/ml

South Walnut Creek receives discharges from the Plant's tertiary sewage treatment facility after passage through Holding Ponds B-1, B-3, and B-4 During 1978, Plant wastewater discharged through this facility consisted of cooling-tower blowdown, steam condensate, and sanitary waste These liquid wastes were subjected to tertiary treatment before being discharged from the Plant Solids resulting from this operation were decomposed in an anaerobic digestor After drying, the contents of the digestor were packaged in 55-gallon drums and shipped, in compliance with applicable regulations, to a DOE waste-storage facility

After treatment, the liquid effluents were impound-discharged from the B-series holding ponds to South Walnut Creek. (See Figure 3) Pond B-2 is isolated from this discharge stream and is used for impoundment of water containing less than $1,667 \times 10^{-9}$ μCi/ml alpha activity This water consists of Rocky Flats laundry wastewater and water from one Plant cooling tower

Discharges from the Rocky Flats Plant are monitored for compliance with appropriate Colorado Department of Health standards and EPA-NPDES permit

limitations Average concentrations of chemical and biological constituents of routine liquid effluent samples collected from Pond A-3, the sewage treatment plant, and Pond C-1 during 1978 are presented in Table 9 This table is divided into sections that list the appropriate Colorado Department of Health standards and the EPA-NPDES permit limitations in effect during 1978 Daily NPDES effluent concentrations for fluoride were exceeded at the sewage treatment facility on two occasions The daily maximum limitation for this parameter is 1 7 mg/l The two violations occurred in January 1978 when daily values of 3 7 and 2 4 were recorded

Investigations conducted in January and February 1978 revealed the fluoride violations were caused by a floor sealing compound being discarded into the sanitary drains The floor sealer is a magnesium fluosilicate compound used by an independent subcontractor at the Rocky Flats Plant to harden, densify, and retard the dusting of newly poured concrete floors Corrective actions have been taken to limit and control the use of this compound and to ensure that solutions containing this material are not discharged to the sanitary drain system

Daily NPDES effluent concentrations for pH, suspended solids, and biochemical oxygen demand were exceeded on several occasions A pH violation occurred in February when a value of 3 4 was recorded The pH violation was the result of an acid release from the steam plant In attempting to neutralize this acid with lime, two suspended solids (30 and 67 mg/l) violations occurred In addition, a biochemical oxygen demand (58 mg/l) violation occurred as a result of the accidental acid release to the sewage treatment plant During the latter part of February, another biochemical oxygen demand (27 mg/l) violation occurred as the result of polisher backwash water being released from the steam plant This backwash water contained iron oxide particles, which placed an extra oxygen demand on the sewage treatment plant The monthly average for February 1978, for biochemical oxygen demand (15 5 mg/l), was in excess of the allowable limit of 10 mg/l

During the month of March, two biochemical oxygen demand (29 and 28 mg/l) violations occurred These two violations were associated with increases in total suspended solids which remained within the allowable limit The monthly average of 11 7 mg/l for biochemical oxygen demand was in excess of the allowable limit of 10 mg/l

During the month of July, one biochemical oxygen demand (45 mg/l) violation occurred The cause of this violation was due to the failure of an aerator blower in one of two secondary treatment processes of the sewage treatment plant

When planned discharges are made from Holding Pond A-3, the water is sampled continuously These samples are analyzed for plutonium, uranium, americium, and tritium Water is sampled continuously and collected daily from the outfalls of Ponds B-4 and C-1 These daily samples are composited into weekly samples for plutonium, uranium, and americium analyses Weekly grab samples at Ponds B-4 and C-1 are analyzed for tritium

Concentrations of plutonium, uranium, and americium in water samples at the outfalls of Ponds A-3, B-4, and C-1 are presented in Table 10 Tritium concentrations are presented in Table 11 All plutonium, uranium, americium, and tritium concentrations in these ponds were less than 0 09 percent of the applicable RCG_W Walnut Creek is sampled continuously at Indiana Street, which is downstream from the confluence of the stream tributaries and approximately at the Plant's east perimeter These samples are composited weekly and analyzed for plutonium, uranium, and americium Results of these analyses are presented in Table 12 Weekly grab samples are analyzed for tritium, the results for 1978 are presented in Table 11 The 1978 average concentrations for plutonium uranium, americium, and tritium in Walnut Creek at the Indiana Street location were less than 0 09 percent of the applicable RCG_W The plutonium and tritium concentrations were well below limits set forth in the new Colorado Stream Quality Standards.

Ralston Reservoir, which is located near a uranium mine, serves as the primary source of raw water for the Rocky Flats Plant From March through December 1978, the impact of this water source

was evaluated by conducting weekly uranium analysis on samples of Rocky Flats raw and treated water The uranium concentrations measured during this period are summarized in Table 13

Uranium concentrations measured during 1978 in raw water and treated water averaged 6 8 X 10^{-9} and 6 2 X 10^{-9} μCi/ml respectively After this water was used throughout the Plant, it was discharged to the sanitary sewage system and ultimately to Pond B-4 and then to Walnut Creek

As shown in Tables 10 and 12, the 1978 average uranium concentration in effluent waters, as determined at the Pond B-4 and Walnut Creek sampling locations, was 5 8 X 10^{-9} μCi/ml A comparison of influent and effluent uranium concentrations suggests that effluent water showed no increase in uranium concentration from Rocky Flats operations

Groundwater Monitoring

The Rocky Flats Plant routinely samples 43 hydrologic test holes at approximately five-month intervals Analyses are conducted to determine if there is any movement of chemical or radioactive materials of possible Plant origin into waterbearing strata underlying the site

Five of the test holes are approximately 46 meters (150 feet) deep or deeper These test holes, numbered 1-66, 2-66, 3-66, 22-74, and 21-74, are located near the west security fence, northeast of the solar ponds, east of the solar ponds, east of the east security fence, and at the south security fence respectively These test holes provide information concerning water movement in bedrock formations The remaining test holes range from 1 to 15 meters (4 to 50 feet) deep and generally are located near three on-site solar evaporation ponds and other holding ponds Locations of the 43 test holes are identified in Figure 9

During March and July, test holes containing water were sampled and analyzed for plutonium, uranium, americium, and tritium Table 14 presents measured depths and radioactivity concentrations in the test holes during 1978

Americium, tritium, and uranium have appeared in test holes in close proximity with the solar evaporation ponds As these ponds are hydraulically upgradient from the test holes and have been used to store process wastewaters prior to treatment, it appears that some seepage may have occurred Plutonium, however, has not been found in concentrations greater than MDA since 1977, when values of 0 2 X 10^{-9} μCi/ml were reported in Test Holes 2-60 and 4-60

Three sites were reported with plutonium activities above MDA 1-71, 3-71, and 15-74 The March sample at 1-71, yielding 1 14 X 10^{-9} μCi/ml, has been attributed to windblown particulate material Subsequent analyses, following capping of the well, have yielded activities of 0 171 X 10^{-9} μCi/ml (July 1978) and <0 1 X 10^{-9} μCi/ml (January 1979), indicating remedial actions taken were sufficient Test Hole 3-71 yielded a July plutonium level of 0 225 X 10^{-9} μCi/ml Although located directly south of Pond A-2, which is a process-waste holding basin, activities measured in all prior analyses (<0 1 X 10^{-9} μCi/ml) at this site suggest an irregularity such as sample cross-contamination rather than aquifer contamination Test Hole 15-74 yielded anomalous concentrations of plutonium (0 135 X 10^{-9} μCi/ml) and tritium (2,796 X 10^{-9} μCi/ml) in the March sampling In July, the plutonium and tritium concentrations for Test Hole 15-74 were <0 1 X 10^{-9} μCi/ml and 627 X 10^{-9} μCi/ml, respectively

Test Hole 17-74 was found to have an americium activity of 0 126 X 10^{-9} μCi/ml in July Prior to 1978, the last value reported at greater than 0 1 X 10^{-9} μCi/ml was 0 112 X 10^{-9} μCi/ml in May 1976 Anomalous values reported at Test Holes 15-74, and 17-74 cannot be explained at this time

Regional Water Monitoring

Water samples are collected weekly from Great Western Reservoir, which is a water supply for the city of Broomfield, and from Standley Lake, which supplies the city of Westminster and portions of the Thornton-Northglenn area. Concentrations of plutonium, uranium, americium, and tritium in

water samples collected at these two locations were less than 0 07 percent of the applicable RCG_W Tap or finished water from Boulder, Broomfield, and Westminster is collected weekly Quarterly samples of tap water also are collected from the surrounding communities of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton These samples are analyzed specifically for plutonium, uranium, and americium The resulting data for 1978 are summarized in Table 15 Plutonium and americium concentrations in community taps were less than the minimum detectable concentration of $0\ 1 \times 10^{-9}$ μCi/ml More sensitive measurements were made on monthly composite samples from five sampling locations during a six-month period These measurements provided results that were very near or less than a minimum detectable concentration of $0\ 02 \times 10^{-9}$ μCi/ml All values were less than 0 01% of the applicable RCG s

Drinking water standards have been adopted by the EPA and the State of Colorado for alpha-emitting radionuclides (excluding uranium and radon) and for tritium These standards are 15×10^{-9} μCi/ml and $20{,}000 \times 10^{-9}$ μCi/ml, respectively During 1978, the sum of the concentrations of plutonium and americium (alpha-emitting radionuclides) in all community tap samples was less than $0\ 2 \times 10^{-9}$ μCi/ml This value is less than 1 5% of the alpha standard The tritium concentration in Great Western Reservoir and Standley Lake averaged less than 700×10^{-9} μCi/ml This value is typical of background tritium in Colorado and represents less than 3 5% of the EPA and State of Colorado Drinking Water Standard for tritium

In September 1978, single water samples were collected from 16 additional lakes, reservoirs, and streams in the region Samples were collected at distances of 8 to 32 kilometers (5 to 20 miles) from the Plant and were analyzed specifically for plutonium, uranium, americium, and tritium As shown in Table 16, the 1978 average plutonium concentration was less than 0 01 percent of the soluble plutonium RCG_W for the general population.

Soil Sampling and Analyses

Soil samples were collected on a special project basis during 1976, 1977, and 1978 One hundred sixty samples were collected from surveyed sites at distances up to 1 6 kilometers (one mile) from the Rocky Flats Plant boundary—in all directions except north The geometry of all soil samples was controlled by driving a 10- X 10-centimeter (4 X 4 inch) cutting tool 5 centimeters (2 inches) into undisturbed soil The soil sample contained within the tool cavity was removed for analysis [11]

Sample preparation and analysis was conducted according to a procedure developed by personnel from Rockwell International and from Eberline Instrument Corporation (EIC) in Albuquerque, New Mexico This procedure is adapted from the Nuclear Regulatory Guide 4 5 [12] The entire sample is oven dried, sieved through a 10-mesh sieve, weighed, and the fine material is ball milled A 10-gram aliquot of the pulverized soil is analyzed for plutonium Chemical recovery from the radiochemical procedure is determined by adding plutonium-236 as a tracer The analytical results are reported in units of disintegrations per minute per gram of dry soil fines These values are converted to picocuries per gram of dry soil (less than 10 mesh or 2 mm)

The 1978 soil data are displayed in Figure 10 for locations surrounding the Plant The values given are for the range and median value (in parentheses) The maximum value detected was 1 4 picocuries per gram

On-site soil samples were collected and analyzed during 1978 in preparation for soil excavation required for a Plant construction project related to surface water control Locations of samples taken and concentrations of plutonium in those samples are shown in Figure 11

Soil Removal Operation

During the summer of 1978, contaminated soil was removed from an area designated as the 903 Lip Area and from an area where an off-site contractor is to install a portion of a new security fence These two areas are shown in Figure 12

The operations were conducted under restrictions imposed by the Operational Safety Analysis (OSA) for soil removal Excavation of the soil was carried

out using front-end loaders, with hand digging in areas where heavy equipment could not be used The soil removed was loaded into 2-ft X 4-ft X 7-ft plastic-lined plywood boxes for shipment off site Background radioactivity was approximately 250 counts per minute, as measured by a field instrument for the detection of low energy radiation (FIDLER) which is sensitive to the 17 keV plutonium photon emission Soil which had a FIDLER reading at, or in excess of 2,000 counts per minute, was removed to the background level of approximately 250 counts per minute Four to eight inches of soil were removed

All soil was premoistened prior to removal The soil removal operation was monitored for resuspension of contamination by a minimum of two portable ambient air samplers and visual inspection by a representative of Environmental Analysis and Control Wind restrictions were imposed by the OSA, and any wind in excess of 15 mph resulted in shutdown

The soil removal operation resulted in 1,282 plywood boxes of contaminated soil being shipped from the Plant site Based on an average soil concentration of 1,200 d/m/g and a density of 1 g/cm^3, the amount of plutonium removed from the lip area was calculated to represent approximately 0 5 curies [13]

Upon completion of the project, top soil was spread over the excavated area and the area was seeded

External Gamma Radiation Dose Monitoring

Thermoluminescent dosimeters (TLD's) are used to measure external penetrating gamma radiation exposure at 45 locations on and off the Plant site The gamma radiation exposure is due to cosmic rays, natural gamma-ray emitters in the earth's crust, and surface deposition of fission products from worldwide fallout

Individual measurements are made over a period of three months. The dosimeters (TLD's) are placed at 17 locations within the property enclosed by the security fence shown in Figure 2 Measurements are also made at 16 perimeter locations at 3 to 6 kilometers (2 to 4 miles) from the Plant and in 12 communities located within about 32 kilometers (20 miles) of the Plant The TLD's are placed at a height of 1 8 to 2 4 meters (6 to 8 feet) above ground level

Each TLD consists of a sealed glass bulb enclosing two extruded ribbons of CaF_2 Mn (TLD-400) that sandwich a central metal heater strip The TLD's are encased in an energy compensating shield to reduce over-response to photons with energies less than about 100 keV The use of TLD's for assessing external penetrating radiation in the environment has been evaluated under field and laboratory conditions and has been found to be a sensitive and reliable tool for environmental measurement of gamma radiation exposure [14]

The 1978 environmental measurements made using TLD's are shown in Table 17 The average annual dose equivalents as measured on site, in the environs, and in the communities were 131 ±37, 124 ±30, and 131 ±30 millirems respectively These dose values, which are not significantly different, represent an unavoidable dose from natural radiation sources

ASSESSMENT OF POTENTIAL PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

The Rocky Flats Plant strives to minimize the concentrations of all radioactive effluents being discharged to the environment. Removal and disposal of known radioactively contaminated soil, application of dust palliatives for the suppression of fugitive dust emissions, and administrative control of all waterborne effluent discharges are methods being employed in this effort

Plutonium in the Rocky Flats environs is the combined result of fallout deposition from past atmospheric weapons testing and past releases from the Plant. Uranium, a naturally occurring radionuclide, is indigenous to many parts of the state and is used in Plant operations in various isotopic ratios. Tritium, a radionuclide formed by natural atmospheric processes, also is associated with Plant operations and fallout

Potential radiation doses to the public, which could have resulted from Plant effluents, were calculated

using environmental measurements made at the DOE property boundaries and in surrounding communities Inhalation and water consumption were found to be the principal pathways of exposure Swimming and consumption of foodstuffs and fish were found to be insignificant This results from limited swimming and fishing in the area and the fact that most food consumed locally is produced at considerable distances from the Plant

Dose assessment for 1978 Plant operations was conducted for the Plant boundary, the nearby communities, and to a distance of 80 kilometers (50 miles) Dose conversion factors used for the 1978 dose calculations are shown in Table 18 and were generated by computer codes that are described in detailed reports [15-17]

These conversion factors together with radionuclide concentrations were utilized to calculate the 70-year dose commitment that could have resulted from site operations at the Rocky Flats Plant during 1978 Concentrations of plutonium in ambient air that could be inhaled and possible ingestion of plutonium, americium, uranium, and tritium from water were considered Chronic inhalation and ingestion intake rates of $2\ 66 \times 10^{-4}$ cubic meters per second and 1 65 liters per day respectively are derived from data for reference man [18]

Inhalation Source Terms

During 1978, the concentration of plutonium measured in ambient air at Plant perimeter locations and in the surrounding communities averaged $<0\ 06 \times 10^{-15}$ μCi/ml Directional comparisons of the perimeter ambient air concentrations revealed no differences between the normally upwind and downwind locations Similarly, among the communities, none could be identified as having an ambient air concentration that was significantly different from other communities The source term contribution from Rocky Flats is lower than the measured air concentration at perimeter and community locations would indicate Dose impact calculated from this inhalation is maximum, in that it is assumed that the minimum detectable amount is the Rocky Flats contribution, without correction for background, except for the fallout from specific atmospheric tests

As stated in this report, above-ground atmospheric testing of nuclear weapons conducted by The People's Republic of China on March 14, 1978 and December 20, 1978 resulted in increased plutonium concentrations in ambient air The influence of this testing on the measured plutonium concentrations at perimeter and community locations is shown in Figure 7 In the absence of this influence, the average concentrations of plutonium in ambient air, attributable to the combined contributions from Rocky Flats and the resuspended plutonium deposited from pre-1978 atmospheric testing, is less than $0\ 02 \times 10^{-15}$ μCi/ml at perimeter locations and at community locations Therefore, this concentration of $0\ 02 \times 10^{-15}$ μCi/ml is the maximum concentration that could reasonably be assumed to be attributed to Rocky Flats Plant operations From these data, the Plant site boundary maximum source term for airborne plutonium that could be inhaled and then contribute to radiation dose is the concentration as measured at Air Sampler S-36 That sampler is in the immediate vicinity of Walnut Creek at the Plant's east boundary Uncorrected for fallout, this concentration during 1978 was $0\ 07 \times 10^{-15}$ μCi/ml

In the communities, after being corrected for 1978 fallout, the maximum concentration that could be related to Rocky Flats is less than $0\ 02 \times 10^{-15}$ μCi/ml This is an overestimate as some fallout from nuclear testing in past years is included In addition, this value represents our lower level of detection Radiation exposure in the surrounding communities was assumed to be constant to a distance of 80 kilometers (50 miles) These inhalation source terms are summarized in Table 19

Ingestion Source Terms

Walnut Creek flows off site and provides the possible source term for waterborne radionuclides at the Plant perimeter During 1978, the plutonium concentration in Walnut Creek averaged less than $0\ 2 \times 10^{-9}$ μCi/ml This concentration included some contribution from fallout, and several analytical results showed the concentration to be below the minimum detectable amount, that is, the samples did not have measurable plutonium This concentration is the maximum value that

might be attributed to the Rocky Flats Plant Americium at this location averaged less than 0.1×10^{-9} μCi/ml This concentration contained some fallout contribution and is the maximum concentration considered

The primary raw-water supply for Rocky Flats is Ralston Reservoir As described earlier, measurements of uranium concentrations in the Plant's treated water influent show an average concentration of 6 2 pCi/l, which is essentially the same as the concentration measured in the Plant's wastewater effluent (5 8 pCi/l)

The tritium concentration in Walnut Creek averaged less than 900×10^{-9} μCi/ml Tritium concentrations in the treated Plant influent averaged 700×10^{-9} μCi/ml, a concentration found to be typical of regional waters Therefore, the difference of 200×10^{-9} μCi/ml could be considered to be the maximum probable concentration of Plant origin

In the community treated water, the average plutonium and americium concentrations were generally undetectable at concentrations of less than 0.1×10^{-9} μCi/ml Measurements made on 18 treated community water tap samples from three communities, at a detection level of less than 0 02 μCi/ml, provided only two positive results Current measurement techniques for plutonium and americium are not sufficiently sensitive to positively identify any contribution beyond that of fallout. For uranium, all average concentrations were in the range expected from natural sources Tritium is not routinely monitored in treated water The concentration in Great Western Reservoir and Standley Lake were measured, however, and averaged less than 700×10^{-9} μCi/ml, which is within the range attributable to natural sources

A maximum possible dose from drinking water in any community will therefore be from the minimum detectable concentration for plutonium and americium of $<0.02 \times 10^{-9}$ μCi/ml. Tritium and uranium are considered to be at background with no measurable contributions from Rocky Flats. This resultant dose will represent an upper limit or maximum that might be experienced by any segment of the metropolitan population irrespective of the contributions from Rocky Flats. Also, the dose from drinking water at distances to 80 kilometers (50 miles) will be assumed to be the same as that for the community locations These waterborne source terms concentrations are summarized in Table 19

Maximum Site Boundary Dose

The maximum dose to an individual continuously present at the site boundary is based on the nuclide concentrations shown in Table 20, which were determined at the Walnut Creek-at-Indiana Street perimeter location Using these concentrations plus conversion factors, a 70-year dose commitment of 0 05 millirem is calculated for the total body during 1978, with a corresponding bone dose of 3 70 millirem This dose commitment at the site boundary represents the exposure from all sources whether natural or man-made

When the influences of fallout and natural background are considered, this maximum probable 70-year dose commitment is reduced to 0 02 millirem to the total body and 2.31 millirem to the bone This dose commitment is an upper limit because of the large number of sample concentrations below minimum detectable concentrations for the types of analyses performed. By comparison, annual doses to the total body and bone, from natural radiation background in the Denver area, are 150 and 168 millirem per year, respectively [1] (See Table 20)

The 70-year dose commitments of 0.02 millirem total body and 2 31 millirem to the bone represents a maximum probable estimate of the radiation dose from exposure at the site perimeter that could have resulted from site operations during 1978 These 70-year doses represent 0 004% and 0 15% of DOE's radiation protection standards of 500 millirem annually for total body and 1,500 millirem each year for mineral bone [2]

Maximum Community Dose

Because of the similarity of radionuclide concentrations in all communities' air and water, the community receiving the maximum dose could

not be identified Therefore, the dose described applies to any of several unspecified community locations Based on the maximum probable nuclide concentrations in the surrounding communities (Table 19), a 70-year dose commitment of <0 003 millirem to the total body and <0 83 millirem to the bone was determined These values represent <0 002% and <0 17%, respectively, of the 170 millirem annual total body dose standard, and 500 millirem annual dose standard for mineral bone [2] These values also may be compared to an average dose reported in the Denver area of 150 and 168 millirem per year to the total body and bone, respectively, from natural radiation background (See Table 20)

Eighty-Kilometer Total Body Dose

The estimated total-body, 70-year dose commitment is based on nuclide concentrations for several surrounding communities and from the 1978 demographic estimates shown in Figure 13 The population residing within 80 kilometers of the Rocky Flats Plant is estimated to be 1,911,000 persons It is assumed that this population received the same 70-year total body dose as described for the community locations (<0 003 millirem) On this basis, the 80-kilometer total body dose is estimated to be <5 7 man-rem This dose represents <0 002% of the DOE general population exposure standard of 170 millirem per year for the population The corresponding dose from natural radiation background of 150 millirem per year is 287,000 man-rem

Table 21 provides a summary of the 70-year dose commitments to total body, liver, bone, and lung, which could have resulted from site operations during 1978

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TABLES
1 through 21

TABLE 1 Temperature, Precipitation, and Wind Data

	24-Year Period (1953-1976)		
	Average	Record High	Record Low
Annual Mean Temperature*			
°C	9 8	11 4	7 4
(°F)	(49 6)	(52.5)	(45 4)
Annual Maximum Temperature*			
°C	35 1	38 9	32 0
(°F)	(95 1)	(102 0)	(89 6)
Annual Minimum Temperature*			
°C	−22 1	−17 2	−32 3
(°F)	(−7.8)	(1 0)	(−26 0)
Annual Precipitation			
cm	38 7	63 2	19 7
(in)	(15.2)	(24 9)	(7 8)
Annual Mean Wind Speed*			
m/sec	3 68	4.20	3 08
(mph)	(8.24)	(9 40)	(6 90)
Annual Peak Gust*			
m/sec	41 3	47 0	33 0
(mph)	(92 4)	(106 0)	(74 0)

*Six meters (20 feet) above ground

TABLE 2 Radioactivity and Nonradioactivity Detection Limits and Applicable Standards

Legend

μCi = microcuries	g = grams
μg = micrograms	RF = Rocky Flats
m^3 = cubic meters	40 CFR 61 = Code of Federal Regulations, National Emission Standards for Hazardous Air Pollutants (USEPA)
ml = milliliters	
pCi = picocuries	ERDAMC = ERDA Manual Chapter (DOE adopted)
mg/l = milligrams per liter	NPDES = National Pollutant Discharge Elimination System
SU = standard units	

Parameter	Approximate Detection Limit (per sample)	Approximate Sample Volume Analyzed[a]	Approximate Minimum Detectable Concentration	Applicable Guides and Standards	Reference
Stack Samples					
Plutonium-239, -240	1.0×10^{-7} μCi	3,200 m^3[b]	0.03×10^{-15} μCi/ml	Not Applicable	Not Applicable
Uranium-233, 234, -238	2.0×10^{-7} μCi	3,200 m^3[b]	0.06×10^{-15} μCi/ml	Not Applicable	Not Applicable
Tritium	2.5×10^{-6} μCi	0.2 m^3	$10{,}000 \times 10^{-15}$ μCi/ml	Not Applicable	Not Applicable
Beryllium	1.0×10^{-3} μg	128 m^3[b]	8×10^{-6} $\mu g/m^3$	<10.0 g/day	40 CFR 61.32(a)
Ambient Air Samples					
Plutonium-239, 240	1.0×10^{-7} μCi	10,000 m^3[c]	0.01×10^{-15} μCi/ml	<20.0 $\times 10^{-15}$ μCi/ml	ERDAMC 0524
Effluent Water Samples, Radioactive					
Plutonium-239, -240	1.0×10^{-7} μCi	1,000 ml	0.1×10^{-9} μCi/ml[e]	<1,667.0 $\times 10^{-9}$ μCi/ml	ERDAMC 0524
Uranium-233, 234, 238	2.0×10^{-7} μCi	1,000 ml	0.2×10^{-9} μCi/ml	<10,000.0 $\times 10^{-9}$ μCi/ml	ERDAMC 0524
Americium-241	1.0×10^{-7} μCi	1,000 ml	0.1×10^{-9} μCi/ml[e]	<1,330.0 $\times 10^{-9}$ μCi/ml	ERDAMC 0524
Tritium	2.5×10^{-6} μCi	5 ml	0.5×10^{-6} μCi/ml	<1,000.0 $\times 10^{-6}$ μCi/ml	ERDAMC 0524
Soil Samples, Radioactive					
Plutonium-239, -240	1.0×10^{-1} pCi	10 g	0.01 pCi/g	Not Applicable	Not Applicable
Effluent Water Samples, Nonradioactive				Discharge Limitations: Monthly Average / Daily Maximum	
pH		Not Applicable	0-14	6.0-9.0 SU	NPDES Permit
Total Nitrogen		10 ml	0.2 mg/l	20 mg/l (30-day average)	NPDES Permit
Nitrate as N		10 ml	0.3 mg/l	10 mg/l / 20 mg/l	NPDES Permit
Total Phosphorus		50 ml	0.2 mg/l	8 mg/l / Not Applicable	NPDES Permit
Fluoride		20 ml	0.2 mg/l	Not Applicable / 1.7 mg/l	NPDES Permit
Biochemical Oxygen Demand, 5-Day		10 ml	1.0 mg/l	10 mg/l / 25 mg/l	NPDES Permit
Dissolved Oxygen		300 ml	1.0 mg/l	>4 mg/l (minimum) / >2 mg/l	NPDES Permit
Suspended Solids		100 ml	2.0 mg/l	15 mg/l / 25 mg/l	NPDES Permit
Total Chromium		5 ml	0.05 mg/l	0.05 mg/l / 0.1 mg/l	NPDES Permit
Residual Chlorine[d]		10 ml	<0.1 mg/l	Not Applicable / 0.1 mg/l	NPDES Permit
Oil and Grease		500 ml	0.1 mg/l	Not Applicable / 10 mg/l	NPDES Permit
Fecal Coliform Count		10-100 ml	1 organism/100 ml	400 organisms/100 ml (7 day) / 200 organisms/100 ml (30 day)	NPDES Permit

a Volume analyzed is usually an aliquoted fraction of the total sample volume collected
b Monthly composite
c. Two-week composite
d Monitored at Pond B-4
e A lower MDC is reported at selected locations as listed in Table 15

TABLE 3 Health and Environmental Laboratory Measurement Control Data
(March-August 1978)

Isotopes Reported	Matrix	Method	Average Standard Value	Normal Sample Range	Relative Error (%)[a]	Bias (%)[b]	Total Control Analyses
Pu-239 240	Gelman E Filter	Pulse Height Analysis	12 4 d/m/filter	0-20 d/m/filter	16 3	3 9	75
U-233, 234 238	Gelman E Filter	Pulse Height Analysis	21 0 d/m/filter	0-40 d/m/filter	14 1	0 1	25
Pu-239 240	Surface Water	Pulse Height Analysis	5 9 d/m/l	0-20 d/m/l	54 7	29 7	30
U 233, 234, 238	Surface Water	Pulse Height Analysis	11 0 d/m/l	0-40 d/m/l	19 1	8 6	30
H-3	Surface Water	Liquid Scintillation	2.23 x 10^4 pCi/l	0-1 x 10^4 pCi/l	7 03	−4 0	30
Pu-239, -240	Whatman Filter	Pulse Height Analysis	13 9 d/m/filter	0-20 d/m/filter	8 7	5.0	24

a The ratio of the standard deviation of the six-month differences to the average standard value in percent, i e , observed value minus standard value divided by average standard value times 100 equals the ratio as expressed in percent The relative error for control measurements is often called the coefficient of variation where the dispersion of data (in this case, the average differences between measured and standard values) is divided by the average standard value submitted This term is inclusive of all random and systematic error in the standards, analytical chemistry, and measurement processes for a given nuclide, matrix, and procedure

b The six-month average bias in percent A minus sign indicates a negative bias, i e , the values were low No sign indicates a positive bias

TABLE 4 Rocky Flats Health and Environmental Laboratory Cross Check Program

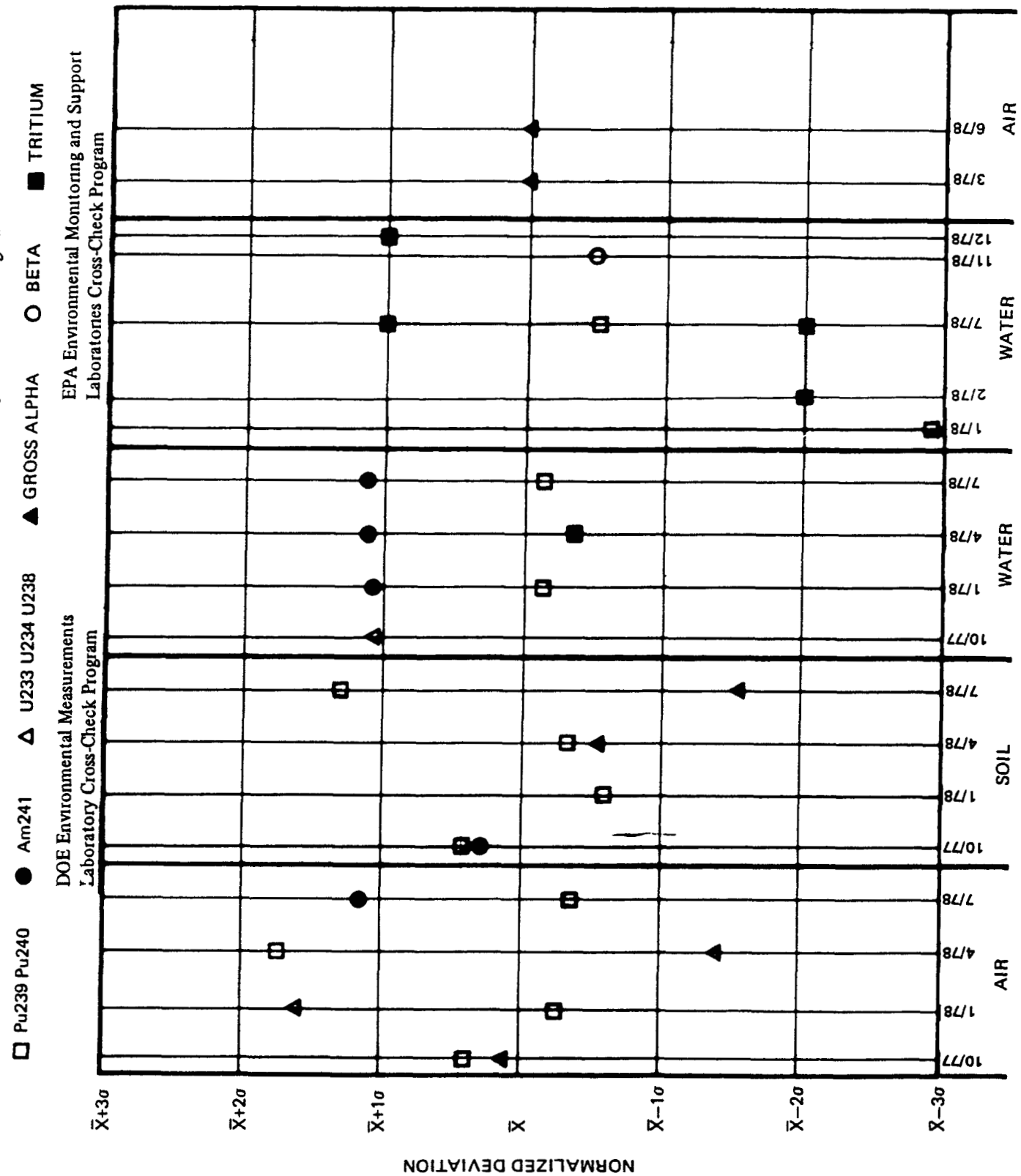


TABLE 5 Airborne Effluent Releases to the Atmosphere

Sample Period	Plutonium[a]			Uranium[b]			Tritium			Beryllium[c]		
	Number of Analyses	C_{max}[d]	μCi	Number of Analyses	C_{max}[d]	μCi	Number of Analyses	C_{max}[d]	Ci	Number of Analyses	C_{max}[d]	g
January	125	2 60	0 26	144	32 90	<3 32	168	3130	<0 032	155	1 90	<0 167
February	28	1 36	<0 10	38	47.59	2 25	160	3850	<0 036	38	522 84[e]	<15.575
March	27	1 09	0 10	36	6 93	2 23	143	2740	<0 065	36	1 99	<0 468
April	27	1 50	0 23	37	34 19	2 78	161	2680	<0 112	37	1 87	<0 207
May	27	0 97	<0 13	36	15 96	3 61	158	1350	<0 070	36	1.28	<0 173
June	29	1 04	0 23	42	73 20	4 38	195	1250	<0 093	42	0 44	<0 116
July	31	4.54	<0 20	45	66 60	5 06	200	2150	<0 147	45	1 41	<0 236
August	29	1 43	0 19	51	46 63	7 71	200	1820	<0 126	51	1 06	<0 072
September	31	1 19	0 18	43	151 17	<6 40	201	800	<0 075	43	2 45	<0 187
October	31	246 43[e]	<0.56	45	156 00	5 14	199	380	<0 063	45	3 49	<0 065
November	28	8 76	0 37	44	131 70	<7.26	213	750	<0 075	44	5 95	<0 127
December	28	3.53	0 21	38	45.95	2.93	153	490	<0 047	38	1 30	<0 180
Summary	441	246 43[e]	<2 76	599	156 00	<53 07	2151	3850	<0 941	610	522 84[e]	<17.573

a Radiochemically determined as plutonium-239, -240

b Radiochemically determined as uranium-233, -234, and -238

c The beryllium emission standard for stationary sources is 10 grams over a 24-hour period under the provisions in subpart C of 40 CFR 61.32(a)

d C_{max} are the single-sample maximum concentrations for the species shown
C_{max} for plutonium and uranium have units of femtocuries per cubic meter
C_{max} for tritium has units of picocuries per cubic meter
C_{max} for beryllium has units of nanograms per cubic meter

e The plutonium C_{max} for October is based on a 6.5-hour sample collection time, the beryllium C_{max} for February is based on a 30 75-hour sample collection time versus a routine 720-hour sampling period

TABLE 6 Plutonium-239 and -240 Radioactivity in On-Site Ambient Air at Selected Locations[a]

Station	Number of Analyses	Volume (X 1,000 m^3)	Concentration[b] (X 10^{-15} μCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_a[c]
S-2	21	340	0 01	0 17	0 05	0 09
S-5	27	495	0 02	0 33	0 14	0 23
S-6	27	516	0 03	1 98	0 26	0 44
S 7	27	516	0 07	1 02	0.28	0 46
S-8	26	479	0 13	3.52	0 69	1 15
S-9	27	466	0 07	2 13	0.86	1 43
S-15	21	290	0 01	0.29	0 08	0 13
S-16	21	347	0 01	0.68	0 10	0 17
S-19	27	513	0 02	0 49	0 13	0 22
S-20	27	456	0 02	0.25	0 09	0 15
S-21	27	480	0 01	0.26	0 08	0 13
Summary	278	4,898	0 01	3.52	–	–

a. These selected air-sampling locations are in the proximity of areas where there is a potential for airborne activity No less than detectable concentrations were measured

b Two-week composites of station concentrations

c The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air in uncontrolled areas is 60 X 10^{-15} μCi/ml

TABLE 7 Plutonium-239 and -240 Radioactivity in Perimeter Ambient Air
[3 to 6 kilometers (2 to 4 miles) from Rocky Flats]

Station	Number of Analyses	Less Than Detectable	Volume (X 1,000 m^3)	Concentration (X 10^{-15} µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_a*
S-31	17	0	411	0 01	0 19	0 07	0 35
S-32	16	1	501	<0 01	0.24	<0 06	<0 30
S-33	17	1	477	<0 01	0 24	<0 06	<0 30
S-34	17	1	479	<0 01	0 27	<0 07	<0 35
S-35	17	1	513	<0 01	0 22	<0 06	<0 30
S-36	17	0	478	0 01	0 34	0 07	0 35
S-37	17	0	530	0 01	0.21	0 06	0 30
S-38	17	0	509	0 01	0 19	0 05	0 25
S-39	16	0	433	0 01	0.28	0 07	0.35
S-40	17	1	461	<0 01	0.39	<0 07	<0 35
S-41	17	1	449	<0 01	0 40	<0 07	<0 35
S-42	17	0	435	0.02	0.22	0 06	0 30
S-43	17	1	442	<0.01	0 33	<0 06	<0 30
S-44	17	1	464	<0 01	0 34	<0 06	<0 30
Summary	236	8	6,582	<0 01	0 40		
Average Concentration						<0 06	<0 30

*The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air available to the general population is 20 X 10^{-15} µCi/ml

TABLE 8 Plutonium-239 and -240 Radioactivity in Community Ambient Air

Location	Number of Analyses	Less Than Detectable	Volume (X 1,000 m^3)	Concentration (X 10^{-15} µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_a*
Boulder	17	0	490	0 01	0 33	0 07	0 35
Broomfield	17	1	467	<0 01	0 24	<0 06	<0 30
Denver	15	0	356	0 01	0 15	0 05	0 25
Golden	17	0	462	0 01	0 16	0 05	0 25
Jeffco Airport	17	0	456	0 01	0 39	0 07	0 35
Lafayette	17	0	475	0 02	0 31	0 07	0.35
Leyden	17	0	482	0 01	0 18	0 06	0 30
Marshall	17	0	459	0 01	0 30	0 07	0 35
Superior	17	0	437	0 01	0 20	0 07	0 35
Wagner	17	1	496	<0 01	0 24	<0 06	<0 30
Walnut Creek	17	0	491	0 02	0 43	0 07	0 35
Westminster	16	0	420	0 01	0 11	0 04	0 20
Summary	201	2	5,491	<0 01	0 43		
Average Concentration						<0 06	<0 30

*The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air available to the general population is 20 X 10^{-15} µCi/ml

TABLE 9 Chemical and Biological Constituents of Liquid Effluents

Parameter	Annual Average Concentration	Average Quantity	Limitations (daily maximum)	Agency[a]	Percent of Limitations
Discharge Point 001 [b]					
pH	7 1 s u	NA[c]	6 0-9 0 s u	USEPA/CDH	In Range
Fecal Coliform Count	0 1/100 ml	NA	200/100 ml[d]	USEPA/CDH	In Range
Dissolved Oxygen	6 8 mg/l	NA	>4 mg/l	USEPA/CDH	In Range
Residual Chlorine	<0 1 mg/l	NA	0 1 mg/l	USEPA/CDH	In Range
Suspended Solids	<5 1 mg/l	<2 9 kg/day	25 mg/l	USEPA/CDH	20
Biochemical Oxygen Demand 5 day	<7 1 mg/l	<4 5 kg/day	25 mg/l	USEPA/CDH	28
Total Phosphorus	2 0 mg/l	NA	8 mg/l[d]	USEPA/CDH	25
Nitrate as N	<6 2 mg/l	NA	NA	NA	NA
Total Nitrogen	<12 9 mg/l	<7 1 kg/day	20 mg/l[d]	USEPA/CDH	64
Fluoride	<0 4 mg/l	NA	1 7 mg/l	USEPA/CDH	24
Total Chromium	<0 05 mg/l	NA	0 05 mg/l	USEPA/CDH	In Range
Oil and Grease	<0 5 mg/l	NA	10 mg/l	USEPA/CDH	5
Turbidity	3 8 NTU[e]	NA	30 NTU	CDH	In Range
Color	28 2 units	NA	30 units	CDH	In Range
Discharge Point 002					
pH	7 8 s.u	NA	6 0-9 0 s u	USEPA/CDH	In Range
Nitrate as N	<6 0 mg/l	NA	10 mg/l[d]	USEPA/CDH	60
Discharge Point 003					
Nitrate as N	<0 2 mg/l	NA	NA	USEPA/CDH	NA
Total Dissolved Solids	205 mg/l	NA	NA	USEPA/CDH	NA
pH	8 1 s u	NA	NA	USEPA/CDH	NA
Chemical Oxygen Demand	16 3 mg/l	NA	NA	USEPA/CDH	NA

a. USEPA - U S Environmental Protection Agency, Washington, D C (Region Office VIII, Denver, Colorado)
CDH - Colorado Department of Health, Water Quality Control Commission, Denver, Colorado
b The USEPA-NPDES discharge permit defines Discharge Points 001, 002, and 003 as the sewage treatment plant, Pond A-3, and Pond C-1, respectively
c. NA - Not applicable
d. Monthly average limitations
e NTU - Nepholometer turbidity unit

TABLE 10 Plutonium, Uranium, and Americium Radioactivity in Rocky Flats Ponds

Location	Number of Analyses	Plutonium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[a]	Number of Analyses	Uranium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[b]
Pond A-3	35	<0 1	0 7	<0 2	<0 01	35	2 0	29 2	6 7	0 07
Pond B-4	52	<0 1	2 4	<0 6	<0 04	52	0 6	17 9	5 8	0 06
Pond C-1	52	<0 1	0 5	<0 1	<0 01	52	<0 2	7 9	2 5	0 02

Location	Number of Analyses	Americium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[c]
Pond A-3	35	<0 1	0 4	<0 1	<0 01
Pond B-4	52	<0 1	0.5	<0 2	<0 02
Pond C-1	52	<0 1	0 2	<0 1	<0 01

a. Radiochemically determined as plutonium-239, -240 The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is $1,667 \times 10^{-9}$ µCi/ml.
b Radiochemically determined as uranium-233, -234, and -238 The most restrictive RCG_w for these soluble uranium isotopes is $10,000 \times 10^{-9}$ µCi/ml.
c. The RCG_w for soluble americium-241 is $1,330 \times 10^{-9}$ µCi/ml.

TABLE 11 Tritium Radioactivity in Water Samples

Location	Number of Analyses	Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[a]
Pond A-3	35	<500	1700	<900	<0 09
Pond B-4	52	<500	1400	<800	<0 08
Pond C-1	52	<500	1000	<700	<0 07
Walnut Creek at Indiana Street	52	<500	1400	<900	<0 09
Great Western Reservoir[b]	44	<500	1500	<700[c]	<0 07
Standley Lake[b]	53	<500	1300	<700[c]	<0 07

a. The Radioactivity Concentration Guide (RCG_w) for tritium in water released to uncontrolled areas is $1,000,000 \times 10^{-9}$ µCi/ml.
b The State of Colorado Primary Drinking Water Regulation limit for tritium is 20,000 pCi/l ($20,000 \times 10^{-9}$ µCi/ml)
c These tritium concentrations are less than 3 5% of the drinking water regulation

TABLE 12 Plutonium, Uranium, and Americium Radioactivity in Walnut Creek

Location	Number of Analyses	Plutonium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[a]	Number of Analyses	Uranium Concentration ($\times 10^{-9}$ µCi/ml)[a] C_{min}	C_{max}	C_{avg}	Percent of RCG_w[b]
Walnut Creek at Indiana Street	52	<0 1	0 7	<0 2	<0 01	52	1 4	17 6	5 8	0 06

Location	Number of Analyses	Americium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[c]
Walnut Creek at Indiana Street	52	<0 1	0 2	<0 1	<0 01

a. Radiochemically determined as plutonium-239, -240 The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is $1,667 \times 10^{-9}$ µCi/ml.
b Radiochemically determined as uranium-233, -234, and -238 The most restrictive RCG_w for these soluble uranium isotopes is $10,000 \times 10^{-9}$ µCi/ml.
c The RCG_w for soluble americium-241 in water is $1,330 \times 10^{-9}$ µCi/ml.

TABLE 13 Uranium Radioactivity in the Rocky Flats Raw and Treated Water Supply

Location	Number of Samples	Concentration ($\times 10^{-9}$ µCi/ml)[a] C_{min}	C_{max}	C_{avg}
Raw Water	39	0 6	61 8	6 8
Treated Water	38	0 1	61 7	6 2

NOTE Results are for weekly samples collected from March through December 1978

a Concentrations are for uranium-233, -234, and -238

TABLE 14 Plutonium Uranium, Americium, and Tritium Radioactivity in Hydrologic Test Holes

Location Number	Depth (feet)[d]	Plutonium Concentration[a] ($\times 10^{-9}$ µCi/ml)		Uranium Concentration[b] ($\times 10^{-9}$ µCi/ml)		Americium Concentration[c] ($\times 10^{-9}$ µCi/ml)		Tritium Concentration ($\times 10^{-9}$ µCi/ml)	
		March	July	March	July	March	July	March	July
59-1	20	NA[e]	<0 1	NA	2 3	NA	<0 1	NA	1,200
1-60	23	NA	<0 1	NA	26 9	NA	0 95	NA	1,312
2-60	30	<0 1	<0 1	14 9	11 1	<0 1	<0 1	626	2,285
3-60	30	NA	<0 1	NA	5 8	NA	<0 1	NA	1,409
4-60	30	<0 1	<0 1	26 8	14.8	<0 1	<0 1	15,526	8,812
5-60	30	dry	dry	dry	dry	dry	dry	dry	dry
6-60	30	<0 1	<0 1	3 9	4.2	<0 1	<0 1	3,574	3,755
1-66	148	<0 1	<0 1	1.5	0.5	<0 1	<0 1	701	MDA[f]
2-66	146	<0 1	<0 1	1 3	0 3	<0 1	<0 1	896	1,066
3-66	153	NA	<0 1	NA	2 8	NA	<0 1	NA	1,003
1-68	4	dry	dry	dry	dry	dry	dry	dry	dry
2-68	4	dry	dry	dry	dry	dry	dry	dry	dry
3-68	4	dry	dry	dry	dry	dry	dry	dry	dry
4-68	4	dry	dry	dry	dry	dry	dry	dry	dry
1-71	30	1 14	0 171	2 1	0 9	<0 1	<0 1	MDA	MDA
2-71	30	NA	dry	NA	dry	NA	dry	NA	dry
3-71	25	NA	0.225	NA	1 8	NA	<0 1	NA	MDA
4-71	22	NA	<0 1	NA	1 0	NA	<0 1	NA	MDA
5-71	28	NA	dry	NA	dry	NA	dry	NA	dry
6-71	30	<0 1	<0 1	23.5	2 3	<0 1	<0 1	NA	3,943
1-74	24	dry	<0 1	dry	3.5	dry	<0 1	dry	741
2-74	10	dry	dry	dry	dry	dry	dry	dry	dry
3-74	24	dry	<0 1	dry	2.5	dry	<0 1	dry	MDA
4-74	6	dry	dry	dry	dry	dry	dry	dry	dry
5-74	18	dry	dry	dry	dry	dry	dry	dry	dry
6-74	7	dry	dry	dry	dry	dry	dry	dry	dry
7-74	50	NA	<0 1	NA	31.2	NA	<0 1	NA	MDA
8-74	40	dry	dry	dry	dry	dry	dry	dry	dry
9-74	19	<0 1	<0 1	44 4	20 7	<0 1	<0 1	MDA	952
10-74	10	dry	dry	dry	dry	dry	dry	dry	dry
11-74	20	<0 1	<0 1	2 2	1 3	<0 1	<0 1	MDA	787
12-74	4	dry	dry	dry	dry	dry	dry	dry	dry
13-74	19	<0 1	<0 1	7 7	6 3	<0 1	<0 1	MDA	580
14-74	4	dry	dry	dry	dry	dry	dry	dry	dry
15-74	19	0 135	<0 1	15 0	12.5	<0 1	<0 1	2,796	627
16-74	4	dry	dry	dry	dry	dry	dry	dry	dry
17-74	16	<0 1	<0 1	13 2	17 9	<0 1	0 126	MDA	1,991
18-74	7	NA	dry	NA	dry	NA	dry	NA	dry
21-74	265	<0 1	<0 1	1.5	1 4	0 109	<0 1	MDA	MDA
22-74	315	<0 1	<0 1	3.5	3 3	<0 1	<0 1	MDA	MDA
WS-1	13	dry	<0 1	dry	1 4	dry	<0 1	dry	1,097
WS-2	11	dry	<0 1	dry	4 7	dry	<0 1	dry	861
WS-3	13	NA	<0 1	NA	2 9	NA	<0 1	NA	MDA

a. Radiochemically determined as plutonium-239, -240
b Radiochemically determined as uranium-233, -234, -238
c. Radiochemically determined as americium-241
d Depth is to bottom of well
e. NA - Not Analyzed
f. MDA - Minimum Detectable Activity

TABLE 15 Plutonium, Uranium, and Americium Radioactivity in Public Water Supplies

Reservoirs	Number of Analyses	Plutonium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[a]	Number of Analyses	Uranium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[b]
Great Western	18[d]	<0 1	0 2	<0 1	<0 01	44	0 9	9 6	3 2	0 03
	6[e]	<0 007	<0 020	<0 012	<0 01	–	–	–	–	–
Standley Lake	26[d]	<0 1	<0 1	<0 1	<0 01	53	1 0	32 3	5 2	0 05
	6[e]	<0 007	<0 018	<0 011	<0 01	–	–	–	–	–
Drinking Water										
Arvada	4	<0 1	<0 1	<0 1	<0 01	4	0 7	21 7	6 1	0 06
Boulder	26[d]	<0 1	0 2	<0 1	<0 01	53	<0 2	6 9	<1 1	<0 01
	6[e]	<0 007	<0 020	<0 011	<0 01	–	–	–	–	–
Broomfield	26[d]	<0 1	<0 1	<0 1	<0 01	53	<0 2	6 7	<1 9	<0 02
	6[e]	<0 007	<0 015	<0 010	<0 01	–	–	–	–	–
Denver	4	<0 1	<0 1	<0 1	<0 01	4	1 8	5 6	2 8	0 03
Golden	4	<0 1	<0 1	<0 1	<0 01	4	1 6	8 2	3 9	0 04
Lafayette	4	<0 1	<0 1	<0 1	<0 01	4	0 3	1 7	0 8	0 01
Louisville	4	<0 1	<0 1	<0 1	<0 01	4	<0 2	2 8	1 0	<0 01
Thornton	4	<0 1	<0 1	<0 1	<0 01	4	0 6	6 9	3 1	0 03
Westminster	26[d]	<0 1	0 3	<0 1	<0 01	53	<0 2	10 0	2 7	<0 03
	6[e]	<0 007	0 028	<0 014	<0 01	–	–	–	–	–

Reservoirs	Number of Analyses	Americium Concentration ($\times 10^{-9}$ µCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[c]
Great Western	18[d]	<0 1	0 2	<0 1	<0 01
	6[e]	<0 010	<0 018	<0 013	<0 01
Standley Lake	26[d]	<0 1	0 2	<0 1	<0 01
	6[e]	<0 009	<0 019	<0 013	<0 01
Drinking Water					
Arvada	4	<0 1	<0 1	<0 1	<0 01
Boulder	26[d]	<0 1	0 4	<0 1	<0 01
	6[e]	<0 009	<0 012	<0 011	<0 01
Broomfield	26[d]	<0 1	<0 1	<0 1	<0 01
	6[e]	<0 010	<0 015	<0 012	<0 01
Denver	4	<0 1	<0 1	<0 1	<0 01
Golden	4	<0 1	<0 1	<0 1	<0 01
Lafayette	4	<0 1	<0 1	<0 1	<0 01
Louisville	4	<0 1	<0 1	<0 1	<0 01
Thornton	4	<0 1	<0 1	<0 1	<0 01
Westminster	26[d]	<0 1	0 4	<0 1	<0 01
	6[e]	<0 010	0 030	<0 015	<0 01

a Radiochemically determined as plutonium-239, -240 The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is $1,667 \times 10^{-9}$ µCi/ml

b Radiochemically determined as uranium-233, -234, -238. The most restrictive RCG_w for these soluble uranium isotopes is $10,000 \times 10^{-9}$ µCi/ml

c The RCG_w for soluble americium-241 is $1,330 \times 10^{-9}$ µCi/ml

d These weekly grab samples were collected and analyzed from January through June The minimum detectable activity was 0 1 pCi/l ($0 1 \times 10^{-9}$ µCi/ml)

e. These monthly composite samples were collected and analyzed from July through December The minimum detectable activity for each sample is denoted by a less-than sign (<) preceding the values

TABLE 16 Plutonium, Uranium, and Americium Radioactivity in Regional Waters Greater Than Five Miles From Rocky Flats Plant

Site	Location[a]	Concentration ($\times 10^{-9}$ µCi/ml)			
		Plutonium[b]	Uranium[c]	Americium[d]	Tritium
Coal Creek	5 0, SE	<0 1	1 7	<0 1	600
Nissen Reservoir No 2	8 4, NE	0 1	1 4	<0 1	700
Lower Church Lake	7 1, E	<0 1	3 3	<0 1	900
Louisville Reservoir	8 2, N	<0 1	0 5	<0 1	900
Long Lake	6 4, SW	<0 1	325	<0 1	600
Near Eldorado Springs	6 2, NW	<0 1	0 6	NA[e]	900
Eastlake Reservoir No 3	15 1, E	<0 1	3 6	<0 1	700
Sloans Lake	14 4, SE	<0 1	1 0	<0 1	700
Rocky Mountain Lake	13 3, SE	<0 1	1 8	<0 1	700
Berkeley Lake	12 4, SE	<0 1	5 0	<0 1	600
Denver City Park Lake	19 1, SE	<0 1	3 8	<0 1	600
Baller Lake	35 0, SE	<0 1	2 3	<0 1	600
Clear Creek	11 1, S	<0 1	1 4	<0 1	700
McKay Lake	12 0, NE	<0 1	1 0	<0 1	700
Washington Park, North Lake	20 4, SE	<0 1	3 8	<0 1	900
Stearns Lake	6 9, NE	<0 1	0 8	<0 1	800
Average Concentration		<0 1	25 3	<0 1	700
Minimum Concentration		<0 1	0 5	<0 1	600
Maximum Concentration		<0 1	325	<0 1	900

a. Data represents distance (in miles) and direction from the Rocky Flats Plant
b Radiochemically determined as plutonium-239, -240
c Radiochemically determined as uranium-233, 234, -238
d Radiochemically determined as americium-241
e NA - not analyzed

TABLE 17 Environmental Thermoluminescent Dosimeter Measurements

Location	Number of Measurements	Annual Dose (mrem*)
17 On Site	126	131 ±37
16 Perimeter	123	124 ±30
12 Communities	84	131 ±30

* The error term represents two standard deviations about the mean value

TABLE 18 Dose Conversion Factors for the 70-Year Dose Commitment From One Year of Chronic Intake, Via Air and Water[a]

$$\left[\text{Dose Conversion Factors}\left(\frac{\text{rem}}{\text{curie}}\quad\frac{\text{cubic meters}}{\text{second}}\right)\right]$$

	Air Factor[b]	Water Factor[c]			
Organ	Pu-239, -240	Pu-239, -240	U-233, -234, -238	Am-241	H-3
Total Body	$2\,724 \times 10^{3}$	$8\,66 \times 10^{-3}$	$4\,53 \times 10^{-4}$	$8\,84 \times 10^{-2}$	$7\,33 \times 10^{-6}$
Liver	$3\,165 \times 10^{5}$	1 0	(e)	$1\,03 \times 10^{1}$	(e)
Bone	$7\,919 \times 10^{5}$	2.51	$3\,22 \times 10^{-2}$	2.48×10^{1}	(e)
Lungs	$1\,999 \times 10^{5}$[d]	(e)	(e)	(e)	(e)

a. These factors are taken from the Rocky Flats Plant Environmental Impact Statement (to be published)
b For 0 3 μm AMAD (Activity Median Aerodynamic Diameter), inhalation rate of $2\,66 \times 10^{-4}$ m^3/s for chronic exposure [18]
c. For intake rate of 1 65 liters (1 75 quarts) per day [18]
d Assumed to be Class Y solubility
e The values for the conversion factor are taken to be equal to that for the total body

TABLE 19 Radioactivity Concentrations Used for 1978 Dose Calculations

	Air (μCi/ml)	Water (μCi/ml)			
	Pu-239, -240	Pu-239, 240	Am-241	U-233 234, 238	H 3
Site Boundary[a] (maximum)	0.07×10^{-15}	$<0.2 \times 10^{-9}$	$<0.1 \times 10^{-9}$	5.8×10^{-9}	$<900 \times 10^{-9}$
Site Boundary[b] (maximum probable)	$<0.02 \times 10^{-15}$	$<0.2 \times 10^{-9}$	$<0.1 \times 10^{-9}$	0	$<200 \times 10^{-9}$
Community[b] (maximum probable)	$<0.02 \times 10^{-15}$	$<0.02 \times 10^{-9}$	$<0.02 \times 10^{-9}$	0	0

a. These concentrations include natural radioactivity, radioactivity from fallout, and some radioactivity of Plant origin, they represent maximum conditions

b These concentrations are adjusted to mitigate known concentrations that are not of Rocky Flats origin and represent a reasonable set of values for maximum probable dose calculations

TABLE 20 Denver-Area Dose From Natural Radiation Background[a] (mrem/yr)

Source	Total Body[b]	Liver[b]	Bone	Lungs
Cosmic Radiation	50	50	50	50
Cosmogenic Radionuclides	0 7	0 7	0 8	0 7
External Terrestrial	72	72	57	72
Inhaled Radionuclides		-		100
Radionuclides in the Body	27	27	60	24
Total for One Year	149 7	149 7	167 8	246 7
Total for 70 Years	10480	10480	11750	17270

a The values in this table are a summary of values derived from Reference 1

b The values for the total body and liver are considered to be the same as the values reported for the gonads in Reference 1

TABLE 21 70-Year Dose Commitment (millirem)

	Total Body	Liver	Bone	Lung
Site Boundary (maximum)	<0 05	<1 48	<3 70	0 49
Site Boundary (maximum probable)	<0 02	<0 96	<2 31	<0 14
Community (maximum probable)	<0 003	<0 34	<0 83	<0 13
80 Kilometer[a]	<0 003	<0 34	<0 83	<0 13

a Dose commitment is assumed to be the same as that calculated at community locations No environmental measurements were made to this distance (50 miles) Due to the additional distance, lower dose commitments can be assumed

ILLUSTRATIONS
(Figures 1 through 13)

FIGURE 1 Location of the Rocky Flats Plant and Surrounding Communities

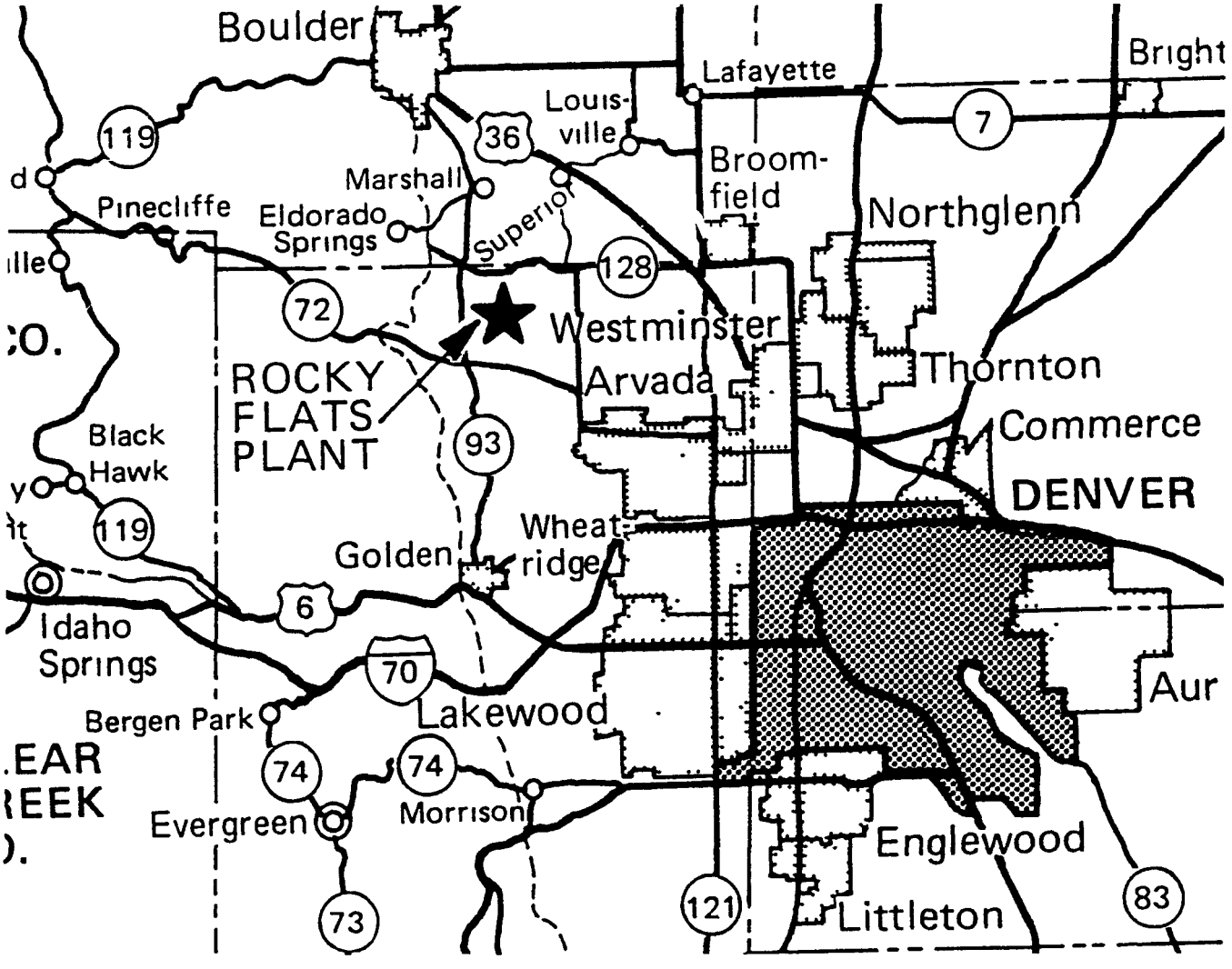


FIGURE 2 Location of the Rocky Flats Plant Boundaries

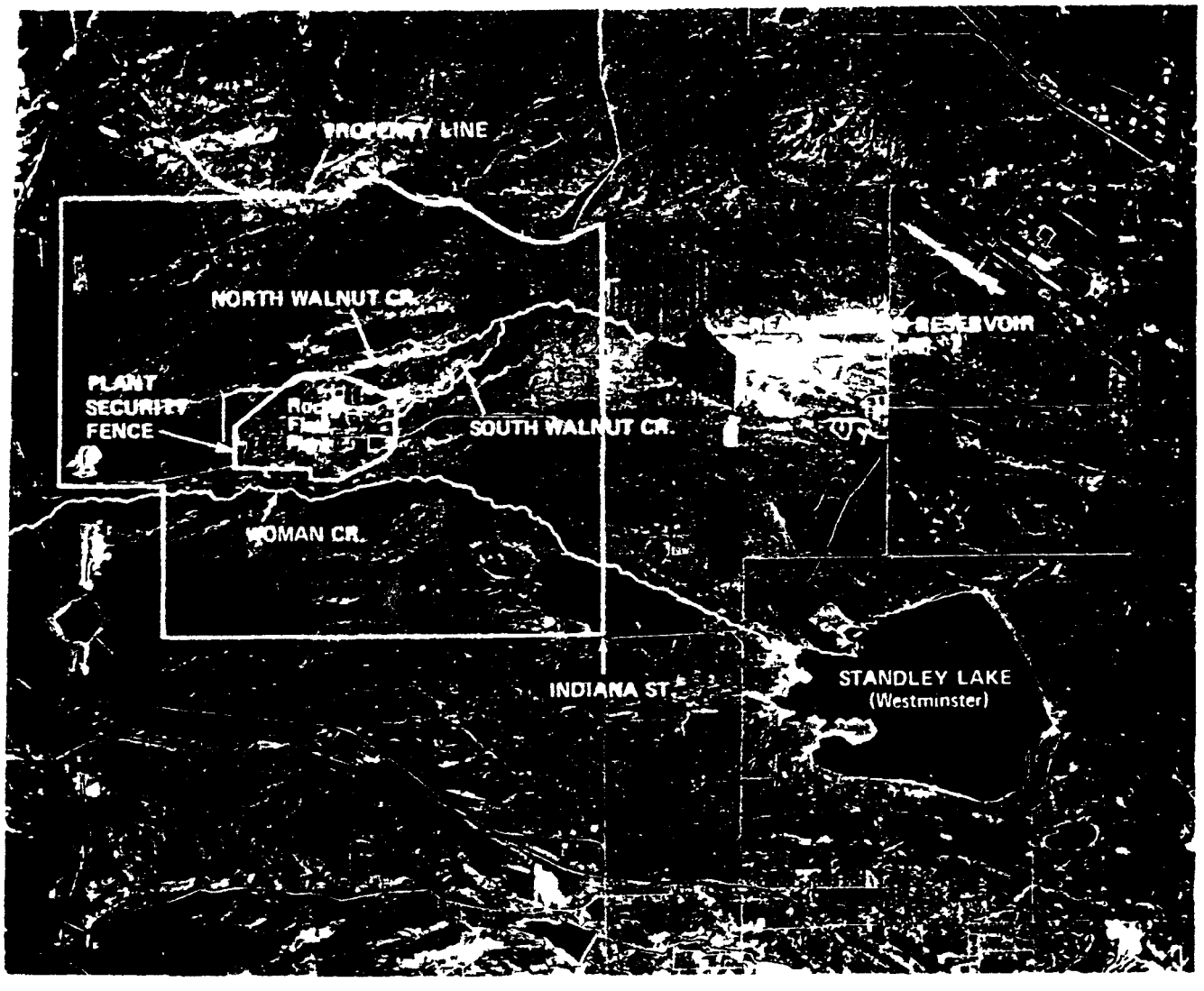


FIGURE 3 Holding Ponds and Liquid Effluent Watercourses

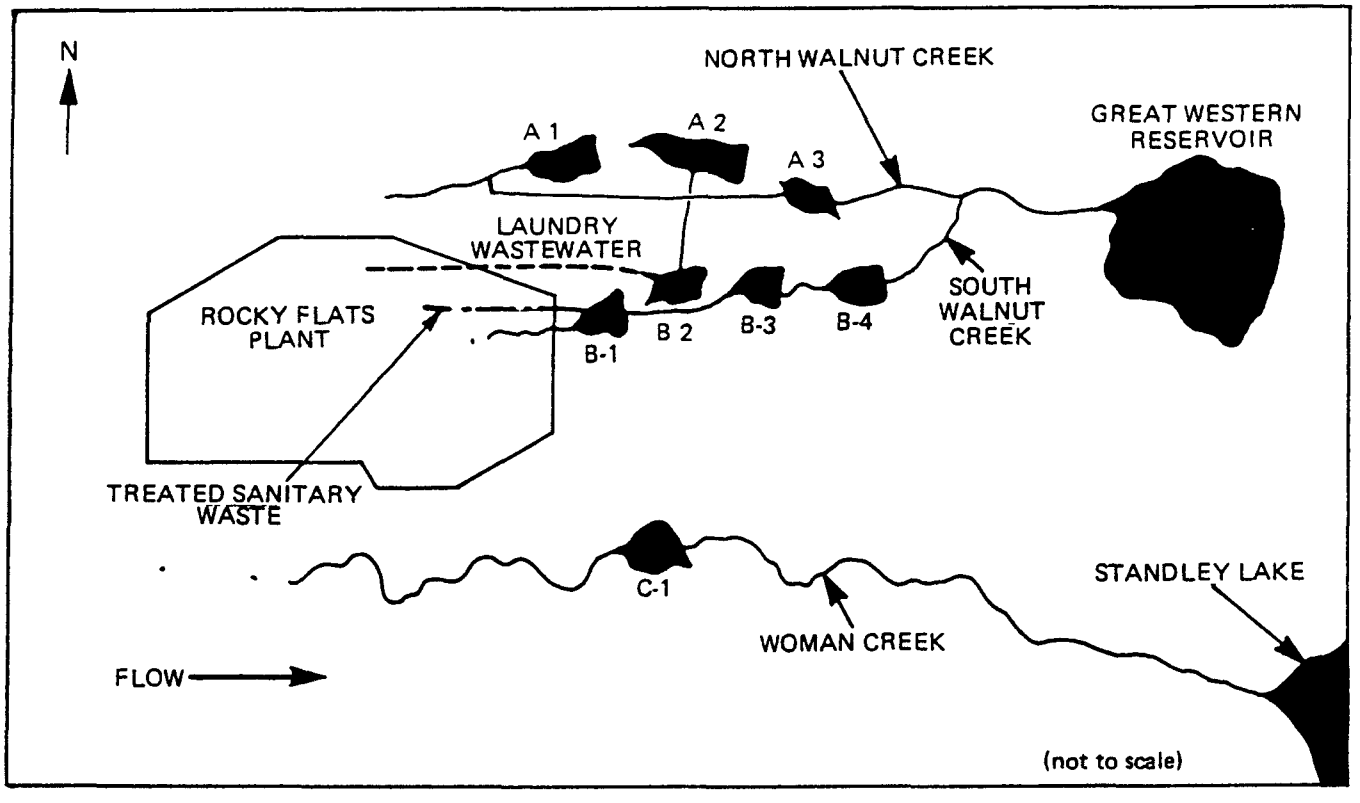


FIGURE 4 Typical Wind Rose for Rocky Flats Plant

NOTE This wind rose is derived from 1975 wind data and typifies wind speed and direction of the past 25 years

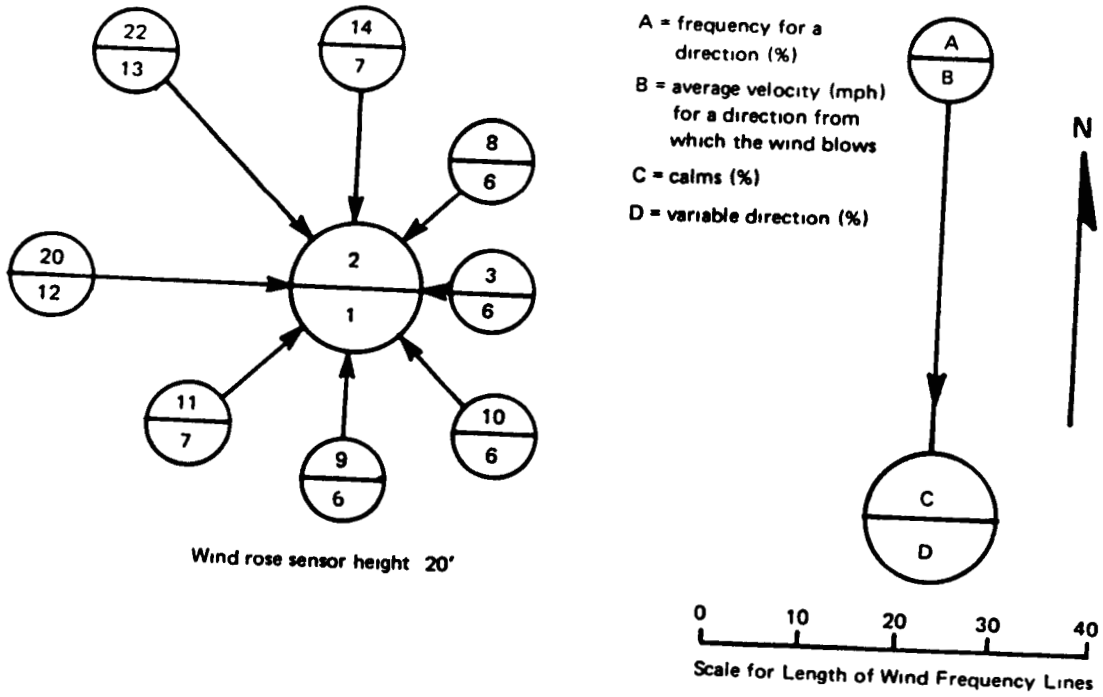


FIGURE 5 Location of On-Site Ambient Air Samplers

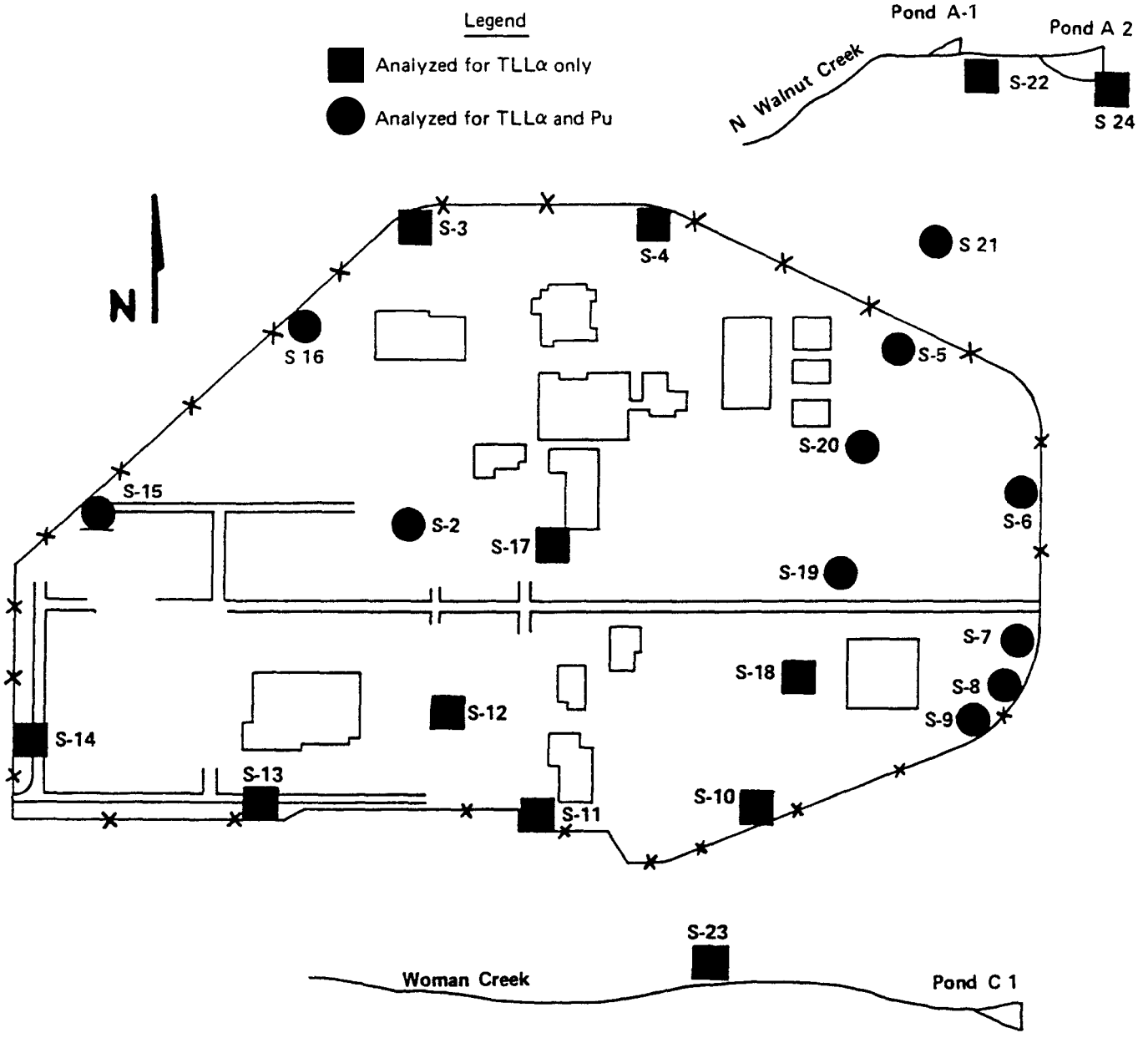


FIGURE 6 Location of Off-Site Ambient Air Samplers

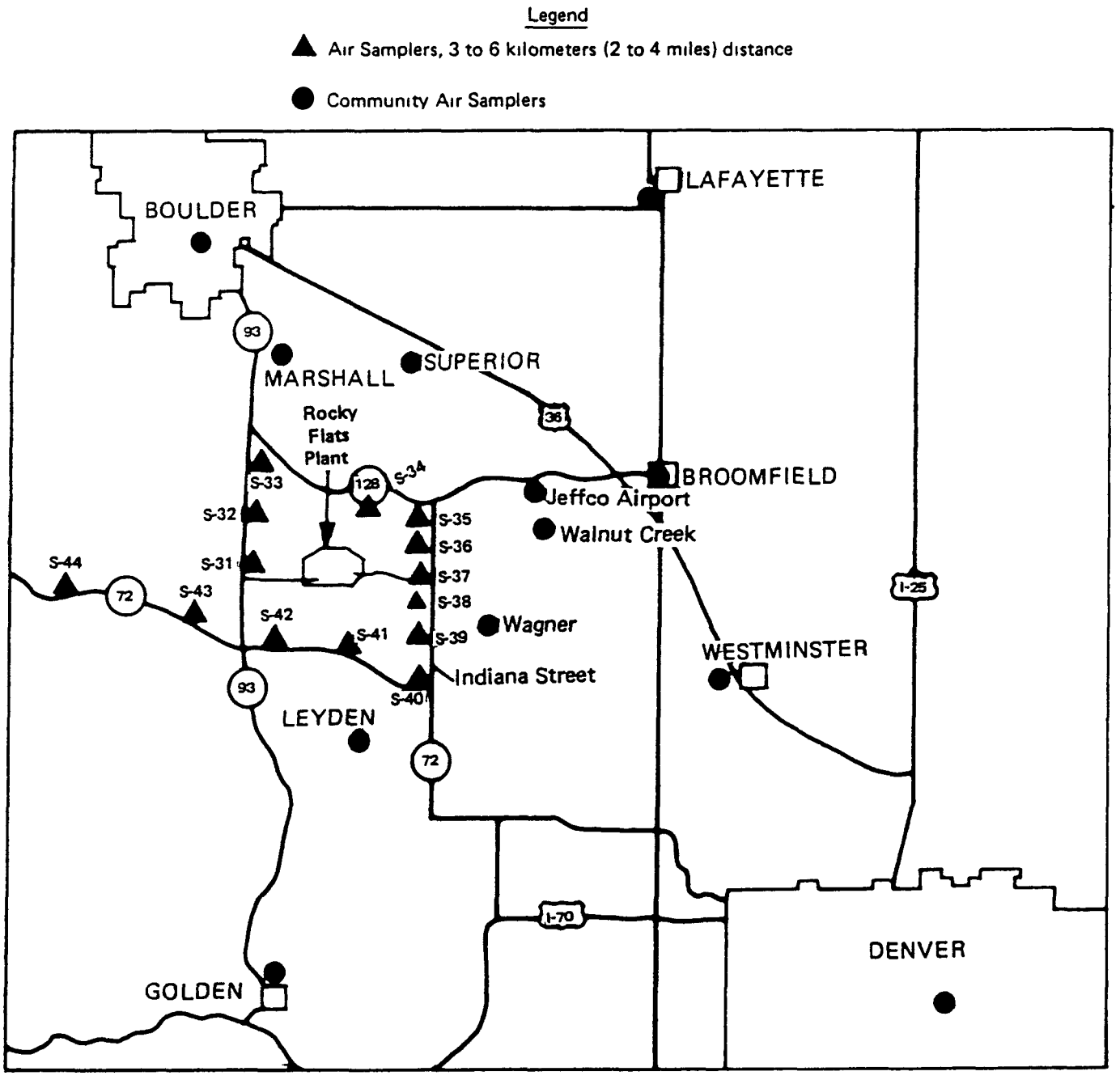


FIGURE 7 Plutonium-239 and -240 Concentration Data at Perimeter and Community Locations During 1978

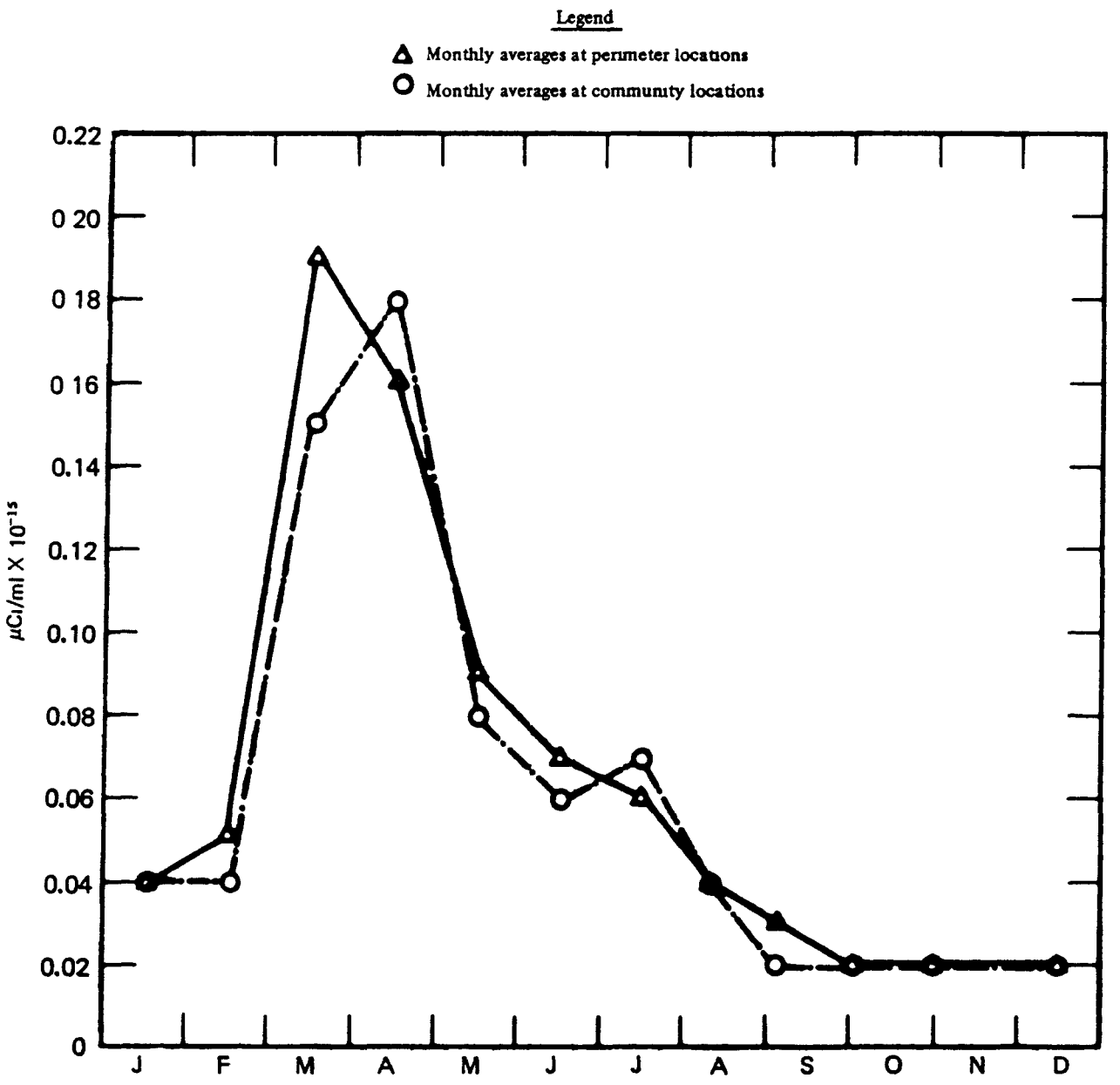


FIGURE 9 Location of Hydrologic Test Holes

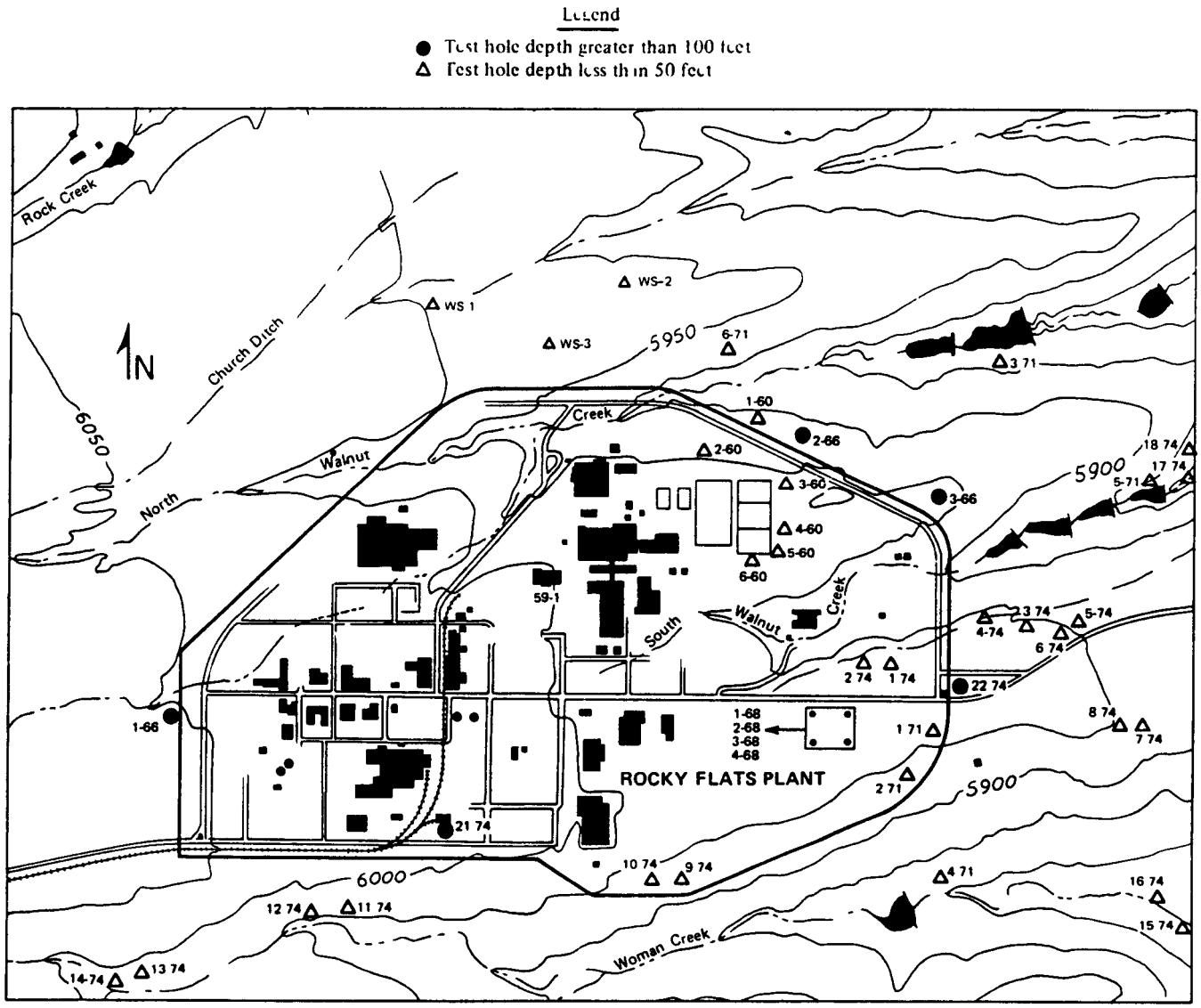


FIGURE 8 Total Long-Lived Beta Activity During 1978
(Data from Colorado Department of Health)

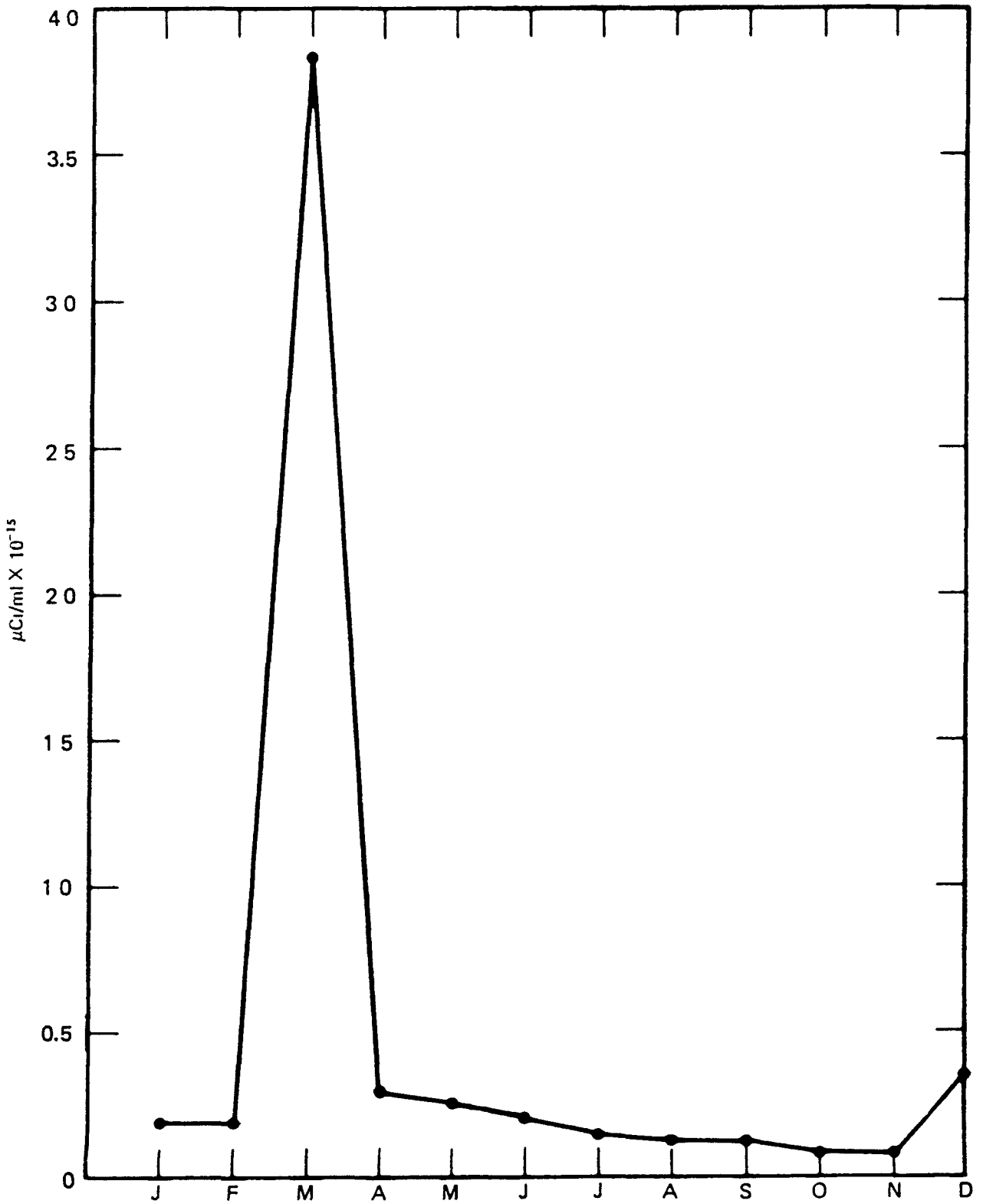


FIGURE 10 Plutonium Concentrations in Off-Site Soils During 1978
[Units are picocuries per gram of less than 2-mm size fraction
Concentrations are minimum-maximum (median)]

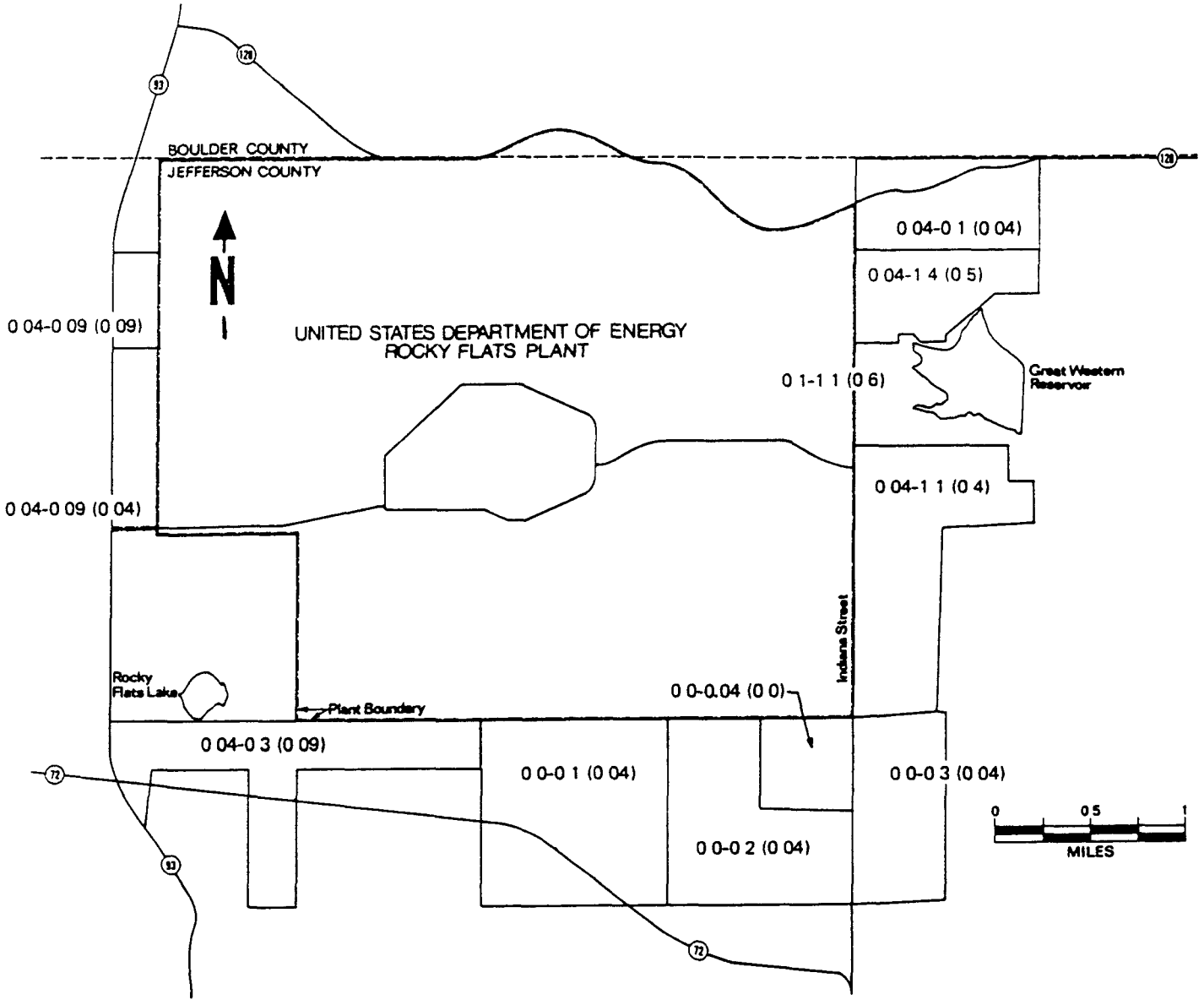


FIGURE 11 Plutonium Concentrations in Rocky Flats Soils During 1978
(Values are in picocuries per gram)

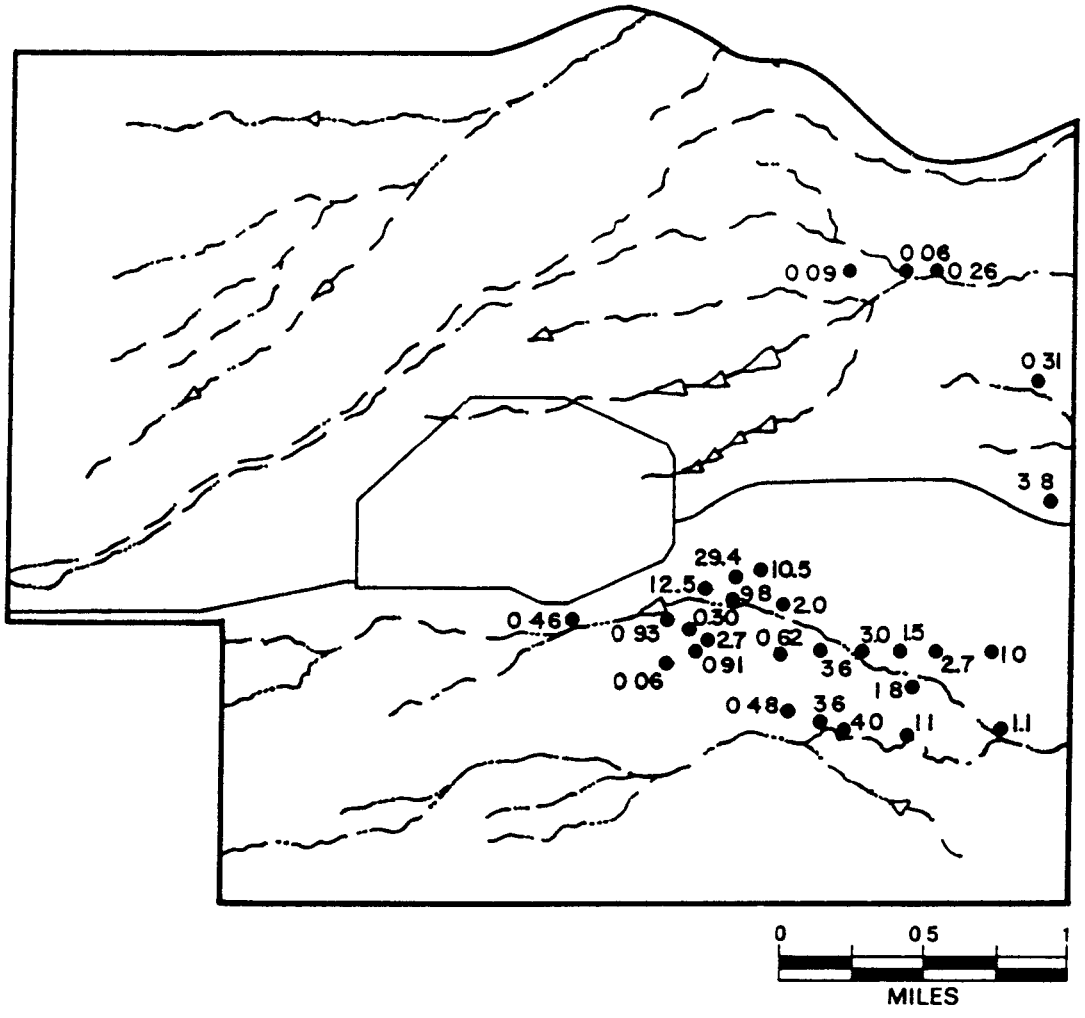


FIGURE 12 Locations of Soil Removal Operations

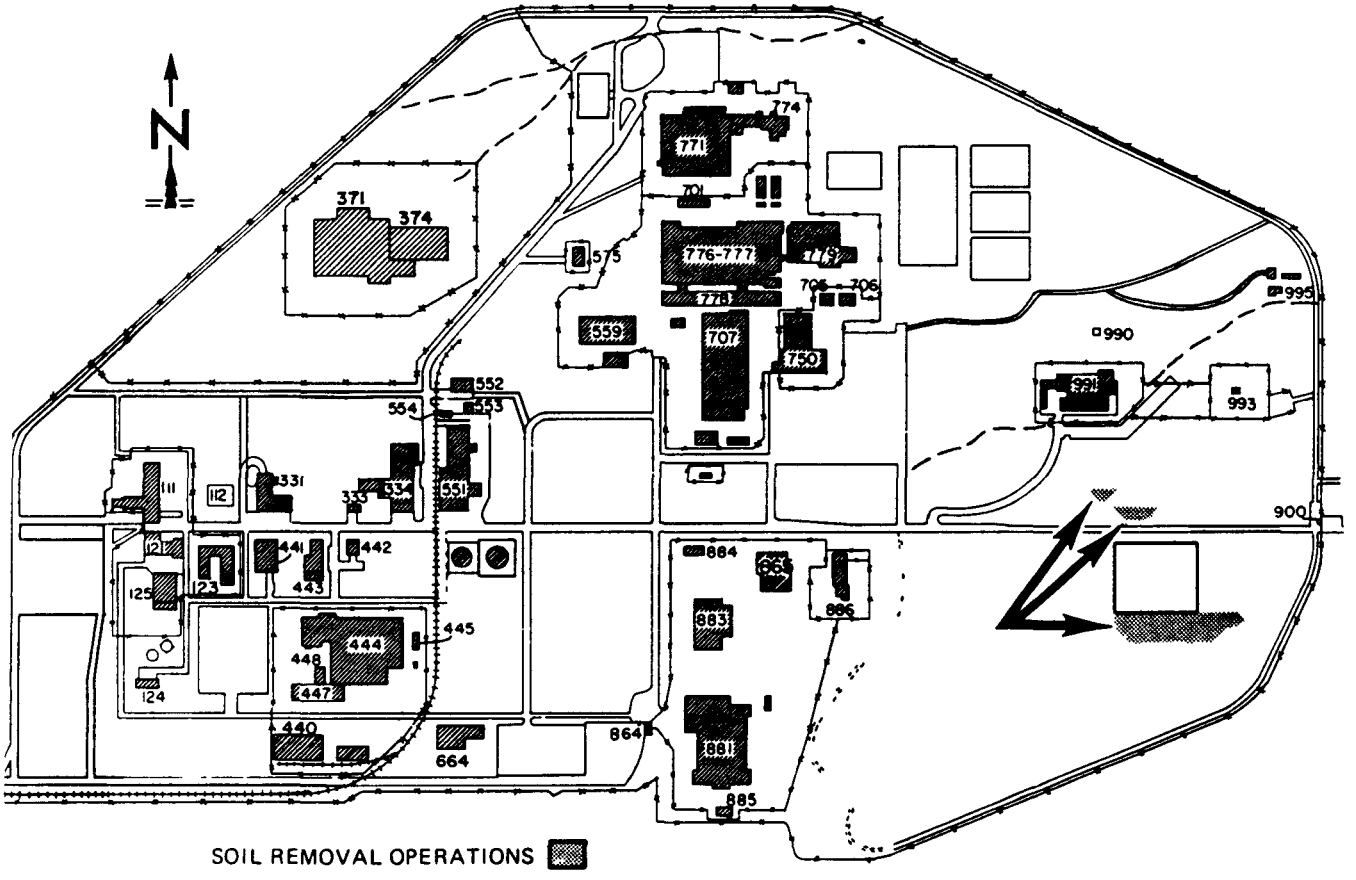
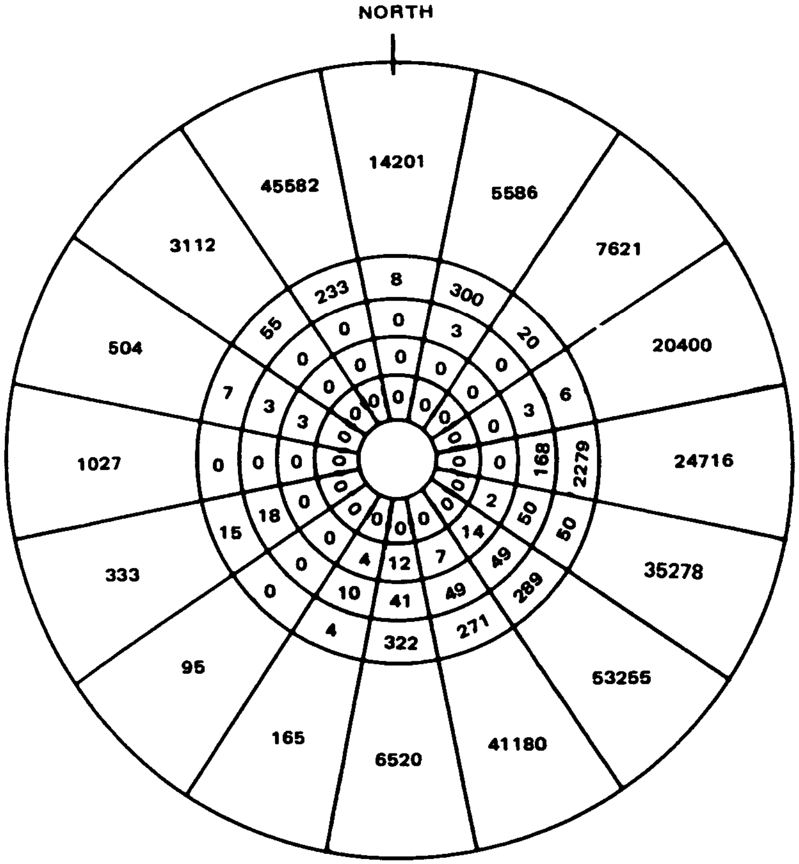
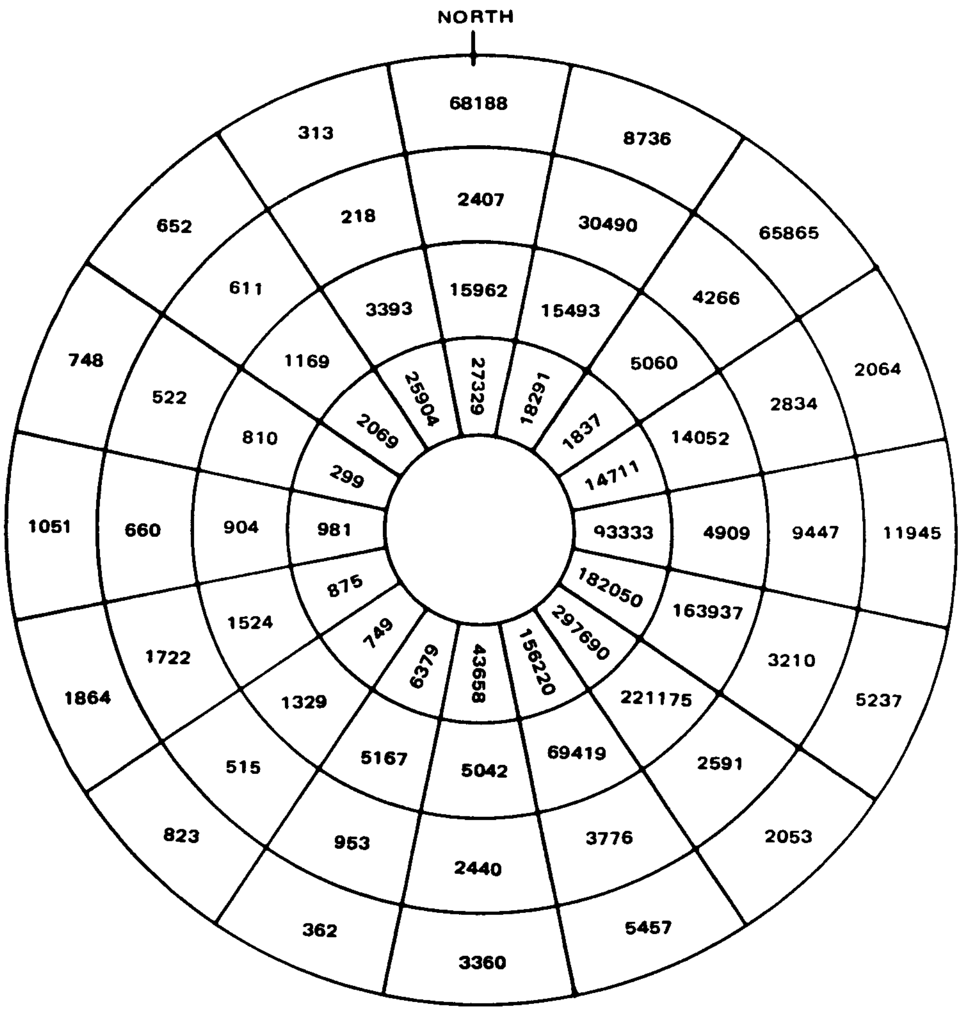


FIGURE 13 Demographic Estimates-1978

NOTE These population estimates were calculated, based on 1977 population and growth estimates obtained from Denver Regional Council of Governments, the State Planning Department and Larimer and Weld County Planning Departments



0-16 Kilometers (0-10 Miles) From Rocky Flats



16-80 Kilometers (10-50 Miles) From Rocky Flats