



ANNUAL ENVIRONMENTAL MONITORING REPORT

JANUARY-DECEMBER 1985



Rockwell International

NORTH AMERICAN SPACE OPERATIONS
ROCKY FLATS PLANT



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ANNUAL ENVIRONMENTAL MONITORING REPORT
U S. DEPARTMENT OF ENERGY, ROCKY FLATS PLANT
January Through December 1985

ENVIRONMENTAL ANALYSIS AND CONTROL SECTION
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ROCKY FLATS PLANT VIEWED FROM THE EAST

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ABSTRACT

This report documents the environmental surveillance program at the Rocky Flats Plant, conducted by the Environmental Analysis and Control Section of the Environmental and Occupational Health 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. This report was prepared to fulfill reporting requirements of DOE Order 5484.1 and includes an evaluation of plant compliance with all appropriate guides, limits, and standards for radioactive and non-radioactive materials. Potential public dose commitments from radioactive effluents were calculated from average radionuclide concentrations measured at the plant property boundary and in surrounding communities. The radioactive and non-radioactive effluents from the Rocky Flats Plant meet the appropriate guides and standards and represent no adverse environmental effects from the operation of the plant during calendar year 1985. The estimated potential radiation doses to the public from plant effluents are well below background dose levels experienced in this region from natural and other non-plant sources.

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U. S. DEPARTMENT OF ENERGY, ROCKY FLATS PLANT**

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I 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 complex 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 North American Space Operations Group of Rockwell International.

The Rocky Flats Plant is located at 105°11'30" west longitude and 39°53'30" north latitude in northern Jefferson County, Colorado. The plant-site consists of 2,650 hectares (6,550 acres) of federally owned land. As shown in Figure 1, major plant structures are located within a security-tenced area of 155 hectares (384 acres). The plant is approximately 26 kilometers (16 miles) northwest of downtown Denver and is almost equidistant from the cities of Boulder, Golden, and Arvada (see Figure 2). Demographic estimates based on the 1980 census are shown in Figure 3. There is a population of approximately 2 million people within a 50-mile radius of the plant.

The plant is a key DOE facility that produces components for nuclear weapons, therefore, 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 metal fabrication and assembly, chemical recovery and purification of process-produced transuranic radionuclides, and related quality control functions. Research and engineering programs supporting these activities involve chemistry, physics, materials technology, nuclear safety, and mechanical engineering.

Approximately 129 structures on the plantsite contain approximately 244,685 square meters (2.63 million square feet) of floor space. Of this space, major manufacturing, chemical processing,

plutonium recovery, and waste treatment facilities occupy about 153,285 square meters (1.65 million square feet).

Major laboratory and research buildings occupy about 15,800 square meters (170,000 square feet). The remaining floor space is divided among administrative, utility, security, warehouse storage, and construction contractor facilities, and occupies about 75,600 square meters (814,000 square feet).

All of the plant heating requirements are met by in-plant steam boilers that normally use natural gas and are capable of using fuel oil. During CY 1985, approximately 17.5 million cubic meters (620 million cubic feet) of natural gas were used. Three million, seven hundred thousand liters (983,000 gallons) of fuel oil were used during 1985.

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 513 million liters (136 million gallons) of water during 1985.

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) from the plant. The natural environment of the plantsite and vicinity is influenced primarily by the Front Range of the Rocky Mountains and the site elevation, which is 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 (20- to 49-foot) thick layer of coarser, clayey gravel. This is underlain by an impermeable bedrock structure upon which plant building foundations are supported. Area hydrology is influenced by the topsoil, which consists of gravelly and highly permeable alluvium. Water retention in the soil is poor, and vegetation in the area is sparse. Cacti, Spanish bayonet, and grasses

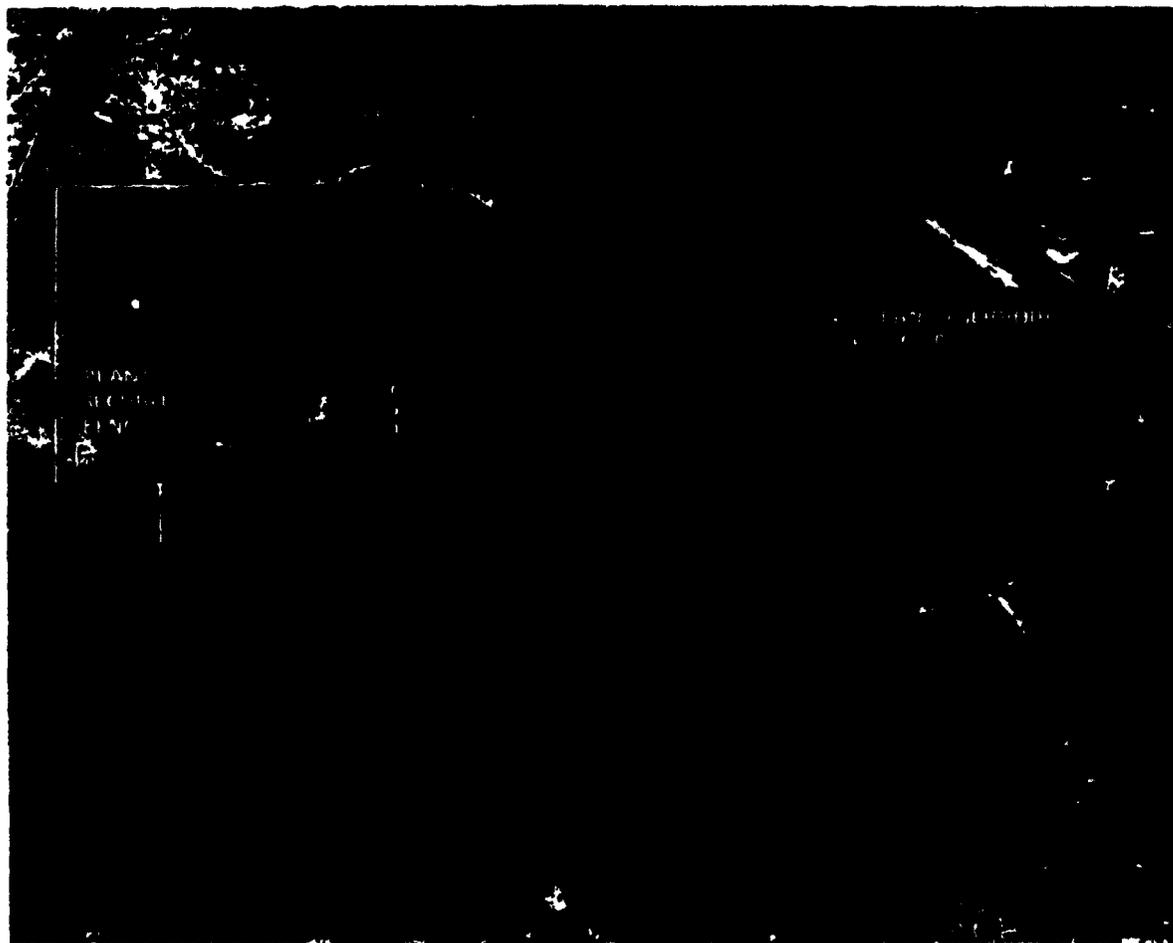


FIGURE 1 Aerial Photograph of the Rocky Flats Plant and Immediate Vicinity

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representative of a mixed short- and mid-grass plain constitute the main ground cover. Introduced Eurasian weeds also make up part of the flora. Cottonwood trees grow adjacent to watercourses.

The climate at Rocky Flats is characterized by dry cool winters with some snow cover and warm somewhat moist summers. There is considerable clear-sky sunshine and the average precipitation and relative humidity are low. The elevation of the plant and the major topographical features of the area significantly influence climate and meteorological dispersion characteristics of the site.

Winds at Rocky Flats although variable are predominantly northwesterly with stronger winds occurring during the winter. During 1985 approximately 60 percent of the winds had a westerly component.

Annual average precipitation at the Rocky Flats Plant is slightly over 38.5 centimeters (15.16 inches). The maximum annual precipitation recorded over a 24-year period was 63.17 centimeters (24.87 inches) in 1969. The annual precipitation during 1985 was 32.97 centimeters (12.9 inches). Typically, more than 80 percent of the precipitation falls as rain between April and

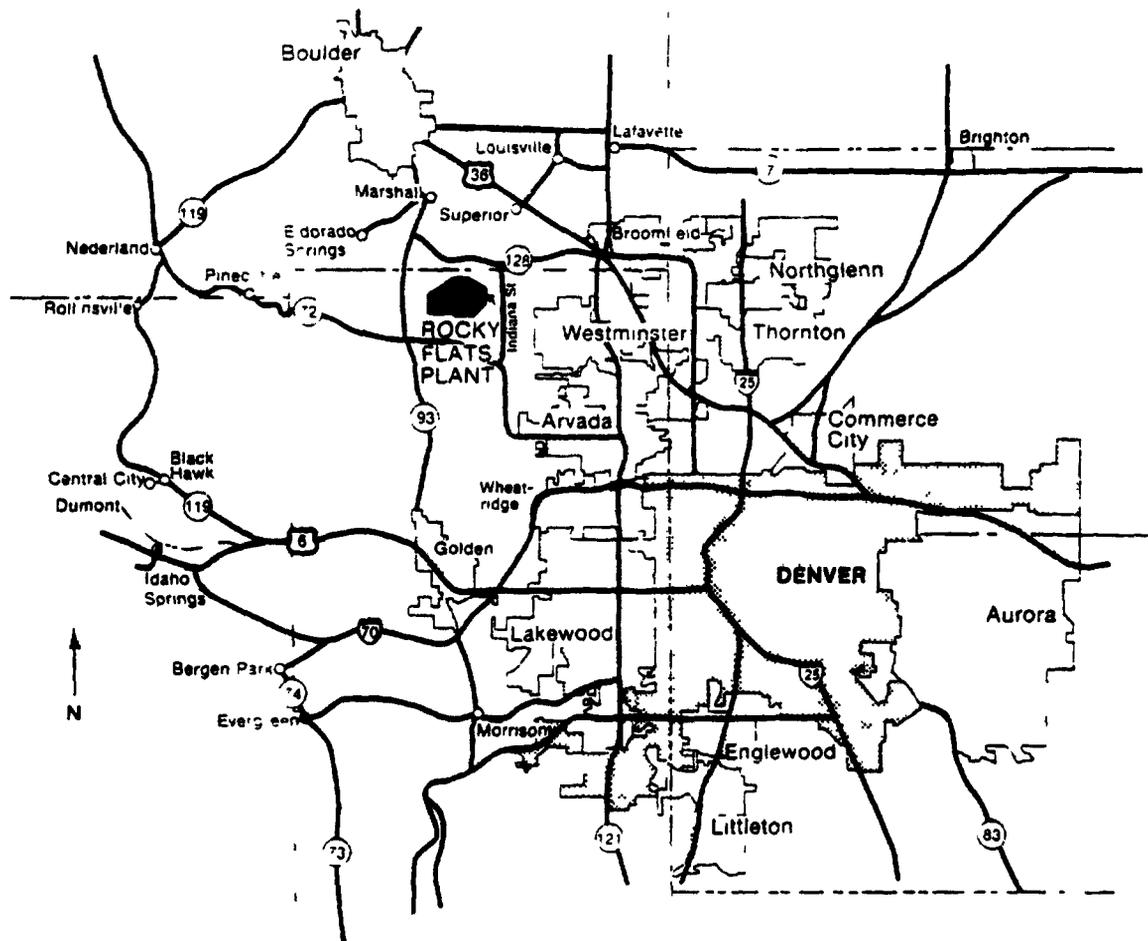


FIGURE 2 Area Map of Rocky Flats Plant and Surrounding Communities

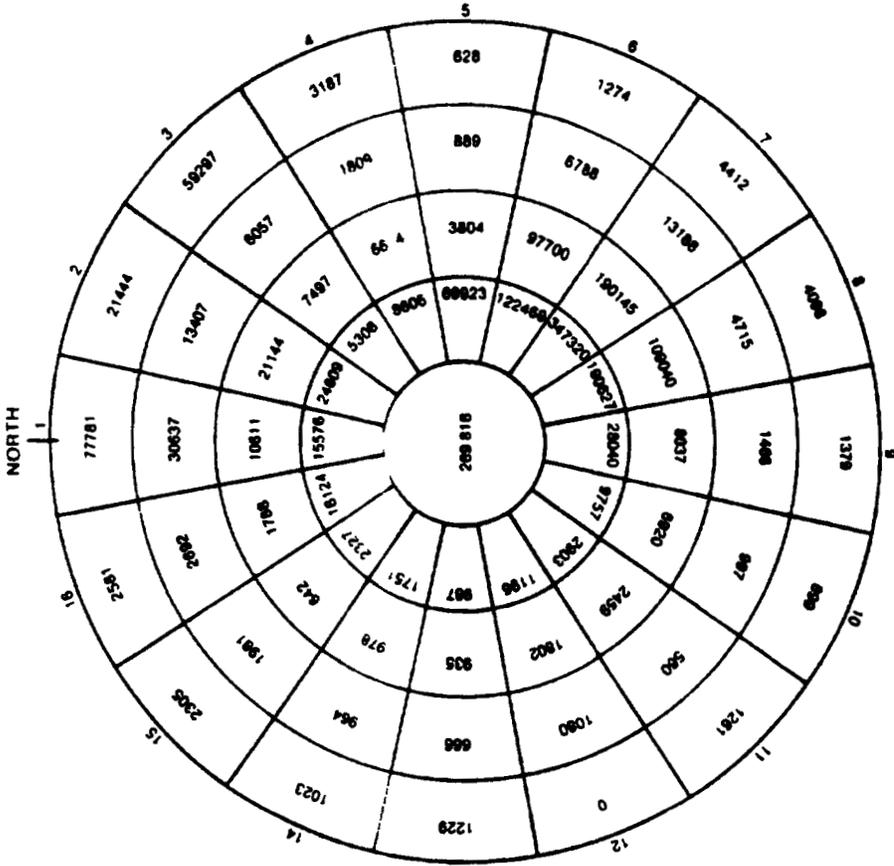
September Most of the remaining precipitation is in the form of snow

Air from production and research facilities is continuously discharged to the atmosphere by 43 ventilation exhaust systems. Prior to atmospheric discharge, the exhaust air passes through particulate filtration systems. These filtration systems employ High Efficiency Particulate Air (HEPA) filters that are purchased to equal or exceed the DOE specified filtration efficiency standard of 99.97 percent for 0.3- μ m particles. Prior to installation in the filter plenums, each filter is tested at the

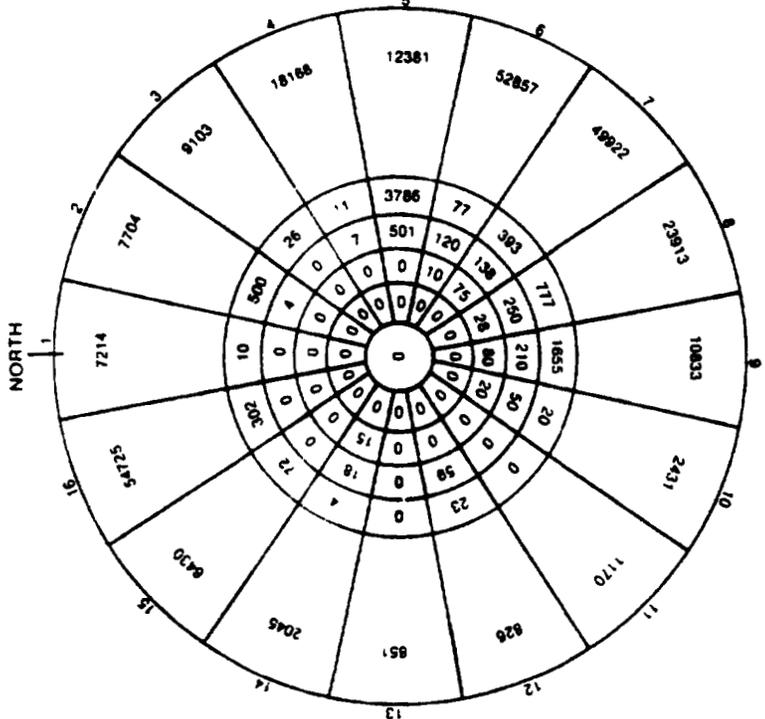
plant to ensure that the filtration efficiency is not less than the standard. Airborne radioactivity released to the environment from process operations is kept to a minimum and is well within plant health and safety guidelines.

As shown in Figure 4, 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 receives most of the stormwater runoff from areas surrounding plant buildings.

FIGURE 3 Demographic Estimates 1980^a



10-50 Kilometers (10-50 miles) From Rocky Flats^b



0-10 Kilometers (0-10 miles) From Rocky Flats^b

- a. These population estimates (0-16 kilometers) were calculated from 1980 Census Tract Data assuming even population distribution throughout the sector
- b. Concentric circles represent 1-to-2, 2-to-3, 3 to-4, 4-to-5 and 5-to-10-mile mileage bands
- c. Concentric circles represent 10-to-20, 20-to-30, 30-to-40, and 40-to-50-mile mileage bands

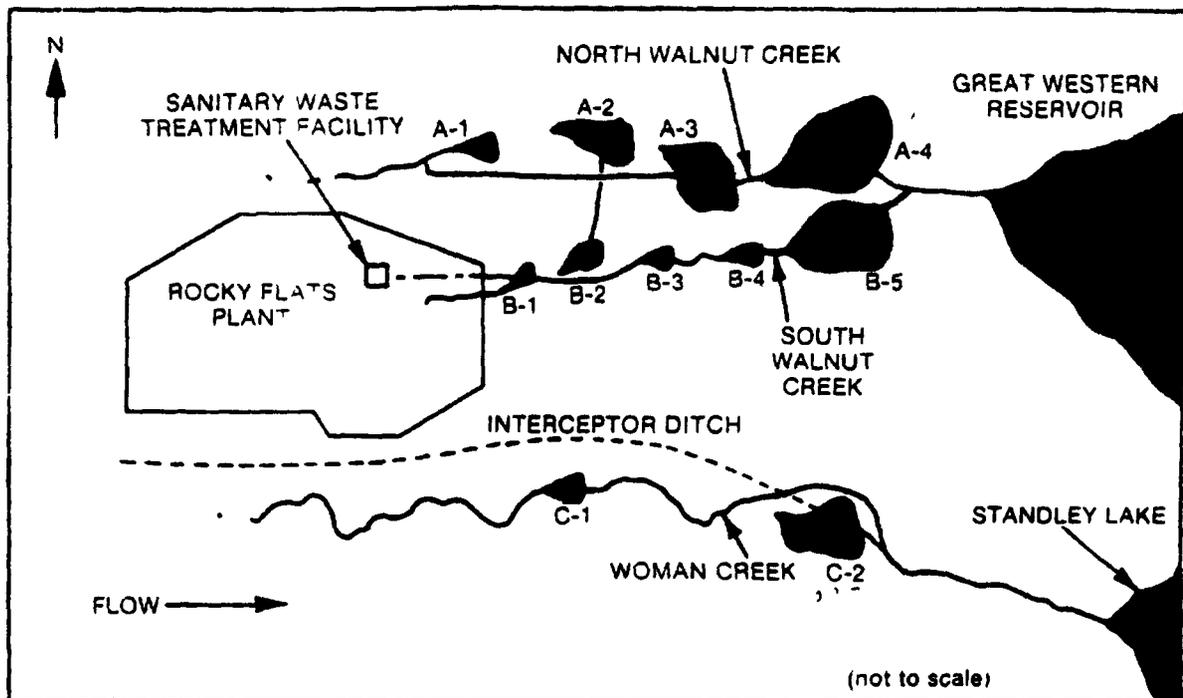


FIGURE 4 Holding Ponds and Liquid Effluent Watercourses

Also shown in Figures 1 and 4 is the confluence of the north and south forks of Walnut Creek which is 11 kilometers (0.7 mile) west of the eastern perimeter of the plant. Great Western Reservoir, a water supply for a part of the City of Broomfield, is 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 through A-4. Ponds on the south fork are designated B-1 through B-5. These ponds receive runoff and/or treated sanitary wastewater. Pond C-1 is located on the Woman Creek watercourse. Pond C-2, located near the Woman Creek watercourse, receives surface runoff water from an interceptor ditch parallel to the south side of the plant production areas.

Certain operations at the Rocky Flats Plant involve or produce liquids, solids, and gases containing radioactive materials. Radioactive materials are

handled in accordance with stringent procedures and within multiple containments (physical barriers) designed to minimize the release of contaminants to the workplace and the environment. The radioactive waste systems include collection, filtration, liquid processing and temporary storage facilities for those process wastes known, or suspected to have been in contact with radioactive materials. The liquid waste process system concentrates liquid wastes containing unrecoverable radioactive materials into solid wastes suitable for shipment along with other contaminated solid wastes to a DOE-approved storage facility. Specific details of plant waste processing facilities are described in the Rocky Flats Plant Site Final Environmental Impact Statement.¹

Sanitary waste is processed by the sanitary waste treatment plant and is isolated from process waste throughout the plant. Conditioning chemicals are added to assist in the destruction of biologically degradable organic waste. The treatment plant is of the activated sludge type and has three stages of

treatment. It has a design capacity of 946 250 liters (250 000 gallons) per day. Present daily flows usually vary between 757 000 and 1 135 500 liters (200 000 and 300 000 gallons) per day. One of two 265 000-liter (70 000-gallon) pre-aeration holding tanks located upstream from the sewage plant, serves as a surge basin to smooth out peak flows. A second holding tank provides storage capacity for sanitary wastes should emergency retention be required. Liquid effluents from the sanitary waste treatment plant can be released to Walnut Creek, released to holding ponds for subsequent onsite irrigation, or pumped to a reverse osmosis facility for further treatment. After treatment, product water from the reverse osmosis facility can be recycled for use in plant cooling towers, spray irrigation, or may be released to Walnut Creek. The plant is meeting the Clean Water Act's zero discharge goal with respect to downstream discharges except when storm events prevent effective spray irrigation activities.

Residual solids from the sanitary waste treatment plant are concentrated, dried, packaged, and shipped to a DOE-approved waste facility in Nevada. Reverse osmosis brine is sent to process waste treatment for evaporation and drying, and the salts are packaged and shipped to the same DOE-approved waste facility in Nevada.

Nonradioactive solid wastes are transferred to an onsite sanitary landfill for disposal. This landfill was designed and constructed in 1974 with an impervious clay seal layer and surface water diversion ditches. Routine materials are checked daily for radioactivity at the landfill site before final burial. The disposal of nonroutine or special nonradioactive waste materials is administratively controlled.

Groundwater and surface water flow in and around the sanitary landfill is controlled by interceptor trenches and by engineered drains. The trenches divert all upgradient waters around the landfill. The drains collect groundwater from the perimeter of the landfill and divert it into a holding pond. The holding pond collects subsurface drainage from the landfill. Water samples from this holding pond, the drains, and the three test wells in the vicinity are collected periodically and are analyzed for a series of parameters including radioactivity.

Land use at the Rocky Flats Plant is managed by Rockwell International for the Department of Energy. This includes land utilization planning and environmental and physical control of the land. Since 1977, all major activities conducted on plantsite land have required approval by the Rockwell Executive Committee based upon the recommendations of a Land Management Coordinator. The Coordinator evaluates all research projects and other nonroutine activities on plant lands by means of a Land Use Request system. The effects of such activities are evaluated by Environmental Analysis and Control personnel through field observations and remote sensing techniques.

Personnel in the Environmental and Occupational Health Branch of Rockwell International conduct an extensive environmental surveillance program at the plant. Environmental and Occupational Health personnel assist 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."² The surveillance program is designed to provide assurance that the many safeguards at the plant effectively limit the release of radioactive or toxic materials. The results of this environmental monitoring program indicate that effluent treatment and control processes at the plant were effective during 1985.

The Rocky Flats environs are monitored for penetrating ionizing radiation and for pertinent radioactive, chemical, and biological pollutants. Air, water (both surface and ground), soil, and vegetation are sampled on the plantsite and throughout the surrounding region. Several Federal, State, and local governmental agencies independently conduct audits and additional environmental surveys on and off the plantsite. The Colorado Department of Health samples air, soil, and water at the Rocky Flats site and in surrounding communities. It also operates an onsite continuous, particulate air sampler for the Jefferson County Health Department. The DOE Environmental Measurements Laboratory (EML) has conducted particulate air sampling at the Rocky Flats Plant and periodically performs special studies, including sediment and soil analyses. Additional special analyses have been performed.

by Region VIII of the U. S. Environmental Protection Agency (EPA)

Plutonium concentrations in this report represent the alpha radioactivity from plutonium isotopes 239 and 240, which constitute over 97 percent of the alpha radioactivity in plutonium handled at the plant. Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Components containing fully enriched uranium metal are handled at the Rocky Flats Plant. Depleted uranium metal is fabricated and also is handled as process waste material. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium, however, uranium -234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium the combined alpha activity from uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity. The Derived Concentration Guides (DCGs) used in this report for uranium in air and water are those for uranium-233, -234, and uranium-238 which are the most restrictive.*

The information contained in this report is submitted in compliance with DOE Order 5484 1, Chapter IV and is a compilation of data provided monthly to the DOE Rocky Flats Area Office, the Radiation 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 from communities near the plant.

II SITE METEOROLOGY AND CLIMATOLOGY

Wind, temperature, and precipitation data were collected on the plantsite during 1985. Table 1 is the 1985 annual summary of the percent frequency of wind directions (16 compass points) divided into four speed categories. The compass point designations indicate the true bearing when facing against the wind. These frequency values are represented graphically in Figure 5. The wind rose vectors also represent the bearing against the wind (i.e., wind along each vector blows toward the center). The predominance of northwesterly winds

*The Derived Concentration Guides used throughout this report were calculated using the methodology described in Appendix A.

TABLE 1 Wind Direction Frequency (Percent), by Four Wind-Speed Classes, at the Rocky Flats Plant

(Fifteen Minute Averages--1985^a)

	Calm	1-3 (m/s) ^b	3-7 (m/s)	7-15 (m/s)	>15 (m/s)	TOTAL
-	1.33	-	-	-	-	1.33
N	-	2.98	3.56	0.40	0.00	6.95
NNE	-	3.19	2.40	0.33	0.00	5.91
NE	-	2.79	1.15	0.02	0.00	3.95
ENE	-	2.45	0.62	0.00	0.00	3.07
E	-	2.66	0.54	0.00	0.00	3.20
ESE	-	2.57	1.45	0.01	0.00	4.02
SE	-	2.92	2.68	0.03	0.00	5.64
SSE	-	2.78	3.25	0.14	0.00	6.16
S	-	2.58	2.67	0.15	0.00	5.40
SSW	-	2.72	2.62	0.19	0.00	5.53
SW	-	2.36	2.52	0.20	0.00	5.08
WSW	-	2.85	4.87	0.81	0.00	8.53
W	-	3.46	3.16	1.79	0.26	8.67
WNW	-	3.13	3.94	4.59	0.58	12.24
NW	-	2.63	3.48	1.39	0.03	7.54
NNW	-	2.70	3.43	0.53	0.00	6.67
TOTALS	1.33	44.77	42.34	10.57	0.87	100.00

a. Data obtained from sensors located ~10 m (33 ft) above the ground.
 b. For conversion purposes, miles per hour (mph) equals 2.237 multiplied by meters per second (m/s).

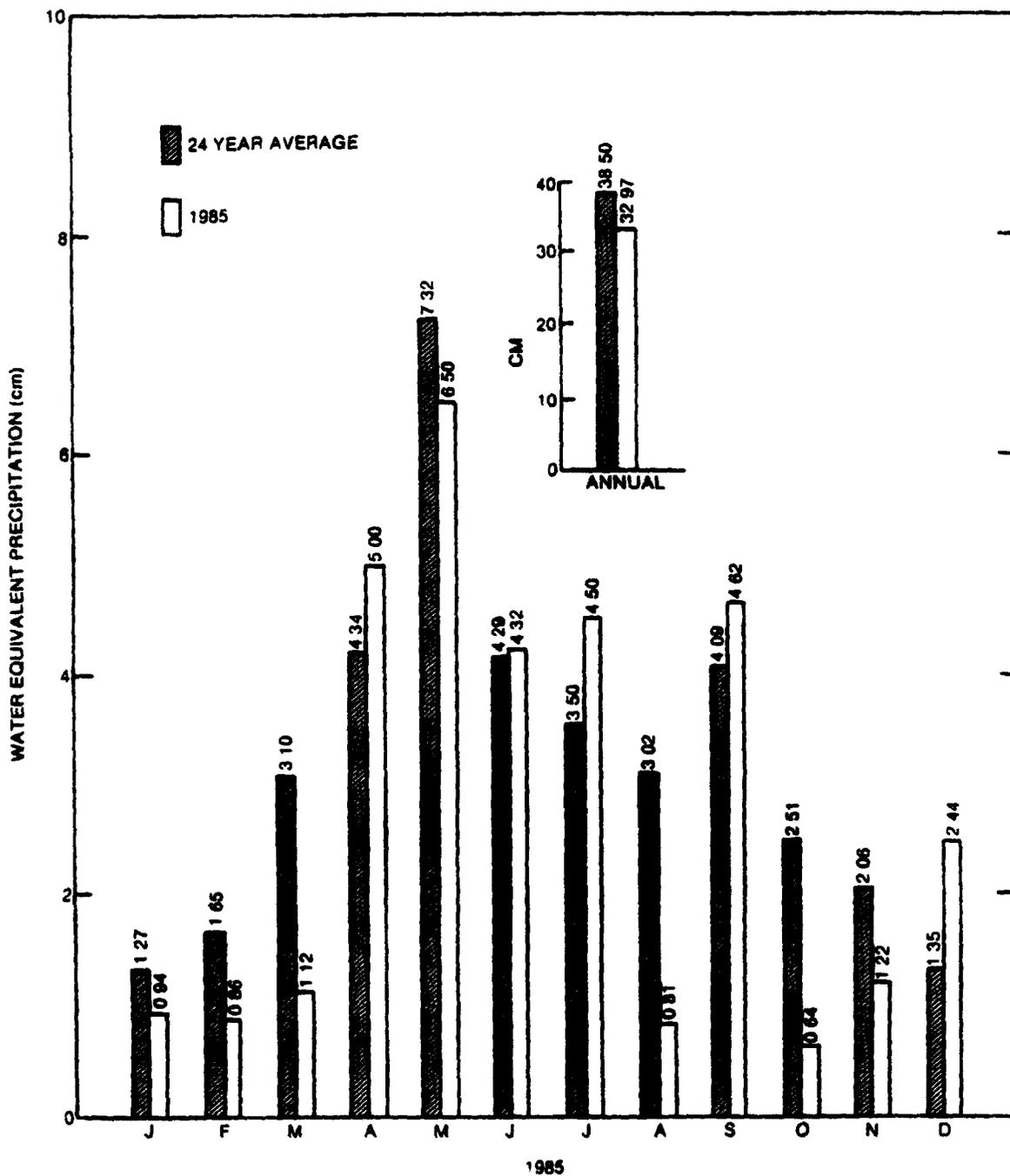
is typical of Rocky Flats. The low frequency of winds greater than 7 meters per second (15.6 mph) with easterly components is also normal.

Monthly averaged daily maximum temperatures were above normal between the months of March and June. The remaining eight months showed below normal daily maximum temperatures. Monthly average daily minimum temperatures were above normal between the months of March and June, normal for August and below normal for the remaining seven months of 1985.

A summary of monthly water-equivalent precipitation is shown in Figure 6, along with the 1953-1976 monthly averages for comparison. Precipitation was below normal during seven months of the year and April, June, July, September, and December were the only months

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FIGURE 6 Monthly and Annual Water-Equivalent Precipitation at the Rocky Flats Plant



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with normal or above normal precipitation. The annual precipitation of 32.97 centimeters (12.98 inches) was 14 percent below the 24-year mean of 38.50 centimeters.

III MONITORING SUMMARY

During 1985, the Rocky Flats Plant conducted an environmental monitoring program that included the sampling and analysis of airborne effluents, ambient air surface and groundwater, and soil. External penetrating gamma radiation exposures were also measured using thermoluminescent dosimeters. The monitoring program consists of collecting samples from onsite, boundary, and offsite locations. Ambient air quality monitoring and monitoring of water for trace quantities of toxic materials, metals, nitrates, biocides, herbicides, volatile organic compounds (VOCs), and polychlorinated biphenyls (PCBs) also were performed. Specific details of the routine Rocky Flats Environmental Monitoring Program are documented in the 'Catalogue of Monitoring Activities at Rocky Flats'.³

Several environmental permits have been issued to the plant by Federal and State agencies. Currently, the following permits are in "Active" status:

National Pollutant Discharge Elimination System Permit CO-0001333, issued by the U.S. Environmental Protection Agency, December 26, 1984.

Building 122 Incinerator Permit C-12, 931, issued by the Colorado Department of Health, March 25, 1982.

Building 771 Incinerator Permit C-12, 932, issued by the Colorado Department of Health, November 3, 1981.

Building 776 Fluid Bed Incinerator Permit C-13, 922, issued by the Colorado Department of Health, March 25, 1984.

Fugitive Dust Emission Permit 85JE052L for remedial action program, issued by

Colorado Department of Health on May 28, 1985.

Particulate and tritium sampling of building exhaust systems was conducted continuously. Overall, 1985 emission data were in the ranges projected in the Plant Impact Statement¹ and presented no significant insult to the environment.

Particulate samples are collected from ambient air samplers operated continuously onsite at the plant perimeter, and in fourteen community locations. Analysis of the samples indicated that the concentrations of airborne plutonium at all locations were far below the DOE interim standard DCGs for the 100 mrem limit for continuous exposures. (See Appendix A.) At the plant perimeter and at the community locations, the 1985 average plutonium concentrations in ambient air were 0.01 percent of the DOE interim standard DCGs.

During 1985, monitoring of ambient air for total suspended particulates (TSP), ozone (O₃), sulfur dioxide (SO₂), carbon monoxide (CO), nitrogen dioxide (NO₂), and lead (Pb) was conducted utilizing a self-contained, Mobile Ambient Air Monitoring (MAAM) van. These six parameters are criteria pollutants regulated by the EPA and the State of Colorado through the Clean Air Act of 1970 that includes the National Ambient Air Quality Standards (NAAQS).⁴ For TSP, the calculated annual geometric mean was 37 percent of the annual primary geometric mean standard prescribed by the NAAQS. The highest one-hour concentration of O₃ was 158 percent of the EPA primary one-hour standard. This value was consistent with levels reported in the Denver Metropolitan area. For SO₂, the annual arithmetic mean was 10 percent of the EPA annual primary mean standard. The maximum one-hour concentration of CO was 18 percent of the EPA primary one-hour standard. The arithmetic mean of the NO₂ concentrations for 1985 was 22 percent of the EPA annual primary mean standard. The quarterly lead concentrations measured during 1985 were less than 3 percent of the EPA quarterly standard.

The majority of the water used during 1985 for plant process operations and sanitary purposes was

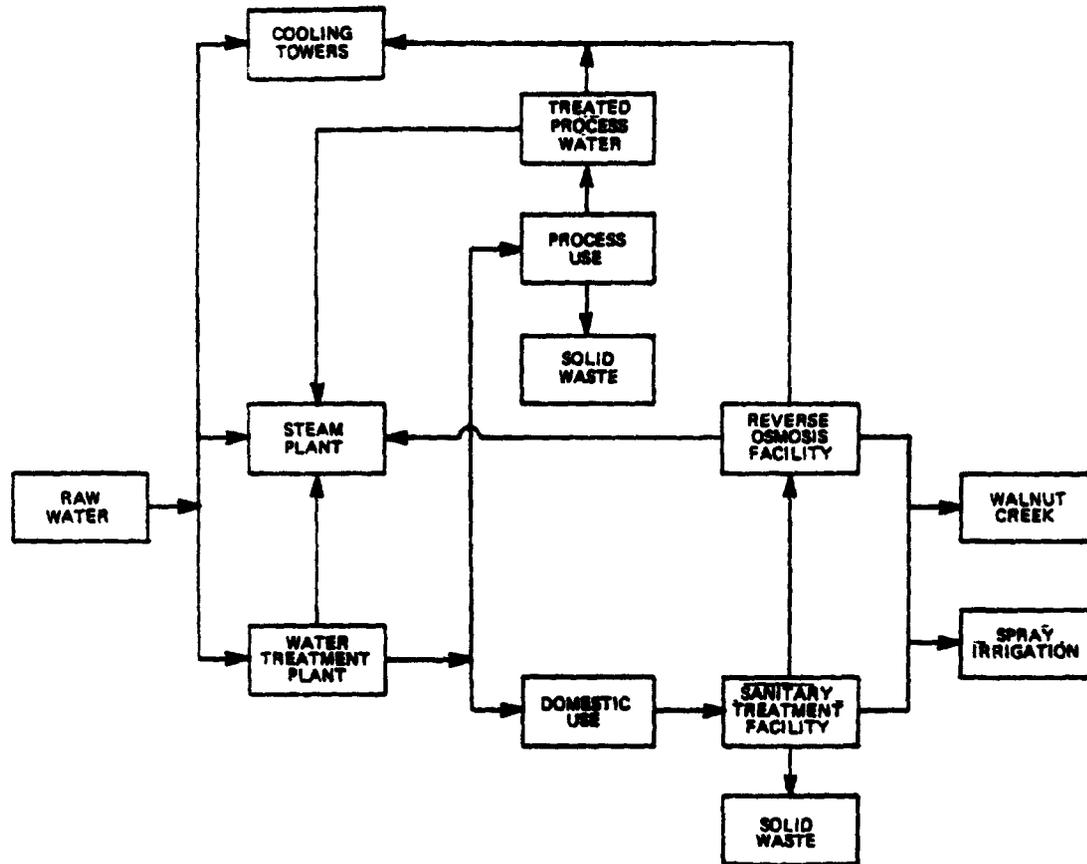


FIGURE 7 Water Use at the Rocky Flats Plant

treated and evaporated and/or reused for cooling tower makeup, steam plant use, or for spray irrigation within the plant boundaries. A schematic diagram of water use is shown in Figure 7.

Surface runoff from precipitation is collected in surface water control ponds. After monitoring, this water is discharged offsite. These discharges are monitored for compliance with an EPA National Pollutant Discharge Elimination System (NPDES) permit.⁵ During 1985, the Rocky Flats Plant had one technical violation of its NPDES permit which resulted in no offsite impact.

Routine water monitoring is conducted for two downstream reservoirs and for drinking water sources in nine communities. The average radioactivity concentrations for plutonium, uranium,

americium, and tritium measured at these locations were found to be 0.4 percent or less of the DOE interim standard DCGs for water. (See Appendix A.) The sum of the average concentrations for plutonium and americium in all community drinking water samples was 0.2 percent or less of the State of Colorado regulations for alpha-emitting radionuclides⁶ and the EPA National Interim Primary Drinking Water Regulations.⁷ Average concentrations of tritium in community drinking water samples were all within local background range and were 10 percent or less of the applicable State of Colorado and EPA drinking water standards.^{6, 7}

Groundwater monitoring was conducted during 1985 at 56 sampling locations. Concentrations of plutonium, uranium, americium, and tritium at all

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locations were well below the calculated DOE interim standard DCGs for surface water discharged to uncontrolled areas

Biocides and herbicides are used for pest and weed control at the Rocky Flats Plant. Water samples collected during the period of application indicated concentrations of the chemicals were well below recommended concentration limits. Also, polychlorinated biphenyl (PCB) monitoring showed no concentrations in excess of the analytical detection limit (one part per billion).

Soil samples were collected in 1985 from 40 sites located on radii from Rocky Flats at distances of 1.6 and 3.2 kilometers (1 and 2 miles). The purpose of the program was to determine if there had been any changes in plutonium concentrations in the soil around the plant since the last similar set of samples was collected in 1977. This program was reinitiated during 1984 after completion of the migration and the EPA-comparison studies. The plutonium concentrations in the samples were in the range of from 0.01 to 2.5 pCi/g (0.37 to 18.5 Bq/kg) which is almost identical to the soil data reported in 1977. This program will be repeated annually to demonstrate that additional contamination has not been released to the environment by plant operations.

The 1985 environmental measurement of external penetrating gamma radiation using thermoluminescent dosimeters (TLDs) showed that the annual dose equivalent onsite at the plant perimeter, and at community locations was within the range of regional background.

Potential public radiation dose commitments, which could have resulted from plant operations, were calculated from average radionuclide concentrations measured at the Rocky Flats Plant property boundaries and in surrounding communities. Dose assessment for 1985 was conducted for the property (site) boundary, nearby communities, and to a distance of 80 kilometers (50 miles). At the plant boundary, the maximum 50-year dose commitment to an individual was calculated to be 6×10^{-6} rem (6×10^{-6} Sv*) effective dose equivalent and 9×10^{-3} rem (9×10^{-5} Sv) to bone surfaces. By comparison, annual effective dose equivalent from

the natural radiation in the Denver area is about 2.6×10^{-1} rem (2.6×10^{-3} Sv) annually. The 50-year dose commitment of 6×10^{-6} rem represents 0.6 percent of the DOE interim radiation protection standard of 0.1 rem effective dose equivalent for all pathways. If all of the dose were received from the air pathway, the bone surfaces dose of 9×10^{-3} rem would represent 12 percent of the air emission standard for an organ.¹¹

For community locations, the maximum radiation dose resulted in a 50-year dose commitment of 3×10^{-5} rem (3×10^{-7} Sv) effective dose equivalent and 6×10^{-4} rem (6×10^{-6} Sv) to bone surfaces. These values represent 0.03 percent of the DOE interim standard for effective dose equivalent and 0.8 percent of the air emission standard for any organ from the air pathway only.¹¹ These values include contributions from fallout caused by atmospheric weapons testing. The 50-year committed effective dose equivalent to the population living within 80 kilometers (50 miles) of the plant was based on the maximum community dose estimates. For the community, the maximum effective dose equivalent and the specific organ doses were all less than the 1×10^{-3} rem dose equivalent specified by DOE as *de minimis* (inconsequential).¹² The dose commitment for all individuals to a distance of 80 kilometers, was therefore considered to be *de minimis*.

IV MONITORING DATA COLLECTION ANALYSES, AND EVALUATION

This section describes Rockwell International's environmental monitoring program for 1985, results of sample analyses, and evaluation of the data with regard to applicable guides and standards. The reader is directed to the appendixes at the end of this report for detailed information concerning applicable guides and standards, quality control, analytical procedures, detection limits, error term propagation, and reporting of minimum detectable concentrations. Appendix I includes a discussion of the methodology used for reporting measurements that were at or below the minimum detectable concentrations (MDC) and the inclusion of negative values in reported data. This appendix

*1 Sv (Sievert) = 1.1×10^{-2} rem

also discusses the use of the less-than sign (<) and defines the use of plus or minus (\pm) error terms in the data

A Airborne Effluent Monitoring

Production and research facilities at Rocky Flats are equipped with 43 ventilation exhaust systems. Particulates generated by production and research activities are entrained by exhaust air streams. These particulate materials are removed from the air stream in each exhaust system by means of High Efficiency Particulate Air (HEPA) filters. Residual particulates in each of these systems are continuously sampled downstream from the final stage of HEPA filters. For immediate detection of abnormal conditions, ventilation systems that service areas containing plutonium are equipped with Selective Alpha Air Monitors (SAAMs). These SAAMs are sensitive to selected alpha energy peaks and are set to detect plutonium-239 and -240. These detectors are tested and calibrated routinely to maintain sensitivity. The monitors alarm automatically if out-of-tolerance conditions are experienced. No such conditions occurred during 1985.

Three times each week continuously collected particulate samples are removed from each exhaust system and are radiometrically analyzed for long-lived alpha emitters. The concentration of long-lived alpha emitters is indicative of the effluent quality and the overall performance of the HEPA filtration systems. If the total long-lived alpha concentration for an effluent sample exceeds the plant action guide value of $0.020 \times 10^{-12} \mu\text{Ci}/\text{m}^3$ ($7.4 \times 10^{-6} \text{ Bq}/\text{m}^3$), a followup investigation is conducted to determine the cause and to evaluate the need for corrective action.

At the end of each month, samples from each ventilation system are composited into a single sample for specific chemical analysis. An aliquot of each of the dissolved composite-samples from the 43 exhaust systems is analyzed for beryllium particulates, using a flameless atomic absorption spectrometry technique.¹³ The remainder of the dissolved sample is subjected to chemical separation and alpha spectral analysis to quantify specific alpha-emitting radionuclides. Analyses for uranium isotopes are conducted on the com-

posite samples from each of the 43 exhaust systems. Thirty-five of the ventilation exhaust systems are located in buildings that contain plutonium. Particulate samples from those 35 systems are also analyzed for specific isotopes of plutonium.

Continuous sampling for tritium is conducted in 23 ventilation exhaust systems. A bubbler-type sampler is used to collect samples three times each week. Tritium concentrations in the sample are measured on a liquid scintillation photometer.

Table 2 presents the quantitative data for radioisotopes in airborne effluents during 1985. During 1985 the total quantity of plutonium discharged to the atmosphere from 35 ventilation exhaust systems was less than $9.11 \mu\text{Ci}$ ($3.37 \times 10^5 \text{ Bq}$).

The maximum plutonium concentration of $1.57 \times 10^{-13} \mu\text{Ci}/\text{m}^3$ ($5.81 \times 10^{-3} \text{ Bq}/\text{m}^3$) was measured during a 2-day period in February from an exhaust system servicing a waste treatment facility. The quantity of plutonium from this discharge [$0.087 \mu\text{Ci}$ ($3.22 \times 10^3 \text{ Bq}$)] presented no adverse environmental impact. Samples collected prior to, and following this two-day period were within the range typically measured in this exhaust system. The total discharge of uranium from 43 exhaust systems was less than $38.24 \mu\text{Ci}$ ($1.41 \times 10^6 \text{ Bq}$). The maximum uranium concentration of $9.24 \times 10^{-13} \mu\text{Ci}/\text{m}^3$ ($3.42 \times 10^{-2} \text{ Bq}/\text{m}^3$) was measured during February from a production facility processing depleted uranium. The quantity of uranium from this discharge [$0.848 \mu\text{Ci}$ ($3.24 \times 10^4 \text{ Bq}$)] presented no adverse environmental impact. The tritium discharged from 23 ventilation systems was 0.155 Ci ($5.74 \times 10^9 \text{ Bq}$) and includes contributions from background radioactivity.

Overall, the 1985 data were in the normal ranges projected in the Plant Environmental Impact Statement, and represent no adverse environmental impact.

Table 3 presents the beryllium airborne effluent data for 1985. The total quantity of beryllium discharged from the 43 ventilation exhaust systems was not significantly different from the background associated with the analyses, and these values are well below the 10 gram per 24 hour emission

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TABLE 2 Radioisotopes in Airborne Effluents

Sample Period	Plutonium ^a			Uranium ^b			Tritium		
	Number of Analyses	Total Discharge (μCi)	C _{max} ^c (× 10 ⁻¹³ μCi/m ³)	Number of Analyses	Total Discharge (μCi)	C _{max} ^c (× 10 ⁻¹² μCi/m ³)	Number of Analyses	Total Discharge (Ci)	C _{max} ^c (× 10 ¹² μCi/m ³)
January	38	2.43	0.030 ± 0.0063	48	1.92	0.057 ± 0.0145	299	0.012	300 ± 80
February	38	1.03	0.157 ± 0.0303	52	4.43	0.924 ± 0.0206	298	0.026	300 ± 100
March	35	0.39	0.002 ± 0.0005	46	2.95	0.075 ± 0.0140	296	0.017	450 ± 200
April	37	0.74	0.002 ± 0.0004	44	2.51	0.004 ± 0.0009	274	0.013	290 ± 60
May	35	0.42	0.002 ± 0.0004	42	2.39	0.010 ± 0.0026	273	0.019	290 ± 70
June	35	0.39	0.003 ± 0.0008	45	5.14	0.287 ± 0.0235	299	0.008	240 ± 80
July	38	0.58	0.003 ± 0.0006	45	4.30	0.054 ± 0.0054	299	0.003	270 ± 50
August	35	0.54	0.008 ± 0.0009	42	6.57	0.023 ± 0.0029	298	0.013	270 ± 50
September	35	0.42	0.002 ± 0.0001	43	2.28	0.005 ± 0.0006	291	0.017	1360 ± 280
October	35	0.69	0.005 ± 0.0009	43	1.77	0.005 ± 0.0006	299	0.015	590 ± 160
November	36	0.58	0.007 ± 0.0001	44	1.81	0.076 ± 0.0093	302	0.008	580 ± 140
December	35	0.91	0.029 ± 0.0040	45	2.17	0.005 ± 0.0006	247	0.004	290 ± 65
Summary	432	9.1	0.157 ± 0.0303	539	38.24	0.924 ± 0.0206	3475	0.155	1360 ± 280

a. Radiochemically determined as plutonium-239, -240

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

c. C_{max} is the maximum measured concentration.

TABLE 3 Beryllium in Airborne Effluents

Sample Period	Number of Analyses	Total Discharge ^a (g)	C _{max} (μg/m ³)
January	48	0.026	0.0016
February	52	0.093	0.0169
March	46	0.030	0.0007
April	44	0.142	0.0010
May	42	0.115	0.0021
June	45	-0.018	0.0023
July	45	0.022	0.0002
August	42	0.004	0.0001
September	43	0.031	0.0003
October	43	-0.005	0.0001
November	44	0.038	0.0004
December	45	0.018	0.0001
Summary	539	0.496 ^b	0.0169

a. 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) ¹⁴

b. This value is not significantly different from the background associated with the analyses.

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standard established in Subpart C of 40 CFR 61.32(a)¹⁴

B Radioactive Ambient Air Monitoring

High-volume ambient air samplers are located on the Rocky Flats Plantsite at the plant perimeter [at distances of approximately 3 to 6 kilometers (2 to 4 miles) from the plant's center], and in surrounding communities. These Rocky Flats-designed air samplers operate continuously at a volume flow rate of approximately 12 l/sec (25 ft³/min), collecting particulates on 20- X 25-cm (8- X 10-in) Schleicher and Schuell, Inc., S & S 29 filter media. Manufacturer's test specifications rate this filter media to be 99.97% efficient for the relevant particle sizes under conditions typically encountered in routine ambient air sampling.¹⁵

Airborne particulates in ambient air are sampled continuously at 23 locations within and adjacent to the Rocky Flats exclusion area (Figure 8). The sample filters are collected biweekly and analyzed for total long-lived alpha (TLL α). If the TLL α concentration for an ambient air sample exceeds the plant guide value [10×10^{-15} μ Ci/ml (3.7×10^{-6} Bq/m³)], a specific plutonium analysis is performed. During 1985 all TLL α concentrations were less than this guide value.

Filters from 5 of the 23 samplers are routinely composited and analyzed biweekly for plutonium. These five samplers have historically shown the highest plutonium concentrations for the onsite sampling network. Table 4 contains the average concentrations of plutonium in ambient air at these stations during 1985. The calculated value for the mean concentration at each location is referred to as the "point estimate." For each plutonium concentration point estimate, a Lower Confidence Limit (LCL) and an Upper Confidence Limit (UCL), which define a 95 percent confidence interval, have been included in the table. The derivation of the point estimates, the LCL, and the UCL is discussed in Appendix E. The average concentrations of plutonium in ambient air at the five onsite stations during 1985 ranged from 0.041×10^{-15} to 0.406×10^{-15} μ Ci/ml (1.52×10^{-6} to 1.50×10^{-5} Bq/m³). These concentrations were less than 2.03 percent of the Derived

Concentration Guide (DCG) for inhalation of plutonium by members of the public.

Monitoring for tritium in ambient air water vapor is conducted at onsite locations S-4, S-5, and S-16 (Figure 8). Samples are collected and analyzed weekly. The tritium sampler utilizes a one liter/minute air pump that operates continuously. The sample is collected in a Pyrex tube filled with silica gel, which collects moisture from the ambient air. The sampling equipment is contained in an aluminum case that is insulated, weathertight and lockable. Temperature inside the case is controlled by a small heater and fan that maintain a temperature between 4.44 and 32.2 °C (40 and 90 °F). Table 5 presents the average concentrations of tritium in ambient air water vapor at these three onsite stations during 1985. The maximum average concentration of tritium in ambient air at the three onsite stations during 1985 was less than 150×10^{-9} μ Ci/ml (5.55 Bq/l). This concentration was less than 0.0075 percent of the DCG for oral intake of tritium by members of the public.

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 8). The samplers are numbered S-31 through S-44. Samples from each location are collected biweekly, composited by location, and analyzed for a four-week period for plutonium. Table 6 presents the average concentrations of plutonium radioactivity in airborne particulates at Stations S-31 through S-44 during 1985. The average concentration of plutonium in ambient air at these locations during 1985 was 0.002×10^{-15} μ Ci/ml (7.40×10^{-8} Bq/m³). This concentration was 0.01 percent of the DCG for inhalation of plutonium by members of the public.

Samples of airborne particulates are also collected at 14 locations in or near communities in the vicinity of the Rocky Flats Plant. These locations, shown in Figure 9, are Boulder, Broomfield, Cotton Creek, Denver, Golden, Jeffco Airport, Lafayette, Lakeview Pointe,* Lyden, Marshall, Superior, Wagner, Walnut Creek, and Westminster.

*New location added to community network in January 1985.

FIGURE 8 Location of Onsite and Plant Perimeter Ambient Air Samplers
(Portions of figure are not to scale)

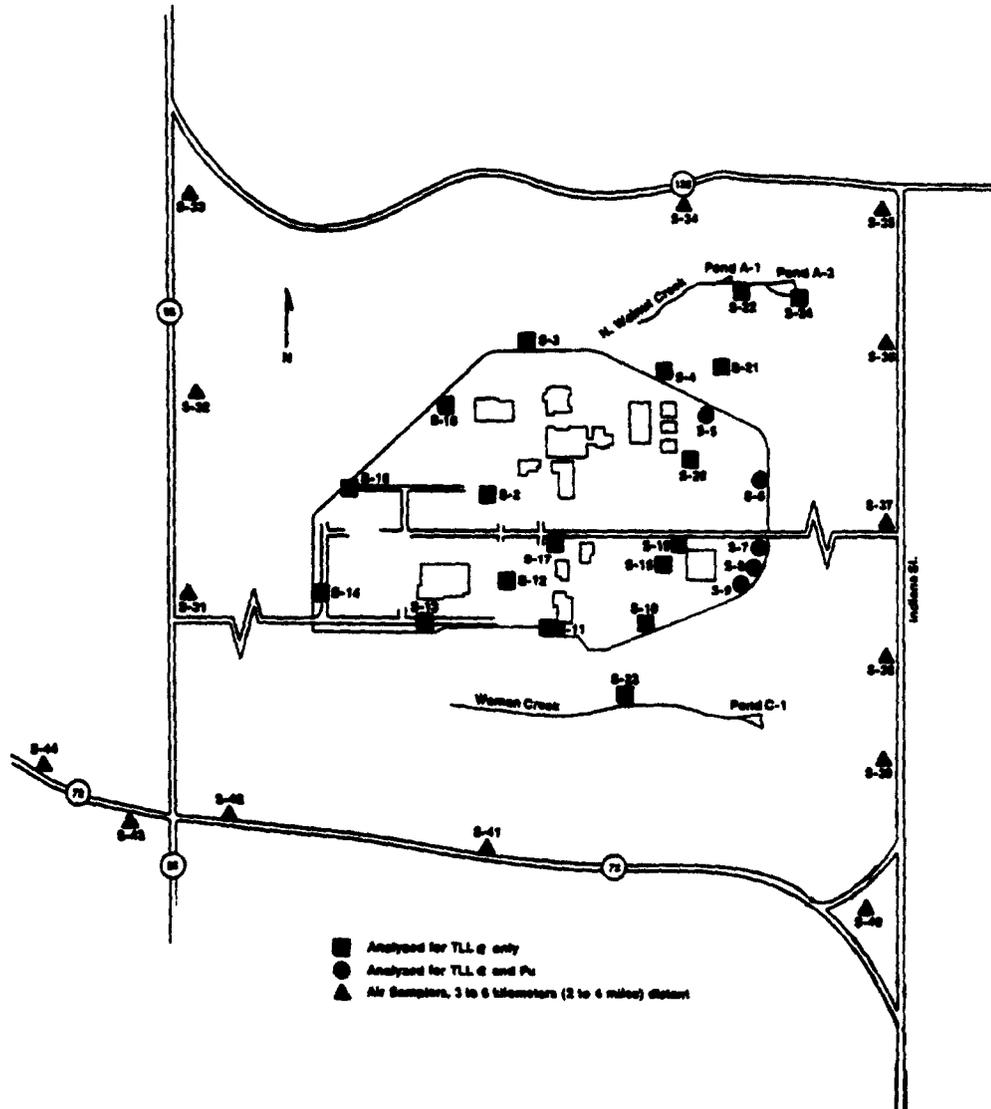


TABLE 4 Plutonium 239 and -240 Activity Concentrations in Onsite Ambient Air at Selected Locations^a

Station	Number of Analyses	Volume (x 1000 m ³) ^g	Concentration ^b (x 10 ⁻¹⁵ μCi/ml) ^c									Percent ^h of DCG
			C _{min} ^d			C _{max} ^d			C _{mean} ^d			
			LCL ^f	Point Estimate	UCL ^g	LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	
S-5	25	351	0.002	0.003	0.004	0.057	0.072	0.087	0.029	0.041	0.052	0.21
S-6	25	351	0.005	0.016	0.027	0.278	0.310	0.342	0.077	0.095	0.113	0.48
S-7	25	343	0.086	0.101	0.116	0.355	0.445	0.335	0.201	0.245	0.290	1.23
S-8	25	344	0.040	0.063	0.086	1.189	1.306	1.423	0.327	0.390	0.452	1.95
S-9	25	304	0.028	0.041	0.054	0.944	1.169	1.394	0.337	0.406	0.475	2.03

- a. These selected air-sampling locations are in the proximity of areas where potential for airborne radioactivity exists (see Figure 8).
- b. Two-week composites of station concentrations.
- c. To obtain the proper concentration, multiply the numbers in the table by 10⁻¹⁵ μCi/ml. For example, the average point estimate at S-5 was 0.041 x 10⁻¹⁵ μCi/ml.
- d. C_{min} = minimum measured concentration, C_{max} = maximum measured concentration, C_{mean} = average measured concentration.
- e. To obtain the proper volume multiply the numbers listed in the table by 1000 m³. For example, the volume samples at S-5 was 351,000 m³.
- f. LCL = lower confidence limit.
- g. UCL = upper confidence limit.
- h. The interim standard calculated Derived Concentration Guide (DCG) for inhalation of Class W plutonium by members of the public is 20 x 10⁻¹⁵ μCi/ml. (See Appendix A.)

TABLE 5 Tritium Activity Concentrations in Onsite Ambient Air Water Vapor

Station	Number of Analyses	Concentration (x 10 ⁻⁹ μCi/ml) ^a			Percent of DCG ^c
		C _{min}	C _{max}	C _{mean} ^b	
S-4	38	-320 ± 550	630 ± 1150	<150 ± 660	<0.0075
S-5	37	-310 ± 350	630 ± 670	<140 ± 670	<0.0075
S-16	37	-140 ± 640	480 ± 710	<150 ± 625	<0.0075

- a. To obtain the proper concentration, multiply the number in the table by 10⁻⁹ μCi/ml. For example, the average concentration at S-4 was <150 x 10⁻⁹ μCi/ml.
- b. The average tritium concentrations are less than 0.75 percent of the EPA and State of Colorado primary drinking water limits of 20,000 x 10⁻⁹ μCi/ml.
- c. The interim standard calculated Derived Concentration Guide (DCG) for ingestion of tritium by members of the public is 2,000,000 x 10⁻⁹ μCi/ml. (See Appendix A.)

Sample filters are collected biweekly, composited by location, and analyzed for a four-week period for plutonium radioactivity. Table 7 presents the average concentrations of plutonium in airborne particulates at the community stations during

1985. The average concentration of plutonium in ambient air at the community stations was 0.002 x 10⁻¹⁵ μCi/ml (7.40 x 10⁻⁸ Bq/m³). This value is 0.01 percent of the DCG for inhalation of plutonium by members of the public.

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TABLE 6 Plutonium-239 and -240 Activity Concentrations in Perimeter Ambient Air

Station	Number of Analyses	Volume ^b (x 1000 m ³)	Concentration (x 10 ⁻¹⁰ μCi/ml) ^a									Percent ^c of DCG
			C _{min}			C _{max}			C _{mean}			
			LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	
S-31	12	366	-0.007	-0.003	0.001	-0.003	0.002	0.007	-0.004	0.000	0.005	0.06
S-32	12	314	-0.008	-0.003	0.002	0.000	0.004	0.008	-0.004	0.001	0.005	0.01
S-33	12	407	-0.007	-0.002	0.003	0.009	0.012	0.015	-0.002	0.001	0.005	0.01
S-34	12	361	-0.007	-0.001	0.005	-0.001	0.003	0.007	-0.004	0.001	0.005	0.11
S-35	11	268	-0.008	-0.002	0.004	-0.002	0.005	0.012	-0.005	0.000	0.006	0.00
S-36	11	404	-0.006	-0.002	0.002	0.010	0.017	0.024	-0.002	0.002	0.006	0.01
S-37	12	389	-0.004	0.001	0.006	0.019	0.027	0.035	0.003	0.008	0.012	0.04
S-38	11	336	-0.007	-0.002	0.003	0.025	0.031	0.037	0.000	0.005	0.010	0.02
S-39	11	363	-0.009	-0.002	0.005	0.004	0.009	0.014	-0.002	0.002	0.007	0.01
S-40	12	382	-0.009	-0.003	0.003	0.000	0.005	0.010	-0.004	0.000	0.004	0.00
S-41	12	338	-0.007	-0.003	0.001	0.018	0.026	0.034	-0.004	0.002	0.007	0.01
S-42	12	350	-0.005	-0.001	0.003	0.014	0.021	0.028	-0.002	0.002	0.007	0.01
S-43	12	374	-0.007	-0.002	0.003	0.004	0.009	0.014	-0.002	0.002	0.007	0.01
S-44	12	378	-0.008	-0.003	0.002	-0.001	0.004	0.009	-0.004	0.001	0.005	0.01
Summary	166	-	-	-0.003	-	-	0.031	-	-	-	-	-
Average Concentration	-	-	-	-	-	-	-	-	-	0.002	-	0.01

- a. To obtain the proper concentration, multiply the numbers listed in the table by 10⁻¹⁰ μCi/ml. For example, the mean point estimate at S-31 was 0.000 x 10⁻¹⁰ μCi/ml.
- b. To obtain the proper volume, multiply the numbers listed in the table by 1000 m³. For example, the volume sampled at S-31 was 336,000 m³.
- c. The interim standard calculated Derived Concentration Guide (DCG) for inhalation of Class W plutonium is 20 x 10⁻¹⁰ μCi/ml. (See Appendix A.)

C Nonradioactive Ambient Air Monitoring

During 1985, monitoring of ambient air included the following total suspended particulates (TSPs), ozone, sulfur dioxide, carbon monoxide, nitrogen dioxide, and lead. This monitoring utilized instrumentation in a self-contained van equipped for Mobile Ambient Air Monitoring (MAAM). These six parameters are criteria pollutants regulated by the EPA and the State of Colorado through the Clean Air Act Amendments of 1970 and 1977 which includes the National Ambient Air Quality Standards (NAAQS) and Colorado Air Quality Control Commission Ambient Air Standards. Table 8 identifies the detection methods and operating ranges of the MAAM monitoring analyzers with corresponding compliance standards. During 1985, the van remained stationary at a location near the east entrance to the plant. This is an open area

near a traffic zone and is generally downwind from plant buildings. Ambient air data were collected over the entire year, including several months of data from a prototype inhalable particulate type sampling inlet (Wedding PM-10). Proposed regulatory requirements may require sampling particulates in the range of <10 microns, total suspended particulate sampling may be required for tracking 24-hour secondary standards. In early 1986 the Environmental Analysis and Control (EA&C) Section at Rocky Flats will implement the use of both co-located PM-10 and TSP samplers at the present sampling location. The Wedding PM-10 sampler is certified to meet the EPA proposed standard at a flow rate of 40 CFM. Some statistical data on the PM-10 sampling are presented in Table 9 for information purposes only. No comparisons to standards will be made until the new standards are fully promulgated. Particulate and PM-10 data are shown in Table 9.

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TABLE 7 Plutonium -239 and -240 Activity Concentrations in Community Ambient Air

Station	Number of Analyses	Volume ^b (x 1000 m ³)	Concentration (x 10 ⁻¹⁰ μCi/m ³) ^a									Percent of DCG
			C _{min}			C _{max}			C _{mean}			
			LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	LCL	Point Estimate	UCL	
Marshall	12	368	-0.007	-0.002	0.003	0.004	0.008	0.012	-0.003	0.001	0.006	0.01
Jeffco Airport	12	382	-0.005	-0.001	0.003	0.007	0.014	0.021	-0.002	0.002	0.007	0.01
Superior	12	355	-0.007	-0.002	0.003	-0.002	0.003	0.008	-0.004	0.000	0.005	0.00
Boulder	12	407	-0.005	-0.002	0.001	0.003	0.008	0.013	-0.003	0.001	0.005	0.01
Lafayette	12	333	-0.006	-0.001	0.004	0.017	0.022	0.027	-0.002	0.003	0.008	0.02
Broomfield	12	383	-0.007	-0.002	0.003	0.000	0.004	0.008	-0.004	0.000	0.004	0.00
Walnut Creek	12	396	-0.004	-0.001	0.002	0.002	0.008	0.014	-0.002	0.002	0.006	0.01
Wagner	12	376	-0.007	-0.003	0.001	0.004	0.010	0.016	-0.003	0.002	0.006	0.01
Leyden	12	406	-0.004	-0.001	0.002	0.003	0.009	0.015	-0.002	0.002	0.006	0.01
Westminster	11	313	-0.003	0.000	0.003	0.010	0.018	0.026	0.001	0.006	0.012	0.03
Denver	12	315	-0.006	-0.003	0.000	0.003	0.007	0.011	-0.003	0.002	0.007	0.01
Golden	12	323	-0.007	-0.002	0.003	0.000	0.007	0.014	-0.004	0.001	0.006	0.01
Lakeview Points	12	409	-0.005	-0.002	0.001	0.004	0.009	0.014	-0.002	0.002	0.006	0.01
Cotton Creek	11	305	-0.021	-0.004	0.013	-0.002	0.004	0.010	-0.005	0.001	0.006	0.01
Summary	167		-	-0.004	-	-	0.027	-	-	-	-	-
Average Concentration	-		-	-	-	-	-	-	0.002	-	-	0.01

- a. To obtain the proper concentration, multiply the numbers listed in the table by 10⁻¹⁰ μCi/m³.
For example, the mean point estimate at Marshall was 0.001 x 10⁻¹⁰ μCi/m³.
- b. To obtain the proper volume, multiply the numbers listed in the table by 1000 m³.
For example, the volume sampled at Marshall was 368,000 m³.
- c. The interim standard calculated Derived Concentration Guide (DCG) for inhalation of Class W plutonium is 20 x 10⁻¹⁰ μCi/m³. (See Appendix A.)

Measurement of TSPs and lead were conducted using the EPA reference high-volume air sampling method. The primary ambient air particulate sampler and a co-located duplicate sampler were operated on the EPA once-every-sixth day sampling schedule. The highest TSP value recorded (a 24-hour sample) was 90 μg/m³, which is 34 percent of the 24-hour primary standard of 260 μg/m³. The annual geometric mean value for 1985 was 47 μg/m³, which was 34 percent of the NAAQS primary annual geometric mean standard of 75 μg/m³. These numbers are comparable to mean values reported by the Colorado Department of Health (CDH) for TSP measurements at the south-eastern plant boundary at Woman Creek and Indiana Street. These measurements have yielded annual average particulate levels in the range between 30 and 66 μg/m³, which is lower than the

NAAQS. The quarterly average lead concentrations for the four quarters of 1985 were at minimum detectable levels, except during the first quarter when the concentration was 0.119 μg/m³. These values are less than 4 percent of the NAAQS primary standard of 15 μg/m³. Ambient ozone data were collected using an ultraviolet (UV) photometric type analyzer. During 1985, a total of 8,620 1-hour ozone samples were collected. The maximum 1-hour value was 0.286 ppm, which is 158 percent of the NAAQS primary one-hour standard of 0.120 ppm. The second highest 1-hour ozone value, which occurred during the same afternoon in May was 0.195 ppm. These values are consistent with levels measured in the general Denver metropolitan area during high pollution episodes.

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TABLE 8 Mobile Ambient Air Monitoring (MAAM) Van Detection Methods and National Ambient Air Quality Standards (NAAQS) for Total Suspended Particulates, Ozone, Sulfur Dioxide, Carbon Monoxide, Nitrogen Dioxide, and Lead

Parameter	Detection Methods and Analyzer Ranges	NAAQS Averaging Time	Concentration
Total Suspended Particulates (TSP)	Reference Method (Hi Volume) 24-Hour sampling (6th-day scheduling)	Annual Geometric Mean Primary ^a	75 $\mu\text{g}/\text{m}^3$
		Secondary ^b	60 $\mu\text{g}/\text{m}^3$
Ozone (O ₃)	Beckman Model 950 Chemiluminescent 0-0.5 ppm (ThermoElectron Model 49)	24-Hour Primary ^{a,c}	260 $\mu\text{g}/\text{m}^3$
		Secondary ^{b,c}	150 $\mu\text{g}/\text{m}^3$
Sulfur Dioxide (SO ₂)	ThermoElectron Model 43 Pulsed Fluorescence 0-0.5 ppm	1-Hour Primary ^{a,d}	0.12 ppm
		Annual Arithmetic Mean Primary ^a	0.030 ppm
		24-Hour Primary ^{a,c}	0.140 ppm
Carbon Monoxide (CO)	ThermoElectron Model 48 Gas Filter Correlation (Infrared) 0-50 ppm	3-Hour Secondary ^{b,c}	0.500 ppm
		1-Hour Primary ^{a,c}	35 ppm
		8-Hour Primary ^{a,c}	9 ppm
Nitrogen Dioxide (NO ₂)	Monitor Labs Model 8840 Chemiluminescent 0-0.5 ppm	Annual Arithmetic Mean Primary ^a	0.05 ppm
Lead	Reference Method (Hi Volume) 24-Hour Sampling (Atomic Absorption Analysis)	Calendar Quarter Primary ^a	1.5 $\mu\text{g}/\text{m}^3$

- a. Primary NAAQS are intended to protect public health.
- b. Secondary NAAQS are intended to protect public welfare.
- c. Not to be exceeded more than once per year
- d. Statistically estimated number of days with concentrations in excess of the standard is not to be more than 1.0 per year

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TABLE 9 Onsite MAAM Van Ambient Air Quality Data (Nonradioactive)

Total Suspended Particulates ($\mu\text{g}/\text{m}^3$)				
Total Number of Samples - A ^a	60			
Total Number of Samples - B ^b	10			
Geometric Mean, Sampler A ^c	47.0			
Geometric Mean, Sampler B ^c	55.8			
Standard Deviation, Sampler A ^c	16.9			
Standard Deviation, Sampler B ^c	22.4			
Observed 24-Hour Maximum A ^c	88.5			
Observed 24 Hour Maximum, B ^c	91.8			
Second Highest Maximum A ^c	84.3			
Second Highest Maximum B ^c	88.5			
Lowest Observed Value, A	20.0			
Lowest Observed Value, B	24.0			
PM-10 Particulates ($\mu\text{g}/\text{m}^3$)				
Total Number of Samples B ^c (3/24/85 - 12/31/85)	47			
Geometric Mean B ^c	21.2			
Standard Deviation B ^c	8.8			
Observed 24-Hour Maximum B ^c	43.4			
Second Highest Maximum B ^c	35.8			
Lowest Observed Value B ^c	6.3			
Ozone (ppm)				
Number of Observations, Hourly ^c	8,620			
Arithmetic Mean, Annual	0.044			
Maximum 1-Hour Concentration	0.286			
Second Highest 1-Hour Concentration	0.195			
Minimum Observation, Hourly	0.001			
Carbon Monoxide (ppm)				
Number of Observations, Hourly ^c	8,620			
Arithmetic Mean, Annual	0.67			
Maximum 1-Hour Concentration	6.3			
Maximum 8-Hour Concentration	2.20			
Minimum Observation Hourly	0.10			
Nitrogen Dioxide (ppm)				
Number of Observations, Hourly ^c	8,640			
Arithmetic Mean, Annual	0.011			
Maximum 1-Hour Concentration	0.116			
Minimum Observation Hourly	0.001			
Sulfur Dioxide (ppm)				
Number of Observations Hourly ^c	8,115			
Arithmetic Mean, Annual	0.003			
3 Hour Average, Highest	0.026			
24-Hour Average, Highest	0.012			
Maximum 1-Hour Concentration	0.035			
Airborne Lead ($\mu\text{g}/\text{m}^3$)				
	Jan-Mar	Apr-June	Jul-Sep	Oct-Dec
Total Number of Samples	6	6	6	8
Quarterly Avg.	0.119	0.098	0.105	0.072

- a. Primary ambient air particulate sampler
- b. Co-located duplicate sampler
- c. Continuous millivolt analyzer output is composited and converted to engineering units for comparison to NAAQS (see Table 8)

Sulfur dioxide sampling was conducted using a continuously operating pulsed fluorescence type analyzer calibrated by use of a certified cylinder gas and a dynamic gas dilution calibration system. The cylinder gases, as well as the mass flowmeters, have traceability to primary standards set by the National Bureau of Standards. The maximum 1-hour SO₂ value recorded at the plant was 0.035 ppm and the maximum observed 3-hour average value was 0.026 ppm which is 5 percent of the NAAQS 3 hour standard of 0.500 ppm. The calculated annual arithmetic mean value of 0.003 ppm is 10 percent of the NAAQS annual mean standard of 0.030 ppm. The maximum observed 24-hour average for SO₂ was 0.012 ppm, which is 9 percent of the NAAQS 24-hour standard of 0.140 ppm.

The 8,500 hourly averages of carbon monoxide (CO) data collected during 1985 using a gas filter correlation (IR) type analyzer, yielded an annual arithmetic mean of 0.67 ppm, including a maximum 1-hour average value of 6.3 ppm which is 18 percent of the NAAQS primary 1-hour standard of 35 ppm. A maximum 8-hour average concentration value of 2.20 ppm was recorded which is 24 percent of the 8-hour NAAQS primary standard of 9 ppm.

The nitrogen dioxide (NO₂) data contain 8,640 hourly averages of continuous sampling and gave an arithmetic mean of 0.011 ppm which is 22 percent of the NAAQS primary mean standard value of 0.05 ppm. The maximum 1-hour value noted during this time period was 0.116 ppm.

The data for all parameters were assessed with an accuracy of ± 12 percent based on routine precision and operational span checks, multipoint dynamic calibrations, and established quality assurance procedures.

As part of an ongoing Environmental Analysis & Control quality assurance program all of the MAAM van analyzers were subjected to an independent audit during 1985. Responses of all analyzers were within the range of established EPA guidelines for ambient air monitoring networks (± 15%).

D Waterborne Effluent Monitoring

North Walnut Creek receives stormwater runoff from the north side of the plantsite (See Figure 4)

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TABLE 8 Mobile Ambient Air Monitoring (MAAM) Van Detection Methods and National Ambient Air Quality Standards (NAAQS) for Total Suspended Particulates, Ozone, Sulfur Dioxide, Carbon Monoxide, Nitrogen Dioxide, and Lead

Parameter	Detection Methods and Analyzer Ranges	NAAQS Averaging Time	Concentration
Total Suspended Particulates (TSP)	Reference Method (HI Volume) 24-Hour sampling (6th-day scheduling)	Annual Geometric Mean Primary ^a Secondary ^b	75 $\mu\text{g}/\text{m}^3$ 60 $\mu\text{g}/\text{m}^3$
		24-Hour Primary ^{a,c} Secondary ^{b,c}	260 $\mu\text{g}/\text{m}^3$ 150 $\mu\text{g}/\text{m}^3$
Ozone (O ₃)	Beckman Model 950 Chemiluminescent 0-0.5 ppm (ThermoElectron Model 49)	1-Hour Primary ^{a,d}	0.12 ppm
Sulfur Dioxide (SO ₂)	ThermoElectron Model 43 Pulsed Fluorescence 0-0.5 ppm	Annual Arithmetic Mean Primary ^a	0.030 ppm
		24-Hour Primary ^{a,c}	0.140 ppm
		3-Hour Secondary ^{b,c}	0.500 ppm
Carbon Monoxide (CO)	ThermoElectron Model 48 Gas Filter Correlation (Infrared) 0-50 ppm	1-Hour Primary ^{a,c}	35 ppm
		8-Hour Primary ^{a,c}	9 ppm
Nitrogen Dioxide (NO ₂)	Monitor Labs Model 8840 Chemiluminescent 0-0.5 ppm	Annual Arithmetic Mean Primary ^a	0.05 ppm
Lead	Reference Method (HI Volume) 24-Hour Sampling (Atomic Absorption Analysis)	Calendar Quarter Primary ^a	1.5 $\mu\text{g}/\text{m}^3$

- a. Primary NAAQS are intended to protect public health.
- b. Secondary NAAQS are intended to protect public welfare.
- c. Not to be exceeded more than once per year
- d. Statistically estimated number of days with concentrations in excess of the standard is not to be more than 1.0 per year

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TABLE 9 Onsite MAAM Van Ambient Air Quality Data (Nonradioactive)

Total Suspended Particulates ($\mu\text{g}/\text{m}^3$)				
Total Number of Samples - A ^a	60			
Total Number of Samples - B ^b	10			
Geometric Mean, Sampler "A"	47.0			
Geometric Mean, Sampler "B"	55.8			
Standard Deviation, Sampler "A"	16.9			
Standard Deviation, Sampler "B"	22.4			
Observed 24-Hour Maximum "A"	88.5			
Observed 24-Hour Maximum "B"	91.8			
Second Highest Maximum "A"	84.3			
Second Highest Maximum "B"	88.5			
Lowest Observed Value, A	20.0			
Lowest Observed Value, B	24.0			
PM 10 Particulates ($\mu\text{g}/\text{m}^3$)				
Total Number of Samples "B" (3/24/85 - 12/31/85)	47			
Geometric Mean "B"	21.2			
Standard Deviation "B"	8.8			
Observed 24-Hour Maximum "B"	43.4			
Second Highest Maximum "B"	35.8			
Lowest Observed Value "B"	6.3			
Ozone (ppm)				
Number of Observations, Hourly ^c	8,620			
Arithmetic Mean, Annual	0.044			
Maximum 1 Hour Concentration	0.286			
Second Highest 1-Hour Concentration	0.195			
Minimum Observation, Hourly	0.001			
Carbon Monoxide (ppm)				
Number of Observations, Hourly ^c	8,620			
Arithmetic Mean, Annual	0.67			
Maximum 1-Hour Concentration	6.3			
Maximum 8-Hour Concentration	2.20			
Minimum Observation Hourly	0.10			
Nitrogen Dioxide (ppm)				
Number of Observations, Hourly ^c	8,640			
Arithmetic Mean, Annual	0.011			
Maximum 1-Hour Concentration	0.116			
Minimum Observation, Hourly	0.001			
Sulfur Dioxide (ppm)				
Number of Observations, Hourly ^c	8,115			
Arithmetic Mean, Annual	0.003			
3 Hour Average, Highest	0.026			
24-Hour Average, Highest	0.012			
Maximum 1 Hour Concentration	0.035			
Airborne Lead ($\mu\text{g}/\text{m}^3$)				
	Jan-Mar	Apr-June	Jul-Sep	Oct-Dec
Total Number of Samples	6	6	6	8
Quarterly Avg.	0.119	0.098	0.105	0.072

- a. Primary ambient air particulate sampler
- b. Co-located duplicate sampler
- c. Continuous millivolt analyzer output is composited and converted to engineering units for comparison to NAAQS (see Table 8)

Sulfur dioxide sampling was conducted using a continuously operating pulsed fluorescence type analyzer calibrated by use of a certified cylinder gas and a dynamic gas dilution calibration system. The cylinder gases, as well as the mass flowmeters, have traceability to primary standards set by the National Bureau of Standards. The maximum 1-hour SO₂ value recorded at the plant was 0.035 ppm and the maximum observed 3-hour average value was 0.026 ppm which is 5 percent of the NAAQS 3 hour standard of 0.500 ppm. The calculated annual arithmetic mean value of 0.003 ppm is 10 percent of the NAAQS annual mean standard of 0.030 ppm. The maximum observed 24-hour average for SO₂ was 0.012 ppm, which is 9 percent of the NAAQS 24-hour standard of 0.140 ppm.

The 8,500 hourly averages of carbon monoxide (CO) data collected during 1985, using a gas filter correlation (IR) type analyzer yielded an annual arithmetic mean of 0.67 ppm, including a maximum 1-hour average value of 6.3 ppm which is 18 percent of the NAAQS primary 1-hour standard of 35 ppm. A maximum 8-hour average concentration value of 2.20 ppm was recorded which is 24 percent of the 8-hour NAAQS primary standard of 9 ppm.

The nitrogen dioxide (NO₂) data contain 8,640 hourly averages of continuous sampling and gave an arithmetic mean of 0.011 ppm which is 22 percent of the NAAQS primary mean standard value of 0.05 ppm. The maximum 1-hour value noted during this time period was 0.116 ppm.

The data for all parameters were assessed with an accuracy of ± 12 percent based on routine precision and operational span checks, multipoint dynamic calibrations, and established quality assurance procedures.

As part of an ongoing Environmental Analysis & Control quality assurance program, all of the MAAM van analyzers were subjected to an independent audit during 1985. Responses of all analyzers were within the range of established EPA guidelines for ambient air monitoring networks (± 15%).

D Waterborne Effluent Monitoring

North Walnut Creek receives stormwater runoff from the north side of the plantsite (See Figure 4)

Holding Pond A-3 on North Walnut Creek is used to impound this surface runoff for analysis prior to discharge. A second control point, holding Pond A-4 is located further downstream.

Ponds A-1 and A-2 are isolated by valves from North Walnut Creek. In the past, these ponds have been used for storage and evaporation of laundry water. This practice was discontinued in 1980. These ponds currently are maintained in a state of readiness for control of possible chemical spills into the North Walnut Creek drainage basin. Disposition of Pond A-1 and A-2 runoff water is through natural evaporation and is enhanced by spraying water through fog nozzles over the surface of the ponds. Excess water that does not evaporate is then recollected by the ponds.

South Walnut Creek receives surface water runoff from the central portion of the plant. This water is diverted through a culvert system to Pond B-4 and then to Pond B-5 where the water is impounded for analysis prior to controlled offsite discharge.

In the past, treated sanitary wastewater was also routinely discharged to South Walnut Creek. This practice was discontinued in 1979. Between 1981 and 1985, some treated sanitary wastewater has been recycled through the plant Reverse Osmosis (RO) Facility for further treatment and reused in plant cooling towers. Excess water that could not be recycled was discharged directly to Pond B-3 or pumped into the RO holding ponds and spray-irrigated onto Rocky Flats buffer zone areas. Ponds B-1 and B-2, also located in the central drainage, are reserved as backup control ponds. These ponds can be used to retain chemical spills, surface water runoff or treated sanitary wastewater.

Surface runoff water from the south side of the plant is collected in an interceptor ditch and flows into Pond C-2, where the water is impounded and analyzed before discharge offsite. Woman Creek, also in the south drainage, is isolated from this diversion system. Pond C-1 is used as the monitoring point for Woman Creek.

Discharges from the Rocky Flats Plant are monitored for compliance with appropriate Colorado Department of Health Standards and EPA National Pollutant Discharge Elimination

System (NPDES) permit limitations.⁵ Annual average concentrations of chemical and biological constituents of liquid effluent samples collected from Ponds A-3, A-4, B-3, B-5, and C-2 during 1985 are presented in Table 10. The data are indicative of overall water quality for these ponds.

During 1984, the plant NPDES permit expired and was renewed with the same seven discharge locations-001, 002, 003, 004, 005, 006, and 007. The discharge locations are identified in Table 10. The NPDES permit places monitoring and reporting requirements and limitations on daily concentrations and monthly average concentrations for some specific parameters. There was one technical violation of the NPDES permit during 1985. This February 1985 violation involved an accidental discharge of excess chlorinated treated sewage wastewater to Pond B-3 (discharge location 001). The water should have been processed through the RO plant, but a faulty valve caused leakage to Pond B-3. A technical violation occurred when the water was discharged from Pond B-3 into Pond B-5 containing 1.0 mg/l of total residual chlorine. The allowable limit is 0.5 mg/l. There was no downstream discharge of this chlorinated water, the chlorine levels in Pond B-5 dissipated to background levels when ambient air temperatures increased. The violation was reported to Region VIII of the EPA by the Rocky Flats Plant. No offsite environmental impact occurred.

Prior to discharge from Ponds A-4, B-5 and C-2, water is sampled and analyzed for gross alpha, gross beta, tritium, gamma activity, pH, nitrate as N, and nonvolatile suspended solids. Water is not released if the plant action level for any parameter is exceeded.

During releases from Ponds A-4, B-5, and C-2 in 1985, the water was sampled continuously. The samples were analyzed for plutonium, uranium, americium, tritium, pH, nitrate as N, and non-volatile suspended solids. Water is also sampled continuously and collected daily from the outfall of Pond C-1 and collected from the Walnut Creek at Indiana Street sampling station (when there is flow). Daily samples were composited into weekly samples for plutonium, uranium, and americium analyses. Once each week, daily samples

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TABLE 10 Annual Average Concentrations of Chemical and Biological Constituents in Liquid Effluents^a

Parameters	Number of Analyses	C _{min}	C _{max}	C _{mean}
Discharge 001^b				
pH, SU ^c	17	6.9	10.3	-
Nitrate as N, mg/l	17	0.4	5.8	2.9
Total Suspended Solids, mg/l	17	2.0	42.0	11.2
Total Residual Chlorine, mg/l	17	0.0	1.0	0.2
Total Chromium, mg/l	11	<0.05	<0.05	<0.05
Total Phosphorus, mg/l	17	2.2	5.2	3.5
Fecal Coliform, #/100 ml	14	<1.0	2.3	<1.1
Biochemical Oxygen Demand (BOD ₅), mg/l	8	3.7	15.8	8.0
Discharge 002^b				
pH, SU	8	7.6	8.1	-
Nitrates as N, mg/l	8	1.2	11.0	5.2
Discharge 003^b				
During 1985, no discharges were made to offsite waters from the Reverse Osmosis Pilot Plant.				
Discharge 004^b				
During 1985, no discharges were made to offsite waters from the Reverse Osmosis Plant.				
Discharge 005^b				
pH, SU	12	7.7	8.6	-
Nitrates as N, mg/l	12	1.4	8.2	4.6
Nonvolatile Suspended Solids, mg/l	12	1.0	25	7.7
Discharge 006^b				
pH, SU	50	7.4	8.8	-
Nitrates as N, mg/l	50	<0.2	9.2	<1.6
Nonvolatile Suspended Solids, mg/l	50	0.0	9.2	7.7
Discharge 007^b				
pH, SU	2	8.1	8.2	-
Nitrates as N, mg/l	2	0.2	0.2	0.2
Nonvolatile Suspended Solids, mg/l	2	4.0	9.0	6.5

a. Examples of NPDES Permit Limitations are presented in Table A-1

b. The Environmental Protection Agency NPDES discharge permit defines the discharge locations as follows:

- 001 - Pond B-3
- 002 - Pond A-3
- 003 - Reverse Osmosis Pilot Plant
- 004 - Reverse Osmosis Plant
- 005 - Pond A-4
- 006 - Pond B-5
- 007 - Pond C-2

c. SU - Standard Units

at Pond C-1 and Walnut Creek at Indiana Street are analyzed for tritium. Concentrations of plutonium, uranium, americium, and tritium in water samples from the outfalls of Ponds A-4, B-5, C-1, C-2, and from Walnut Creek at Indiana Street are

presented in Tables 11 and 12. All plutonium, uranium, americium, and tritium concentrations at these locations were 10 percent or less of the DOE interim standard Derived Concentration Guides (DCGs).

TABLE 11 Plutonium, Uranium, and Americium Concentrations at the Rocky Flats Plant

Location	Number of Analyses	C _{min}	C _{max}	C _{mean}	Percent of DCG
<u>Plutonium Concentration (x 10⁻⁹ µCi/ml)^a</u>					
Pond A-4	5	0.01 ± 0.02	0.04 ± 0.02	0.02 ± 0.01	0.007
Pond B-5	17	-0.020 ± 0.05	0.05 ± 0.02	0.013 ± 0.007	0.004
Pond C-1	51	0.00 ± 0.02	0.010 ± 0.02	0.027 ± 0.002	0.009
Pond C-2	1	0.05 ± 0.03	0.05 ± 0.03	0.05 ± 0.03	0.02
Walnut Creek at Indiana Street	48	-0.01 ± 0.05	0.08 ± 0.01	0.018 ± 0.002	0.006
<u>Uranium Concentration (x 10⁻⁹ µCi/ml)^b</u>					
Pond A-4	5	3.0 ± 0.2	6.6 ± 0.8	5.0 ± 0.2	1.0
Pond B-5	17	3.2 ± 0.3	10 ± 1	6.1 ± 0.2	1.2
Pond C-1	51	0.14 ± 0.09	6.5 ± 0.8	2.84 ± 0.05	0.6
Pond C-2	1	3.7 ± 0.5	3.7 ± 0.5	3.7 ± 0.5	0.7
Walnut Creek at Indiana Street	48	0.3 ± 0.1	8.3 ± 0.8	3.96 ± 0.07	0.8
<u>Americium Concentration (x 10⁻⁹ µCi/ml)^c</u>					
Pond A-4	5	-0.03 ± 0.05	0.07 ± 0.02	0.01 ± 0.02	0.02
Pond B-5	17	-0.05 ± 0.05	0.13 ± 0.06	0.01 ± 0.01	0.02
Pond C-1	51	-0.04 ± 0.06	0.08 ± 0.02	0.011 ± 0.002	0.02
Pond C-2	1	0.04 ± 0.02	0.04 ± 0.02	0.04 ± 0.02	0.07
Walnut Creek at Indiana Street	48	-0.05 ± 0.05	0.05 ± 0.06	0.013 ± 0.003	0.02

a. Radiochemically determined as plutonium-239 and -240. The interim standard calculated Derived Concentration Guide (DCG) for plutonium in water available to members of the public is 300 x 10⁻⁹ µCi/ml. (See Appendix A.)

b. Radiochemically determined as uranium -233, -234, and -238. The interim standard calculated Derived Concentration Guide (DCG) for uranium in water available to members of the public is 500 x 10⁻⁹ µCi/ml. (See Appendix A.)

c. Radiochemically determined as americium -241. The interim standard calculated Derived Concentration Guide (DCG) for americium in water available to members of the public is 60 x 10⁻⁹ µCi/ml. (See Appendix A.)

TABLE 12 Tritium Concentrations in Water at the Rocky Flats Plant

Location	Number of Analyses	Tritium Concentration (x 10 ⁶ µCi/ml)			Percent of DCG*
		C _{min}	C _{max}	C _{mean}	
Pond A-4	15	-200 ± 600	1200 ± 700	200 ± 200	0.01
Pond B-5	50	-500 ± 1100	800 ± 900	200 ± 100	0.01
Pond C-1	49	-1000 ± 1100	300 ± 700	100 ± 100	0.005
Pond C-2	2	0 ± 600	300 ± 700	200 ± 500	0.01
Walnut Creek at Indiana Street	48	-900 ± 1100	700 ± 700	100 ± 100	0.005

*The interim standard calculated Derived Concentration Guide (DCG) for tritium in water available to the members of the public is 2,000,000 x 10⁻⁹ µCi/ml. (See Appendix A.)

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TABLE 13 Uranium Concentrations in Rocky Flats Raw Water Supply

Location	Number of Analyses	Uranium Concentration ($\times 10^{-6}$ $\mu\text{Ci}/\text{ml}$) ^a			Percent of DCG
		C_{min}	C_{max}	C_{mean}	
Rocky Flats Raw Water ^b	12	0 ± 1	3.20 ± 0.3	1.2 ± 0.1	0.2

a. Radiochemically determined as uranium 233, -234, and -238. The interim standard calculated Derived Concentration Guide (DCG) for uranium in water available to members of the public is 500×10^{-6} $\mu\text{Ci}/\text{ml}$. (See Appendix A.)

b. Source of raw water - Ralston Reservoir and South Boulder Diversion Canal.

As previously mentioned surface runoff water from the Rocky Flats Plant passes through Ponds A-4, B-5, and C-2 where the water is sampled and analyzed for radionuclides during the discharge process. During 1985, the total curies measured for plutonium from Ponds A-4, B-5, and C-2 were 1.14×10^{-6} , 1.71×10^{-6} , and 1.09×10^{-6} , respectively. The total curies measured for uranium were 2.86×10^{-4} , 8.04×10^{-4} , and 0.81×10^{-4} , respectively. The total curies measured for americium were 5.72×10^{-7} , 13.2×10^{-7} , and 8.74×10^{-7} , respectively. And finally, the total curies measured for tritium from Ponds A-4, B-5, and C-2 were 1.14×10^{-2} , 2.64×10^{-2} , and 0.44×10^{-2} , respectively.

During 1985, Rocky Flats Plant raw water supply was obtained from Ralston Reservoir and from the South Boulder Diversion Canal. Ralston Reservoir water usually contains more natural uranium radioactivity than the water flowing from the South Boulder Diversion Canal. During the year, uranium analyses were performed monthly on samples of Rocky Flats raw water. The uranium concentrations measured during 1985 are presented in Table 13. Uranium concentrations measured during 1985 in raw water averaged 1.2×10^{-9} $\mu\text{Ci}/\text{ml}$ (0.05 Bq/l) or 0.002 $\mu\text{g}/\text{ml}$.

Biocides and herbicides are used for pest and weed control on the Rocky Flats plantsite, and water samples are collected from Ponds B-4 and C-1 during application. Analytical results for the materials used, 2,4-D and Bromacil, have consistently been

less than 2 parts per billion. The recommended concentration limit for these materials is 100 parts per billion.

Approximately 2000 gallons of polychlorinated biphenyls (PCBs) containing low-level plutonium radioactivity are stored at the Rocky Flats Plant. The EPA has been requested to approve a plan for removal of these contaminated materials. Some operating transformers contain PCBs, and each is identified and protected according to EPA regulations. Analytical results from downstream waters during 1985 showed no concentrations of PCBs in excess of the analytical detection limit of approximately 1 part per billion.

E Groundwater Monitoring

Extensive hydrogeologic and groundwater quality investigations were conducted during 1985. Hydrogeologic projects included reviews of all geologic reports prepared from 1952 through 1984, reviews of lithologic logs and well construction data, geologic mapping, surface and borehole geophysical investigations, soil vapor sampling feasibility studies, and well hydraulic tests. All existing wells were field surveyed and their total depths measured. The existing groundwater quality data base (1973-1984) was reviewed, site groundwater quality was characterized, and the existing groundwater monitoring program was evaluated. Based on that evaluation several changes to the program are being implemented.

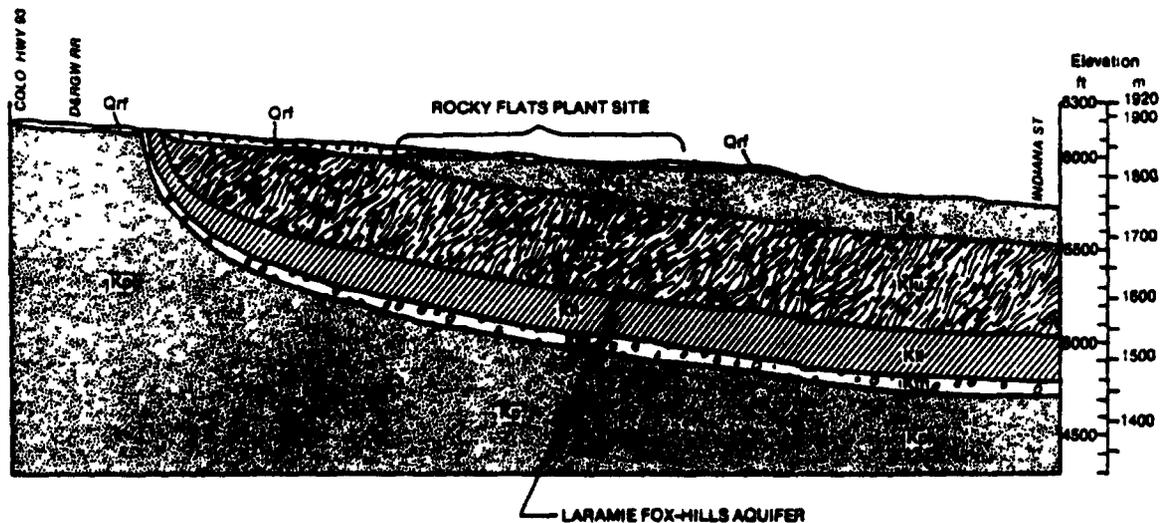
Hydrogeology—Two hydraulically connected groundwater flow systems are present at the Rocky Flats Plant. Flow occurs in the Rocky Flats Alluvium and valley fill materials, and in the Arapahoe Formation. The Laramie-Fox Hills Aquifer also underlies the plant, but is separated from the Arapahoe Formation by several hundred feet of the relatively impermeable shales of the Upper Laramie Formation. There is little, if any, hydraulic connection between the Arapahoe and Laramie-Fox Hills Formations. Figure 10 shows the general relationships between geologic units underlying the plant area.

The Rocky Flats Alluvium overlies the Arapahoe Formation. The alluvium is a poorly sorted deposit of sand, gravel and cobbles which is up to 50 feet thick west of the plant but has been completely eroded east of the plant. The alluvium forms a gravel-capped surface which is dissected by North Walnut, South Walnut and Woman Creeks.

The Arapahoe Formation dips approximately 5 to 15 degrees eastward toward the center of the Denver Basin. The Arapahoe is composed of thick claystone with mostly discontinuous, interbedded sandstone lenses. Some continuous lenses occur at

depths of approximately 135 to 175 feet. The majority of the groundwater movement in the Arapahoe Formation occurs in sandstone lenses. Recharge to the sandstones occurs at their subcrops beneath the alluvium and by downward leakage through

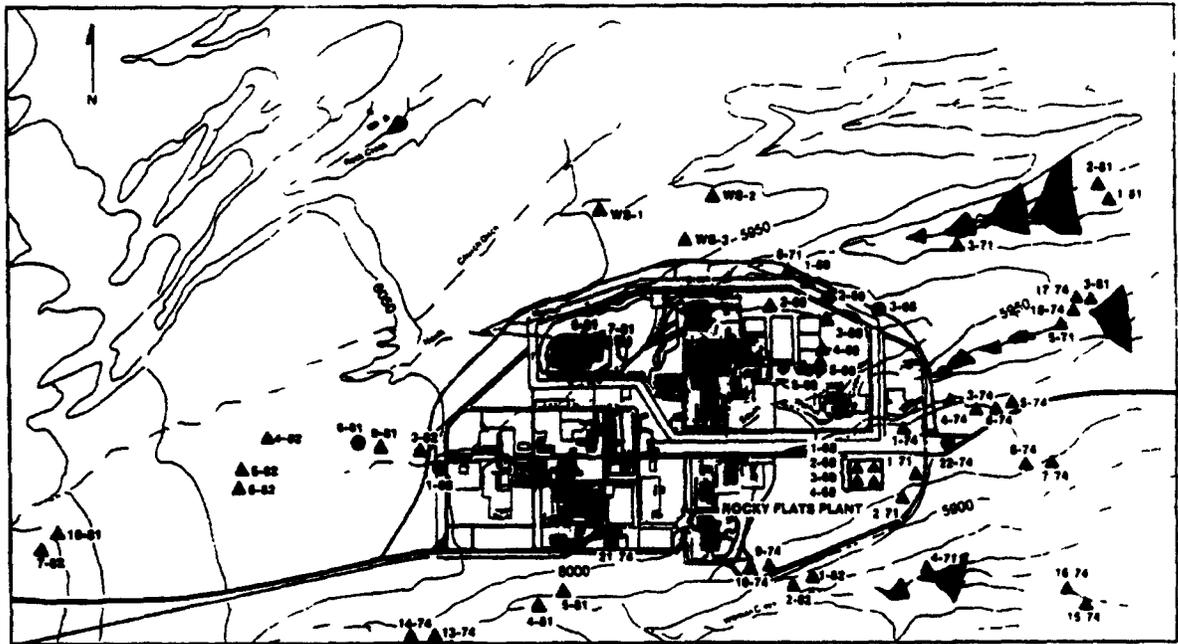
FIGURE 10 Geologic Cross-Section in the Rocky Flats Plant Area



- | | | | |
|-----|-------------------------|-----|-------------------------|
| Grf | ROCKY FLATS ALLUVIUM | KII | LOWER LARAMIE FORMATION |
| Ka | ARAPAHOE FORMATION | KM | FOX HILLS SANDSTONE |
| KIu | UPPER LARAMIE FORMATION | Kp | PIERRE SHALE |

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FIGURE 11 Locations of Groundwater Monitoring Wells at Rocky Flats



LEGEND

- MONITORING WELL GREATER THAN 30 METERS
- ▲ MONITORING WELL LESS THAN 15 METERS

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the claystones. Flow is generally eastward toward the regional discharge area along the South Platte River

a landfill, spray irrigation sites, and Walnut and Woman Creeks.

Sampling and Analysis—During 1985, samples were collected in March, July, October, and December from the 56 monitoring wells shown in Figure 11. Six of the wells range from 30 to 79 meters (100 to 258 feet) in depth. All remaining wells range from 1 to 19 meters (3 to 64 feet) deep and are located near solar evaporation ponds, holding ponds, underground tanks, old waste burial sites,

Groundwater samples are analyzed for inorganic, organic, radioactive, and water quality indicator parameters. The specific parameters analyzed are listed in Table 14. Conductivity and pH are determined electrometrically. Total dissolved solids (TDSs) are determined by standard gravimetric techniques. Alkalinity and hardness are determined by electrometric titration. Anions are analyzed by ion chromatography. The cations and metals are analyzed by atomic absorption and

TABLE 14 Chemical Parameters in the Groundwater Monitoring Program

Indicators

- Total Dissolved Solids
- Total Organic Carbon
- Conductivity
- pH
- Hardness

Major Cations

- Calcium
- Magnesium
- Sodium
- Potassium

Major Anions

- | | |
|-----------------------|-----------|
| Chloride | Nitrate |
| Sulfate | Fluoride |
| Carbonate/Bicarbonate | Hydroxide |

Radiometrics

- | | |
|-------------|-----------|
| Gross Alpha | Tritium |
| Gross Beta | Plutonium |
| Radium | Americium |
| | Uranium |

Metals

- | | | |
|-----------|-------------|-----------|
| Silver | Copper | Selenium |
| Aluminum | Iron | Tin |
| Arsenic | Germanium | Strontium |
| Boron | Mercury | Tantalum |
| Barium | Lithium | Tellurium |
| Beryllium | Manganese | Thallium |
| Bismuth | Molybdenum | Thorium |
| Cadmium | Niobium | Titanium |
| Cerium | Nickel | Vanadium |
| Cobalt | Phosphorous | Tungsten |
| Chromium | Lead | Zinc |
| Cesium | Rubidium | Zirconium |
| Antimony | | Uranium |

Organics

- Phenols
- Volatile Organic Compounds

emission spectroscopy Radiometric analyses are performed using standard counting techniques Total organic carbon (TOC) and volatile organic compound (VOC) concentrations are determined according to standard EPA procedures

Results of the laboratory analyses are presented in Tables 15-18 for the plutonium, americium, uranium, and tritium As identified in Tables 15 and 16, plutonium and americium are barely detectable

Uranium exceeding the plant's internal control guide of $300 \times 10^{-9} \mu\text{Ci}/\text{mL}$ was detected only in Well 4-60 Anomalous concentrations of uranium ($>15 \times 10^{-9} \mu\text{Ci}/\text{mL}$) were found in Wells 1-60, 6-71, 9-74, 10-74, 15-74, 17-74, and 1-82 (see Table 17) Pockets of uranium occur naturally in the soils and rocks surrounding the plantsite Some of these uranium deposits have proven rich enough to be commercially exploited Thus, native rock, rather than plant operations, is the source of much or all of the uranium detected in groundwater Regardless of the source, uranium concentrations in groundwater samples did not exceed historical concentration levels

Tritium was detected in Wells 4-60 and 6-71 in concentrations exceeding the plant control guideline of $1500 \times 10^{-9} \mu\text{Ci}/\text{mL}$ (see Table 18) A review of the previous data indicates that tritium levels in groundwater samples from these wells fluctuate considerably No tritium concentrations in 1985 samples exceeded those of previous years

There are no applicable Derived Concentration Guides (DCGs) for groundwater However, the concentrations of plutonium, americium, uranium, and tritium in all samples were well below the calculated Department of Energy interim standard DCGs for water discharged to uncontrolled areas (See Appendix A) Groundwater data for the other parameters listed in Table 14 have been compiled and summarized in the Rocky Flats Resource Conservation and Recovery Act (RCRA) Part B Permit Application for Radioactive Mixed Wastes submitted to both the US Environmental Protection Agency and the Colorado Department of Health (US Department of Energy, 1985) Based on the detection of VOCs in several wells on plantsite, comprehensive hydrogeologic investigations were initiated during 1985 to determine the sources, concentrations and extent of VOCs in

Rocky Flats groundwater Briefings and updates on the progress of the hydrogeological site characterization were presented at several State exchange public meetings in 1985 Involvement by the Colorado Health Department (CDH) on split sampling of groundwater samples and inspection of groundwater monitoring wells and sampling activities also occurred during 1985 Installation of new high quality monitoring wells and further groundwater assessment studies are scheduled for CY1986 Results from these groundwater initiatives will be forthcoming in the CY1986 annual Environmental Monitoring Report

F Regional Water Monitoring

Regional water monitoring includes sampling and analysis of public water supplies and tap water from several surrounding communities Of the regional water supplies, only Great Western Reservoir and Standley Lake receive runoff from Rocky Flats drainage systems (Figure 4) The Rocky Flats contributions to radionuclides in regional water supplies through airborne emissions were estimated in the Plant Environmental Impact Statement¹ These contributions were insignificant compared to contributions from fallout and natural background

Water samples were collected weekly during 1985 from Great Western Reservoir, a water supply for the city of Broomfield, and from Standley Lake a water supply for the city of Westminster and portions of the cities of Thornton and Northglenn The weekly samples were composited into a monthly sample, and analyses were performed for plutonium, uranium and americium concentrations Tritium analysis was conducted for each weekly sample Annual grab samples were also collected from three regional reservoirs (Ralston Dillon, and Boulder) and one stream (South Boulder Diversion Canal) at distances ranging from 1.6 to 96 kilometers (1 to 60 miles) from the plant These samples were collected to determine background data for plutonium, uranium, americium, and tritium in water These data are presented in Tables 19 and 20

Drinking water from Boulder, Broomfield and Westminster was collected weekly, composited monthly, and analyzed for plutonium, uranium and americium Tritium analyses were performed

TABLE 15 Plutonium Concentrations in Groundwater Monitoring Wells

Location Number	Depth (meters)	Plutonium Concentration ($\times 10^{-6}$ $\mu\text{Ci}/\text{m}^3$) ^a			
		March	July	October ^c	December ^d
1-60	8	0.03 \pm 0.03	Dry		Dry
2-60	7	Dry	-0.03 \pm 0.12		0.02 \pm 0.02
3-60	6	0.04 \pm 0.03	-0.01 \pm 0.12		0.06 \pm 0.03
4-60	5	-0.01 \pm 0.02	0.13 \pm 0.12		0.03 \pm 0.02
5-60	6	Dry	0.00 \pm 0.12		Dry
6-60	9	0.00 \pm 0.02	-0.03 \pm 0.12		0.05 \pm 0.02
1-66	46	0.02 \pm 0.02	-0.02 \pm 0.12		0.07 \pm 0.02
2-66	43	-0.03 \pm 0.01	-0.05 \pm 0.11		ND
3-66	44	0.01 \pm 0.02	-0.03 \pm 0.13		0.01 \pm 0.01
1-68	1	Dry		Dry	
2-68	1	Dry	Dry	Dry	
3-68	1	Dry	Dry	Dry	
4-68	1	Dry	Dry	Dry	
1-71	9	-0.01 \pm 0.02	-0.03 \pm 0.12	ND	
2-71	9	0.03 \pm 0.02	-0.03 \pm 0.12	ND	
3-71	9	-0.02 \pm 0.01	-0.03 \pm 0.12		0.03 \pm 0.02
4-71	7	-0.01 \pm 0.01	-0.02 \pm 0.12	0.03 \pm 0.03	
5-71	8	Dry	Dry		Dry
6-71	19	ND ^b	-0.03 \pm 0.12		0.05 \pm 0.02
1-74	7	-0.01 \pm 0.02	-0.01 \pm 0.12	0.01 \pm 0.03	
3-74	7	Dry	Dry	Dry	
4-74	2	Dry	Dry	Dry	
5-74	6	Dry	Dry	Dry	
6-74	2	Dry	Dry	Dry	
7-74	15	0.04 \pm 0.02	-0.02 \pm 0.12	ND	
8-74	12	Dry	Dry	Dry	
9-74	6	0.01 \pm 0.02	-0.02 \pm 0.12	-0.01 \pm 0.03	
10-74	3	0.03 \pm 0.02	Dry	Dry	
13-74	6	0.01 \pm 0.02	-0.02 \pm 0.12	0.00 \pm 0.03	
14-74	1	Dry	Dry	Dry	
15-74	6	0.03 \pm 0.02	-0.04 \pm 0.12		0.02 \pm 0.02
16-74	1	Dry	Dry	Dry	
17-74	4	0.01 \pm 0.02	0.01 \pm 0.12		0.05 \pm 0.02
18-74	2	Dry	Dry		Dry
21-74	79	0.01 \pm 0.02	-0.02 \pm 0.12	ND	
22-74	61	0.02 \pm 0.02	0.00 \pm 0.12	0.03 \pm 0.04	
WS-1	8	0.02 \pm 0.02	-0.04 \pm 0.11	0.03 \pm 0.03	
WS-2	4	0.02 \pm 0.02	-0.03 \pm 0.13	Dry	
WS-3	4	Dry	Dry	Dry	
1-81	6	-0.01 \pm 0.02	-0.03 \pm 0.13		0.03 \pm 0.02
2-81	6	0.00 \pm 0.02	-0.02 \pm 0.13		0.03 \pm 0.02
3-81	6	0.03 \pm 0.02	-0.02 \pm 0.12		ND
4-81	1	Dry	Dry	Dry	
5-81	6	0.00 \pm 0.02	0.03 \pm 0.12	0.01 \pm 0.03	
6-81	9	0.02 \pm 0.02	-0.02 \pm 0.12	-0.01 \pm 0.02	
7-81	9	0.01 \pm 0.02	0.00 \pm 0.12	-0.03 \pm 0.02	
8-81	30	0.00 \pm 0.02	-0.02 \pm 0.11	0.00 \pm 0.03	
9-81	9	-0.00 \pm 0.02	0.01 \pm 0.13	0.01 \pm 0.03	
10-81	9	0.04 \pm 0.03	-0.02 \pm 0.13	-0.01 \pm 0.02	
1-82	6	-0.03 \pm 0.01	-0.03 \pm 0.12	0.00 \pm 0.03	
2-82	3	Dry	Dry	Dry	
3-82	8	-0.02 \pm 0.02	-0.02 \pm 0.13	0.00 \pm 0.02	
4-82	9	Dry	Dry	Dry	
5-82	9	0.08 \pm 0.03	-0.01 \pm 0.12	-0.00 \pm 0.02	
6-82	9	0.01 \pm 0.02	-0.01 \pm 0.12	-0.01 \pm 0.02	
7-82	7	Dry	Dry	Dry	

a. Radiochemically determined as plutonium 239, 240.

b. No Data Available.

c. Non-Resource Conservation and Recovery Act (RCRA) wells.

d. RCRA wells (plus 15-74) Seventeen existing wells were designated as "interim status" groundwater monitoring wells in 1981 as part of the Department of Energy's RCRA-equivalent program.

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TABLE 16 Americium Concentrations in Groundwater Monitoring Wells

Location Number	Depth (meters)	Americium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{ml}$) ^a			
		March	July	October ^c	December ^d
1-60	8	0.04 ± 0.02	Dry		Dry
2-60	7	Dry	-0.05 ± 0.06		0.04 ± 0.06
3-60	6	0.04 ± 0.02	-0.01 ± 0.06		0.06 ± 0.06
4-60	5	0.03 ± 0.02	0.00 ± 0.06		0.02 ± 0.06
5-60	6	Dry	-0.01 ± 0.06		Dry
6-60	9	0.02 ± 0.03	-0.01 ± 0.07		0.00 ± 0.06
1-66	46	0.05 ± 0.02	0.03 ± 0.06		0.14 ± 0.07
2-66	43	0.04 ± 0.02	-0.04 ± 0.06		ND
3-66	44	0.04 ± 0.02	0.02 ± 0.06		ND
1-68	1	Dry	Dry	Dry	
2-68	1	Dry	Dry	Dry	
3-68	1	Dry	Dry	Dry	
4-68	1	Dry	Dry	Dry	
1-71	9	0.00 ± 0.02	-0.04 ± 0.06	ND	
2-71	9	0.02 ± 0.02	0.16 ± 0.08	0.02 ± 0.06	
3-71	9	0.08 ± 0.02	0.01 ± 0.06		0.05 ± 0.06
4-71	7	0.05 ± 0.02	-0.04 ± 0.06	0.02 ± 0.06	
5-71	8	Dry	Dry		Dry
6-71	19	ND ^b	-0.03 ± 0.07		0.11 ± 0.07
1-74	7	0.01 ± 0.02	0.00 ± 0.06	0.03 ± 0.06	
3-74	7	Dry	Dry	Dry	
4-74	2	Dry	Dry	Dry	
5-74	6	Dry	Dry	Dry	
6-74	2	Dry	Dry	Dry	
7-74	15	0.01 ± 0.01	0.01 ± 0.06	ND	
8-74	12	Dry	Dry	Dry	
9-74	6	0.03 ± 0.02	0.04 ± 0.07	0.08 ± 0.06	
10-74	3	0.01 ± 0.02	Dry	Dry	
13-74	6	0.02 ± 0.02	-0.02 ± 0.06	0.00 ± 0.06	
14-74	1	Dry	Dry	Dry	
15-74	6	0.10 ± 0.03	0.01 ± 0.06		0.06 ± 0.06
16-74	1	Dry	Dry	Dry	
17-74	4	0.02 ± 0.01	0.16 ± 0.08		0.06 ± 0.07
18-74	2	Dry	Dry		Dry
21-74	79	0.01 ± 0.02	-0.02 ± 0.06	0.03 ± 0.06	
22-74	61	0.03 ± 0.07	0.00 ± 0.06	-0.02 ± 0.06	
WS-1	8	-0.01 ± 0.01	-0.02 ± 0.06	0.02 ± 0.06	
WS-2	4	0.03 ± 0.02	0.02 ± 0.06	Dry	
WS-3	4	Dry	Dry	Dry	
1-81	6	0.02 ± 0.02	-0.04 ± 0.06		0.05 ± 0.06
2-81	6	0.01 ± 0.02	-0.06 ± 0.07		0.09 ± 0.06
3-81	6	0.06 ± 0.02	0.02 ± 0.07		ND
4-81	1	Dry	Dry	Dry	
5-81	6	0.02 ± 0.02	0.06 ± 0.07	0.01 ± 0.06	
6-81	9	0.04 ± 0.02	-0.01 ± 0.06	0.14 ± 0.07	
7-81	9	0.07 ± 0.02	0.05 ± 0.07	0.08 ± 0.06	
8-81	30	0.02 ± 0.02	-0.04 ± 0.06	0.06 ± 0.06	
9-81	9	0.03 ± 0.02	0.00 ± 0.06	-0.03 ± 0.06	
10-81	9	0.02 ± 0.02	-0.02 ± 0.06	0.04 ± 0.06	
1-82	6	0.04 ± 0.02	-0.04 ± 0.06	0.17 ± 0.07	
2-82	3	Dry	Dry	Dry	
3-82	8	0.04 ± 0.02	0.03 ± 0.07	0.10 ± 0.07	
4-82	9	Dry	Dry	Dry	
5-82	9	0.00 ± 0.02	0.00 ± 0.06	0.08 ± 0.07	
6-82	9	0.07 ± 0.02	0.02 ± 0.06	0.02 ± 0.06	
7-82	7	Dry	Dry	Dry	

a. Radiochemically determined as americium -241

b. No Data Available.

c. Non-Resource Conservation and Recovery Act (RCRA) wells.

d. RCRA wells (plus 15-74) Seventeen existing wells were designated as "interim status" groundwater monitoring wells in 1981 as part of the Department of Energy's RCRA-equivalent program.

TABLE 17 Uranium Concentrations in Groundwater Monitoring Wells

Location Number	Depth (meters)	Uranium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{ml}$) ^a			
		March	July	October ^c	December ^d
1-60	8	18.4 ± 2.2	Dry		Dry
2-60	7	Dry	13.3 ± 3.8		ND
3-60	6	6.6 ± 0.8	5.1 ± 3.5		10.4 ± 1.4
4-60	5	23.9 ± 2.7	45.4 ± 7.0		ND
5-60	6	Dry	4.4 ± 3.5		Dry
6-60	9	2.8 ± 0.4	2.8 ± 3.5		2.3 ± 0.4
1-66	46	0.3 ± 0.1	0.0 ± 3.4		0.4 ± 0.2
2-66	43	1.4 ± 0.2	-0.2 ± 3.4		ND
3-66	44	2.8 ± 0.4	1.8 ± 3.4		ND
1-68	1	Dry	Dry	Dry	
2-68	1	Dry	Dry	Dry	
3-68	1	Dry	Dry	Dry	
4-68	1	Dry	Dry	Dry	
1-71	9	2.6 ± 0.4	2.2 ± 3.6		ND
2-71	9	1.1 ± 0.2	2.0 ± 3.4	0.2 ± 0.2	
3-71	9	0.1 ± 0.1	0.4 ± 3.4		ND
4-71	7	0.1 ± 0.1	0.6 ± 3.4	1.0 ± 0.3	
5-71	8	Dry	Dry		Dry
6-71	19	ND ^b	29.4 ± 6.9		27.7 ± 4.6
1-74	7	5.6 ± 0.7	3.1 ± 3.5	4.9 ± 0.7	
3-74	7	Dry	Dry	Dry	
4-74	2	Dry	Dry	Dry	
5-74	6	Dry	Dry	Dry	
6-74	2	Dry	Dry	Dry	
7-74	15	4.1 ± 0.8	4.2 ± 3.5	4.1 ± 0.7	
8-74	12	Dry	Dry	Dry	
9-74	6	21.5 ± 3.0	15.4 ± 3.9	20.9 ± 3.3	
10-74	3	15.1 ± 1.7	Dry	Dry	
13-74	6	5.5 ± 0.7	4.7 ± 3.5	5.6 ± 0.8	
14-74	1	Dry	Dry	Dry	
15-74	6	23.0 ± 2.8	17.1 ± 4.4		25.4 ± 4.2
16-74	1	Dry	Dry	Dry	
17-74	4	16.2 ± 2.2	14.9 ± 4.0		22.0 ± 3.5
18-74	2	Dry	Dry		Dry
21-74	79	1.4 ± 0.3	0.6 ± 3.4	0.3 ± 0.2	
22-74	61	6.9 ± 1.0	7.4 ± 3.6	7.6 ± 0.9	
WS-1	8	0.0 ± 0.1	-0.4 ± 3.4	-0.1 ± 0.2	
WS-2	4	4.1 ± 0.7	2.2 ± 0.6	Dry	
WS-3	4	Dry	Dry	Dry	
1-81	6	3.5 ± 0.5	2.0 ± 0.5		2.4 ± 0.5
2-81	6	2.4 ± 0.4	2.7 ± 0.8		2.9 ± 0.5
3-81	6	1.2 ± 0.2	4.2 ± 3.5		ND
4-81	1	Dry	Dry	Dry	
5-81	6	12.2 ± 1.4	10.1 ± 3.6	12.5 ± 1.6	
6-81	9	12.0 ± 1.5	0.6 ± 3.4	1.4 ± 0.3	
7-81	9	1.5 ± 0.3	7.7 ± 3.8	2.0 ± 0.4	
8-81	30	3.9 ± 0.5	3.8 ± 0.8	3.6 ± 0.5	
9-81	9	0.5 ± 0.2	0.2 ± 0.4	1.0 ± 0.3	
10-81	9	0.1 ± 0.1	-0.1 ± 0.4	0.1 ± 0.2	
1-82	6	26.6 ± 3.7	19.9 ± 4.5	18.1 ± 2.4	
2-82	3	Dry	Dry	Dry	
3-82	8	0.0 ± 0.1	-0.4 ± 3.7	0.0 ± 0.2	
4-82	9	Dry	Dry	Dry	
5-82	9	0.2 ± 0.1	-0.2 ± 3.4	-0.1 ± 0.2	
6-82	9	0.5 ± 0.2	-0.1 ± 3.4	0.6 ± 0.3	
7-82	7	Dry	Dry	Dry	

a. Radiochemically determined as uranium -233, -234, and -238.

b. No Data Available.

c. Non-Resource Conservation and Recovery Act (RCRA) wells.

d. RCRA wells (plus 15-74) Seventeen existing wells were designated as "interim status" groundwater monitoring wells in 1981 as part of the Department of Energy's RCRA-equivalent program

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TABLE 18 Tritium Concentrations in Groundwater Monitoring Wells

Location Number	Depth (meters)	Tritium Concentration ($\times 10^{-3}$ $\mu\text{Ci}/\text{m}^3$)			
		March	July	October ^b	December ^c
1-60	8	340 ± 690	Dry		Dry
2-60	7	Dry	-280 ± 290		540 ± 920
3-60	6	ND ^a	170 ± 650		600 ± 860
4-60	5	300 ± 780	80 ± 920		4590 ± 1530
5-60	6	Dry	500 ± 670		Dry
6-60	9	650 ± 710	570 ± 670		220 ± 1350
1-66	46	ND	500 ± 680		660 ± 1570
2-66	43	1480 ± 750	690 ± 680		ND
3-66	44	1050 ± 730	310 ± 660		-20 ± 90
1-68	1	Dry	Dry	Dry	
2-68	1	Dry	Dry	Dry	
3-68	1	Dry	Dry	Dry	
4-68	1	Dry	Dry	Dry	
1-71	9	820 ± 710	250 ± 660	-30 ± 630	
2-71	9	130 ± 680	130 ± 650	190 ± 410	
3-71	9	-200 ± 390	480 ± 680		300 ± 880
4-71	7	220 ± 680	300 ± 660	20 ± 650	
5-71	8	Dry	Dry		Dry
6-71	19	ND	1810 ± 710		500 ± 1410
1-74	7	380 ± 690	590 ± 690	340 ± 650	
3-74	7	Dry	Dry	Dry	
4-74	2	Dry	Dry	Dry	
5-74	6	Dry	Dry	Dry	
6-74	2	Dry	Dry	Dry	
7-74	15	210 ± 680	500 ± 680	-130 ± 640	
8-74	12	Dry	Dry	Dry	
9-74	6	220 ± 680	460 ± 680	50 ± 630	
10-74	3	270 ± 680	Dry	Dry	
13-74	6	-280 ± 650	40 ± 650	110 ± 640	
14-74	1	Dry	Dry	Dry	
15-74	6	80 ± 640	220 ± 670		180 ± 860
16-74	1	Dry	Dry	Dry	
17-74	4	1050 ± 690	150 ± 670		520 ± 1380
18-74	2	Dry	Dry		Dry
21-74	79	-190 ± 680	80 ± 650	70 ± 640	
22-74	61	600 ± 700	50 ± 650	-90 ± 400	
WS-1	8	220 ± 680	-220 ± 630	-110 ± 400	
WS-2	4	0 ± 670	10 ± 640	Dry	
WS-3	4	Dry	Dry	Dry	
1-81	6	390 ± 690	-240 ± 630		750 ± 1380
2-81	6	320 ± 690	-290 ± 630		420 ± 1440
3-81	6	210 ± 700	40 ± 650		20 ± 1380
4-81	1	Dry	Dry	Dry	
5-81	6	340 ± 690	140 ± 630	180 ± 410	
6-81	9	100 ± 680	210 ± 660	1090 ± 440	
7-81	9	-340 ± 650	-260 ± 630	390 ± 650	
8-81	30	-260 ± 650	-190 ± 630	80 ± 650	
9-81	9	80 ± 670	170 ± 650	-160 ± 400	
10-81	9	150 ± 680	50 ± 640	190 ± 410	
1-82	6	530 ± 700	280 ± 670	-150 ± 640	
2-82	3	Dry	Dry	Dry	
3-82	8	380 ± 690	-360 ± 620	230 ± 420	
4-82	9	Dry	Dry	Dry	
5-82	9	260 ± 680	20 ± 640	170 ± 410	
6-82	9	1000 ± 720	280 ± 630	180 ± 910	
7-82	7	Dry	Dry	Dry	

a. No Data Available.

b. Non-Resource Conservation and Recovery Act (RCRA) wells.

c. RCRA wells (pits 15-74) Seventeen existing wells were designated as "interim status" groundwater monitoring wells in 1981 as part of the Department of Energy's RCRA-equivalent program

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on weekly grab samples. Quarterly grab samples of tap water were collected from the surrounding communities of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton. Samples were analyzed for plutonium, uranium, americium, and tritium. These data are presented in Tables 19 and 20.

Evaluation of the regional reservoir and drinking water data indicates no unusual results. The plutonium, uranium, americium, and tritium concentrations for the regional reservoirs represented a small fraction (0.5 percent or less) of the DOE interim standard Derived Concentration Guides (DCGs). The average plutonium concentration in Great Western Reservoir was 0.009×10^{-9} $\mu\text{Ci}/\text{mL}$ (3.2×10^{-4} Bq/L). This value is in the range of concentrations predicted for Great Western Reservoir in the Plant Environmental Impact Statement¹. The values given in the Impact Statement are based on known low-level plutonium concentrations in the reservoir sediments. Results of the 1985 plutonium, uranium, americium, and tritium data for drinking water in nine communities were within the background range. All drinking water values were 0.3 percent or less of the applicable DCG.

Drinking water standards have been adopted by the State of Colorado⁶ and the Environmental Protection Agency (EPA)⁷ for alpha-emitting radionuclides (excluding uranium and radon) and for tritium. These standards are 15×10^{-9} $\mu\text{Ci}/\text{mL}$ and $20,000 \times 10^{-9}$ $\mu\text{Ci}/\text{mL}$ (5.55×10^{-1} Bq/L and 740 Bq/L) respectively. During 1985, the sum of the average concentrations of plutonium and americium (alpha-emitting radionuclides) in each community tap water sample was 0.03×10^{-9} $\mu\text{Ci}/\text{mL}$ (1.1×10^{-3} Bq/L) or less. That value is 0.6 percent or less of the EPA and State of Colorado drinking water standard for alpha activity. The average tritium concentrations in Great Western Reservoir, Standley Lake and in all community tap water samples was 200×10^{-9} $\mu\text{Ci}/\text{mL}$ (7.4 Bq/L). That value is typical of background tritium concentrations in Colorado and represents 10 percent or less of the EPA and State of Colorado drinking water standard for tritium^{6,7}.

G Soil Sampling and Analysis

Forty soil samples were collected in September 1985 at radial intervals of approximately 18

degrees and at approximate distances of 1.6 and 3.2 kilometers (1 and 2 miles) from the center of the plant. The geometry of the soil samples was controlled by driving a 10 X 10 centimeters (4 X 4 inches) cutting tool 5 centimeters (2 inches) into undisturbed soil¹⁶. The soil sample within the tool cavity was removed for analysis. Five subsamples were collected from the corners and center of two one-meter squares, which were spaced one meter apart. Each set of ten subsamples was composited for the radiochemical analysis for plutonium.

The 1985 plutonium in soil data are summarized in Table 21 and displayed in Figure 12. Within the plant security area, plutonium concentrations were in the range from 0.02 to 1.0 pCi/g (0.74 to 37 Bq/kg). Outside the plant security area (in the plant buffer zone) plutonium concentrations were in the range from 0.01 to 2.5 pCi/g (0.37 to 18.5 Bq/kg). The maximum values are in the eastern sector and are due east of the previously contaminated oil storage area. The plutonium concentrations measured in 1985 were almost identical to those reported for samples collected at the same sites in 1984. The major exceptions are at site 1-090 where the 1984 value is eight times higher than that for 1985 and at site 2-090 where the 1984 value is four times higher than that for 1985. Possible explanations for these decreased concentrations are continuous weathering and downward migration of plutonium and the existence of "hot particles" in those areas containing elevated plutonium in soil concentrations.

H External Gamma Radiation Dose Monitoring

Thermoluminescent dosimeters (TLDs) are used to measure external penetrating gamma radiation exposure at 47 locations on and off the plantsite. Replicate TLDs are located at each site for an exposure period of three months. The TLDs are placed at 19 locations within the property enclosed by the security fence shown in Figure 1. Measurements are also made at 16 perimeter locations 3 to 6 kilometers (2 to 4 miles) from the plant and in 12 communities located within 50 kilometers (30 miles) of the plant. The TLDs are placed at a height of 1 meter (3 feet) above ground level.

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TABLE 19 Plutonium, Uranium, and Americium Concentrations in Public Water Supplies

Location	Number of Analyses	C_{min}	C_{max}	C_{mean}	Percent of DCG
Reservoir					
Plutonium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{ml}$)^a					
Boulder	1	0.02 \pm 0.02	0.02 \pm 0.02	0.02 = 0.02	0.007
Dillon	1	0.04 \pm 0.02	0.04 \pm 0.02	0.04 = 0.02	0.01
Great Western	12	-0.005 \pm 0.005	0.06 \pm 0.02	0.009 \pm 0.002	0.003
Ralston	1	0.01 \pm 0.02	0.01 \pm 0.02	0.01 = 0.02	0.003
South Boulder Diversion Canal	1	0.01 \pm 0.02	-0.01 \pm 0.02	-0.01 = 0.02	<0.001
Standley	12	-0.001 \pm 0.007	0.011 \pm 0.004	0.004 = 0.004	0.001
Drinking Water					
Arvada	4	-0.02 \pm 0.05	0.01 \pm 0.03	-0.002 = 0.02	<0.001
Boulder	12	0.000 \pm 0.008	0.015 \pm 0.009	0.006 = 0.003	0.002
Broomfield	12	-0.04 \pm 0.02	0.05 \pm 0.02	0.004 = 0.003	0.001
Denver	4	-0.02 \pm 0.02	0.02 \pm 0.03	0.00 = 0.02	<0.001
Golden	4	-0.03 \pm 0.02	0.02 \pm 0.03	0.00 = 0.02	<0.001
Lafayette	4	-0.01 \pm 0.05	0.06 \pm 0.03	0.02 = 0.02	0.007
Louisville	4	-0.02 \pm 0.05	0.00 \pm 0.02	-0.01 = 0.02	<0.001
Thornton	4	0.00 \pm 0.03	0.01 \pm 0.03	0.00 = 0.02	<0.001
Westminster	12	-0.002 \pm 0.006	0.01 \pm 0.004	0.003 = 0.002	0.001
Reservoir					
Uranium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{ml}$)^b					
Boulder	1	0.9 \pm 0.1	0.9 \pm 0.1	0.9 = 0.1	0.2
Dillon	1	1.8 \pm 0.2	1.8 \pm 0.2	1.8 = 0.2	0.3
Great Western	12	1.8 \pm 0.2	3.3 \pm 0.4	2.35 \pm 0.08	0.4
Ralston	1	2.0 \pm 0.2	2.0 \pm 0.2	2.0 = 0.2	0.3
South Boulder Diversion Canal	1	0.6 \pm 0.1	0.6 \pm 0.1	0.6 = 0.1	0.1
Standley	12	1.1 \pm 0.2	2.1 \pm 0.2	1.60 \pm 0.06	0.3
Drinking Water					
Arvada	4	0.20 \pm 0.08	0.9 \pm 0.1	0.41 \pm 0.05	0.07
Boulder	12	-0.02 \pm 0.07	0.41 \pm 0.05	0.16 \pm 0.02	0.03
Broomfield	12	1.0 \pm 0.1	2.0 \pm 0.3	1.45 \pm 0.06	0.2
Denver	4	0.5 \pm 0.1	2.1 \pm 0.2	1.25 \pm 0.08	0.2
Golden	4	0.5 \pm 0.1	2.0 \pm 0.2	1.26 \pm 0.08	0.2
Lafayette	4	0.0 \pm 0.1	0.3 \pm 0.1	0.13 \pm 0.05	0.02
Louisville	4	-0.02 \pm 0.08	0.07 \pm 0.08	0.03 \pm 0.04	0.005
Thornton	4	0.8 \pm 0.1	2.6 \pm 0.3	1.7 = 0.1	0.3
Westminster	12	0.3 \pm 0.1	1.3 \pm 0.2	0.65 = 0.03	0.1
Reservoir					
Americium Concentration ($\times 10^{-9}$ $\mu\text{Ci}/\text{ml}$)^c					
Boulder	1	-0.01 \pm 0.06	-0.01 \pm 0.06	-0.01 = 0.06	<0.001
Dillon	1	0.05 \pm 0.06	0.05 \pm 0.06	0.05 = 0.06	0.08
Great Western	12	0.00 \pm 0.01	0.05 \pm 0.02	0.012 \pm 0.004	0.02
Ralston	1	0.04 \pm 0.06	0.04 \pm 0.06	0.04 = 0.06	0.07
South Boulder Diversion Canal	1	0.02 \pm 0.06	0.02 \pm 0.06	0.02 = 0.06	0.03
Standley	12	-0.01 \pm 0.06	0.03 \pm 0.02	0.006 = 0.006	0.01
Drinking Water					
Arvada	4	-0.02 \pm 0.06	0.04 \pm 0.06	0.00 = 0.03	<0.001
Boulder	12	-0.01 \pm 0.01	0.06 \pm 0.02	0.015 = 0.004	0.02
Broomfield	12	-0.01 \pm 0.01	0.05 \pm 0.02	0.007 = 0.003	0.01
Denver	4	-0.04 \pm 0.05	0.05 \pm 0.06	0.00 = 0.03	<0.001
Golden	4	-0.04 \pm 0.05	0.10 \pm 0.06	0.00 = 0.03	<0.001
Lafayette	4	-0.01 \pm 0.06	0.03 \pm 0.06	0.01 = 0.03	0.02
Louisville	4	-0.04 \pm 0.05	0.06 \pm 0.06	0.02 = 0.03	0.03
Thornton	4	-0.01 \pm 0.06	0.03 \pm 0.06	0.01 = 0.03	0.02
Westminster	12	-0.01 \pm 0.01	0.06 \pm 0.02	0.011 = 0.004	0.02

a Radiochemically determined as plutonium -239 and -240. The interim standard calculated Derived Concentration Guide (DCG) for plutonium in water available to members of the public is 300×10^{-9} $\mu\text{Ci}/\text{ml}$. (See Appendix A.)

b Radiochemically determined as uranium -233, -234, and -238. The interim standard calculated Derived Concentration Guide (DCG) for uranium in water available to members of the public is 500×10^{-9} $\mu\text{Ci}/\text{ml}$. (See Appendix A.)

c Radiochemically determined as americium -241. The interim standard calculated Derived Concentration Guide (DCG) for americium in water available to members of the public is 60×10^{-9} $\mu\text{Ci}/\text{ml}$. (See Appendix A.)

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TABLE 20 Tritium Concentrations in Public Water Supplies

Location	Number of Analyses	C _{min}	C _{max}	C _{mean}	Percent of DCG
<u>Reservoir</u>					
Tritium Concentration ($\times 10^{-6}$ $\mu\text{Ci}/\text{ml}$) ^a					
Boulder	1	-100 \pm 600	-100 \pm 600	-100 \pm 600	<0.001
Dillon	1	-200 \pm 600	-200 \pm 600	-200 \pm 600	<0.001
Great Western	49	-600 \pm 600	700 \pm 800	100 \pm 100	0.005
Ralston	1	-300 \pm 600	-300 \pm 600	-300 \pm 600	<0.001
South Boulder Diversion Canal	1	0 \pm 600	0 \pm 600	0 \pm 600	<0.001
Standley	49	-400 \pm 700	900 \pm 700	200 \pm 100	0.01
<u>Drinking Water</u>					
Arvada	4	-200 \pm 600	300 \pm 800	0 \pm 400	<0.001
Boulder	49	-1000 \pm 1000	800 \pm 700	100 \pm 100	0.005
Broomfield	49	-500 \pm 700	1000 \pm 600	200 \pm 100	0.01
Denver	4	-400 \pm 600	400 \pm 800	0 \pm 400	<0.001
Golden	4	-100 \pm 600	600 \pm 800	100 \pm 400	0.005
Lafayette	4	-400 \pm 600	300 \pm 800	0 \pm 400	<0.001
Louisville	4	-600 \pm 600	100 \pm 800	-100 \pm 400	<0.001
Thornton	4	-300 \pm 100	500 \pm 800	100 \pm 300	0.005
Westminster	49	-300 \pm 700	900 \pm 800	100 \pm 100	0.005

^aThe interim standard calculated Derived Concentration Guide (DCG) for tritium in water available to members of the public is $2,000,000 \times 10^{-6} \mu\text{Ci}/\text{ml}$. The EPA and State of Colorado Primary Drinking Water Regulation limits for tritium are $20,000 \times 10^{-6} \mu\text{Ci}/\text{ml}$

TABLE 21 Plutonium Concentration in Rocky Flats Area Soil Samples^a at One and Two Miles From the Plant

Location	Pu (pCi/g) ^b	Location	Pu (pCi/g) ^b
1-018	0.15 \pm 0.02	2-018	0.04 \pm 0.01
1-036	0.08 \pm 0.01	2-036	0.02 \pm 0.01
1-054	0.02 \pm 0.01	2-054	0.03 \pm 0.01
1-072	0.32 \pm 0.03	2-072	0.33 \pm 0.03
1-090	1.0 \pm 0.09	2-090	2.5 \pm 0.25
1-108	13.0 \pm 1.3	2-108	0.41 \pm 0.04
1-126	1.9 \pm 0.17	2-126	0.42 \pm 0.04
1-144	0.32 \pm 0.03	2-144	0.04 \pm 0.01
1-162	0.10 \pm 0.01	2-162	0.01 \pm 0.00
1-180	0.06 \pm 0.01	2-180	0.11 \pm 0.01
1-198	0.16 \pm 0.02	2-198	0.02 \pm 0.01
1-216	0.05 \pm 0.01	2-216	0.04 \pm 0.01
1-234	0.05 \pm 0.01	2-234	0.05 \pm 0.01
1-252	0.14 \pm 0.02	2-252	0.04 \pm 0.01
1-270	0.07 \pm 0.01	2-270	0.04 \pm 0.01
1-288	0.05 \pm 0.01	2-288	0.04 \pm 0.01
1-306	0.09 \pm 0.01	2-306	0.06 \pm 0.01
1-324	0.15 \pm 0.02	2-324	0.04 \pm 0.01
1-342	0.02 \pm 0.01	2-342	0.13 \pm 0.01
1-360	0.11 \pm 0.01	2-360	0.09 \pm 0.01

^a Sampled to a depth of 5 cm

^b Concentrations are for the fraction of soil measuring less than 2 mm in diameter

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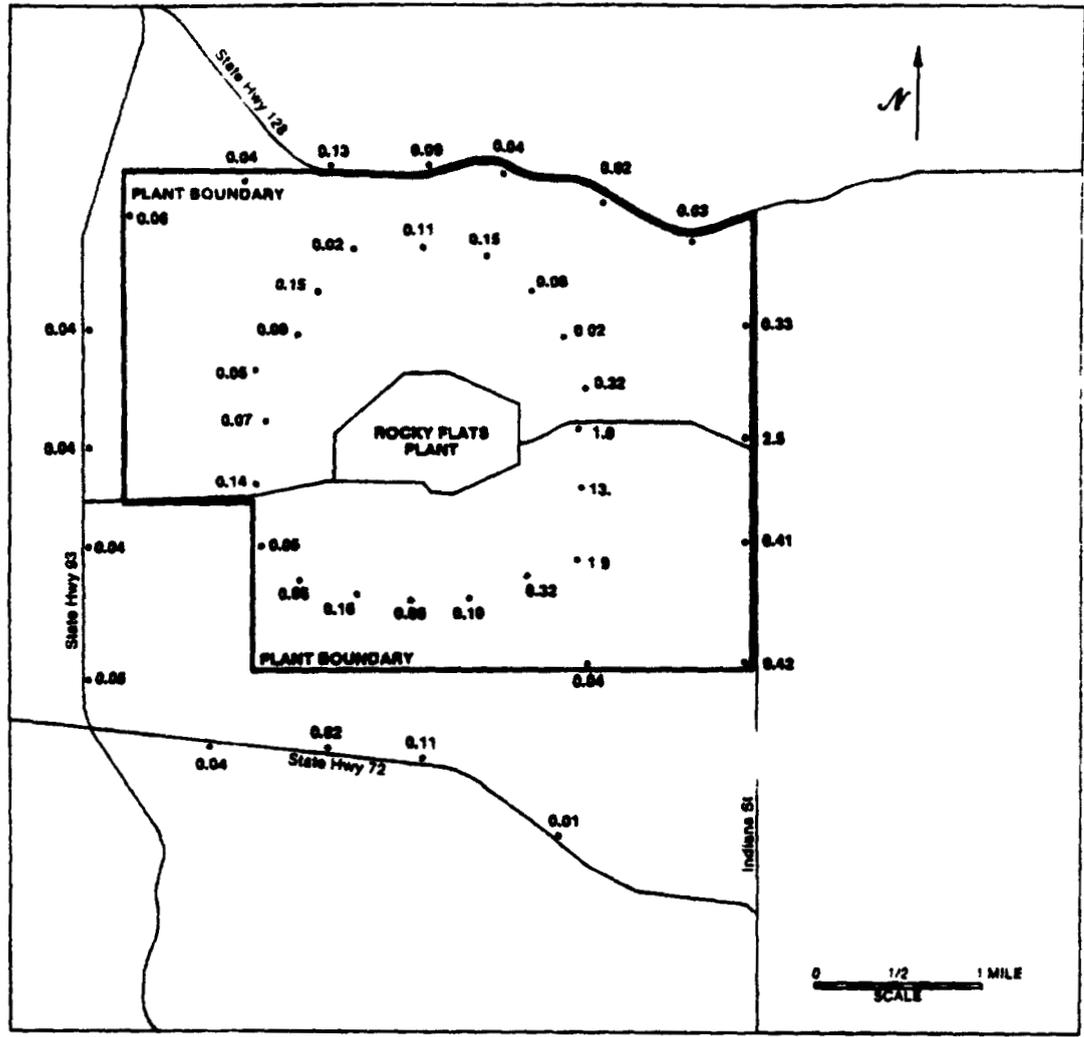


FIGURE 12 Plutonium Concentrations in Soil
(Values in Picocuries Per Gram)

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During 1983, conversion from a Harshaw TLD system to a Panasonic system was initiated. For one complete calendar year, two TLDs of each type were used at each monitoring location. Beginning in 1984 only the Panasonic TLDs were used.

The environmental TLDs consist of two Panasonic 802 dosimeters, each of which has four elements. Only one of the elements of each dosimeter is used. This element consists of $\text{CaSO}_4 \cdot \text{Tm}$ deposited on a polyimide surface. The phosphor is covered with a clear Teflon, and backed with an opaque ABS plastic. The TLDs are packaged in a small plastic bag, a paper envelope, and another plastic bag to protect them from the weather. Total filtration over the phosphor is 178.5 mg/cm^2 .

The environmental dosimeters have been individually calibrated against a Cs-137 gamma source. Calibration linearity studies have confirmed that TLD response is linear for exposure levels ranging from 10 mrem to 6000 mrem. The average calibration factor for each dosimeter is applied to measurements taken with that dosimeter. An additional correction is applied to correct for day-to-day variations in reader calibration.

It was determined that a statistically significant ($p = 0.05$) difference in response exists between the Harshaw environmental monitoring system used prior to 1984, and the Panasonic environmental monitoring systems used beginning in 1984. In order to compare the 1985 values with the previously reported Harshaw data, it is necessary to multiply the Panasonic results given in Table 22 by 1.046.

The data sheets with the locations of the dosimeters for the second quarter 1985 were lost during a staff relocation, so it was not possible to determine a dose equivalent for that quarter for each of the three location categories. Procedures have been changed to preclude recurrence of this problem. The average dose equivalent was determined for the second quarter for all locations to be 40 mrem (0.40 mSv), which was comparable to the values obtained for the other three quarters for all three location categories. At the 95 percent confidence level, there was no significant difference between the total mean dose of the second quarter and the total mean doses for the first, third, or fourth quarters. The annual dose equivalent for each location category was calculated by determining the average mrem/day for each of the three categories using data from Quarters 1, 3, and 4. These values were then multiplied by 365.25 to obtain yearly totals.

In previous Annual Reports, the Annual Measured Dose was reported with a 95 percent confidence interval on the mean using the standard error of the mean, calculated from the variance of the individual measured values. This year, the 95 percent confidence interval on an individual observation within each location category - calculated as 1.96 standard deviations - has been added to the report. This latter interval may be used for assessing the variability of the individual location measurements within a location category.

The 1985 environmental measurements using TLDs are summarized in Table 22. The average annual

TABLE 22 Environmental Thermoluminescent Dosimeter Measurements

Location Category	Number of Locations	Number of Measurements	Mean Annual Measured Dose (mrem) ^a	95% Confidence Interval on the Mean (mrem) ^b	95% Confidence Interval on an Individual Measurement (mrem) ^c
Onsite	19	93	151	± 4	± 37
Perimeter	16	75	137	± 2	± 22
Community	12	56	153	± 5	± 39

a. Second quarter measurements were not used in calculating the annual measured dose for each location category because location information was lost. The mean total dose for all locations for the second quarter was not significantly different at the 95% confidence level than for the 1st, 3rd, or 4th quarters for all locations.

b. Calculated as 1.96 standard deviations of the mean ($1.96 \sigma_x$).

c. Calculated as 1.96 standard deviations of the individual measurements ($1.96 \sigma_x$).

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dose equivalents, as measured onsite, in the perimeter environs, and in communities, were 151, 137, and 153 mrem (1.51, 1.37, and 1.53 mSv), respectively. These values are indicative of background gamma radiation in the area.⁸

V ASSESSMENT OF POTENTIAL PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

In August 1985, the Department of Energy (DOE) adopted an interim radiation protection standard for DOE environmental activities to be implemented in CY1985.¹¹ This interim standard incorporates guidance from the National Council on Radiation Protection and Measurements (NCRP), as well as the Environmental Protection Agency air emission standards of 40 CFR 61, Subpart H. Included in the interim standard is a revision of the dose limits for members of the public and tables of radiation dose conversion factors to be used for calculating dose from intakes of radioactive materials. The dose factors are based on the International Commission on Radiological Protection (ICRP) Publication 30 methodology for radiation dosimetry. The DOE interim standard and the dose conversion factor tables have been used in this 1985 "Annual Environmental Monitoring Report" for assessment of the potential Rocky Flats Plant contribution to public radiation dose. As in past Annual Reports,

the dose limits and dose conversion factors used are specified, and comparisons can be made with information in past Annual Reports to determine the magnitude of the changes.

Potential public radiation dose commitments which could have resulted from plant operations were calculated from average radionuclide concentrations measured at the DOE property boundary and in surrounding communities. Inhalation, water ingestion, and ground-plane irradiation are the principal pathways of exposure. Swimming and consumption of foodstuffs are insignificant pathways. This latter finding 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.

The dose assessment for 1985 was conducted for several locations: the Rocky Flats Plant Property (site) boundary, nearby communities, and sites to a distance of 80 kilometers (50 miles). Dose Conversion factors used for the inhalation and water ingestion pathways were derived from the tables provided by DOE.¹¹ The relative abundances of plutonium and americium isotopes in plutonium used at Rocky Flats (shown in Table 23) were used to calculate composite dose conversion factors for inhalation. The fractions of ingested radionuclides that are absorbed from the gastrointestinal tract and the lung clearance classes for inhaled radionuclides were chosen to maximize

TABLE 23 Isotopic Composition of Plutonium Used at Rocky Flats¹

Isotope	Relative Weight (%)	Specific Activity (Ci/g)	Relative Activity ^a (Ci)	Fraction of Pu Alpha Activity ^b
Pu-238	0.01	17.1	0.00171	0.0233
Pu-239	93.79	0.0622	0.05834	0.7962
Pu-240	5.80	0.228	0.01322	0.1804
Pu-241	0.36	103.5 ^c	0.37260	5.085
Pu-242	0.03	0.00393	1.18 x 10 ⁻⁴	1.61 x 10 ⁻³
Am-241	-	-	-	0.20 ^c

^a Beta Activity

¹ Obtained by multiplying the percent by weight by the specific activity

^b Obtained by dividing the relative activity by the sum of the relative activities for the plutonium alpha emitters.

^c The value for Am-241 is taken to be 20% of the plutonium alpha activity

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the associated dose conversion factors. The inhalation rate of 2.66×10^{-4} m³/s and the water ingestion rate of 2 l (2 l quarts) per day were derived from data for reference man and were included in the factors¹⁷. Each of these dose conversion factors is for a 50-year dose commitment from one year of chronic exposure. Ground-plane irradiation dose conversion factors are from published data by D. C. Kocher^{18, 19}. The dose conversion factors used in this report are listed in Table 24.

A. Dose Assessment Source Terms

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

Inhalation source terms for the 1985 dose assessment were based on plutonium -239 and -240 concentrations measured in ambient air samples.

Although it is known that much of this plutonium in air is from residual fallout from past global atmospheric weapons testing, for the purpose of this dose assessment it was assumed that all of the plutonium originated from the Rocky Flats Plant. The ingestion source terms were based on measured concentrations of plutonium, americium, uranium, and tritium in water. The ground-plane source terms were based on measured values of plutonium in soil and an assumed ratio of 0.20 for the americium to plutonium alpha activity in the soil. This ratio is the maximum level of americium in-growth from Rocky Flats plutonium.¹

The maximum site-boundary dose assessment assumes that an individual is continuously present at the plant perimeter, which actually is uninhabited. The plutonium inhalation source term of 8×10^{-18} $\mu\text{Ci}/\text{m}^3$ (3×10^{-7} Bq/m³) was the maximum annual average concentration of plutonium-239 and -240, as measured for a single location in the perimeter ambient air sampling network.

The water supply for the individual at the site boundary was assumed to be Walnut Creek which intermittently flows offsite and provides the liquid effluent source term at the site boundary. During

TABLE 24 Dose Conversion Factors Used in Dose Assessment Calculations

Organ	Inhalation ^{a, b} (rem milliliter / microcurie)		Water Ingestion ^{a, c} (rem milliliter / microcurie)			Ground-Plane Irradiation ^d (rem square meter / microcurie)	
	Pu-239 -240	Pu-239, -240	Am-241	U-233, 234, 238	Pu-239, 240	Am 241	
Effective Dose Equivalent:	5.57×10^{13}	3.14×10^8	1.63×10^6	1.68×10^5	8.92×10^{-3}	3.05×10^{-3}	
Liver	2.17×10^{13}	1.17×10^8	6.21×10^6	(e)	4.85×10^{-6}	1.78×10^{-1}	
Bone Surfaces	1.02×10^{14}	5.69×10^8	2.97×10^7	2.70×10^6	2.01×10^{-3}	3.69×10^{-3}	
Lung	1.36×10^{13}	(f)	(f)	(f)	1.20×10^{-3}	2.01×10^{-3}	

- a. Inhalation and water ingestion dose conversion factors were adopted from DOE and are for a 50-year dose commitment period and a 1- μm Activity Median Aerodynamic Diameter (AMAD) particle size.¹¹ GI absorption fractions and lung clearance classes were chosen to maximize the dose conversion factors.
- b. An inhalation rate of 2.66×10^{-4} m³/s for 1 year was assumed.
- c. A water intake rate of 2×10^3 ml (2 l quarts) per day for 1 year was assumed.
- d. Ground plane irradiation dose conversion factors were adopted from D. C. Kocher^{18, 19}. For Pu-239, -240 the higher of the factors for the two isotopes was used.
- e. The liver receives no significant dose from this pathway.
- f. The lung receives no significant dose from this pathway.

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1985, the plutonium concentration in Walnut Creek averaged 1.8×10^{-11} $\mu\text{Ci}/\text{mL}$ (6.7×10^{-4} Bq/L). The average americium concentration was 1.3×10^{-11} $\mu\text{Ci}/\text{mL}$ (4.8×10^{-4} Bq/L). These concentrations were used as the water ingestion source term for the maximum site boundary dose assessment. The average concentration of uranium in Walnut Creek was 3.96×10^{-9} $\mu\text{Ci}/\text{mL}$ (1.47×10^{-1} Bq/L) while the average concentration in incoming raw water was 1.2×10^{-9} $\mu\text{Ci}/\text{mL}$ (4.4×10^{-2} Bq/L). The source term for uranium ingestion was the difference between these two values [2.8×10^{-9} $\mu\text{Ci}/\text{mL}$ (1.0×10^{-1} Bq/L)]. The average tritium concentration in Walnut Creek was 1.0×10^{-7} $\mu\text{Ci}/\text{mL}$ (3.7 Bq/L), which is within the background range typically measured in regional waters. This concentration of tritium is an insignificant contributor to dose. Tritium in the water was, therefore, omitted from the dose assessment.

The ground-plane irradiation source term is based on the maximum plutonium in soil deposition at the plant perimeter, as reported by the Environmental Measurements Laboratory²⁰. This source term is 3×10^{-3} $\mu\text{Ci}/\text{m}^2$ (1×10^3 Bq/m²). The americium is assumed to be present at an alpha activity level of 20 percent of that of the plutonium, which is the maximum quantity of americium that can be present in Rocky Flats plutonium from the decay of plutonium-241.¹ The americium source term, therefore, is conservatively estimated to be 6×10^{-3} $\mu\text{Ci}/\text{m}^2$ (2×10^3 Bq/m²).

Source terms and corresponding dose commitments were evaluated for each of the surrounding communities to determine the maximum community exposure. Ground-plane irradiation and water

ingestion pathways were insignificant for all of the communities. The only significant pathway for radiation exposure was inhalation of plutonium in air. The source term for inhalation used in the dose assessment was the maximum annual average plutonium concentration measured in community ambient air [6×10^{-18} $\mu\text{Ci}/\text{mL}$ (2×10^{-7} Bq/m³)]. This concentration was the annual average concentration measured in the Westminster ambient air sampler.

A summary of the source terms for the maximum site boundary and for community locations is tabulated in Table 25.

B. Maximum Site Boundary Dose

The maximum dose to an individual continuously present at the site boundary is based on the radionuclide concentrations shown in Table 25. From these concentrations and the dose conversion factors in Table 24, a 50-year dose commitment of 6×10^{-4} rem (6×10^{-6} Sv) is calculated as the effective dose equivalent from all pathways. The corresponding bone surfaces dose is 9×10^{-3} rem (9×10^{-5} Sv). The Department of Energy (DOE) interim radiation protection standard for members of the public for prolonged periods of exposure is 0.1 rem per year (1×10^{-3} Sv per year) effective dose equivalent. The interim air emission standard is 7.5×10^{-2} rem per year (7.5×10^{-4} Sv per year) for any organ for internally-deposited radionuclides.¹¹ The maximum site boundary dose represents 0.6 percent of the DOE interim standard for all pathways for the effective dose equivalent. If all of the dose were received from the air pathway, it would represent 12 percent of the air emission standard for any organ.

TABLE 25 Radioactivity Concentrations Used for 1985 Dose Calculations

Location	Air ($\mu\text{Ci}/\text{mL}$)		Water ($\mu\text{Ci}/\text{mL}$)		Surface Deposition ($\mu\text{Ci}/\text{m}^2$)	
	Pu-239, 240	Pu-239, -240	Am-241	U-233, 234	Pu-239, 240	Am-241
Maximum Site Boundary	8×10^{-18}	1.8×10^{-11}	1.3×10^{-11}	2.8×10^{-9}	3×10^{-3}	6×10^{-3}
Community	6×10^{-18}	-	-	-	-	-

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C Maximum Community Dose

Based on radionuclide concentrations in surrounding communities (Table 25), the calculated 50-year dose commitments were 3×10^{-3} rem (3×10^{-7} Sv) effective dose equivalent and 6×10^{-4} rem (6×10^{-6} Sv) to bone surfaces. These values represent 0.03 percent of the DOE interim standard for effective dose equivalent and 0.8 percent of the air emission standard for any organ

The maximum site boundary and community 50-year committed dose equivalents are summarized in Table 26. The effective dose equivalents may be compared to an average annual effective dose equivalent for the Denver area of about 2.6×10^{-1} rem (2.6×10^{-3} Sv) from natural background radiation,^{8,9,10} (See Table 27). Thus natural background radiation level for Denver is higher than that shown for the total body in past Annual Reports and reflects the significant contribution to effective dose equivalent from inhaled indoor radon, as well as the adoption of the ICRP 30 methodology of radiation dosimetry.

D Eighty-Kilometer Dose Estimates

The dose commitment for all individuals, to a distance of 80 kilometers (50 miles), is based on the

calculated maximum community dose estimates shown in Table 26. The estimated committed effective dose equivalent and committed dose equivalents for each of the specific organs are all less than 1×10^{-3} rem or 1 mrem (1×10^{-5} Sv). A level of "1 mrem/yr" or less is specified as a *de minimis* (inconsequential) level of exposure in the DOE Guide entitled, "A Guide to Reducing Radiation Exposure to As Low As Reasonably Achievable (ALARA)"¹². The Guide further states

"Radiation-induced mutations and diseases have not been discovered in populations that are or have been exposed to doses of 100 mrem/yr or less. Hence, it is reasonable to suggest that no health effects will be discerned if a population is exposed to an additional 1 percent of the level, i.e., 1 mrem/yr. An annual dose of 1 mrem should be regarded as a level which is clearly *de minimis*."

Based on the *de minimis* concept in the Guide and on the maximum community dose estimates, the dose commitment for all individuals to 80 kilometers is considered to be *de minimis*.

TABLE 26 Fifty-Year Committed Dose Equivalent From One Year of Chronic Intake/Exposure

Source	Effective Dose Equivalent (rem)	Liver (rem)	Bone Surfaces (rem)	Lung (rem)
Maximum Site Boundary Location	6×10^{-4}	3×10^{-4}	9×10^{-3}	1×10^{-4}
Community	3×10^{-4}	1×10^{-4}	6×10^{-4}	6×10^{-4}

TABLE 27 Estimated Annual Natural Background Radiation Dose for the Denver Metropolitan Area^{8,9,10}

Source	Effective Dose Equivalent (rem)
Cosmic Radiation	0.050
Cosmogenic Nuclides	0.0015
Primordial Nuclides-External	0.072
Primordial Nuclides-Internal	0.1326
Total for one year (rounded)	0.26

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VI APPENDIXES

APPENDIX A
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 have been adopted by the Department of Energy (DOE), the Colorado Department of Health and for the air pathway only by the Environmental Protection Agency (EPA)^{11, 21}. 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). Ambient air data for nonradioactive parameters is collected at Rocky Flats for comparison to the criteria pollutants listed under the EPA National Ambient Air Quality Standards, established by the Clean Air Act.⁴ Instrumentation and methodology follow requirements established by EPA in the Quality Assurance Handbook for Air Pollution Measurement Systems.²² Limits for nonradioactive pollutants in effluent water have been defined by an EPA National Pollutant Discharge Elimination System (NPDES) discharge permit.⁵ In 1976, the EPA also established standards for radionuclides in drinking water.⁷ These drinking water standards have been adopted, in turn, by the State of Colorado.⁶

In a memorandum of August 5, 1985, the DOE adopted an interim radiation protection standard for DOE environmental activities to be implemented in CY1985.¹¹ This interim standard incorporates guidance from the NCRP, as well as the air emission standards of 40 CFR 61, Subpart H. Included in the interim standard is a revision of the dose limits for members of the public and tables of radiation dose conversion factors to be used for calculating dose from intakes of radioactive materials. The dose factors are based on ICRP Publication 30 methodology for radiation dosimetry. Effluent air and water concentration guides (secondary standards derived from the primary dose standards and calculated using dose conversion factors and assumed air and water

intake rates) were not included in the memorandum. In order to provide these secondary concentration guides as a comparison for measured air and water concentrations given in this report we have calculated Derived Concentration Guides (DCGs) based on the interim standard dose limit for all pathways of 0.1 rem/year for a 50-year committed effective dose equivalent. The dose conversion factors provided in the August 5 memorandum were used and intake rates of 8400 cubic meters per year ($2.66 \times 10^{-4} \text{ m}^3/\text{s}$) for air and 730 liters per year (2 l/d) for water were assumed for the calculations. The calculated DCGs are given in Table A-1 and are comparable in concept to the Radioactivity Concentration Guides (RCGs) published by DOE for its previous radiation protection standard.²

The previous RCGs included permissible concentrations of specific radionuclides and mixtures of radionuclides in air (RCG_a) and water (RCG_w) for individuals in the general population.² In addition to restricting specific radionuclides, the guides restricted the concentration of radionuclides in a mixture such that the sum of the ratios of each radionuclide concentration to the appropriate concentration guide would not exceed a value of 1. The guides further stated that a radionuclide might 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 did not exceed one tenth and (b) the sum of such ratios for all radionuclides considered as not present in the mixture did not exceed one fourth.

During 1985, average specific radionuclide concentrations in air and water for the Rocky Flats Plant were all less than one tenth of the appropriate Derived Guides for specific radionuclides. The sum of the ratios of these average concentrations to their respective DCGs was less than one fourth for all air and water sampling locations. Applying the same methodology for reporting mixtures under

the DCG concept as was used with RCGs, the measured concentrations in the tables have been compared to the concentration guides for specific radionuclides rather than to the guide for mixtures

The fractions of ingested radionuclides that are absorbed in the gastro-intestinal tract and the lung clearance classes for inhaled radionuclides were chosen to yield the most restrictive DCGs for comparisons in this report. Throughout this report, where a radionuclide concentration is expressed as the cumulative measurement of more than one isotope, the stated DCG used for comparison represents the most restrictive DCG 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 percent of the alpha radioactivity in plutonium handled at the plant.

Reported uranium concentrations are the cumulative alpha activity from uranium-233, -234, and -238. Components containing fully enriched uranium are handled at the Rocky Flats Plant. Depleted uranium metal is fabricated and is handled as process waste material. Uranium-235 is the major isotope by weight (93 percent) in fully enriched uranium, however, uranium-234 accounts for approximately 97 percent of the alpha activity of fully enriched uranium. In depleted uranium, the combined alpha activity from uranium-234 and -238 accounts for approximately 99 percent of the total alpha activity. The uranium DCGs used in this report for air and water are those for uranium-233, -234, and uranium 238 which are the most restrictive.

Environmental uranium concentrations can be measured by a variety of laboratory techniques. Nonradiological techniques yield concentration units of mass per unit volume such as $\mu\text{g}/\text{m}^3$ and $\mu\text{g}/\ell$. The uranium concentrations given in this report were derived by measuring radioactivity from alpha-emitting uranium isotopes and are expressed in terms of activity units per unit volume. Rocky Flats data include measurements of depleted uranium, fully enriched uranium, and natural uranium.

Conversion factors for specific types of uranium can be used to compare the data in this report to

data from other facilities and agencies that are given in units of mass per unit volume. However, the resulting approximations will not have the same assurance of accuracy as that for the original measured values. Uranium in effluent air from plant buildings is primarily depleted uranium. The conversion factor for these data is $2.6 \times 10^6 \text{ g/Ci}$. Natural uranium is the predominant form found in water. The conversion factor for water data is $1.5 \times 10^6 \text{ g/Ci}$.

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.¹⁴ For ambient air, the calculated DCG for plutonium-239 and 240 for members of the public is $20 \times 10^{-15} \mu\text{Ci}/\text{m}^3$ ($7.4 \times 10^{-4} \text{ Bq}/\text{m}^3$).

The calculated americium-241 DCG in waterborne effluents for members of the public is $60 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ ($2.2 \text{ Bq}/\ell$). The comparable DCG for plutonium-239, -240 in water is $300 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ ($11 \text{ Bq}/\ell$). The most restrictive calculated DCG for uranium-233, -234, and -238 in water is $500 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ ($19 \text{ Bq}/\ell$), which is the DCG for uranium-233. In waterborne effluents available to members of the public, the calculated DCG for tritium is $1,000,000 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ ($74,000 \text{ Bq}/\ell$).

The 1976, the EPA promulgated regulations for radionuclides in drinking water.⁷ 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 responsibility 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 the community drinking water standards are of interest in this report. The State standard for gross-alpha activity (including radium-226 but excluding radon and uranium) in community water systems is a maximum of 15 pCi/l or $15 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ ($5.6 \times 10^{-1} \text{ Bq}/\ell$). 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 or $20,000 \times 10^{-9} \mu\text{Ci}/\text{m}^3$ ($740 \text{ Bq}/\ell$).

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RFP-ENV-85/APPLICABLE GUIDES AND STANDARDS

The Rocky Flats Plant NPDES permit, which the EPA reissued in 1984 to DOE, established sanitary effluent limitations on discharge from Pond B-3 (sewage effluent), limitations for nitrate and pH in the discharge from Pond A-3 in the Walnut Creek drainage, limitations on discharge from the reverse osmosis plant, and control of sediment release during discharge from Ponds A-4, B-5, and C-2

In addition to evaluating compliance with all relevant guides, limits, and standards, the Health,

Safety and Environment Department assists 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 "2

Table A-1 shows applicable standards for radioactive and nonradioactive materials.

TABLE A-1 Applicable Standards for Radioactive and Nonradioactive Materials

Legend	
μCi = microcuries	40 CFR 61 = Code of Federal Regulations National Emission Standards for Hazardous Air Pollutants (USEPA)
m^3 = cubic meters	NPDES = National Pollutant Discharge Elimination System
ml = milliliters	
mg/l = milligrams per liter	
SU = standard units	
NA = not applicable	
g = grams	

Parameter	Applicable Guides and Standards	Reference
Airborne Effluents		
Plutonium-239, 240	NA	NA
Uranium-233 -234, 238	NA	NA
Tritium	NA	NA
Beryllium	<10 0 g/day	40 CFR 61.32(a)
Ambient Air		
Plutonium-239 -240	$200 \times 10^{-10} \mu\text{Ci}/\text{m}^3$	Calculated ^a
Waterborne Effluents (Radioactive)		
Plutonium-239, 240	$300 \times 10^{-9} \mu\text{Ci}/\text{ml}$	Calculated ^a
Uranium-233, 234, 238	$500 \times 10^{-9} \mu\text{Ci}/\text{ml}$	Calculated ^a
Americium-241	$60 \times 10^{-9} \mu\text{Ci}/\text{ml}$	Calculated ^a
Tritium	$2,000,000 \times 10^{-9} \mu\text{Ci}/\text{ml}$	Calculated ^a

Parameter	Discharge Limitations ^b			Reference
	Monthly Average	Weekly Average	Daily Maximum	
Effluent Water Samples (Nonradioactive)				
pH		6.0-9.0 SU		NPDES Permit
Nitrates as N	10 mg/l	20 mg/l	NA	NPDES Permit
Total Phosphorus	8 mg/l	NA	12 mg/l	NPDES Permit
Biochemical Oxygen Demand, 5-Day	10 mg/l	NA	25 mg/l	NPDES Permit
Suspended Solids	30 mg/l	45 mg/l	NA	NPDES Permit
Total Chromium	0.05 mg/l	NA	0.1 mg/l	NPDES Permit
Residual Chlorine	NA	NA	0.5 mg/l	NPDES Permit
Oil and Grease	NA	NA	Visual	NPDES Permit
Fecal Coliform - No./100 ml	200	400	NA	NPDES Permit
Total Organic Carbon	22 mg/l	NA	30 mg/l	NPDES Permit

a. Calculated on the basis of DOE August 5, 1985, memorandum using DOE dose limit of 0.1 rem/yr to members of the public from all pathways, dose conversion factors given in the memorandum, and intake rates of $2.66 \times 10^3 \text{ m}^3/\text{s}$ for air and $2 \times 10^3 \text{ ml}/\text{day}$ for water.¹¹ These values have been compared and are identical to those provided as draft DCG values in the DOE memorandum dated February 28, 1986.¹²

b. These limitations are presented as indicators of the types of parameters and associated concentration limits required by the NPDES permit. Details of these requirements specific to each discharge location are given in the referenced document.⁵ The daily and monthly limitations indicated cannot be correlated with the annual water quality data summarized in Table 11.

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APPENDIX B QUALITY CONTROL

A Quality Program Plan and a Quality Control Program Plan have been developed for the Environmental Analysis and Control (EA&C) and the Health, Safety and Environmental Laboratories (HS&EL) Sections, respectively. Independent audits of these plans, coupled with EA&C's internal environmental audit and controls procedures, ensure that necessary quality assurance and quality control elements exist for a comprehensive environmental monitoring program.

The Quality Program Plan developed by the Environmental Analysis and Control (EA&C) Section provides controls for assurance that

- Current operating procedures exist for all phases of EA&C operations and that these procedures are implemented as written.
- Appropriate approvals are obtained prior to program initiation or change.
- The equipment used in sample collection and data analysis is appropriate to the assigned function and is operating as required.
- Accurate documentation exists for all programs, procedures and actions.
- All variances from procedures or equipment use and performance are documented and explained with an impact assessment.
- Appropriate guidelines and standards for environmental monitoring are identified, and documentation of compliance is provided on a routine basis to Rocky Flats management, Department of Energy (DOE), and State and Federal regulatory agencies.

The EA&C Quality Program Plan establishes control points and delineates responsibilities for specific categories of activities, provides an information base from which procedures can be developed, updated, and/or implemented, establishes a state of emergency preparedness in its contingency plans, and provides documented evidence of intent to comply with rules and regulations of Federal, State, and local regulatory agencies.

The Plan includes quality assurance flow charts and quality matrices that illustrate activity networks and corresponding quality elements of each responsibility area. A complete listing of activities and responsibilities is also included in the Plan.

To ensure data reliability, the Health, Safety and Environmental Laboratories (HS&EL) Quality Control Program Plan outlines the quality control methods used in all phases of laboratory operations.

This quality control program includes the following elements:

- Development, evaluation, improvement modification, and documentation of analytical procedures.
- Scheduled instrument calibration, control charting, and preventive maintenance.
- Participation in interlaboratory quality comparison programs.
- Intralaboratory quality control programs.

All sample batches scheduled for analysis by the HS&EL Central Receiving Laboratory contain an average of 10 percent control samples. The controls consist of analytical blanks prepared in-house and standards prepared by the Rocky Flats Chemistry Standards Laboratory.

An analysis or group of analyses may be rejected and the sample or samples scheduled for reanalysis for one or more of the following reasons:

- 1 The chemical recovery is less than 10 percent or greater than 110 percent.
- 2 The analytical blanks in the analysis batch are out of acceptable range.
- 3 The standards in the analysis batch are not within acceptable limits of error.
- 4 The alpha energy spectrum is not acceptable because of the following:
 - a extra and/or unidentified peaks
 - b excess noise in background areas
 - c poor resolution of peaks

5 The chemist in charge of the laboratory believes there is reason to suspect the analysis

Bioassay and Environmental Measurements Program for 1985

Any unusual condition affecting the results, which is noted either during sample collection or analysis, is reported to Environmental Analysis and Control

The HS&EL participate in two laboratory inter-comparison programs (1) The EPA Environmental Monitoring Systems Laboratory (EMSL) Crosscheck Program and (2) The DOE Environmental Measurements Laboratory (EML) Crosscheck Program. Tables B-2 and B-3 summarize the HS&EL participation in both programs.

Table B-1 is a summary of HS&EL participation in the Rocky Flats Chemistry Standards Laboratories

TABLE B-1 Health, Safety and Environmental Laboratories Bioassay and Environmental Measurements Program Data (January Through December 1985)

Isotopes Reported	Matrix	Method	Standard Range	Normal Sample Range	Annual Relative ^a Error Percent	Total Control Analyses
Pu 239 -240	Water	Alpha Spectral	0-20 d/m/ℓ	0-3 d/m/ℓ	-19	60
Am 241	Water	Alpha Spectral	0-3 d/m/ℓ	0-3 d/m/ℓ	-23	60
U 238 234, -235	Water	Alpha Spectral	0-30 d/m/ℓ	0-30 d/m/ℓ	-1	60
H 3	Water	Beta Liquid Scintillation	0-5000 pCi/ℓ	0-4500 pCi/ℓ	-10	60
Pu 239 240	Whatman Filters	Alpha Spectral	0-30 d/m/f	0-30 d/m/f	12	120
Am 241	Whatman Filters	Alpha Spectral	0-4 d/m/f	0-4 d/m/f	30	120
U-238 234 -235	Whatman Filters	Alpha Spectral	0-30 d/m/f	0-30 d/m/f	13	120
Be ^b	Whatman Filters	Atomic Absorption	0-5 µg/f	0-5 µg/f	3	120
Pu-239, -240	Glass Fiber Filters	Alpha Spectral	0-50 d/m/f	0-50 d/m/f	-13	60
Be	Whatman Filters	Atomic Absorption	0-60 µg/f	0-20 µg/f	-4	1040
Pu-239 240	Urine	Alpha Spectral	0-10 d/m	0-5 d/m	15	144
Am-241	Urine	Alpha Spectral	0-2 d/m	0-2 d/m	18	144
U-238, 234, 235	Urine	Alpha Spectral	0-25 d/m	0-15 d/m	-6	144
H-3	Urine	Beta Liquid Scintillation	0-2700 pCi/ℓ	0-2500 pCi/ℓ	13	48
Pu-239 240	Urine (Special)	Alpha Spectral	0-10 d/m	0-10 d/m	-10	48
Am-241	Urine (Special)	Alpha Spectral	0-10 d/m	0-5 d/m	24	48
Pu 239, -240	Swabs	Alpha Spectral	0-100 d/m	0-40 d/m	-28	36
Am-241	Swabs	Alpha Spectral	0-100 d/m	0-40 d/m	2	36
U 238, 234, 235	Swabs	Alpha Spectral	0-100 d/m	0-40 d/m	-28	36

a. The ratio of the deviations 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. Analyzed by 881 General Laboratory

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TABLE B-2 Health, Safety and Environmental Laboratories Participation in the EPA Environmental Monitoring Systems Laboratory Crosscheck Program During 1985

Isotope Reported	Matrix	Method	Number of Analyses Reported	Relative Percent Error
Gross Alpha	Water	Zinc Sulfide Scintillation Detector	4	-3
Zn-65	Water	Gamma Spectral	2	1.53
Cs-134	Water	Gamma Spectral	2	-1.4
Cs-137	Water	Gamma Spectral	3	-1.26
H-3	Water	Beta Liquid Scintillation	2	-1.11
Gross Alpha	Water	Zinc Sulfide Scintillation Detector	1	-4.15
Co-60	Water	Gamma Spectral	1	1.15

TABLE B-3 Health, Safety and Environmental Laboratories Participation in the DOE Environmental Measurements Laboratory Crosscheck Program During 1985 *

Isotope Reported	Matrix	Method	Number of Analyses Reported	Relative Percent Error
Co-60	Filter	Gamma Spectral	2	.84
Cs-137	Filter	Gamma Spectral	2	1.11
Co-60	Soil	Gamma Spectral	1	1.21
Cs-137	Soil	Gamma Spectral	1	1.43
U-238	Soil	Alpha Spectral	1	1.84
Cs-137	Tissue	Gamma Spectral	1	1.02
Th-228	Tissue	Gamma Spectral	1	1.81
Pu-239	Tissue	Alpha Spectral	1	1.08
U-234	Tissue	Alpha Spectral	1	1.69
U-238	Tissue	Alpha Spectral	1	3.75
Co-60	Vegetation	Gamma Spectral	1	.86
Cs-137	Vegetation	Gamma Spectral	1	1.04
Pu-239	Vegetation	Alpha Spectral	1	1.07
Co-60	Water	Gamma Spectral	2	1.04
Cs-137	Water	Gamma Spectral	2	1.21
H-3	Water	Beta Liquid Scintillation	1	2.05
Mn-54	Water	Gamma Spectral	1	1.12
Cs-144	Water	Gamma Spectral	1	1.18
Cd	Deionized Water	Atomic Absorption	1	1.07
Mn	Deionized Water	Atomic Absorption	1	.83
Pb	Deionized Water	Atomic Absorption	1	1.04
Zn	Deionized Water	Atomic Absorption	1	1.03
Cd	Lake Water	Atomic Absorption	1	1.06
Mn	Lake Water	Atomic Absorption	1	.84
Pb	Lake Water	Atomic Absorption	1	1.13
Zn	Lake Water	Atomic Absorption	1	1.06

*Program reinstated in 1983

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**APPENDIX C
ANALYTICAL PROCEDURES**

The Health Safety and Environmental Laboratories (HS&EL) routinely perform the following analyses on environmental and effluent samples

- 1 Total Air Filter Counting (Pu specific alpha)
- 2 Tennelec Air Filter Counting (Gross alpha & gross beta)
- 3 Gamma Spectral Analysis
- 4 Alpha Spectral Analysis (Pu-239, -238, Am-241, U-238, -233, -234)
- 5 Beta Liquid Scintillation (Tritium)
- 6 Iodometric Titration (Chlorine)
- 7 Bacteria
- 8 Atomic Absorption (Beryllium)

Procedures for these analyses are described in the HS&EL Procedures and Practices Manual²⁴. The procedures for bacteria and chlorine analyses were developed following Environmental Protection Agency (EPA) guidelines. Soil procedures were developed following specifications set forward in "Measurements of Radionuclides in the Environment, Sampling and Analysis of Plutonium in Soil" NRC Reg Guide 4.5. All new procedures and changes to existing procedures must be thoroughly tested, documented, and approved in writing by the Manager of HS&EL before being implemented. Environmental Analysis and Control is notified of any major changes that could affect analytical results. All procedures are reviewed annually for consistency with state-of-the-art techniques, or at any time an analytical problem is suspected. Copies of all procedures are kept on file in the office of the Manager of HS&EL.

The following is a general outline of the analytical procedures followed by the laboratories

Samples received for air filter screening are counted approximately 24 and 48 hours after collection. Samples exceeding the limits set by Environmental Analysis and Control are recounted.

All water samples, except those scheduled for tritium analysis, are acidified immediately upon collection. Water samples scheduled for gamma spectral analysis are poured into one-liter Marinelli[®] containers and are sealed before delivery to the gamma counting area. Routine water samples are counted for approximately eight hours. Samples requiring a lower detection limit are counted from 16 to 72 hours.

Soil samples scheduled for gamma spectral analysis are dried, sieved through a ten-mesh sieve, weighed, and the fine portion is ball-milled. The fine portion is then placed in a 500-ml Marinelli container and counted for at least 16 hours.

Filter samples scheduled for gamma analysis are placed in petri dishes and counted for approximately 16 hours.

All samples scheduled for alpha spectral analysis are analyzed in a similar manner regardless of matrix. Prior to dissolution, a known quantity of nonindigenous radioactive tracer is added to each sample. The tracer is used to determine the chemical recovery for the analysis. Tracers used include Pu-236, Pu-242, U-232, U-236, Am-243, and Cm-244. The type and activity level of the tracer used depends on the type and projected activity level of the sample to be analyzed. All refractory or intractable actinides are dissolved by vigorous acid treatment using oxidizing and complexing acids.

After samples are dissolved, radioisotopes of concern are separated from each other and from the matrix material by various solvent extraction and ion exchange techniques. The purified radioisotopes are electrodeposited onto stainless steel discs. These discs are alpha counted for a minimum of 16 hours. If a lower minimum detection limit is required, samples may be counted from 72 to 168 hours depending upon the need. Samples that exhibit a chemical recovery of less than 10 percent or greater than 110 percent are automatically scheduled for reanalysis.

RFP ENV 85/4 ANALYTICAL PROCEDURES

Tritium analyses are routinely performed on specified environmental water samples as well as stack effluent samples. Five ml of the sample are combined with 17 ml of liquid scintillation cocktail mixture. Environmental samples are counted for 60 minutes and airborne effluent samples are counted for 30 minutes.

The General Laboratory routinely performs the following analyses for environmental monitoring of plant effluent streams, process wastes, and soil residues:

- 1 Dissolved metallic elements including tests for 31 cations by emission spectroscopic techniques and 17 elements by atomic absorption techniques (including beryllium in airborne effluent sample filters)
- 2 Oxygen demand tests, including total organic carbon, dissolved oxygen, chemical oxygen demand, and biological oxygen demand (5 day incubation)
- 3 Nutrient tests including free ammonia and amines, ortho and total phosphate phosphorus, nitrate and nitrite anions, Kjeldahl nitrogen, and total nitrogen
- 4 Physical tests, including pH, conductivity, color, total dissolved solids, suspended solids, turbidity, and specific gravity
- 5 Soap residues (as alkyl sulfonate)
- 6 Oil and grease residues, by extraction and infrared or gravimetric detection, and by visual observation
- 7 Specific chemical species, including total hardness (as calcium carbonate), alkalinity (as hydroxide, bicarbonate, or carbonate), chloride, fluoride, cyanide, sulphate, and hexavalent chromium
- 8 Radioactive species, including gross alpha and beta by gas proportional detection, tritium by liquid scintillation detection, radium, cesium-134, and strontium-89 or -90 by gravimetric separation followed by gas pro-

portional detection. Isotopes of plutonium, americium, thorium, uranium, neptunium, and curium are determined by ion exchange and liquid extraction techniques followed by alpha pulse height analysis.

- 9 Organic toxic species including Bromic, Endrin, Lindane, methoxychlor, toxaphene, phenol, polychlorinated-biphenyls, 2,4-D, 2,4,5-TP, Silvex, and total organic halogen.

Procedures for these analyses were developed by the General Laboratory professional technical staff. Procedures were adopted from EPA-approved sources or from other recognized authoritative publications where EPA-approved procedures were not available. Laboratory operational procedures are documented in a standard format approved by the manager of the Rocky Flats Analytical Laboratories, and distributed to a controlled distribution list to assure that proper testing and approval is performed before changes are adopted. The General Laboratory Quality Assurance Plan requires annual review of procedures for consistency with state-of-the-art techniques and compliance of laboratory practices with written procedures. In addition, a review is performed whenever an analytical problem is detected.

The following is a general outline of the analysis procedures followed by the General Laboratory:

All water samples which are analyzed for radioactive materials - except those scheduled for tritium analysis - are acidified immediately upon collection.

Liquid samples received for gross alpha and beta screening are evaporated directly onto planchets for gas proportional counting within 24 hours of collection. When activities exceeding the action guidelines set by Environmental Analysis and Control (EA&C) are observed, notification to EA&C is made, and reanalysis is begun immediately for verification. For some liquids such as machine oils, a specified volume is evaporated and the residue is taken up in dilute nitric acid for deposit onto the counting planchet. A correction factor is determined for each sample to account for self-absorption effects.

Liquid and solid samples submitted for alpha spectral pulse height analysis are analyzed in a manner similar to procedures followed by HS&EL. Chemical separation of elements is followed by deposition of an organic extract of 2-Thenoyltri-fluoroacetone (TTA) complex onto a planchet for pulse height analysis of the alpha energy spectrum

Water samples to be tested for chemical and physical parameters are analyzed within 24 hours of collection, or they are preserved by refrigeration, freezing, or addition of a chemical preservative when required. The tests performed include gravimetric, titrametric, colorimetric, chromatographic, or electroanalytical methods, following procedures specified in the 15th edition of Standard Methods for the Examination of Water and Waste Water, EPA-600/4-79-020, or other authoritative publications.

Water samples to be analyzed for dissolved metallic ions are filtered through a 4.5 micron filter and evaporated onto a graphite electrode for emission spectrographic analysis. Selected elements are determined for sample solutions by atomic absorption methods after appropriate chemical treatment to prepare the proper analysis matrix.

Organic toxic species are determined by chromatography, following extraction into an appropriate organic solvent or onto a solid resin using flame ionization, electron capture, or ultraviolet detection. Some organics, such as phenol, are determined by developing a chromaphoric complex and measuring light absorption at a specific wavelength with a spectrophotometer. Measuring occurs after extraction into an appropriate solvent phase.

Tritium is determined by intimate mixing of five milliliters of aqueous sample (or of water that has equilibrated with the sample for a predetermined time to ensure change) with 17 milliliters of scintillation cocktail. The mixture is counted for 20 minutes in a scintillation well, and a correction factor is applied to account for quenching effects determined in situ for each sample.

Cesium, radium, and strontium isotopes are chemically separated from the sample matrix using precipitation techniques. Cesium, strontium, and some radium isotopes are deposited on planchets with a carrier element for alpha or beta gas proportional counting. Radium-226 is counted directly measuring the radon-222 emanation in a scintillation well by using a Lucas gas collection cell.

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APPENDIX D
DETECTION LIMITS AND ERROR TERM PROPAGATION

The Rocky Flats Health Safety and Environmental Laboratories (HS&EL) have adopted the following definition for detection limit, as given by Harley ²⁵

"The smallest amount of sample activity using a given measurement process (i.e. chemical procedure and detector) that will yield a net count for which there is confidence at a predetermined level that activity is present"

The minimum detectable amount (MDA) is the term used to describe the detection limit and is defined as the smallest amount of an analytic material in a sample that will be detected with a β probability of non-detection (Type II error), while accepting an α probability of erroneously detecting that analytic in an appropriate blank sample (Type I error). At the 95% confidence level, both α and β are equal to 0.05

Based on the approach presented in draft ANSI standard N13.30 "Performance Criteria for Radiobioassay,"²⁶ the formulation of the MDA for radioactive analyses is

$$MDA = \frac{4.65 S_B + 3/(T_s E_s Y)}{aV}$$

where S_B = standard deviation of the population of appropriate blank values (d/m)

T_s = sample count time (m)

E_s = absolute detection efficiency of the sample detector

Y = chemical recovery for the sample

a = conversion factor (d/m per unit activity)

($a = 2.22 \text{ d/m/pCi}$ when MDA is in units of pCi)

$a = 2.22 \times 10^6 \text{ d/m/}\mu\text{Ci}$ when MDA is in units of μCi)

V = sample volume or weight

($V=1$ if the MDA per sample is desired)

The major component of the MDA equation is the variability of the blanks. In 1985 the procedure to establish a population of appropriate blanks for each analytical procedure was upgraded resulting in an improved measure of the baseline and of the inherent variability of each measurement process.

Table D-1 shows the various formulae used for alpha data reduction during 1985.

Table D-2 shows the typical MDA values for the various analyses performed by the HS&EL and by the General Laboratories. These values are based on the average sample volume, typical detector efficiency, detector background, count time and chemical recovery. MDA values calculated for individual analyses may vary significantly depending on actual sample volume, chemical recovery and analytical blank used.

For nonradioactive parameters, various means are used to estimate a minimum detectable amount depending on the parameter measured. The minimum detectable amount for beryllium in effluent air - analyzed using flameless atomic absorption spectroscopy - is based on a sample absorbance reading of 0.010 above the sample blank absorbance reading. Total chromium in effluent water samples undergoes a four-fold concentration of the received sample prior to its analysis using flame atomic absorption spectroscopy. Its approximate minimum detectable amount is based on a net sample absorbance reading of 0.010.

The parameters of nitrate as N, total phosphorus, suspended solids, oil and grease, and total organic carbon all have minimum detectable amounts.

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that are determined by procedural methods found in EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastewater*²⁷ The parameters of pH and Biochemical Oxygen Demand have minimum detectable amounts that are determined by the minimal readout capability of the instrumentation that is used

The minimum detectable amount for residual chlorine is determined by the procedure found in a publication by Hach Co. "DPD Method for Chlorine"²⁸ For fecal coliform count the minimum detectable amount is calculated as 4.65 times the standard deviation of the blank value from the millipore filter

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TABLE D-1 Formulae for Activity and Uncertainty Calculations for the Alpha Spectral Analysis Systems

Non-Blank Corrected Sample Uncertainty*

$$a_{SI} = A_{SI} \left[\frac{\frac{C_{SI}}{T_s^2} + \frac{C_{BI}}{T_B^2}}{\left(\frac{C_{SI}}{T_s} - \frac{C_{BI}}{T_B}\right)^2} + \frac{\frac{C_{Sj}}{T_s^2} + \frac{C_{Bj}}{T_B^2}}{\left(\frac{C_{Sj}}{T_s} - \frac{C_{Bj}}{T_B}\right)^2} \right]^{1/2}$$

Blank Corrected Sample Uncertainty

$$b_{SI} = (a_{SI}^2 + a_{BI}^2)^{1/2}$$

Non-Blank Corrected Sample Activity

$$A_{SI} = \left[\frac{\frac{C_{SI}}{T_s} - \frac{C_{BI}}{T_B}}{\frac{C_{Sj}}{T_s} - \frac{C_{Bj}}{T_B}} \right] \frac{D_{Sj}}{V \cdot 2.22}$$

Blank Corrected Sample Activity

$$B_{SI} = A_{SI} - A_{BI}$$

*Corrected from 1984 report

(continued)

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TABLE D-1 (Concluded)

Legend

- A_{T1} = Non-blank corrected activity of laboratory reagent blank for isotope 1, expressed as picocuries per unit volume
- a_{T1} = Non-blank corrected uncertainty of laboratory reagent blank, expressed as picocuries per unit volume
- A_{S1} = Sample activity for isotope 1, expressed as picocuries per unit volume
- a_{S1} = Sample activity uncertainty, expressed as picocuries per unit volume
- B_{S1} = Blank corrected sample activity for isotope 1, expressed as picocuries per unit volume
- b_{S1} = Blank corrected sample uncertainty, expressed as picocuries per unit volume
- C_{B1} = Detector background gross counts for isotope 1.
- C_{Bj} = Detector background gross counts for internal standard isotope j
- C_{S1} = Sample gross counts for isotope 1.
- C_{Sj} = Sample gross counts for internal standard isotope j
- D_{Sj} = Activity (disintegrations per minute) of internal standard isotope j added to sample
- T_B = Detector background count time expressed in minutes.
- T_S = Sample count time expressed in minutes.
- V = Sample unit volume or sample unit weight

1.64

TABLE D-2 Detection Limits for Radioactive and Nonradioactive Materials

<u>Legend</u>			
μCi = microcuries		pCi = picocuries	
μg = micrograms		mg/l = milligrams per liter	
m^3 = cubic meters		SU = standard units	
ml = milliliters			
Parameter	Minimum Detectable Amount (per sample)	Approximate Sample Volume Analyzed ^a	Minimum Detectable Amount (per unit volume or mass)
Airborne Effluent Samples			
Plutonium 239, 240	$2.1 \times 10^{-9} \mu\text{Ci}$	5,380 m^3 ^b	$0.04 \times 10^{-12} \mu\text{Ci}/\text{m}^3$
Uranium 233, 234, 238	$4.7 \times 10^{-9} \mu\text{Ci}$	5,380 m^3 ^b	$0.09 \times 10^{-12} \mu\text{Ci}/\text{m}^3$
Tritium	$1.1 \times 10^{-8} \mu\text{Ci}$	0.14 m^3	$79,000 \times 10^{-12} \mu\text{Ci}/\text{m}^3$
Beryllium	$2.5 \times 10^{-1} \mu\text{g}$	5,380 m^3 ^b	$5 \times 10^{-5} \mu\text{g}/\text{m}^3$
Ambient Air Samples			
Plutonium 239, 240	$1.4 \times 10^{-9} \mu\text{Ci}$	20,000 m^3 ^c	$0.007 \times 10^{-12} \mu\text{Ci}/\text{m}^3$
Effluent Water Samples (Radioactive)			
Plutonium 239, 240	$7.8 \times 10^{-9} \mu\text{Ci}$	5,000 ml	$0.02 \times 10^{-9} \mu\text{Ci}/\text{ml}^c$
Uranium 233, 234, 238	$1.5 \times 10^{-9} \mu\text{Ci}$	1,000 ml	$0.15 \times 10^{-9} \mu\text{Ci}/\text{ml}^c$
Americium 241	$1.5 \times 10^{-9} \mu\text{Ci}$	5,000 ml	$0.03 \times 10^{-9} \mu\text{Ci}/\text{ml}^c$
Tritium	$7.1 \times 10^{-9} \mu\text{Ci}$	5 ml	$1,400 \times 10^{-9} \mu\text{Ci}/\text{ml}^c$
Soil Samples (Radioactive)			
Plutonium 239, 240	$7.3 \times 10^{-9} \mu\text{Ci}$	10 g	$7.3 \times 10^{-9} \mu\text{Ci}/\text{g}$
Effluent Water Samples (Nonradioactive)			
pH		100 ml	0-14 SU
Nitrate as N		10 ml	0.2 mg/l
Total Phosphorus		50 ml	0.2 mg/l
Biochemical Oxygen Demand, 5-Day		300 ml	1.0 mg/l
Suspended Solids		100 ml	1.0 mg/l
Total Chromium		100 ml	0.05 mg/l
Residual Chlorine		10 ml	0.1 mg/l
Oil and Grease		1,000 ml	0.1 mg/l
Fecal Coliform Count		10-100 ml	43 organism/100 ml
Total Organic Carbon		5 ml	1.0 mg/l

- a. Volume analyzed is usually an aliquoted fraction of the total sample volume collected.
- b. Monthly composites.
- c. Two-week composites.

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APPENDIX E

REPORTING OF MINIMUM DETECTABLE CONCENTRATION AND ERROR TERMS

Throughout the section entitled "Monitoring Data Collection, Analyses, and Evaluation" in this report, some of the concentrations that are measured at or below the minimum detectable concentration (MDC) are assigned the MDC value. The less-than symbol (<) indicates MDC values and calculated values that include one or more MDCs.

The plutonium, uranium, americium, and beryllium measured concentrations are reported. These reported concentrations include values that are less than the corresponding calculated MDCs and in some cases, values less than zero. Negative values result when the measured value for a laboratory reagent blank is subtracted from an analytical result that was measured as a smaller value than the reagent blank. These resulting negative values are included in any arithmetic calculations on the data set.

Error terms in the form of $a \pm b$ are included with some of the data. For a single sample, "a" is the reagent-blank corrected value, for multiple samples it represents the average value (arithmetic mean). The error term "b" accounts for the propagated statistical counting uncertainty for the sample and the associated reagent blanks at the 95 percent confidence level. These error terms represent a minimum estimate of error for the data. Other analytical and sampling errors are being investigated for future incorporation into an all-inclusive error term for each value.

Ninety-five percent confidence limits for the plutonium concentrations in ambient air have been derived using Fieller's Theorem²⁹. These limits consist of a Lower Confidence Limit (LCL) and an Upper Confidence Limit (UCL) on each point estimate for the various concentrations. The calculation of the limits requires knowledge of the analytical error term "b" as described above, and in addition, the variance of the air volume measurement associated with a specific sample. These variances are calculated from the data reported as part of a routine flow measurement calibration program for ambient air samplers. Bias errors and temperature coefficients of the sampler readout devices are also statistically computed, and the individual readout devices are individually corrected for those factors.

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