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JANUARY DECEMBER 1979

Rockwell International

Energy Systems Group
Rocky Flats Plant

UNITED STATES DEPARTMENT OF ENERGY
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ANNUAL ENVIRONMENTAL MONITORING REPORT
U S DEPARTMENT OF ENERGY, ROCKY FLATS PLANT
January through December 1979

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Air
Americium
Beryllium
Dose Assessment
Effluents
Fallout
Plutonium
Soil
Standards
Tritium
Uranium
Water

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ENERGY SYSTEMS GROUP
ROCKY FLATS PLANT
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ABSTRACT

This report documents the 1979 environmental surveillance program at the Rocky Flats Plant, as conducted by the Environmental Analysis Section of the Environmental Sciences Branch Sample analyses are performed by the Health, Safety, and Environmental Laboratories of the Health, Safety, and Environment Department and by the General Laboratory of the Quality Engineering and Control Department The report includes an evaluation of Plant compliance with all appropriate guides, limits, and standards Potential public radiation dose commitments were calculated from average radionuclide concentrations measured at the Plant property boundaries and in surrounding communities

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 This test facility is a national research center in the development and testing of small wind energy devices

The more than 100 structures that now exist on the Plant site contain about 189,000 square meters (2 03 million square feet) of floor space Of this space, major manufacturing, chemical processing, and waste treatment facilities occupy about 126,000 square meters (1 36 million square feet) About 29,800 square meters (321,000 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 (149,000 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 1979, approximately 19 4 million

cubic meters (685 million cubic feet) of natural gas and approximately 2 65 million liters (700 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 443 million liters (117 million gallons) of water during 1979

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 Rocky Flats Plant 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 50 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,,and 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 During 1979, construction began on a series of interceptor canals and three new surface water control ponds The three ponds are located downstream from the present ponds, and will be designated as Ponds A-4, B-5, and C-2 The new ponds will be completed during the summer of 1980

Personnel in the Environmental Sciences Branch 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, soil, and vegetation 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 Measurements 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 submitted in compliance with Energy Research and Development Administration (now DOE) Manual Chapter 0513,[1] and 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 A monthly meeting is held with the Colorado Department of Health to review the data These meetings are attended by interested citizens and by representatives of the agencies just mentioned

SUMMARY

During 1979, 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 nine communities located near the Plant Analysis of these samples indicated that the average concentrations of airborne plutonium at perimeter and community locations were identical and were within the range attributed to fallout from atmospheric nuclear weapons testing During 1979, the average plutonium concentrations in air at the Plant perimeter and in surrounding communities were less than $7\,4 \times 10^{-7}$ Bq/m^3 ($0\,02 \times 10^{-15}$ μCi/ml) * This value is less than 0 10% of the applicable DOE Radioactivity Concentration Guides (RCG's) and less than 2% of the EPA proposed guidance for plutonium in ambient air

During 1979, start-up testing and preliminary data collection were initiated to monitor ambient air for selected nonradioactive parameters The program was conducted through the use of a self-contained mobile ambient air monitoring (MAAM) van Monthly data were collected for carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone from April to November Regulations controlling these materials have been promulgated by the EPA through the National Ambient Air Quality Standards (NAAQS) Monthly average concentrations for carbon monoxide and ozone at the start-up location ranged from 0 42 to 2 17 ppm and 0 30 to 0 43 ppm, respectively These concentrations are below the NAAQS Nitrogen dioxide monthly average concentrations ranged from 0 019 to 0 042 ppm Some maximum hourly averages indicated concentrations of nitrogen dioxide that exceeded the NAAQS of 0 05 ppm

During 1979, water discharged from the Plant consisted of stormwater runoff and treated sanitary wastewater The sanitary wastewater was processed through the Plant tertiary water treatment facility before discharge, and all discharges were monitored for compliance with the EPA National Pollutant Discharge Elimination System (NPDES) permit One pH violation occurred during May The monthly effluent limitation for total residual chlorine was exceeded during October, November, and December In all cases, causes for the violations were identified and corrective actions taken

The plutonium uranium americium, and tritium radioactivity concentrations measured in Great Western Reservoir and Standley Lake during 1979 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 All annual average concentrations were less than 0 06% of the applicable RCG's The sum of the plutonium and americium concentrations in all community drinking water samples was less than 0 26% of the State of Colorado regulation for alpha-emitting radionuclides in drinking water and the EPA National Interim Primary Drinking Water Regulations

A new soil sampling program was implemented during 1979 It is designed to provide information on the possible migration of radionuclides and for familiarization with the EPA Proposed Guidance on Transuranium Elements in the Environment Only the latter phase was initiated in 1979 with the analysis of 18 samples The highest concentration of plutonium reported was $4\,4 \times 10^8$ Bq/km^2 (11 90 mCi/km^2), which is 6% of the EPA proposed guideline for plutonium in soil

Potential public radiation dose commitments, which could have resulted from Plant effluents, were calculated from average radionuclide concentrations

*Bq - becquerel (1 Bq = 1 disintegration per second)

measured at the DOE property boundaries and in surrounding communities Dose assessment for 1979 was conducted for the DOE property (site) boundary, nearby communities, and to a distance of 80 km (50 mi) Dose conversion factors used for the calculations were generated by computer codes At the Plant boundary, the maximum probable radiation dose was calculated to be a 70-year dose commitment of less than $4\ 1 \times 10^{-4}$ mSv* ($4\ 1 \times 10^{-2}$ mrem) to the total body, and less than $1\ 3 \times 10^{-2}$ mSv (1 3 mrem) to the bone Source terms for the maximum probable dose at the site boundary have been partially adjusted to account for radioactivity that was not of Rocky Flats origin Using these source terms, the organ doses are reduced to less than $4\ 0 \times 10^{-5}$ mSv ($4\ 0 \times 10^{-3}$ mrem) for the total body and less than $1\ 2 \times 10^{-2}$ mSv (1 2 mrem) for the bone By comparison, annual doses to the body and bone from natural radiation in the Denver area are 1 50 and 1 68 mSv (150 and 168 mrem) per year, respectively [2] The 70-year dose commitments of less than $4\ 0 \times 10^{-5}$ mSv ($4\ 0 \times 10^{-3}$ mrem) and less than $1\ 2 \times 10^{-2}$ mSv (1 2 mrem) represent less than 0 0008% and less than 0 08%, respectively, of the annual DOE radiation protection standards for an individual at points of maximum possible exposure

Based on the measured radionuclide concentrations in surrounding communities, 70-year dose commitments of less than $2\ 6 \times 10^{-6}$ mSv ($2\ 6 \times 10^{-3}$ mrem) to the total body and less than $7\ 3 \times 10^{-3}$ mSv ($7\ 3 \times 10^{-1}$ mrem) to the bone were calculated These values include contribution from fallout, and represent less than 0 002% and less than 0 15%, respectively, of the annual DOE standard based on average dose for a suitable sample of the exposed population.

Based on the community radiation dose values, the 70-year total body dose commitment to the population living within 80 km (50 mi) of the Plant is estimated to be less than $5\ 2 \times 10^{-2}$ man-sieverts (5 2 man-rem) The corresponding dose from natural radiation background is 3,000 man-sieverts (300,000 man-rem)

*mSv - millisievert (1 mSv = 100 mrem)

SITE METEOROLOGY AND CLIMATOLOGY

During 1979, complete data were not collected from the Plant's 61-meter (200 foot) meteorological tower Lightning struck the data transmission line at a location between the tower and a Plant building The lightning strike caused extensive damage to a magnetic tape data storage unit and to the processing units of the data aquisition system The system currently is being repaired

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 relevant guides, limits, and standards Guide values for radionuclides in ambient air and waterborne effluents, for example, have been adopted by the Department of Energy [3] 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 EPA National Pollutant Discharge Elimination System (NPDES) discharge permit [4] In 1976, the EPA also established standards for radionuclides in drinking water [5] These drinking water standards have been adopted, in turn, by the state of Colorado [6]

The Radioactivity Concentration Guides (RCG's)[3] adopted by DOE, formerly the Energy Research and Development Administration (ERDA), include 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 of each radionuclide concentration to 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 1979, 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 for 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

For purposes of comparing radionuclide concentrations to the RCG's, the most restrictive RCG is applied without regard to solubility Throughout this report, where a radionuclide concentration is expressed as the cumulative measurement of more than one isotope, the stated RCG used for comparison also 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 alpha radioactivity in the plutonium handled at the Plant

Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238 Uranium-235 is the major isotope (93% by weight) in the enriched uranium at Rocky Flats; however, uranium-234 represents approximately 97% of the alpha activity of enriched uranium The uranium RCG's used in this report for air and water are those for uranium-233 and -234, which are the most restrictive

The applicable EPA standard for beryllium (a nonradioactive material) in airborne effluents from Plant buildings is 10 grams per stationary source in a 24-hour time period [7] For ambient air, the applicable DOE RCG's for soluble plutonium-239 and -240 in uncontrolled areas and for the general population are $2\,2 \times 10^{-3}$ Bq/m^3 (60×10^{-15} μCi/ml) and $7\,4 \times 10^{-4}$ Bq/m^3 (20×10^{-15} μCi/ml), respectively

The DOE RCG for soluble plutonium-239 and -240 in waterborne effluents for the general population is 62 Bq/l ($1{,}667 \times 10^{-9}$ μCi/ml) The comparable RCG for americium-241 in water is 49 Bq/l ($1{,}330 \times 10^{-9}$ μCi/ml) The most restrictive RCG for uranium-233, -234, and -238 in water is 370 Bq/l ($10{,}000 \times 10^{-9}$ μCi/ml), which is the RCG for both uranium-233 and uranium-234

In 1976, the Environmental Protection Agency promulgated regulations for radionuclides in drinking water [5] 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 water standards to include radionuclides [6] 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 $5\,6 \times 10^{-1}$ Bq/l (15 pCi/l) Americium and plutonium, which are alpha-emitting radionuclides, are included in this limit The limit for tritium in drinking water is 740 Bq/l (20,000 pCi/l)

The Rocky Flats Plant NPDES permit, issued in 1974 by the EPA, established sanitary effluent concentration limitations at Discharge Point 001 (sanitary treatment plant), limitations for nitrate and pH at Discharge Point 002 (Holding Pond A-3 in the Walnut Creek drainage), and monitoring requirements for Discharge Point 003 (Pond C-1 in the Woman Creek drainage) [4]

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 past fallout deposition and from naturally occurring radioactive materials. Because of the variability of fallout deposition, 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, respectively, plutonium-236 or -242, uranium-232 or -236, and americium-243 or curium-244.

Separation of the radioisotopes from the environmental and effluent sample matrices is performed by ion exchange techniques. The purified radioisotopes are electrodeposited onto stainless steel disks and their activity is radiometrically determined by alpha pulse height spectrometry.[8] The resulting radionuclide concentrations are cumulative radioactivity from the various isotopes for a given element, as measured by the alpha pulse height spectrometry system.

Specific sampling and analytical methods are presented throughout this report as appropriate.

Detection Limits

Table 2 shows nominal values for the Minimum Detectable Concentrations (MDC's) 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 RCG's applicable to airborne and waterborne effluent.

Data Reduction

Throughout the data presented, samples with concentrations below the MDC were considered to have the MDC value for 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 (<). The average concentrations (C_{avg}) are represented by pairs of numbers (of the form a ± b%) that define the 95% confidence interval for C_{avg}. This interval is centered at the arithmetic mean of the observed concentrations ($\bar{c}$). The probability (P) that C_{avg} lies within the stated interval is 95%, or

$$P\left[\left(\bar{c} - t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_i^2 - n\bar{c}^2}{n(n-1)}}\right) \leq C_{avg} \leq \left(\bar{c} + t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_i^2 - n\bar{c}^2}{n(n-1)}}\right)\right] = 0.95$$

where $\bar{c}$ = the arithmetic mean of observed concentrations

$t_{0.975}$ = value taken from a standard t-test table

n = number of samples

c_i = an individual, observed concentration

Quality Control

An analytical quality control program is conducted by the Rocky Flats Health, Safety, and Environmental Laboratories (HS&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 comparison programs

4 Instrument performance evaluation

The Rocky Flats Chemistry Standards Laboratory prepares "blind" standard samples using calibrated radioisotope solutions traceable to the National Bureau of Standards These standard samples are prepared to simulate routine environmental samples A statistical analysis of quality control data and an assessment of laboratory performance are conducted by the Chemistry Standards Laboratory on a monthly basis Table 3 shows measurement statistics for the control program, based on a 12-month average

The Rocky Flats Health, Safety, and Environmental Laboratories participates in a laboratory intercomparison study program conducted by the EPA's Environmental Monitoring Systems Laboratory, (EMSL) Participation is limited to those programs that 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
- Plutonium in water
- Total uranium 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 a performance chart The computer reports list the results for all of the participating laboratories The results from each laboratory are compared against a normalized grand average of all results and against the known value The performance chart is an updated graph of the laboratories' performance over a two-year period A warning level is established at two standard deviations from the mean

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

Table 4 is a summary of the HS&EL participation in the EPA Environmental Monitoring Systems Laboratory Cross-Check Program This table includes those programs pertinent to the data included in this report The HS&EL reported values, in most cases, are in good agreement with the standard values at stated submission levels

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 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 certain radionuclides, among which are plutonium-239 and americium-241 These monitors alarm automatically if out-of-tolerance conditions are experienced

Three times each week, the 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 If the total long-lived alpha concentration for an effluent sample exceeds a Plant action guide value a follow-up investigation is conducted to determine if a problem exists Also the sample is withheld from monthly compositing and is separately analyzed for radionuclide concentrations of plutonium and uranium

At the completion of each month, the samples for ventilation systems are separately composited and analyzed by alpha pulse-height spectrometry for plutonium and uranium (as described in the Analytical Procedures section of this report) An aliquot of each composite sample is analyzed for beryllium particulates This analysis is done using a flameless atomic absorption spectrophotometer technique [9]

Specific analysis for uranium and beryllium is conducted for composited samples collected at 38 effluent locations Water bubblers are used to sample tritium in effluent air from 15 ventilation systems 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 1979 The concentrations and quantities include background contributions

During 1979, the total amount of plutonium released to the atmosphere from ventilation systems was less than $2\ 09 \times 10^3$ Bq (5 66 μCi) Uranium and beryllium releases from the 38 ventilation systems were less than $1\ 29 \times 10^6$ Bq (34 79 μCi) and 1 553 g, respectively Less than $3\ 12 \times 10^{10}$ Bq (0 844 Ci) of tritium was released

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 data to confirm compliance with appropriate stack emission standards

Radioactive Ambient Air Monitoring

High-volume ambient-air samplers are located on the Rocky Flats Plant site at the Plant perimeter [at a distance approximately 3 to 6 kilometers (2 to 4 miles) from the Plant center], and in nine 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 l/sec (40 cfm) Particulates are collected on a 20- X 25-cm (8 X 10 in) Delbag Microsorban® filter The effectiveness of the high-volume sampler and the filter media has been evaluated by Dr James B Wedding from Colorado State University at Fort Collins Colorado [10] The efficiency of the Rocky Flats–designed sampler is comparable to that of the EPA-specified standard Hi-Volume Sampler for a variety of simulated field conditions The filter media was found to be greater than 99 9% efficient for particle sizes and pressure drops typical of conditions encountered in routine ambient air sampling

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 $3\ 7 \times 10^{-4}$ Bq/m^3 (0 01 pCi/m^3), specific plutonium analysis is performed During 1979, no samples exceeded this activity level On a routine basis, filters from 9 of the 23 samplers are composited and analyzed biweekly for plutonium Table 6 presents the average concentrations of plutonium in ambient air at these nine on-site stations during 1979 The highest percentages of the RCG_a were at Samplers S-8 and S-9 These samplers are located along the east security fence in an area where the soil is known to contain plutonium

The average concentrations of plutonium in ambient air at the nine on-site stations during 1979 ranged from less than $7\ 4 \times 10^{-7}$ to $1\ 8 \times 10^{-5}$ Bq/m^3 ($0\ 02 \times 10^{-15}$ to $0\ 50 \times 10^{-15}$ μCi/ml) These concentrations were less than 0 84% of the RCG_a for soluble plutonium in ambient air in uncontrolled areas

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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 km (2 and 4 mi) from the Plant center (Figure 6) The samplers are numbered S-31 through S-44 Samples from each location are collected weekly, composited by location every four weeks, and analyzed for plutonium Table 7 presents the average concentrations of plutonium radioactivity in airborne particulates at Stations S-31 through S-44 during 1979 The average concentration of plutonium in ambient air at these locations during 1979 was less than 7.4×10^{-7} Bq/m^3 (0.02×10^{-15} μCi/ml) This concentration was less than 0.10% of the soluble plutonium RCG_a for the general population

Samples of airborne particulates also are collected at nine 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, Lafayette, Leyden, Superior, Wagner, and Westminster Sample filters are collected weekly, composited by location every four weeks, and analyzed for plutonium radioactivity

Table 8 presents the average concentrations of plutonium in airborne particulates at the community stations during 1979 The average concentration of plutonium in ambient air at the community stations also was less than 7.4×10^{-7} Bq/m^3 (0.02×10^{-15} μCi/ml) This value is less than 0.10% of the soluble plutonium RCG_a for the general population

Nonradioactive Ambient Air Monitoring

During 1979, start-up testing and preliminary work began toward monitoring ambient air for selected nonradioactive parameters This program was conducted through utilization of a self-contained van for mobile ambient air monitoring (MAAM)

This van is equipped with instruments to measure the concentration of carbon monoxide (CO), total suspended particulates, ozone, oxides of nitrogen sulfur dioxide (SO_2), and total non-methane hydrocarbons These materials are regulated by the Environmental Protection Agency through the National Ambient Air Quality Standards (NAAQS) [11]

Table 9 gives the detection capabilities of the MAAM monitoring instruments and lists the corresponding compliance standards

The van also has a portable tower mounted on the roof with instruments for collecting temperature, wind velocity, and wind direction data For the 1979 start-up test program, the van was located in a production building area This location was chosen because it provided easy accessibility for laboratory personnel supporting the start-up phase In the future, the MAAM van will be used at various sites around the Plant The first of these is in a traffic zone near the east entrance to the Plant It is an open area that is generally downwind from Plant buildings

Table 10 presents monthly data for carbon monoxide (CO) nitrogen dioxide (NO_2) and ozone in ambient air at the start-up location during the period from April through November Because of continuing instrument problems little SO_2 or total non-methane hydrocarbon data were collected During the limited periods when SO_2 data were collected, the SO_2 levels were at or near the detection limit The total non-methane concentration data collected were insufficient to provide a meaningful representation of ambient air concentrations Total suspended particulate measurements were not conducted during 1979 Data routinely collected at the Plant boundary by the Colorado Department of Health have historically been well below the NAAQS, with yearly averages ranging from about 30 to 40 μg/m^3 [12]

Carbon monoxide concentrations at the start-up location during 1979 ranged from a monthly average of 0.420 to 2.17 ppm with ozone averages varying from 0.030 to 0.043 ppm These measurements also indicate levels well below the NAAQS

Monthly average concentrations of nitrogen dioxide (NO_2) varied from 0.019 to 0.042 ppm The maximum hourly averages indicated concentrations in ambient air at the start-up location that were in excess of the NAAQS for NO_2

The accuracy of these data is based on span gas calibration Each gas was introduced as a known concentration of pollutant to each type of monitoring instrument This provided a single concentration

level, or span point, upscale from a zero level of detection At best the data are accurate to within ±10% and represent only an indication of ambient air concentrations at that location

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 62 Bq/l ($1{,}667 \times 10^{-9}$ μCi/ml) of plutonium This water, Rocky Flats laundry wastewater, and water from one Plant cooling tower are 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 $1\ 85 \times 10^{-1}$ Bq/l (5×10^{-9} μCi/ml)

South Walnut Creek receives discharges from the Plant's tertiary sewage treatment facility after passage through Holding Ponds B-3 and B-4 During 1979, Plant wastewater discharged through this treatment 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 to a DOE waste-storage facility

After treatment, the liquid effluents were 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 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 1979 are presented in Table 11

During 1979, the EPA-NPDES permit limits for most parameters were met on a continuing basis In May, one pH violation occurred when a value of 9 7 was recorded The daily limit for pH is 6 0 to 9 0 The pH violation was the result of sewage treatment plant effluent being stored on-site in a holding pond This water was to be used for start-up testing for the reverse osmosis plant Much algal growth took place while the water was standing for several days The natural effect of algal growth is to increase the pH This water was passed through sand filters in the reverse osmosis plant before discharge through the monitoring station

During October, November, and part of December, total residual chlorine, which is monitored at the outfall from Pond B-4, exceeded the effluent limitation of 0 1 mg/l Values ranged from 0 2 to 1 4 mg/l On December 18, 1979, off-site discharge of effluent water from Pond B-4 was discontinued Factors contributing to the total residual chlorine increase included (1) continuation of the normal chlorine feed rate, which could have been reduced during cold weather, (2) ice formation on the retention ponds, and (3) reduced retention time in holding ponds These factors prevented outgassing and decomposition of the residual chlorine The quality of down-stream receiving waters was not affected by the presence of increased total residual chlorine in the effluent water Standard drinking water treatment requires chlorination to levels exceeding those experienced here

During planned discharges from Holding Pond A-3, the water is sampled continuously These samples are analyzed for plutonium, uranium, americium, and tritium Water is also 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 12 Tritium concentrations are presented in Table 13 All plutonium, uranium, americium, and tritium concentrations in these ponds were less than 0 08% 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, americium, and tritium Results of these analyses are presented in Tables 13 and 14 The 1979 average concentrations for plutonium, uranium, americium and tritium in Walnut Creek at the Indiana Street location were less than 0 08% of the applicable RCG_W

Ralston Reservoir, which is located near a uranium mine, serves as the primary source of raw water for the Rocky Flats Plant Throughout the year, weekly uranium analyses were conducted on samples of Rocky Flats raw and treated water The uranium concentrations measured during this period are summarized in Table 15

Uranium concentrations measured during 1979 in raw water and treated water averaged $4\ 4 \times 10^{-1}$ and $3\ 48 \times 10^{-1}$ Bq/l ($11\ 2 \times 10^{-9}$ and $9\ 4 \times 10^{-9}$ μCi/ml), respectively This water was used throughout the Plant, discharged to the sanitary sewage system and ultimately to Pond B-4 and then to Walnut Creek

As shown in Tables 12 and 14, the 1979 average uranium concentrations in effluent waters, as determined at Pond B-4 and Walnut Creek sampling locations, were $2\ 0 \times 10^{-1}$ and $1\ 78 \times 10^{-1}$ Bq/l ($5\ 4 \times 10^{-9}$ and $4\ 8 \times 10^{-9}$ μCi/ml), respectively A comparison of influent and effluent uranium concentrations showed no increase in uranium concentrations in effluent water due to Rocky Flats operations

Groundwater Monitoring

The Rocky Flats Plant routinely samples 42 hydrologic test holes at approximately six-month intervals Analyses are conducted to determine if there is any movement of chemical or radioactive materials of possible Plant origin into water-bearing 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 west of the west security fence, northeast of the solar ponds, east of the solar ponds, east of the east security fence, and near the south security fence, respectively These test holes provide information concerning water movement in gravel and bedrock formations The remaining test holes range from 1 to 15 meters (3 to 50 feet) deep and are generally located near three on-site solar evaporation ponds and other holding ponds Locations of the 42 test holes are identified in Figure 7

During May and November, test holes containing water were sampled and the water was analyzed for plutonium, uranium, americium, and tritium Table 16 presents measured depths of the test holes and radioactivity concentrations for water obtained from each test hole during 1979

Tritium and uranium have been detected at low concentrations in test holes in close proximity to solar evaporation ponds that have been used to store process wastewater prior to treatment These ponds are hydrologically upgradient from the test holes and some seepage has occurred A new facility has been completed for treatment of process wastewaters As a result, use of these ponds for storage of process wastewaters is being phased out They are to be used in conjunction with a sanitary wastewater recycle project

Test holes 17-74 and 18-74, located immediately east and downstream from Pond B-4, were found to contain higher than normal concentrations of uranium and tritium The maximum tritium concentration, 47 9 Bq/l (1294×10^{-9} μCi/ml) in November, was about twice the background value The average uranium concentration for the previous four years was about $9\ 25 \times 10^{-1}$ Bq/l (25×10^{-9} μCi/ml), the maximum value for 1979 was 4 11 Bq/l (111×10^{-9} μCi/ml) The concentrations of plutonium and americium were not higher than normal It should also be noted that the sample

from test hole 18-74 in November was the first water available from this hole in the fall for the past several years The concentration of uranium in Pond B-4 was less than 5 18 X 10^{-4} Bq/l (14 X 10^{-9} μCi/ml) during 1979 A preliminary evaluation of the isotopic ratios indicates that the uranium may be natural material and not of Rocky Flats Plant origin Small pockets of low grade uranium ore are not unlikely in the Arapahoe bedrock formation

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 As shown in Tables 13 and 17, concentrations of plutonium uranium americium, and tritium in water samples collected at these two locations were less than 0 07% of the applicable RCG_W

Tap or finished water from Boulder, Broomfield, and Westminster is collected weekly Quarterly samples of tap water 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 1979 are summarized in Table 17 All values were less than 0 06% 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 5 55 X 10^{-1} and 74 Bq/l (15 X 10^{-9} and 20,000 X 10^{-9} μCi/ml), respectively During 1979, the sum of the concentrations of plutonium and americium (alpha-emitting radionuclides) in all community tap water samples was less than 1 48 X 10^{-3} Bq/l (0 04 X 10^{-9} μCi/ml) This value is less than 0 26% of the alpha standard The tritium concentration in Great Western Reservoir and Standley Lake averaged less than 25 9 Bq/l (700 X 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 1979, single water samples were collected from four additional regional reservoirs and streams at distances ranging from 1 6 to 96 kilometers (1 to 60 miles) from the Plant These samples were collected to determine background data in water for plutonium, uranium, and americium The analytical results for these four samples are shown in Table 18 Comparison of these data to the downstream reservoirs and community tap water data shown in Table 17 indicates no measurable difference in the plutonium, uranium, and americium concentrations

Soil Sampling and Analyses

Soil samples were collected during 1979 as part of a new sampling program The program is designed to provide information on the possible migration of radionuclides and for familiarization with the EPA Proposed Guidance on Transuranium Elements in the Environment Only the latter phase was initiated in 1979 with the collection of 18 samples

Nine samples, made up of nine composites each, were collected at two separate 10-acre plots immediately west of Indiana Street near the Plant's east boundary The samples were collected according to a published procedure [13] The two sites are shown on Figure 8 as numbers 13 and 21 Also shown on this figure is the soil sampling scheme The nine subsamples were collected on a spacing of 20 meters (65 6 feet) and composited to yield nine samples at each plot The geometry of each sample was controlled by use of a 10 X 10 X 1 cm (4 X 4 X 0 4 in) cutting tool The soil contained within the tool cavity was removed for analysis

Sample preparation and analysis were performed according to procedures developed by personnel from Rockwell International [8] The entire sample was dried, sieved through a 10-mesh sieve, weighed, and the fine portion was ball milled A 10-g aliquot of the pulverized soil was then analyzed for plutonium Blank soil and synthetic standard soils were batched with the field samples and replicates in a random manner as quality controls Chemical recovery from the radiochemical procedure was determined by the addition of plutonium-242 for plutonium separations The analytical results were

reported by the laboratory in units of disintegrations per minute per gram of dry soil fines These values were converted to picocuries per gram (pCi/g) of dry soil (less than 10 mesh), and millicuries per square kilometer (mCi/km^2) Surface values were derived by multiplying the sample concentration by the sample weight and then dividing by the sample area to provide Bq/km^2 (mCi/km^2)

The 1979 soil data are shown in Table 19 It should be noted that at Site 13, the range of values is from $6\ 55 \times 10^1$ to $1\ 3 \times 10^2$ Bq/kg (1 77 to 3 52 pCi/g), with a mean of $9\ 92 \times 10^1$ Bq/kg (2 68 pCi/g) and a relative standard deviation of 20% Corresponding values at Site 21 were $7\ 47 \times 10^1$ to $1\ 48 \times 10^2$ Bq/kg (2 02 to 4 01 pCi/g), a mean of $1\ 02 \times 10^2$ Bq/kg (2 75 pCi/g) and a relative standard deviation of 25% These values indicate that the plutonium deposition is uniformly distributed at both locations

It is also significant that the highest surface concentration, $4\ 4 \times 10^8$ Bq/km^2 (11 90 mCi/km^2) is 6% of the EPA proposed guideline for plutonium in soil

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

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 km (2 to 4 mi) from the Plant and in 12 communities located within about 48 km (30 mi) of the Plant The TLD's are placed at a height of 1 m (3 ft) 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 1979 environmental measurements made using TLD's are shown in Table 20 The average annual dose equivalents, as measured on-site, in the perimeter environs, and the communities, were 1 46 ± 3%, 1 31 ± 2%, and 1 42 ± 3% mSv (146 ± 3% 131 ± 2%, and 142 ± 3% mrem), respectively These dose values represent the background dose from natural radiation sources

ASSESSMENT OF POTENTIAL PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

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

Potential public radiation dose commitments, which could have resulted from Plant effluents, were calculated from average radionuclide concentrations measured 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 pathways This is to be expected because of limited swimming and fishing in the area and because most locally consumed food is produced at considerable distances from the Plant

Dose assessment for 1979 Plant operations was conducted for the DOE property (site) boundary, nearby communities, and sites to a distance of 80 km (50 mi) Dose conversion factors used for the calculations, shown in Table 21, were generated by computer codes that are described in detailed reports [15-17]

The 70-year dose commitments that could have resulted from site operations at the Plant during 1979 were calculated from the radionuclide concentrations using the dose conversion factors Concentrations of plutonium in ambient air and plutonium, americium, uranium, and tritium in water were considered Chronic inhalation and ingestion intake rates of 2.66×10^{-4} cubic meters per second and 1.65 liters per day, respectively, are derived from data for "reference man "[18]

Dose Assessment Source Terms

The inhalation source terms for the 1979 dose assessment were based on plutonium-239, -240 concentrations measured in ambient air samples Because of the presence of plutonium from atmospheric weapons testing in previous years these concentrations are an overestimate of the Rocky Flats contribution The ingestion source terms were based on measured concentrations of plutonium americium, uranium, and tritium in water

The maximum site-boundary dose assessment assumes that an individual is continuously present at the Plant perimeter, which is actually uninhabited The plutonium inhalation source term of less than 7×10^{-7} Bq/m^3 (0.02×10^{-15} μCi/ml) was the average 1979 concentration of plutonium-239, -240, as measured for the 14 perimeter ambient air samplers The water supply for the individual at the site boundary was assumed to be Walnut Creek, which flows off-site and provides the liquid effluent source term at the site boundary During 1979, the plutonium concentration in Walnut Creek averaged less than 2.9×10^{-3} Bq/l (0.079×10^{-9} μCi/ml) The average americium, uranium, and tritium concentrations were less than 1.4×10^{-3}, 1.8×10^{-1}, and 3.0×10^{1} Bq/l (0.039×10^{-9}, 4.8×10^{-9}, and 800×10^{-9} μCi/ml), respectively These concentrations were used as source terms for the maximum site boundary dose assessment Natural radiation and fallout contributions are included in these concentrations

For the maximum probable site-boundary dose assessment, the source terms for uranium and tritium in water were reduced to zero The 1979 average concentration of uranium in the Plant's raw water supply was 4.1×10^{-1} Bq/l (11×10^{-9} μCi/ml), which was higher than the corresponding Walnut Creek average concentration The average concentration of tritium in the raw water supply was less than 30 Bq/l (800 μCi/ml) which was the same as that measured in Walnut Creek Based on these comparisons, the Plant's contribution to uranium and tritium in Walnut Creek was considered to be zero for purposes of the maximum probable site-boundary dose assessment The inhalation source term and the plutonium and americium ingestion source terms, for the maximum probable site-boundary dose, were identical to the corresponding terms in the maximum site-boundary dose

The inhalation source term for the community dose assessment was based on the plutonium concentrations measured in nine community air samplers The 1979 average concentration of less than 7×10^{-7} Bq m^3 (0.02×10^{-15} μCi/ml) was used as the inhalation source term The ingestion source term for plutonium and americium in the communities was based on measured concentrations of tap water in nine communities The data did not indicate measurable differences in concentrations for the different communities, therefore, the averages of the 1979 concentrations in each of the communities were used for the source terms These values for plutonium and americium were less than 3.0×10^{-4} and 6.3×10^{-4} Bq/l (0.008×10^{-9} and 0.017×10^{-9} μCi/ml), respectively As explained previously, the Rocky Flats contribution to tritium and uranium in the Plant's effluent watercourse was considered to be zero Therefore, the source term for uranium and tritium in the communities that could have resulted from 1979 site operations was also zero

The airborne and waterborne radionuclide concentrations in the nearby communities were assumed to be constant to a distance of 80 km (50 mi), and were used for the 80-km dose assessment Table 22 is a summary of the inhalation and ingestion source terms for each of the dose assessments

Maximum Site Boundary Dose

The maximum dose to an individual continuously present at the site boundary is based on the radio-

nuclide concentrations shown in Table 22 From these concentrations and the dose conversion factors in Table 21, a 70-year dose commitment of less than 4.1×10^{-4} mSv (4.1×10^{-2} mrem) is calculated for the total body The corresponding bone dose is less than 1.3×10^{-2} mSv (1.3 mrem) This dose commitment represents the exposure from all waterborne and airborne sources of these radionuclides, including natural, fallout, and Rocky Flats origins

Source terms for the maximum probable dose at the site boundary have been partially adjusted to account for natural radioactivity Using these source terms, the calculated dose commitments are less than 4.0×10^{-5} mSv (4.0×10^{-3} mrem) for the total body and less than 1.2×10^{-2} mSv (1.2 mrem) for the bone By comparison, annual doses to the body and bone from natural radiation in the Denver area, are 1.50 and 1.68 mSv per year (150 and 168 mrem per year), respectively [2] (See Table 23)

The 70-year dose commitments of less than 4.0×10^{-5} mSv (4.0×10^{-3} mrem) total body and less than 1.2×10^{-2} mSv (1.2 mrem) to the bone represent a maximum probable estimate of the radiation dose, from exposure at the site perimeter, that could have resulted from 1979 site operations These values represent less than 0.0008% and 0.08%, respectively, of DOE's radiation protection standards for individuals in uncontrolled areas Those standards are 5 mSv (500 mrem) annually for total body and 15 mSv (1500 mrem) each year for mineral bone [3]

Maximum Community Dose

Based on the maximum probable radionuclide concentrations in surrounding communities (Table 22), the calculated 70-year dose commitments were less than 2.6×10^{-5} mSv (2.6×10^{-3} mrem) to the total body and less than 7.3×10^{-3} mSv (7.3×10^{-1} mrem) to the bone These values represent less than 0.002% and 0.15%, respectively, of the 1.7 mSv (170 mrem) annual total body dose standard for a suitable sample of the exposed population, and 5 mSv (500 mrem) annual dose standard for mineral bone [3] These values may be compared to an average dose reported in the Denver area of 1.50 and 1.68 mSv/yr (150 and 168 mrem/yr) to the total body and bone respectively from natural radiation (see Table 23)

Eighty-Kilometer Dose Estimates

The estimated total body 70-year dose commitment is based on radionuclide concentrations measured in several surrounding communities and from a 1979 demographic estimate

The 1979 demographic estimate of 2,000,000 within 80 km (50 mi) of Rocky Flats is based on 1977 population and growth estimates The entire population is assumed to receive the same 70-year total body dose commitment as described for the communities [less than 2.6×10^{-5} mSv (2.6×10^{-3} mrem)] On this basis the 80-km total body dose is estimated to be less than 5.2×10^{-2} man-sieverts (5.2 man-rem) The corresponding dose from natural radiation background of 1.5 millisieverts per year per person (150 millirem per year per person) is 3,000 man-sieverts (300,000 man-rem)

Table 24 provides a summary of the 70-year dose commitments to total body, liver, bone, and lungs that could have resulted from 1979 Plant operations

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TABLES
(1 through 24)

Radioactivity measurements in the following tables are reported only in those units set forth in ERDA Manual Chapter 0513 (adopted by DOE)

TABLE 1 Temperature, Precipitation, and Wind

	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 Detection Limits and Applicable Standards for Radioactive and Nonradioactive Materials

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	ERDAMC = ERDA Manual Chapter (DOE adopted)
pCi = picocuries	NPDES = National Pollutant Discharge Elimination System
mg/l = milligrams per liter	
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} µg/m^3	<10.0 g/day	40 CFR 61.32(a)
Ambient Air Samples					
Plutonium 239 240	$1.0 \times 10^{-}$ µCi	1,000 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 organisms/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

TABLE 3 Health, Safety, and Environmental Laboratories Bioassay and Environmental Measurements Program (January-December 1979)

Isotopes Reported	Matrix	Method	Standard Range	Normal Sample Range	Relative Error (%)[a]	Bias (%)[b]	Total Control Analyses
Pu 239, 240	Water	Alpha spectral	0-20 dpm/l	0 2 dpm/l	-15 2	-23 2	60
Am-241	Water	Alpha spectral	0 3 dpm/l	0-1 dpm/l	+49 5	29 4	60
U 233, 234, 238	Water	Alpha spectral	0 35 dpm/l	0 20 dpm/l	+18 6	4 2	60
Pu-239 240	Whatman filter	Alpha spectral	0 30 dpm/filter	0 10 dpm/filter	-12 1	-23 2	120
Am 241	Whatman filter	Alpha spectral	0-4 dpm/filter	0 2 dpm/filter	+24 0	29 4	120
U 233 234 238	Whatman filter	Alpha spectral	0-30 dpm/filter	0 30 dpm/filter	+16 4	4 2	120
Be	Whatman filter	Atomic absorption	0-1 μg/filter	0-2 μg/filter	+44 4	-67 7	120
Pu 239 240	Microsorban filter	Alpha spectral	0-50 dpm/filter	0 20 dpm/filter	-14 2	-29 2	48
H_3	Water	Beta Liquid scintillation	10^4 - 10^6 pCi/l	0-10^4 pCi/l	-6 6	-8 7	60

a The ratio of the standard deviation of the 12 month differences to standard value in percent, i e , observed value minus standard value divided by 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 process for a given nuclide, matrix and procedure

b The six-month (July-December) 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 EPA Environmental Monitoring Systems Laboratory Cross-Check Program

EPA Environmental Monitoring Systems Laboratory (EMSL)

Matrix	Radioisotope	Submission Range	Ratio R/F/Standard[a]
Air Filter	Alpha	9 pCi/filter	1 0
Water	Pu-239, 240	2 4 to 4 8 pCi/l	0 75
Water	Tritium	1480 to 2270 pCi/l	1 2

DOE Environmental Measurements Laboratory (EML)[b]

Air Filter	Pu-239, -240	0 243 to 0.530 pCi/filter	1 08 ± 0 32
Soil	Pu-239, -240	0 600 to 18.8 pCi/g	1 08 ± 0 32
Soil	U	14 0 μg	1 40 ± 0 37
Water	Pu-239, 240	0 090 ± 0 023 pCi/ml	0 70 ± 0 31
Water	Am-241	0 054 pCi/ml	1 04 ± 0 028
Water	U	0 022 pCi/ml	0 89 ± 0 18

a This value is a one-year average of the ratio of HS&EL reported values to the standard values as stated by the submitting laboratories

b This DOE facility is also a participant in the EPA program

TABLE 5 Airborne Effluent Releases to the Atmosphere

Sample Period	Plutonium[a] Number of Analyses	Plutonium[a] Total (μCi)	Plutonium[a] C_{max} ($\times 10^{-12}$ μCi/ml)	Uranium[b] Number of Analyses	Uranium[b] Total (μCi)	Uranium[b] C_{max} ($\times 10^{-12}$ μCi/ml)	Tritium Number of Analyses	Tritium Total (Ci)	Tritium C_{max} ($\times 10^{-12}$ μCi/ml)	Beryllium[c] Number of Analyses	Beryllium[c] Total (g)	Beryllium[c] C_{max} (μg/m³)
January	34	<0 19	<0 001	51	7 12	0 197	193	<0 092	1 460	51	<0 118	0 001
February	34	0 29	0 006	48	5 49	0 144	180	<0 095	1,310	48	<0 106	0 001
March	33	0 09	0 002	45	3 01	0 256	195	<0 056	430	45	<0 055	<0 001
April	34	0 46	0 032	46	1 46	0 063	191	<0 068	1,460	46	<0 076	0 015
May	38	<0 62	0 029	47	2 07	0 022	194	<0 060	670	47	<0 073	0 020
June	38	<0 60	0 022	47	1 66	0 006	195	<0 066	520	47	<0 044	<0 001
July	36	<1 84	0 008	44	1 66	0 008	196	<0 062	950	44	<0 051	<0 001
August	41	<0 36	0 002	44	1 91	0 005	209	<0 078	440	44	<0 062	<0 001
September	36	<0 19	0 001	44	1 31	0 017	195	<0 093	830	44	<0 062	0 002
October	39	0 46	0 002	48	6 33	0 079	195	<0 068	440	48	<0 237	<0 001
November	36	<0 25	0 009	45	1 77	0 086	180	<0 055	350	45	<0 361	<0 001
December	36	<0 31	0 003	46	1 00	0 013	161	<0 051	390	46	<0 308	0 002
Summary	435	<5 66	0 032	555	34 79	0 256	2284	<0 844	1 460	555	<1.553	0 020

a Radiochemically determined as plutonium-239, 240
b Radiochemically determined as uranium-233, 234, and 238
c The beryllium stationary source emission standard is no more than 10 grams of beryllium over a 24-hour period under the provision in subpart C of 40 CFR 61 32 (a)

TABLE 6 Plutonium-239 and -240 Activity Concentrations in On-Site Ambient Air at Selected Locations

Station[b]	Number of Analyses	Less Than Detectable	Volume ($\times$ 1,000 m³)	Concentration[a] ($\times 10^{-15}$ μCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_a[c]
S-5	25	0	455	0 02	0 30	0 07 ± 46%	0 12
S-6	25	0	483	0 02	0 40	0 10 ± 38%	0 17
S-7	25	0	479	0 02	1 17	0 30 ± 42%	0.50
S-8	25	0	456	0 02	1 62	0 42 ± 36%	0 70
S-9	25	0	437	0 03	1.55	0.50 ± 36%	0 83
S-16	25	4	455	<0 02	0 07	<0 02 ± 37%	<0 03
S-19	25	1	488	<0 02	0 17	<0 03 ± 42%	<0 05
S-20	25	2	433	<0 02	0 79	<0 09 ± 94%	<0 15
S-21	25	4	455	<0 02	0 38	<0 04 ± 79%	<0 07
Summary	225	11	4 141	<0 02	1 62	-	-

a Two-week composites of station concentrations
b These selected air-sampling locations are in the proximity of areas where there is a potential for airborne activity
c The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air in uncontrolled areas is 60 $\times 10^{-15}$ μCi/ml

TABLE 7 Plutonium 239 and 240 Activity Concentrations in Perimeter Ambient Air [3 to 6 Kilometers (2 to 4 Miles) From Center of Plant]

Station	Number of Analyses	Less Than Detectable	Volume (× 1,000 m³)	Concentration (× 10^{-15} μCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_a*
S 31	12	6	404	<0 02	0 03	<0 02 ± 38%	<0 10
S 32	12	8	492	<0 02	0 04	<0 02 ± 45%	<0 10
S-33	12	8	447	<0 02	0 03	<0 02 ± 35%	<0 10
S 34	12	8	458	<0 02	0 04	<0 02 ± 50%	<0 10
S-35	11	6	430	<0 02	0 07	<0 02 ± 68%	<0 10
S 36	12	6	428	<0 02	0 02	<0 02 ± 35%	<0 10
S 37	12	5	473	<0 02	0 03	<0 02 ± 30%	<0 10
S 38	12	8	484	<0 02	0 27	<0 04 ± 123%	<0 19
S-39	12	5	435	<0 02	0 03	<0 02 ± 36%	<0 10
S-40	12	6	445	<0 02	0 02	<0 02 ± 31%	<0 10
S-41	12	6	409	<0 02	0 03	<0 02 ± 38%	<0 10
S-42	12	7	409	<0 02	0 07	<0 02 ± 66%	<0 10
S-43	12	8	416	<0 02	0 03	<0 02 ± 38%	<0 10
S-44	12	8	430	<0 02	0 05	<0 02 ± 58%	<0 10
Summary	167	95	6,160	<0 02	0 27		
Average Concentration						<0 02 ± 21%	<0 10

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

TABLE 8 Plutonium-239 and -240 Activity Concentrations in Community Ambient Air

Location	Number of Analyses	Less Than Detectable	Volume (× 1,000 m³)	Concentration (× 10^{-15} μCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_a*
Boulder	11	5	408	<0 02	0 06	<0 02 ± 63%	<0 10
Broomfield	12	6	453	<0 02	0 11	<0 03 ± 72%	<0 15
Denver	11	6	333	<0 02	0 03	<0 02 ± 40%	<0 10
Golden	11	4	393	<0 02	0 09	<0 02 ± 78%	<0 10
Lafayette	12	7	456	<0 02	0 03	<0 02 ± 35%	<0 10
Leyden	12	7	460	<0 02	0 07	<0 02 ± 72%	<0 10
Superior	12	8	416	<0 02	0 03	<0 02 ± 45%	<0 10
Wagner	12	7	455	<0 02	0 04	<0 02 ± 50%	<0 10
Westminster	12	6	415	<0 02	0 06	<0 02 ± 58%	<0 10
Summary	105	56	3,789	<0 02	0 11		
Average Concentration						<0 02 ± 18%	<0 10

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

TABLE 9 Mobile Ambient Air Monitoring (MAAM) Detection Limits and National Ambient Air Quality Standards (NAAQS)

Parameter	Approximate Minimum Detectable Concentration (ppm)	NAAQS Compliance Level (ppm)	
Carbon Monoxide (CO)	0 01	35	(1-hr avg)
		9	(8-hr avg)
Total Suspended Particulates	no data	75 $\mu g/m^3$	(1 hr avg)
		260 $\mu g/m^3$	(24-hr avg)
Ozone (O_3)	0 005	0 12	(1-hr avg)
Nitrogen Dioxide (NO_2)	0 005	0 05	(1-hr avg)
Sulfur Dioxide (SO_2)	0 01	0 03	(1-hr avg)
		0 14	(24-hr avg)
Total Non-Methane Hydrocarbons*	0 1	0 24	[3-hr avg (6-9 a m)]

* This parameter is for use as a guide in devising implementation plans to achieve oxidant standards

TABLE 10 On-Site Nonradioactive Ambient Air Quality[a]

Sample Period	Carbon Monoxide (ppm)			Nitrogen Dioxide (ppm)			Ozone (ppm)		
	Hourly Average		Monthly	Hourly Average		Monthly	Hourly Average		Monthly
	C_{min}	C_{max}	C_{avg}	C_{min}	C_{max}	C_{avg}	C_{min}	C_{max}	C_{avg}
April	0 200	2.230	0.500	0 009	0 049	0 019		ND[b]	
May	0 210	3 860	0 420	0 011	0 063	0 022	0 017	0 078	0 043
June	0 170	2 290	0 440	0 008	0 059	0 021	0 015	0 093	0 043
July		ND		0 010	0 066	0 025	0 023	0 102	0 041
August		ND		0 013	0 053	0 023	0 010	0 093	0 039
September		ND			ND		0 011	0 075	0 043
October	1.250	11 730	2 170	0 003	0 130[c]	0 030	0 007	0 063	0 032
November		ND		0 009	0 169[c]	0 042	0 005	0 086	0 030

a These data are from a single location in an area of Plant buildings and represent an indication of ambient concentrations at that location Span gases that provide ± 10% accuracy were used for instrument checks Overall accuracy of the data has not been determined

b ND means no data, instrument out of service

c Data suspect because of instrument drift

TABLE 11 Chemical and Biological Constituents of Liquid Effluents

Parameter	Agency[a]	Limitations (daily maximum)	Maximum Concentration	Annual Average Concentration
Discharge Point 001[b]				
pH	USEPA/CDH	6 0–9 0 SU[c]	9 7 SU	7 2 SU
Fecal Coliform Count	USEPA/CDH	200/100 ml[d]	0/100 ml	0/100 ml
Dissolved Oxygen	USEPA/CDH	>2 mg/l (daily minimum)	3 0 mg/l (minimum)	7 4 mg/l
Total Residual Chlorine	USEPA/CDH	0 1 mg/l	1 4 mg/l	<0 1 mg/l
Suspended Solids	USEPA/CDH	25 mg/l	21 0 mg/l	<4 1 mg/l
Biochemical Oxygen Demand, 5-day	USEPA/CDH	25 mg/l	22 0 mg/l	<4 1 mg/l
Total Phosphorus	USEPA/CDH	8 mg/l[d]	7 5 mg/l	1 1 mg/l
Nitrate as N	NA[e]	NA	15 0 mg/l	<5 2 mg/l
Total Nitrogen	USEPA/CDH	20 mg/l[d]	22 2 mg/l	<10 1 mg/l
Fluoride	USEPA/CDH	1 7 mg/l	0 6 mg/l	0 4 mg/l
Total Chromium	USEPA/CDH	0 1 mg/l	0 05 mg/l	<0 05 mg/l
Oil and Grease	USEPA/CDH	10 mg/l	0 7 mg/l	0 3 mg/l
Turbidity	CDH	30 NTU[f]	6 5 NTU	1 7 NTU
Color	CDH	30 units	40 units	17 9 units
Discharge Point 002[b]				
pH	USEPA/CDH	6 0–9 0 SU	8 9 SU	8 2 SU
Nitrate as N	USEPA/CDH	20 mg/l	12 0 mg/l	<5 4 mg/l
Discharge Point 003[b]				
Nitrate as N	USEPA/CDH	NA	0 8 mg/l	<0 3 mg/l
Total Dissolved Solids	USEPA/CDH	NA	255 mg/l	181 mg/l
pH	USEPA/CDH	NA	9 6 SU	8 4 SU
Chemical Oxygen Demand	USEPA/CDH	NA	48 0 mg/l	19 2 mg/l

a USFPA-U S Environmental Protection Agency, Washington, D C (Regional Office VIII, Denver, Colorado) CDH-Colorado Department of Health, Water Quality Control Commission, Denver, Colorado

b The USEPA-NPDES discharge permit defines Discharge Point 001, 002, and 003 as the sewage treatment plant Pond A-3, and Pond C-1, respectively

c SU-Standard Unit

d Monthly average limitations

e NA-Not Applicable

f NTU-Nepholometer Turbidity Unit

TABLE 12 Plutonium, Uranium and Americium Activity Concentrations in Rocky Flats Ponds

Location	Number of Analyses	C_{min}	C_{max}	C_{avg}	Percent of RCG_w
		Plutonium Concentration ($\times 10^{-9}$ μCi/ml)[a]			
Pond A-3	31	0 012	0 204	0 059 ± 29%	<0 01
Pond B-4	52	0 012	0 481	0 234 ± 29%	<0 01
Pond C 1	52	<0 002	0 192	<0 025 ± 47%	<0 01
		Uranium Concentration ($\times 10^{-9}$ μCi/ml)[b]			
Pond A-3	31	<0 2	36 6	6 6 ± 37%	0 07
Pond B-4	52	1 2	13 7	5 4 ± 13%	0 05
Pond C 1	52	0 5	9 4	3 0 ± 14%	0 03
		Americium Concentration ($\times 10^{-9}$ μCi/ml)[c]			
Pond A 3	31	0 013	0 196	0 042 ± 34%	<0 01
Pond B-4	52	0 008	0 217	0 082 ± 20%	<0 01
Pond C-1	52	<0 002	0 188	<0 027 ± 40%	<0 01

a Radiochemically determined as plutonium -239, 240 The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is 1667 X 10^{-9} μCi/ml

b Radiochemically determined as uranium -233, -234, and -238 The RCG_w for soluble uranium is 10,000 X 10^{-9} μCi/ml

c Radiochemically determined as americium-241 The RCG_w for soluble americium-241 is 1330 X 10^{-9} μCi/ml

TABLE 13 Tritium Activity Concentrations in Plant-Site and Regional Waters

Location	Number of Analyses	Concentration ($\times 10^{-9}$ μCi/ml) C_{min}	C_{max}	C_{avg}	Percent of RCG_w[a]
Pond A-3	31	<500	1300	<700 ± 13%	<0 07
Pond B-4	52	<500	1300	<700 ± 8%	<0 07
Pond C-1	52	<500	1200	<700 ± 7%	<0 07
Walnut Creek at Indiana Street	51	<500	1400	<800 ± 9%	<0 08
Great Western Reservoir[b]	52	<500	1200	<700 ± 8%[c]	<0 07
Standley Lake[b]	52	<500	1000	< 600 ± 6%[c]	<0 06

a The Radioactivity Concentration Guide (RCG_w) for tritium in water released to uncontrolled areas is 1 000,000 X 10^{-9} μCi/ml

b The State of Colorado Primary Drinking Water Regulation limit for tritium is 20 000 pCi/l (20 000 X 10^{-9} μCi/ml)

c These tritium concentrations are less than 3 5% of the drinking water regulation

TABLE 14 Plutonium, Uranium, and Americium Activity Concentrations in Walnut Creek

Location	Number of Analyses	C_{min}	C_{max}	C_{avg}	Percent of RCG_w
		Plutonium Concentration ($\times 10^{-9}$ μCi/ml)[a]			
Walnut Creek at Indiana Street	51	<0 010	0 297	<0 079 ± 42%	<0 01
		Uranium Concentration ($\times 10^{-9}$ μCi/ml)[b]			
Walnut Creek at Indiana Street	51	1 9	9 9	4 8 ± 10%	0 05
		Americium Concentration ($\times 10^{-9}$ μCi/ml)[c]			
Walnut Creek at Indiana Street	51	<0 003	0 169	<0 039 ± 23%	<0 01

a Radiochemically determined as plutonium-239, 240 The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is 1667×10^{-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 Radiochemically determined as americium-241 The RCG_w for soluble americium-241 is 1330×10^{-9} μCi/ml

TABLE 15 Uranium Activity Concentrations in the Rocky Flats Raw and Treated Water Supply

Location	Number of Analyses	C_{min}	C_{max}	C_{avg}
		*Uranium Concentration ($\times 10^{-9}$ μCi/ml)**		
Raw Water	49	0 9	59 6	11 2 ± 38%
Treated Water	48	0 3	33 6	9 4 ± 33%

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

TABLE 16 Plutonium, Uranium, Americium, and Tritium Activity Concentrations in Hydrologic Test Holes

Location Number	Depth (ft)[d]	Plutonium Concentration[a] (× 10^{-9} µCi/ml)		Uranium Concentration[b] (× 10^{-9} µCi/ml)		Americium Concentration[c] (× 10^{-9} µCi/ml)		Tritium Concentration (× 10^{-9} µCi/ml)	
		May	November	May	November	May	November	May	November
1-60	23	<0 01	<0 03	23 8	27 7	<0 02	<0 02	1712	3901
2-60	30	<0 02	0 04	11 5	3 4	<0 02	0 09	1954	2626
3-60	30	0 04	<0 01	7 0	11 5	<0 02	<0 02	<500	1356
4-60	30	0 10	0 03	11 3	8 0	0 10	<0 03	820	7660
5-60	30	dry	dry	dry	dry	dry	dry	dry	dry
6-60	30	<0 02	<0 02	5 8	2 8	<0 03	<0 03	2126	1596
1-66	148	0 04	<0 02	1 3	0 8	0 02	<0 03	612	<500
2-66	146	<0 02	<0 02	0 8	1 4	<0 01	<0 03	1764	1355
3-66	153	<0 01	<0 02	1 6	5 1	<0 02	<0 02	939	1448
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	0 02	<0 01	14 0	0 7	0 04	0 04	<500	730
2 71	30	0 01	0 03	0 7	0 5	0 03	<0 04	<500	<500
3 71	25	<0 02	0 03	1 7	3 2	0 03	<0 03	<500	<600
4-71	22	0 02	<0 02	3 1	1 7	0 02	<0 02	<500	841
5-71	28	0 05	<0 02	7 6	0 9	<0 02	<0 04	<500	777
6-71	30	<0 03	<0 01	32 0	29 1	0 10	0 09	3774	3766
1-74	24	<0 03	0 04	4 2	3 8	<0 02	0 09	550	586
2-74	10	dry	dry	dry	dry	dry	dry	dry	dry
3-74	24	<0 02	<0 02	4 6	0 2	<0 02	<0 03	915	<600
4 74	6	<0 03	dry	1 0	dry	<0 02	dry	701	dry
5-74	18	<0 01	<0 03	1 1	2 5	<0 02	<0 04	1953	1867
6-74	7	<0 02	dry	1 4	dry	0 04	dry	1669	dry
7-74	50	<0 02	<0 02	3 1	3 8	<0 01	<0 03	<500	<600
8-74	40	<0 02	dry	8 4	dry	<0 01	dry	<500	dry
9-74	19	<0 01	<0 02	4 3	12 7	<0 05	<0 03	591	1157
10-74	10	<0 02	dry	6 4	dry	<0 03	dry	987	dry
11-74	20	<0 02	<0 01	3 6	1 1	<0 04	0 04	<500	<600
12-74	4	dry	dry	dry	dry	dry	dry	dry	dry
13-74	19	<0 02	<0 02	6 1	5 4	<0 03	0 10	1027	860
14-74	4	<0 01	dry	2 0	dry	<0 03	dry	<500	dry
15-74	19	0 02	<0 03	13 0	16 1	<0 01	<0 02	616	<600
16-74	4	0 09	dry	4.2	dry	0 07	dry	634	dry
17-74	16	<0 01	<0 02	35 5	13 9	<0 01	0 06	1167	1294
18 74	7	<0 01	<0 02	59 6	111 2	<0 02	0 06	<500	880
21 74	265	<0 02	<0 02	13.5	0 8	0 07	<0 02	<500	721
22-74	315	<0 02	NA[e]	3 2	NA[e]	0 03	NA[e]	<500	NA[e]
WS-1	13	<0 02	<0 02	2 1	0 2	<0 02	0 04	<500	<500
WS-2	11	<0 02	0 03	2 4	0 2	<0 02	<0 04	<500	1017
WS-3	13	<0 01	<0 02	0 4	3.2	<0 01	<0 04	<500	652

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

TABLE 17 Plutonium, Uranium, and Americium Activity Concentrations in Public Water Supplies

	Number of Analyses	C_{min}	C_{max}	C_{avg}	Percent of RCG_w
Reservoirs		Plutonium Concentration ($\times 10^{-9}$ μCi/ml)[a]			
Great Western	15	<0 002	<0 024	<0 009 ± 59%	<0 01
Standley Lake	12	<0 003	0 020	<0 007 ± 52%	<0 01
Drinking Water					
Arvada	4	<0 005	0 013	<0 010 ± 68%	<0 01
Boulder	12	<0 002	<0 012	<0 007 ± 41%	<0 01
Broomfield	12	<0 002	0 031	<0 008 ± 66%	<0 01
Denver	4	<0 005	<0 008	<0 007 ± 36%	<0 01
Golden	4	<0 003	0 013	<0 007 ± 98%	<0 01
Lafayette	4	<0 004	0 016	<0 007 ± 151%	<0 01
Louisville	4	<0 004	<0 008	<0 006 ± 48%	<0 01
Thornton	4	<0 005	0 018	<0 009 ± 103%	<0 01
Westminster	12	<0 002	0 018	<0 007 ± 51%	<0 01
Reservoirs		Uranium Concentration ($\times 10^{-9}$ μCi/ml)[b]			
Great Western	44	0 2	7 3	2 7 ± 17%	0 03
Standley Lake	44	2 0	5 1	3 3 ± 11%	0 03
Drinking Water					
Arvada	4	0 3	15 6	4 9 ± 234%	0 05
Boulder	44	0.2	7 2	1 3 ± 32%	0 01
Broomfield	44	0.2	5 4	1 5 ± 45%	0 02
Denver	4	1 0	4 1	2 0 ± 112%	0 02
Golden	4	0 9	5 9	2 6 ± 137%	0 03
Lafayette	4	0 6	2 8	1 4 ± 105%	0 01
Louisville	4	0 7	1 4	1 0 ± 50%	0 01
Thornton	4	1.5	8 1	4 6 ± 105%	0 05
Westminster	44	0 8	9 8	2 8 ± 21%	0 03
Reservoirs		Americium Concentration ($\times 10^{-9}$ μCi/ml)[c]			
Great Western	15	<0 010	0 079	<0 017 ± 65%	<0 01
Standley Lake	12	<0 010	<0 027	<0 016 ± 11%	<0 01
Drinking Water					
Arvada	4	<0 007	0 034	<0 017 ± 120%	<0 01
Boulder	12	<0 010	<0 027	<0 016 ± 10%	<0 01
Broomfield	12	<0 010	<0 027	<0 014 ± 39%	<0 01
Denver	4	<0 008	0 022	<0 015 ± 68%	<0 01
Golden	4	<0 004	0 049	<0 023 ± 138%	<0 01
Lafayette	4	<0 006	0 024	<0 012 ± 121%	<0 01
Louisville	4	0 012	0 060	0 027 ± 133%	<0 01
Thornton	4	<0 007	0 014	0 011 ± 43%	<0 01
Westminster	12	<0 010	<0 027	<0 015 ± 26%	<0 01

a. Radiochemically determined as plutonium-239, -240 The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is 1667 X 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 X 10^{-9} μCi/ml.

c Radiochemically determined as americium-241 The RCG_w for soluble americium-241 is 1330 X 10^{-9} μCi/ml

TABLE 18 Plutonium, Uranium, and Americium Activity Concentrations in Regional Waters

Location	Direction[a]	Concentration (x 10^{-9} μCi/ml) Plutonium[b]	Uranium[c]	Americium[d]
Boulder Diversion Canal	1, W	<0 002	1 2	<0 010
Boulder Reservoir	15 N	<0 044	4 2	<0 07
Dillon Reservoir	60, SW	<0 004	1 4	<0 010
Ralston Reservoir	10, S	<0 004	11 9	<0 010

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

TABLE 19 Plutonium Concentrations in Soil Samples at the East Boundary of the Rocky Flats Plant

Location	pCi/g*	mCi/km²	Location	pCi/g*	mCi/km²
13-1	2 84	8 65	21-1	4 01	10 04
13-2	1 77	6 02	21-2	2 13	7 65
13-3	2 34	6 32	21-3	3 22	8 74
13-4	3.52	11 90	21-4	2 08	9 06
13-5	3 01	6 20	21-5	3 21	9 58
13-6	2 44	5 98	21-6	2 32	8.51
13-7	2 35	7.88	21 7	2 02	9 50
13-8	2.54	6 65	21-8	2 46	7 12
13-9	3.27	8 18	21-9	3 31	9 76
Mean	2 68	7.53	Mean	2 75	8 88
Median	2.54	6 65	Median	2 46	9 06
Percent Relative Standard Deviation	20	25	Percent Relative Standard Deviation	25	11

* Concentrations are for the less than 2-mm size fraction of soil

TABLE 20 Environmental Thermoluminescent Dosimeter Measurements

Location	Number of Measurements	Annual Dose (mrem)
On-Site (17)	133	146 ± 3%
Perimeter (16)	115	131 ± 2%
Communities (12)	92	142 ± 3%

TABLE 21 Dose Conversion Factors Used in Dose Assessment Calculations[a]

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

	Air Factor[b]	Water Factor[c]			
Organ	Pu-239 -240	Pu 239, -240	Am 241	U-233 234, 238	H 3
Total Body	$2\ 724 \times 10^{3}$	$8\ 66 \times 10^{-3}$	$8\ 84 \times 10^{-2}$	$4\ 53 \times 10^{-4}$	$7\ 33 \times 10^{-5}$
Liver	$3\ 165 \times 10^{5}$	1 0	$1\ 03 \times 10^{1}$	(e)	(e)
Bone	$7\ 919 \times 10^{5}$	2 51	$2\ 48 \times 10^{1}$	$3\ 22 \times 10^{-2}$	(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) [17]

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 which is the least soluble of three solubility classes as defined by the ICRP (ICRP Publication 19 International Commission on Radiation Protection May 1972)

e The values for the conversion factor are taken to be equal to that for the total body

TABLE 22 Radioactivity Concentrations Used for 1979 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)	$<0\ 02 \times 10^{-15}$	$0\ 079 \times 10^{-9}$	$<0\ 039 \times 10^{-9}$	$4\ 8 \times 10^{-9}$	$<800 \times 10^{-9}$
Site Boundary[b] (maximum probable)	$<0\ 02 \times 10^{-15}$	$0\ 079 \times 10^{-9}$	$<0\ 039 \times 10^{-9}$	0	0
Community[b] (maximum probable)	$<0\ 02 \times 10^{-15}$	$<0\ 008 \times 10^{-9}$	$<0\ 017 \times 10^{-9}$	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 The concentrations represent a reasonable set of values for maximum probable dose calculations The communities are those within 80 km (50 mi) of Rocky Flats

TABLE 23 Natural Radiation Background Dose for the Denver Metropolitan Area[a]

Source	Total Body[b] (mrem/yr)	Liver[b] (mrem/yr)	Bone (mrem/yr)	Lungs (mrem/yr)
Cosmic Radiation	50	50	50	50
Cosmic Radionuclides	0 7	0 7	0 8	0 7
External Terrestial	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

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 24 70-Year Dose Commitment From One Year of Chronic Intake Via Air and Water

Source	Total Body (mrem)	Liver (mrem)	Bone (mrem)	Lungs (mrem)
Site Boundary (maximum)	$<4\ 1 \times 10^{-2}$	$<5\ 0 \times 10^{-1}$	<1 3	$<1\ 6 \times 10^{-1}$
Site Boundary (maximum probable)	$<4\ 0 \times 10^{-3}$	$<4\ 7 \times 10^{-1}$	<1 2	$<1\ 2 \times 10^{-1}$
Community (maximum probable)	<2 6	<3 0	<7 3	<1 2
80 Kilometer*	$<2\ 6 \times 10^{-3}$	$<3\ 0 \times 10^{-1}$	$<7\ 3 \times 10^{-1}$	$<1\ 2 \times 10^{-1}$

*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 8)

FIGURE 1 Area Map of Rocky Flats Plant and Surrounding Communities

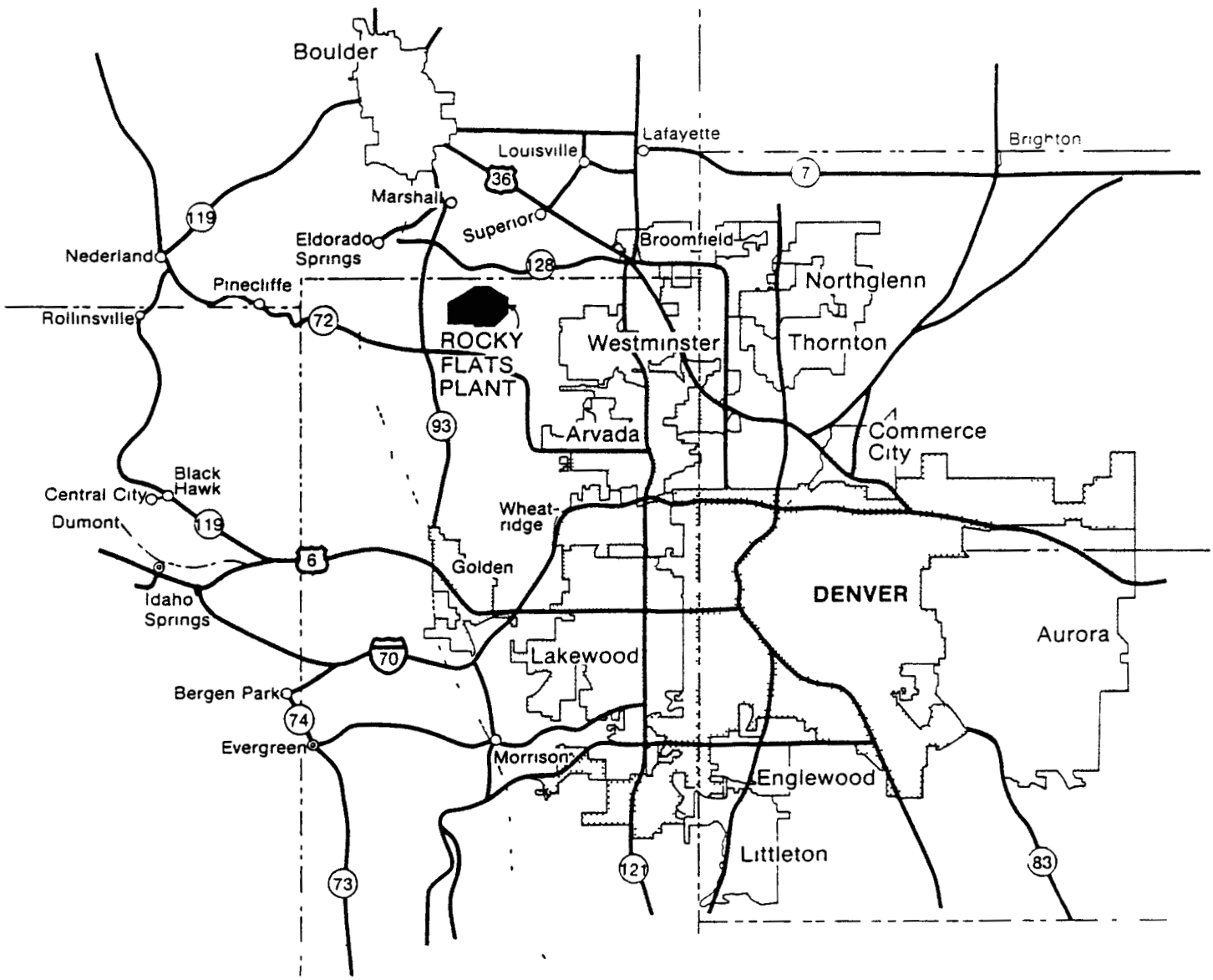

FIGURE 2 Map of the Rocky Flats Plant and Immediate Vicinity

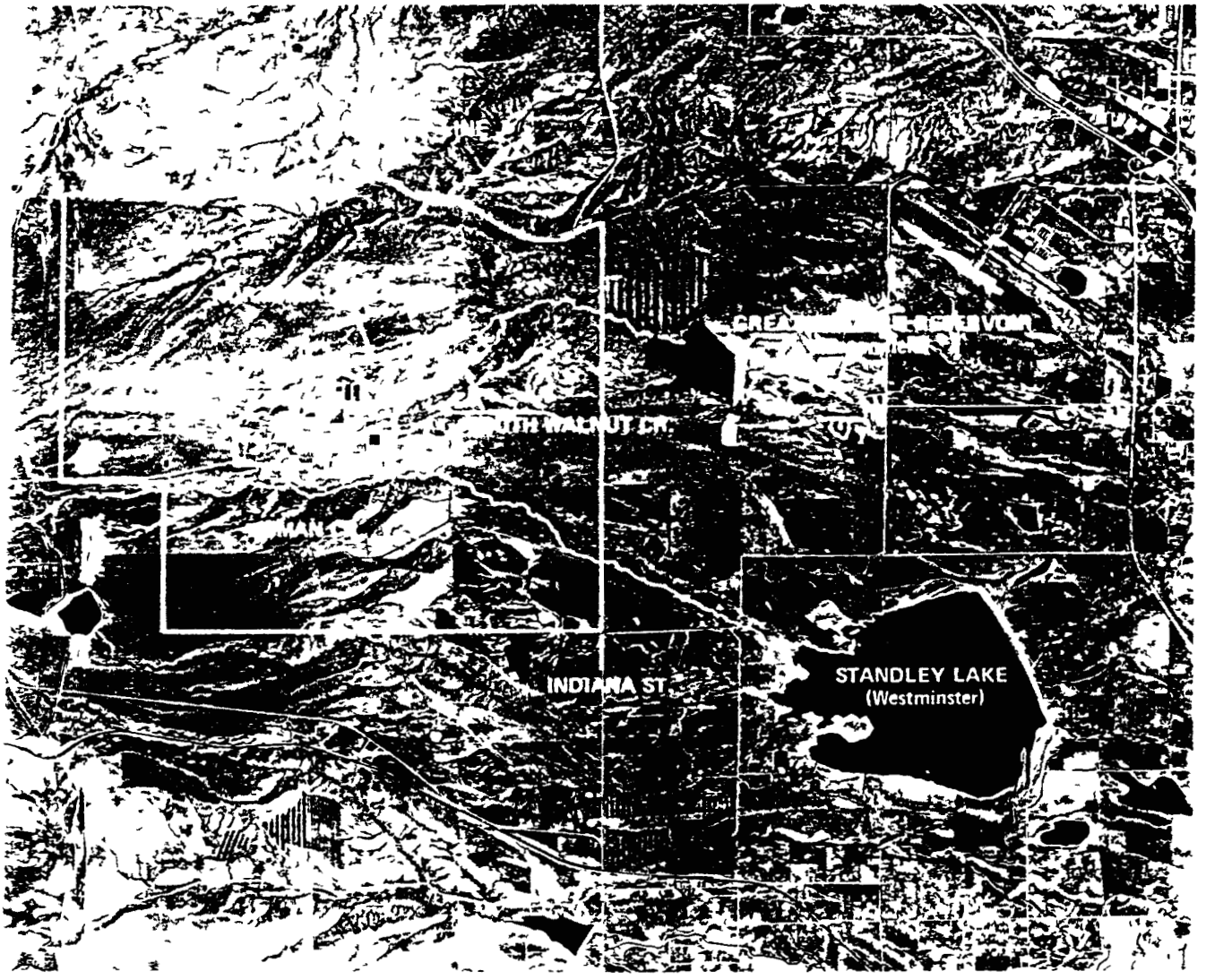

FIGURE 3 Holding Ponds and Liquid Effluent Watercourses

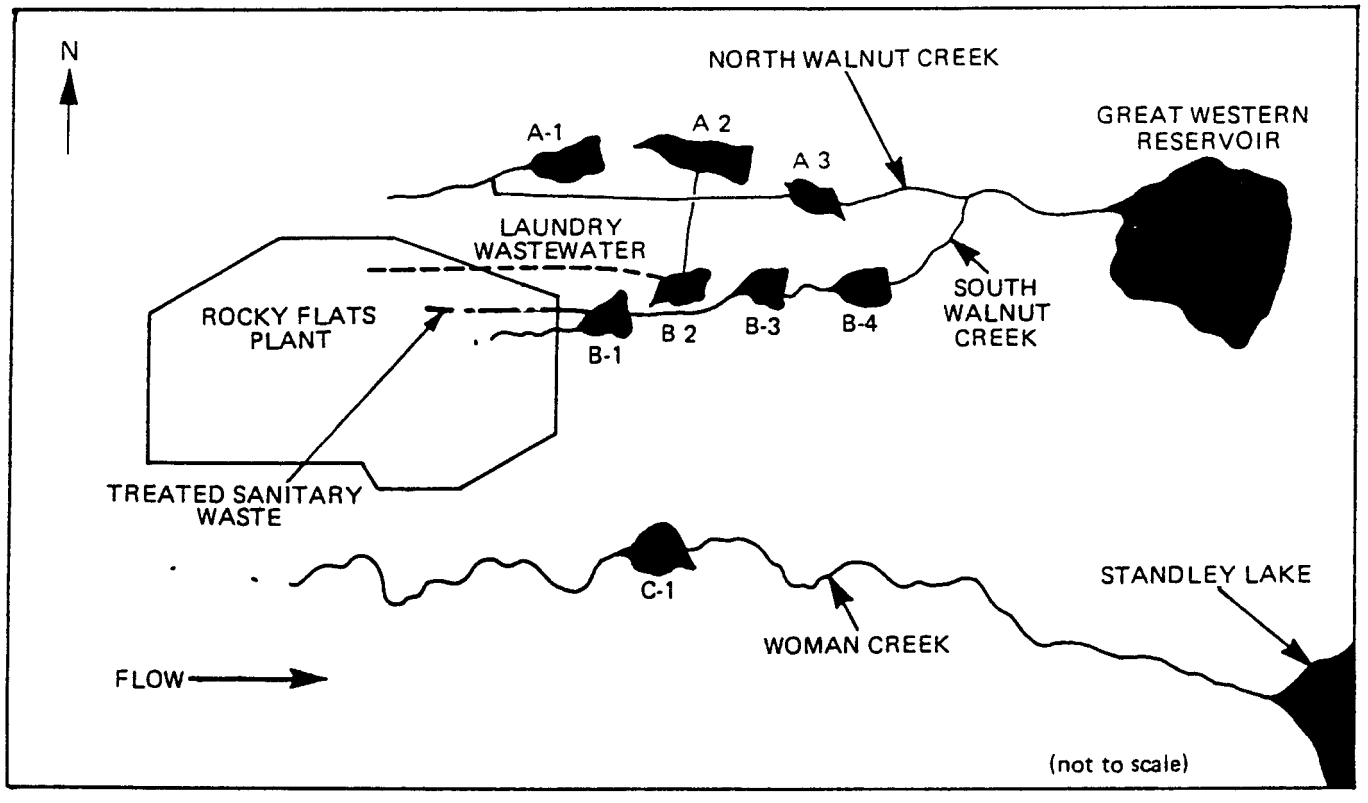

FIGURE 4 Typical Wind Rose for Rocky Flats Plant

NOTE This wind rose is derived from 1975 wind data which is the most recent data that typifies wind speed and direction of the previous 25 years

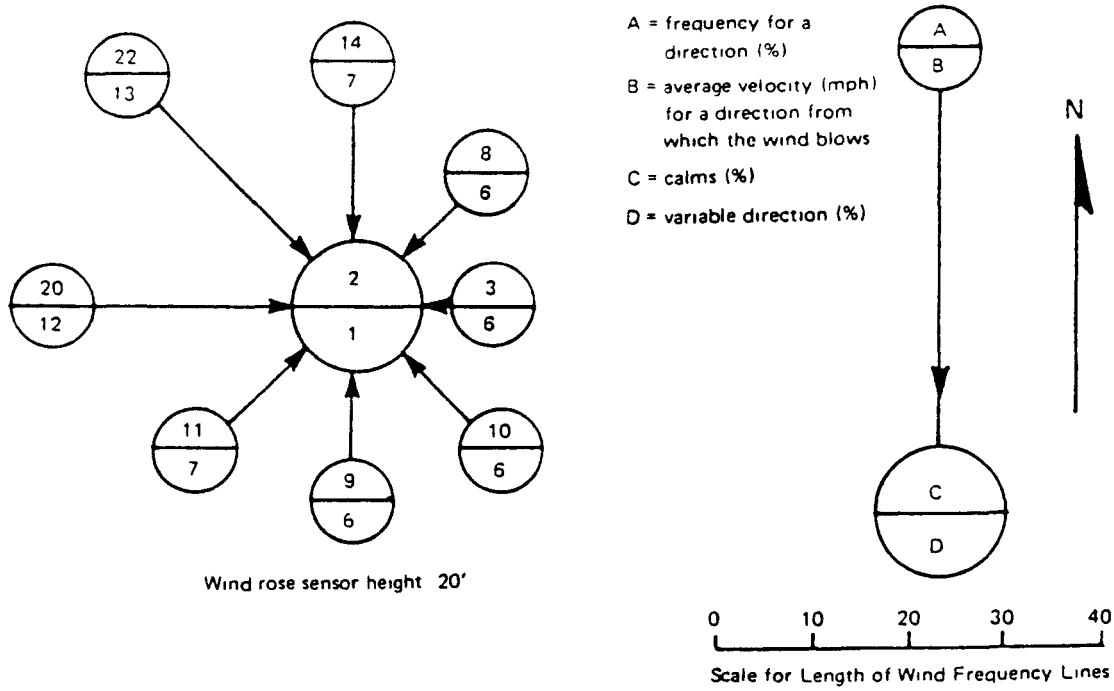

FIGURE 5 Location of On Site Ambient Air Samplers

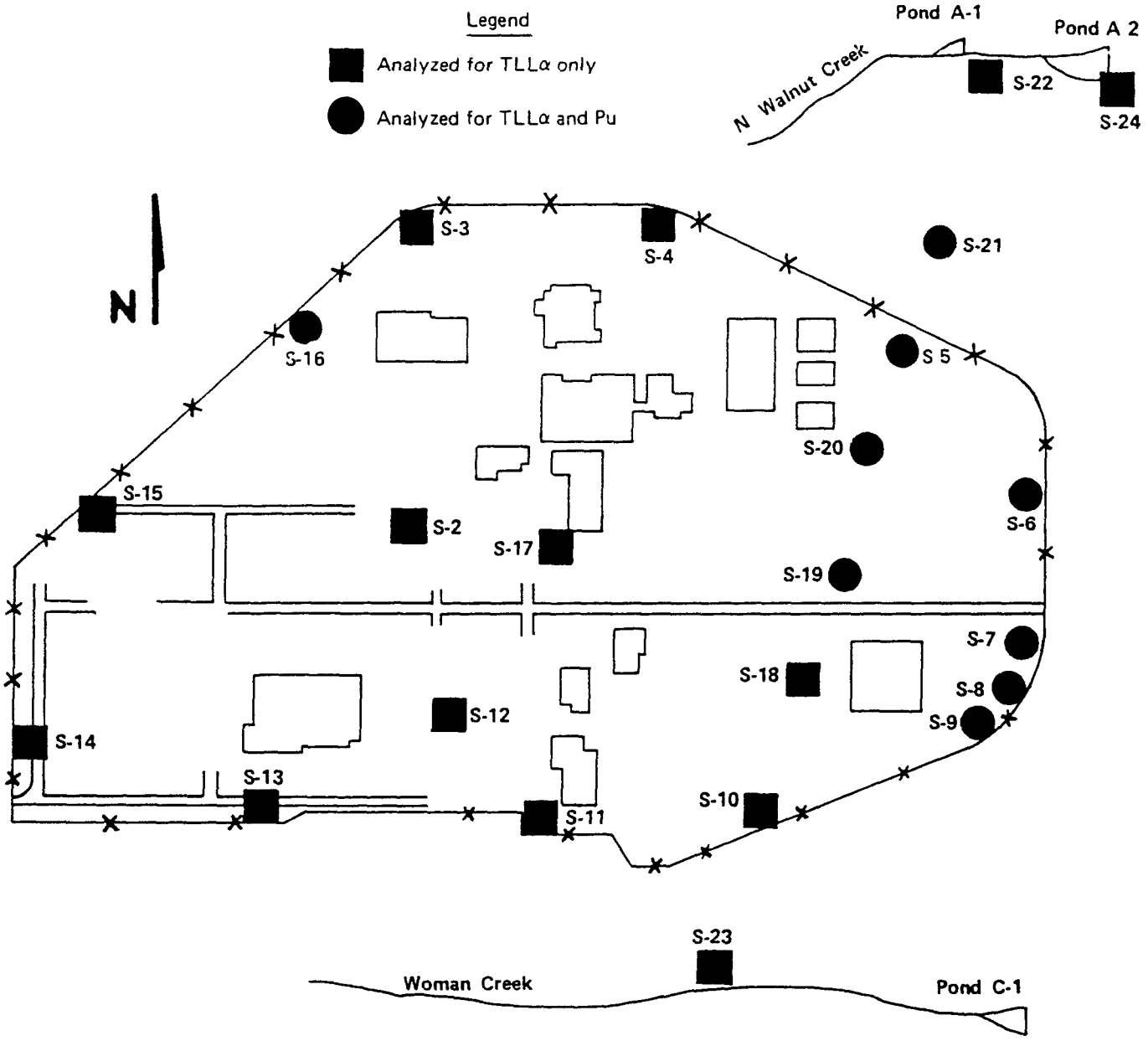

FIGURE 6 Location of Off Site Ambient Air Samplers

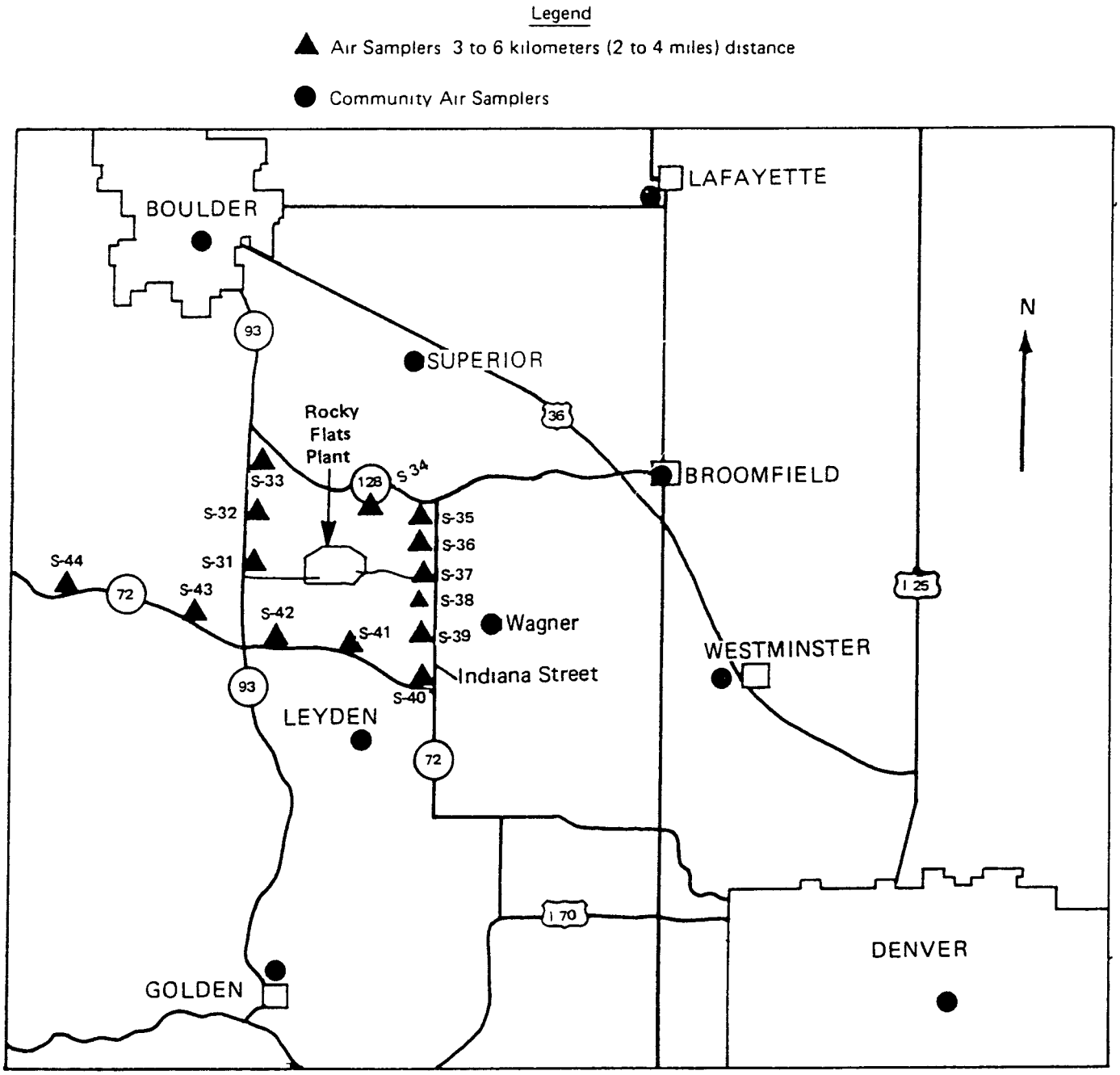

FIGURE 7 Location of Hydrologic Test Holes

Legend

● Test hole depth greater than 100 feet
△ Test hole depth less than 50 feet

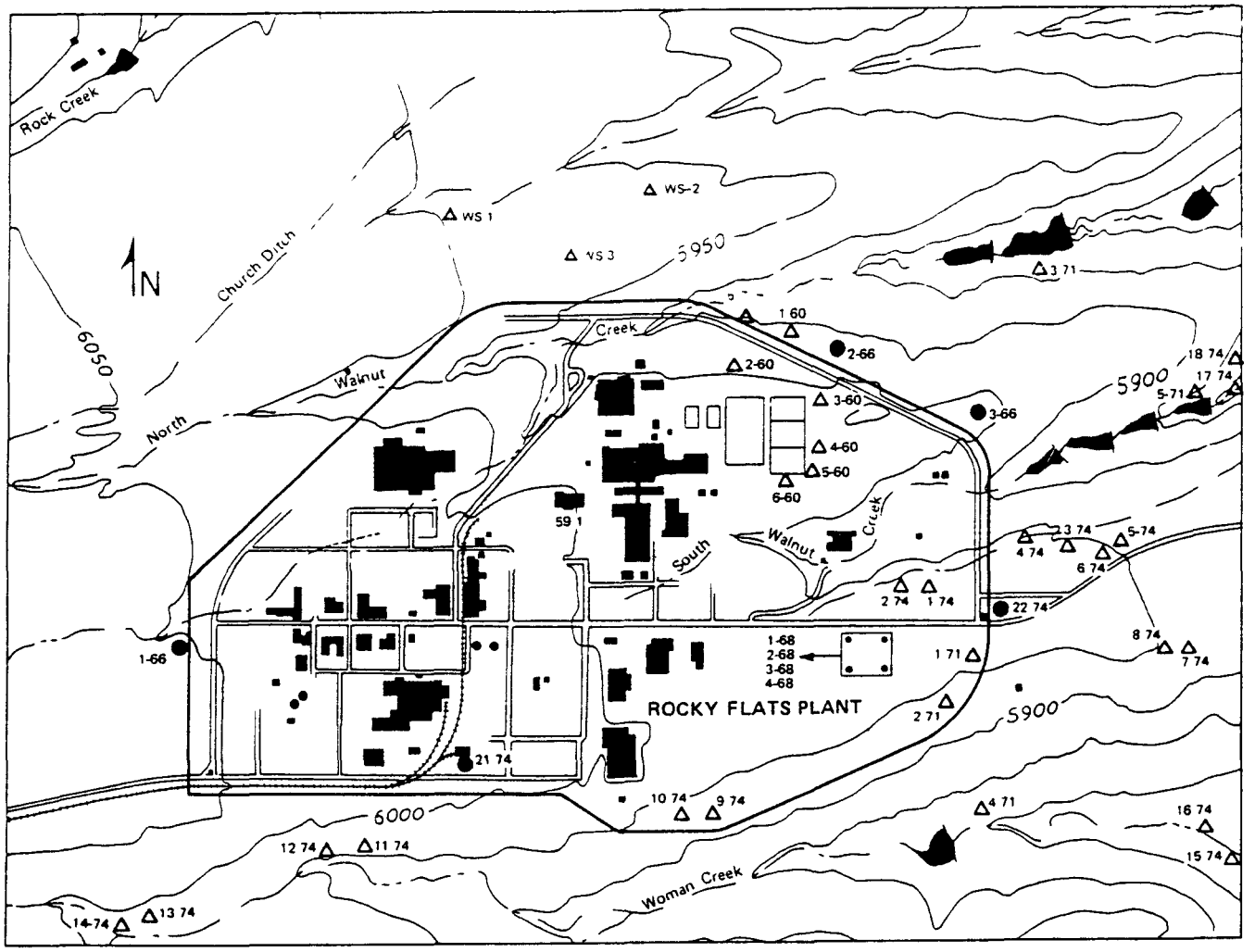

FIGURE 8 Location of Soil Sample Sites for 1979