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ENVIRONMENTAL MONITORING IN THE VICINITY OF THE SAVANNAH RIVER PLANT

Annual Report

For 1976

Prepared for the U. S. Energy Research and Development Administration by the
Health Physics Department of
E. I. du Pont de Nemours & Co., the Administration's Prime Contractor
at the Savannah River Plant, Aiken, South Carolina

PREFIXES FOR UNITS OF MEASURE

	PREFIXES	SYMBOLS	NAMES
0.1 = 10^{-1}	deci	d	tenth
0.01 = 10^{-2}	centi	c	hundredth
0.001 = 10^{-3}	milli	m	thousandth
0.000 001 = 10^{-6}	micro	μ	millionth
0.000 000 001 = 10^{-9}	nano (năn′ oh)	n	billionth
0.000 000 000 001 = 10^{-12}	pico (pee′ ko)	p	trillionth
0.000 000 000 000 001 = 10^{-15}	femto	f	quadrillionth
0.000 000 000 000 000 001 = 10^{-18}	atto	a	quintillionth

CONVERSION TABLE

Multiply	By	To Obtain	Multiply	By	To Obtain
in.	2.54	cm	cm	0.394	in.
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.4536	kg	kg	2.205	lb
liq qt - U.S.	0.946	ℓ	ℓ	1.057	liq qt - U.S.
ft^2	0.093	m^2	m^2	10.764	ft^2
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.31	ft^3
mCi/mi^2	0.386	mCi/km^2 (nCi/m^2)	mCi/km^2	2.59	mCi/mi^2
d/m	0.450	pCi	pCi	2.22	d/m
nCi	1×10^3	pCi	pCi	1×10^{-3}	nCi
d/m/ℓ	0.45×10^{-9}	μCi/cc	μCi/cc	2.22×10^9	d/m/ℓ
$d/m/ft^2$	0.01256	mCi/mi^2	mCi/mi^2	79.6	$d/m/ft^2$
pCi/ℓ (water)	10^{-9}	μCi/mℓ (water)	μCi/mℓ (water)	10^9	pCi/ℓ (water)
pCi/m^3 (air)	10^{-12}	μCi/cc (air)	μCi/cc (air)	10^{12}	pCi/m^3 (air)
mCi/km^2	1	nCi/m^2	nCi/m^2	1	mCi/km^2

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CONTENTS

FOREWORD

This report summarizes results of the environmental monitoring program at the Savannah River Plant (SRP) during 1976. Environmental monitoring has been an integral part of plant operations since the start of activities at SRP. Extensive monitoring was performed to provide baseline data on radiation levels before plant operations began. Monitoring programs have continued throughout the history of the plant, providing reliable measurement of radioactive materials released at the source and in the environment. This annual report describes in detail the plantsite and facilities and the techniques of sample collection and analysis. This report has been expanded to include additional environmental conditions and an inventory of radioactive materials released to the environment.

INTRODUCTION

The Savannah River Plant occupies an area of about 300 square miles along the Savannah River, principally in Aiken and Barnwell Counties of South Carolina. Most of the plant's environs are rural. Population density of nearby counties ranges from 10 to over 400 people per square mile with the greatest concentration in Augusta, Georgia, and its suburbs, which have a population approaching 200,000. The countryside is predominantly forested. Farming is diversified, the main crops being cotton, soybeans, corn, and small grains. Production of beef cattle has rapidly expanded during the past few years. The climate is mild, with an average frost-free season of approximately 246 days. Annual rainfall averages about 45 inches and is fairly evenly distributed throughout the year.

Exclusion of the public from the plantsite creates a refuge for many animal species, both terrestrial and aquatic. Growth of the deer population is limited (to prevent range deterioration and to minimize deer/vehicle accidents) by public hunting which was initiated in 1965. Several hundred to over a thousand deer (1357 in 1976) have been taken annually during controlled hunts.

In 1972, the SRP site was designated as the nation's first National Environmental Research Park (NERP). This designation opened the site to investigators from universities and other research organizations who wish to design and conduct research studies on man's impact on the environment. Over 25 research projects were conducted at the SRP site under the NERP program in 1976. These projects were in addition to the ERDA-funded environmental research programs normally conducted at the site.

Since 1952, the U.S. Forest Service has planted over 100 million pine seedlings on over 80,000 acres of the plantsite. Great quantities of pine and pulpwood, along with some hardwood sawtimber, have been harvested during this same period.

SRP's primary function is the production of plutonium, tritium, and other special nuclear materials for the national defense, for other governmental uses, and for some civilian purposes. Facilities now operating include three nuclear reactors, a fuel and target fabrication plant, two chemical separations plants, a heavy water production plant, and the Savannah River Laboratory (a process development laboratory to support production operations). The reactors and separations plants are located near the center of the site; the other facilities, near its periphery.

The reactors are fueled with uranium and moderated and cooled by heavy water which is circulated in a closed system through heat exchangers. Savannah River water and water from Par Pond, a manmade cooling water impoundment covering 2640 acres, are used only as a secondary coolant in the heat exchangers. Water from the river or Par Pond does not pass directly through the reactors and so is not subject to neutron activation.

Nuclear fuels and targets, together with other components necessary for the reactors, are manufactured in the fuel and target fabrication facility.

Reactor products are recovered in the fuel separations areas. Plutonium-239 and uranium are separated from each other and from fission products by complex chemical processes. Plutonium-238 and californium-252 are also important SRP products that are processed in the separations areas. These areas also have facilities for the purification and packaging of tritium and for storage of fission product wastes.

The heavy water production plant separates and concentrates heavy water from the raw water of the Savannah River. The basic process for extraction of heavy water from river water is chemical exchange with hydrogen sulfide gas at about 300 psig. Heavy water is not radioactive, but a portion of the heavy water production facility is used for the reconcentration of moderator from the reactors and this heavy water contains some tritium.

SRP production areas and effluent streams are shown in figures 1, 1A, 1B, 1C, and 1D.

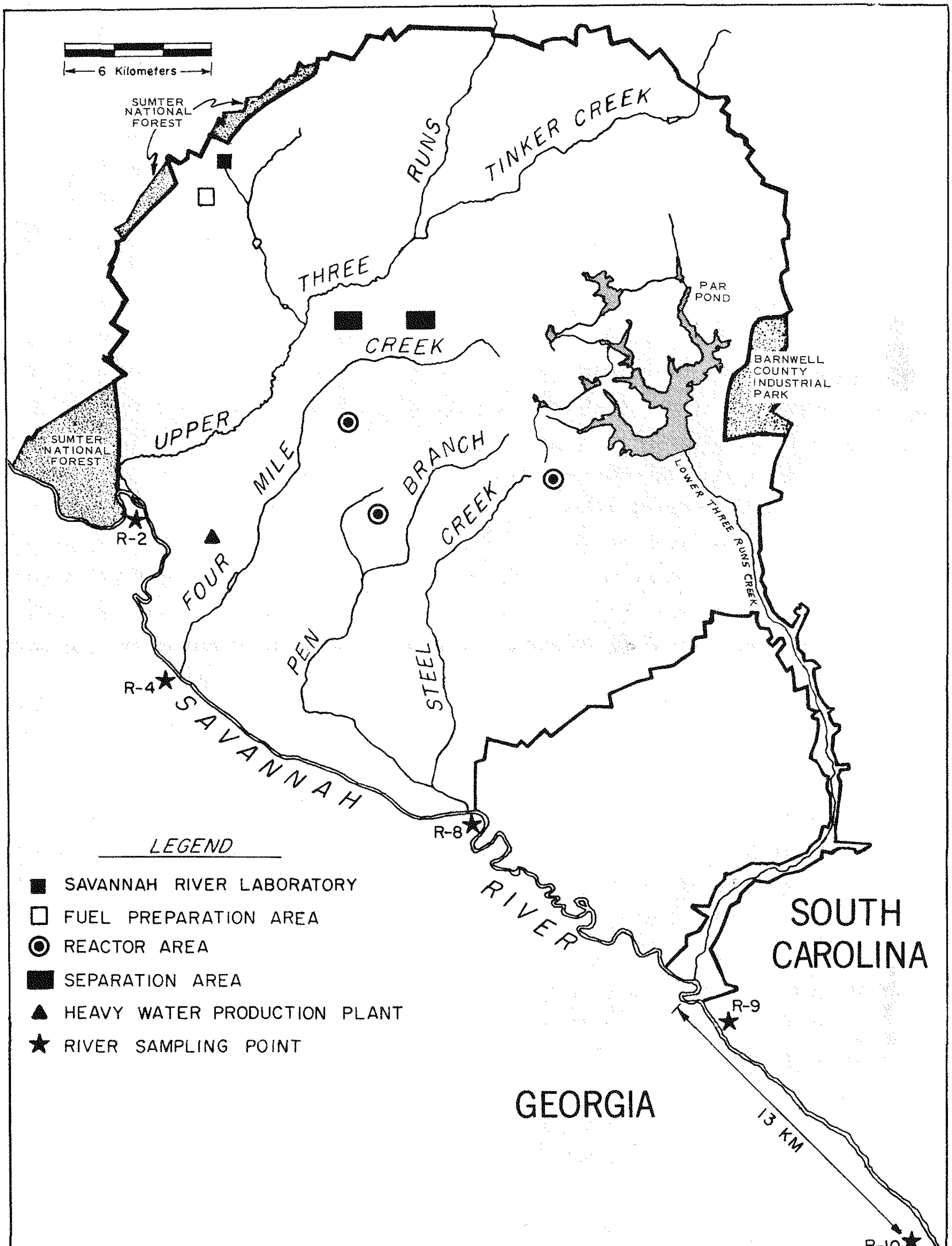


FIGURE 1. SRP PRODUCTION AREAS AND EFFLUENT STREAMS

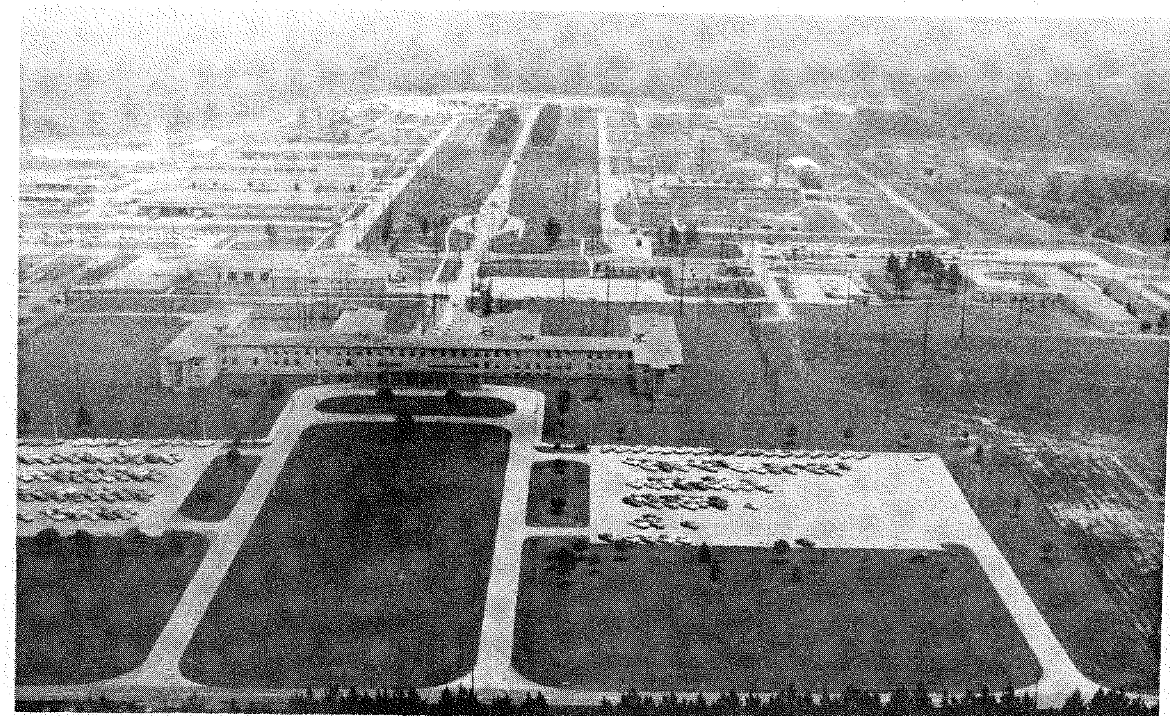


FIGURE 1A. ADMINISTRATION AREA AND FUEL AND TARGET FABRICATION PLANT

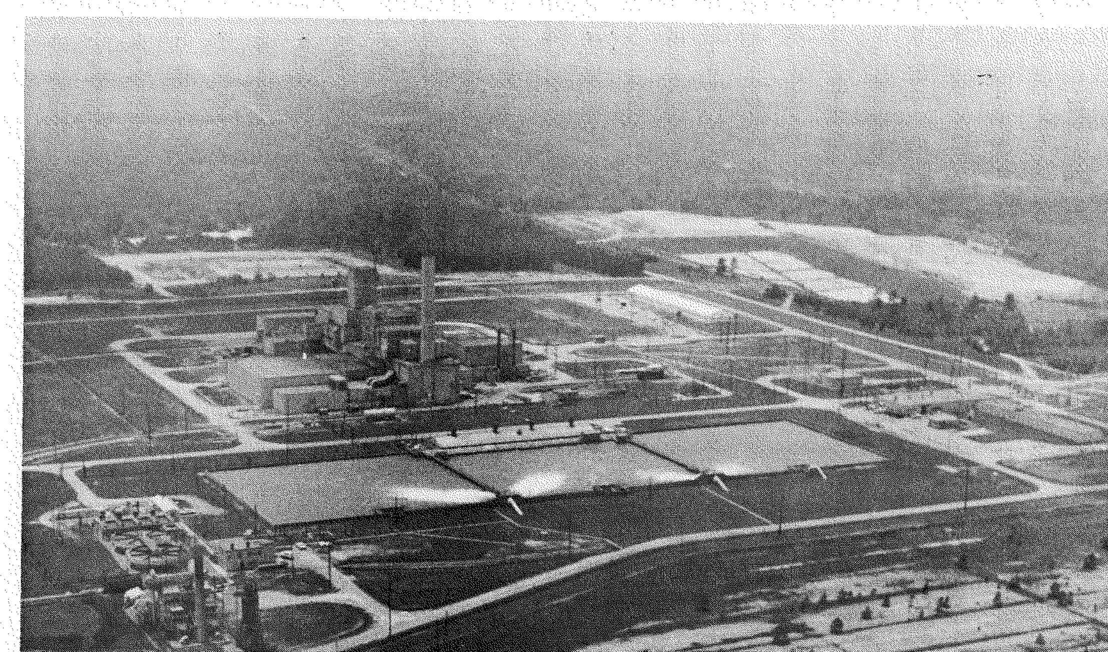


FIGURE 1B. REACTOR PLANT

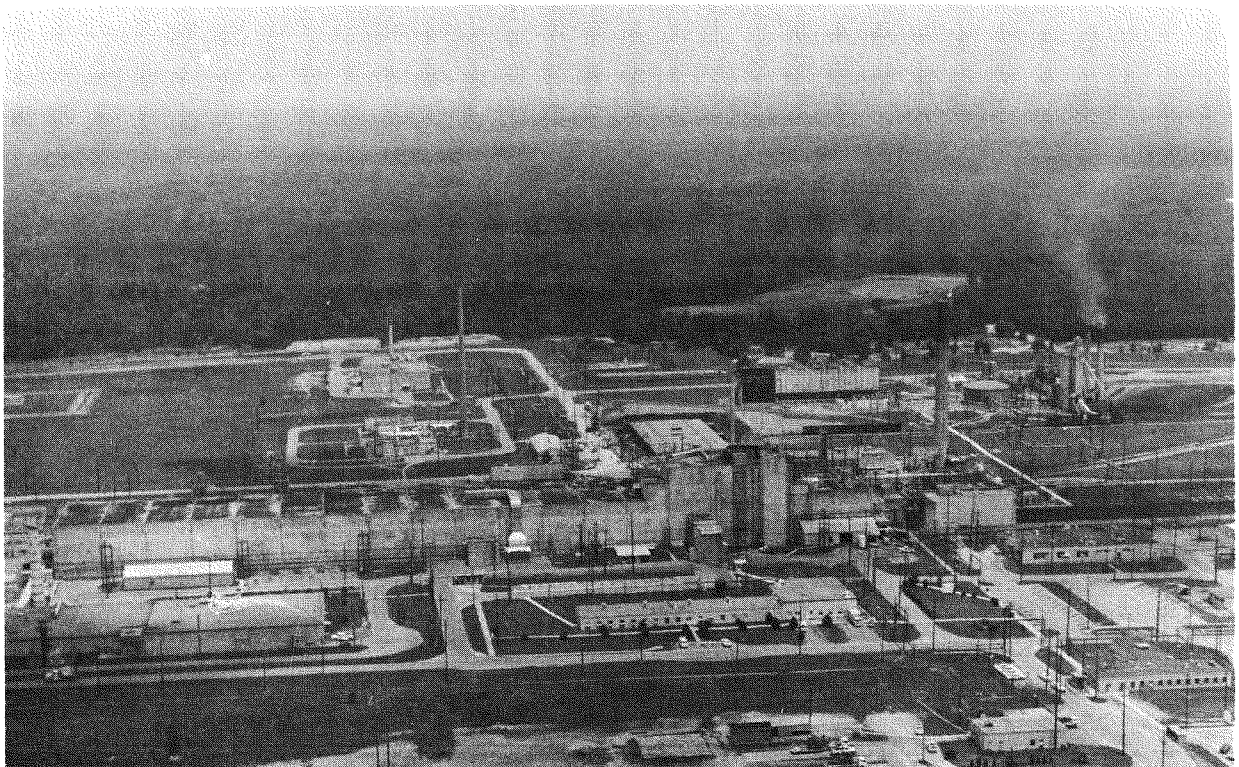


FIGURE 1C. CHEMICAL SEPARATIONS PLANT

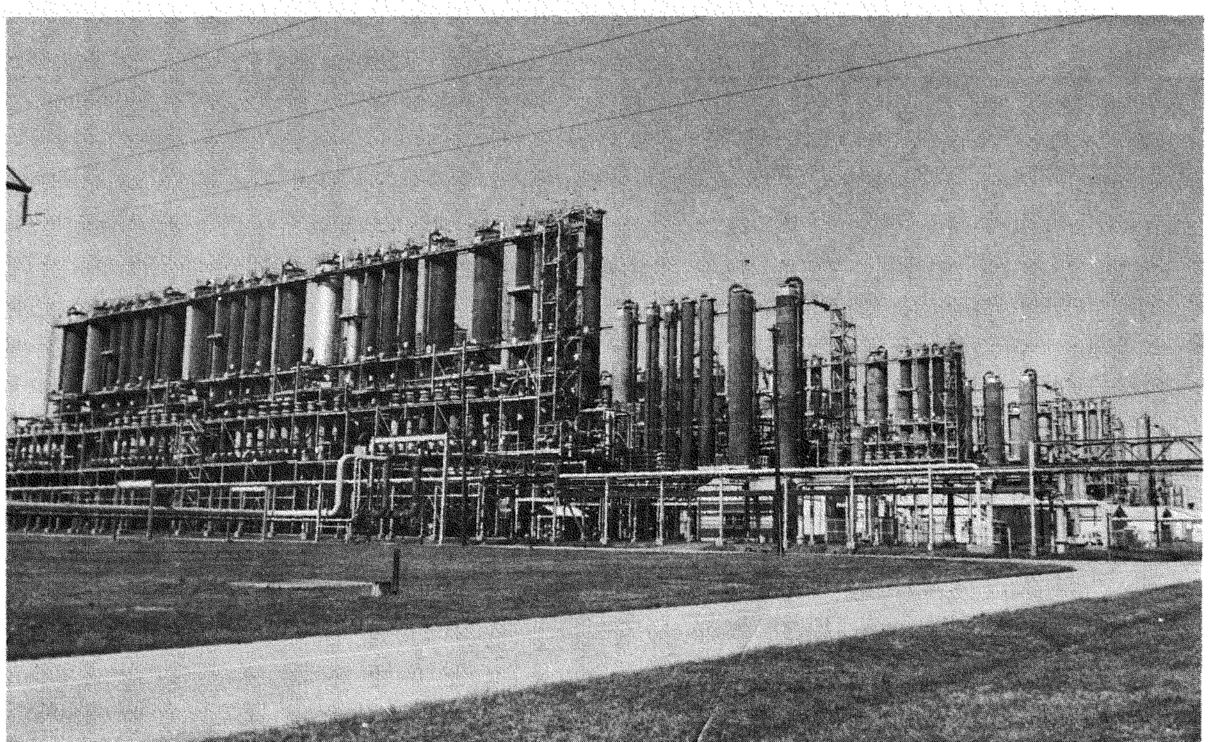


FIGURE 1D. HEAVY WATER PRODUCTION PLANT

SUMMARY

A continuous monitoring program has been maintained since 1951 (before plant startup) to determine concentrations of radioactive materials in a 1200-square-mile area outside SRP. Included are parts of Aiken, Barnwell, and Allendale Counties in South Carolina; Richmond, Burke, and Screven Counties in Georgia. Although some gaseous and liquid radioactive materials are discharged from SRP operations, concentrations and doses to the surrounding population continued to be far below levels considered significant from a public health viewpoint.

The concentration of radioactivity added by SRP to its environs during 1976 was, for the most part, too small to be distinguished from natural background radiation and fallout from worldwide nuclear weapons tests. Beta activity in particulate air filters was about 1.5 times the 1975 level and was due entirely to global fallout. This concentration, both at the plant perimeter and 25 miles away (0.07 pCi/m^3), represents 0.07% of the Concentration Guide (CG) (defined in the Applicable Standards section which follows). Tritium oxide in air at the plant perimeter was greater than in air at more distant locations; the average concentration at the plant perimeter (50 pCi/m^3) was less than 0.1% of the Concentration Guide.

Tritium, cesium-137, and strontium-90 were the only radionuclides of plant origin detectable in river water by routine analyses. None of these had an average concentration exceeding 0.2% of the CG in river water sampled eight miles downstream from the plant. Special research programs using ultra-low-level techniques have detected trace quantities of other radionuclides of plant origin. Radioactive materials in river fish also continued very low.

Monitoring in a five-square-mile swamp bordering the Savannah River immediately below the SRP boundary has shown radioactivity (primarily cesium-137) above the natural background level in soil and vegetation. Only one-third of the swamp, which is largely uninhabited and inaccessible, is affected. Neither restrictions on use of the swamp nor remedial actions are considered warranted. Radiation measurements with thermoluminescent dosimeters and analysis of soil, vegetation, and wildlife showed radioactive concentrations similar to those observed for the past several years.

During 1976 the calculated average dose from atmospheric releases of radioactive materials from SRP was 0.7 millirem (mrem) at the plant perimeter. The calculated maximum dose at the plant perimeter was 0.97 mrem, which is 0.2% of the ERDA Manual chapter 0524 standard. The population dose to people living within 80 km (50 miles) of the center of SRP (population: 465,000) is 95 man-rems. An individual consuming river water downstream from SRP would receive a maximum calculated dose of 0.36 mrem.

Various water-quality analyses of river water samples by SRP during 1976 indicated that Savannah River water was not adversely affected by SRP operations. This was substantiated by surveys of the health of Savannah River biota by the Academy of Natural Sciences of Philadelphia and pesticide analyses of river water and sediment by the US Geological Survey Water Quality Laboratory, Atlanta, GA.

APPLICABLE STANDARDS

The standards applicable to concentration of radionuclides in air and water at SRP are the Concentration Guides (CG's) given in chapter 0524 of the ERDA Manual, and are derived for the most part from the whole body annual dose standard of 500 mrems to individuals at points of maximum probable exposure [1]. These CG's are based on recommendations of the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the Federal Radiation Council (the latter is now a part of the Environmental Protection Agency). Concentration guides are summarized in table 1. For whole-body dose calculations from ingestion of tritium, ICRP values for translating intake to dose are used [2]. Specific guidance of the Federal Radiation Council (Report 7) is used in translation of a given intake of cesium-137 to radiation dose [3].

The National Pollutant Discharge Elimination System (NPDES) permit for SRP, effective November 19, 1976, through November 19, 1981, requires plume temperature monitoring at three locations in the Savannah River. Limitations of maximum plume temperature and the rise above ambient temperature are the same as those in the South Carolina water quality standards.

Chemical and biological quality standards for the Savannah River are the requirements of the State of South Carolina for Class B streams [4] which are: "Waters suitable for domestic supply after complete treatment in accordance with requirements of the South Carolina Board of Health. Suitable also for propagation of fish, industrial and agricultural uses, and other uses requiring water of lesser quality." Specifications are summarized in table 2.

Principal nonradioactive releases to the atmosphere are sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and fly ash. South Carolina emission standards [5] and South Carolina [5] and Georgia [6] ambient air quality standards are summarized in table 3.

TABLE 1
CONCENTRATION GUIDES (CG's)

	In Water, pCi/l	In Air, pCi/m^3
Alpha	30	0.02
Nonvolatile beta	3,000	100
Tritium	3,000,000	200,000
^{239}Np	100,000	20,000
^{131}I	300	100
$^{140}Ba-^{140}La$	20,000	1,000
^{137}Cs	20,000	500
^{144}Ce	10,000	200
$^{103,106}Ru$	10,000	200
$^{95}Zr-^{95}Nb$	60,000	1,000
^{65}Zn	100,000	2,000
^{60}Co	30,000	300
^{89}Sr	3,000	300
^{90}Sr	300	30
^{54}Mn	100,000	1,000
^{51}Cr	2,000,000	80,000
^{35}S	60,000	9,000

TABLE 2
SOUTH CAROLINA WATER QUALITY STANDARDS

1. Fecal coliform. Not to exceed a log mean of 1000/100 ml based on five consecutive samples during any 30-day period; not to exceed 2000/100 ml in more than 20% of the samples examined during such period (not applicable during or following periods of rainfall).
2. pH. Range between 6.0 and 8.5, except that swamp waters may range from pH 5.0 to pH 8.5.
3. Dissolved oxygen. Daily average not less than 5.0 mg per liter with a low of 4.0 mg per liter, except that swamp waters may have an average of 4 mg per liter.
4. Temperature. Maximum temperature increase after mixing: 2.8°C (5°F). Maximum temperature after mixing: 32.2°C (90°F).
5. Phenolic compounds. Not greater than 1 microgram per liter unless caused by natural conditions.

TABLE 3
SOUTH CAROLINA EMISSION STANDARDS

Fly ash - 0.6 lb/10^6 Btu heat input

SO_2 - 3.5 lb/10^6 Btu heat input

SOUTH CAROLINA AND GEORGIA AMBIENT AIR STANDARDS
FOR PARTICULATES, SO_2, NO_x

	South Carolina	Georgia
Suspended particulates, $\mu g/m^3$		
24 hours	250	150
Annual geometric mean	60	60
SO_2, $\mu g/m^3$		
1 hour	-	715
3 hours	1300	-
24 hours	365	229
Annual	80	43
NO_x, $\mu g/m^3$		
24 hours	-	300
Annual	100	100

- No standard.

ROUTINE COLLECTION AND ANALYTICAL PROCEDURES

Air Collection

Particulate airborne radioactivity is sampled continuously by drawing air through 2-inch-diameter high-efficiency asbestos paper filters that are collected weekly. The air is sampled at about 7×10^4 ml/min (2.5 cu ft/minute) with an auxiliary running-time meter and airflow meter at each station providing data on the volume sampled. A cartridge of activated coconut charcoal for collection of gaseous radioiodine is located downline from each paper filter. Moisture is concentrated from the atmosphere for determination of its tritium oxide content by pumping air through a silica gel column at a continuous rate of 100 ml/minute (operated off the manifold of each vacuum pump). The column contains nonindicating silica gel; a backup column of indicating silica gel is used for evidence of any saturation of the desiccant. The concentration of tritium oxide in the air is calculated from the concentration in atmospheric moisture and the absolute humidity.

Deposition rates of radioactive materials are also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). Fallout collection pans (2 ft $\times$ 2 ft) are located at offplant monitoring stations, at stations around the plant perimeter, and at monitoring stations on a 25-mile radius from the center of the SRP site. Rainwater flows by gravity from the collection pan through an ion exchange column (cation and anion resin). The columns are analyzed directly by gamma spectrometry for gamma emitters. Alpha and beta emitters are removed from the column with acid and analyzed by chemical methods. The rainwater passing through the ion exchange column is collected for weekly tritium analyses by liquid scintillation counting.

Alpha, Beta, and Gamma-Emitting Radionuclides are measured by a direct count of the asbestos paper filter; alpha on a ZnS scintillation counter, beta on a gas flow proportional counter, and gamma on a 9-in. $\times$ 9-in. NaI(Tl) well detector with a 400-channel gamma spectrometer.

Strontium-89,90 collected on filter papers is prepared for analyses by the following chemical procedures and counted on a gas flow proportional counter.

1. Filters are leached with hydrochloric acid, precipitated with fuming nitric acid, scavenged with barium chromate, precipitated as an oxalate and transferred to a stainless steel planchet (holder) for beta count.
2. In the presence of significant ruthenium, filters are leached with hydrochloric and hydrofluoric acids and ruthenium removed by thioacetamide precipitation, precipitated with fuming nitric acid, reprecipitated as an oxalate and transferred to a stainless steel planchet for beta counting.
3. In the presence of significant barium-lanthanum, filters are leached with hydrochloric and hydrofluoric acids. Barium-lanthanum is removed by ion-exchange, precipitated with fuming nitric acid, reprecipitated as an oxalate and transferred to a stainless steel planchet for beta count.

Uranium and Plutonium are leached from the filter paper in nitric acid, dried, dissolved in hydrochloric acid and transferred into triisooctylamine (TIOA) by liquid ion exchange. The alpha emitters are stripped from the TIOA organic layer with hydrochloric acid and evaporated to dryness. The residue is dissolved in nitric acid and transferred to a stainless steel planchet for count on a ZnS alpha scintillation counter.

Iodine-131 is measured by a direct count of the charcoal canister using a 9-in. $\times$ 9-in. NaI(Tl) well detector with a 400-channel gamma spectrometer.

Tritium analysis of atmospheric moisture is described in the sample collection section.

Plutonium is leached from the filter paper with 8N nitric acid and fuming nitric acid and passed through anion-exchange resin. The resin column is eluted with 0.35N HCl-0.01N HF and the plutonium in the eluate is electrodeposited on a platinum disk for alpha spectrometric analysis.

Water Collection

Continuous sampling of the Savannah River is accomplished with a sampler consisting of a "Plexiglas" water wheel suspended on two pontoons. As the water wheel is turned by flowing water, a small cup (or cups) on one paddle picks up a sample of water and deposits it into a trough. The sampled water flows by gravity from the trough through connecting tubing into a large polyethylene jug connected to the sampler. The sampled water (up to six gallons) is collected weekly at river locations above and below SRP. Increased analytical sensitivity for water samples (containing insufficient radioactivity for direct processing) is achieved through concentration of radionuclides by ion exchange. The ion exchange column is counted directly for gamma-emitting radionuclides.

Alpha and Beta-Emitting Radionuclides are measured by direct count of dried residue (in planchet) the same as for air.

Gamma-Emitting Radionuclides are measured by passing 25 liters of water through a cation-anion resin column and a direct count of the column using a 9-in. × 9-in. NaI(Tl) well detector with a 400-channel gamma spectrometer. The resin column is then eluted with nitric acid for subsequent strontium analysis.

Strontium-90 is recovered from an aliquot of the above eluate by liquid ion-exchange using di-2-ethylhexyl phosphoric acid. Equilibrium of yttrium-90 (^{90}Y) is allowed over a 15-day period and then the short-lived ^{90}Y daughter is stripped and counted in a low-level gas flow beta proportional counter.

Strontium-89,90 analysis of an aliquot of the above eluate is the same as for air 1, 2, and 3 with the following exceptions.

1. The sample is acidified with nitric acid before precipitation with fuming nitric acid.
2. No acid is added before removal of barium-lanthanum by ion exchange.

Tritium is measured in distilled water samples with a liquid scintillation spectrometer.

Milk

Strontium-90 is removed by a slurry of the whole milk with a cation resin. The resin is leached with nitric acid and then analyzed the same as for water.

Cesium-137 is removed by passing approximately 2 liters of whole milk through a potassium-cobalt-ferro-cyanide resin column and a direct count of the column using a 9-in. × 9-in. NaI(Tl) well detector with a 400-channel gamma spectrometer.

Iodine-131 is the same as for cesium-137 except an anion resin column is used.

Farm Produce

Uranium and Plutonium analysis is the same as for air after drying, ashing in furnace and wet ashing with hydrochloric acid.

Strontium-90 analysis is the same as for air after the pretreatment described for uranium and plutonium.

Gamma-Emitting Radionuclides are determined by counting a bottled sample of the hydrochloric acid solution.

Tritium is measured in water obtained by freeze drying samples and counting in a liquid scintillation counter.

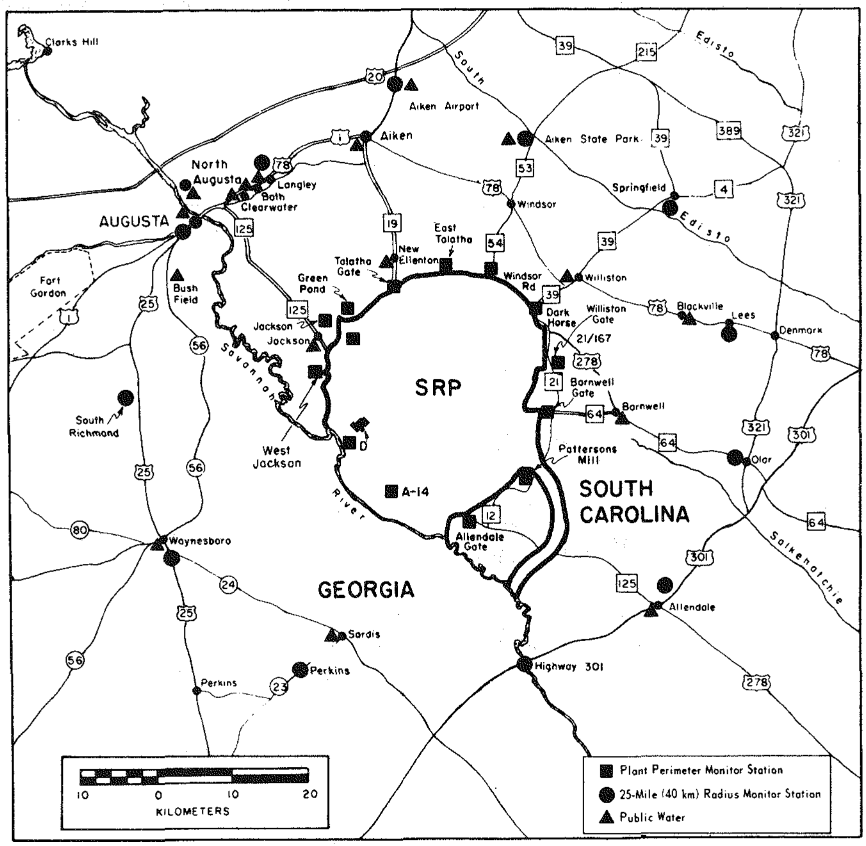


FIGURE 2. CONTINUOUS AIR MONITORING STATIONS AND PUBLIC WATER SAMPLE LOCATIONS

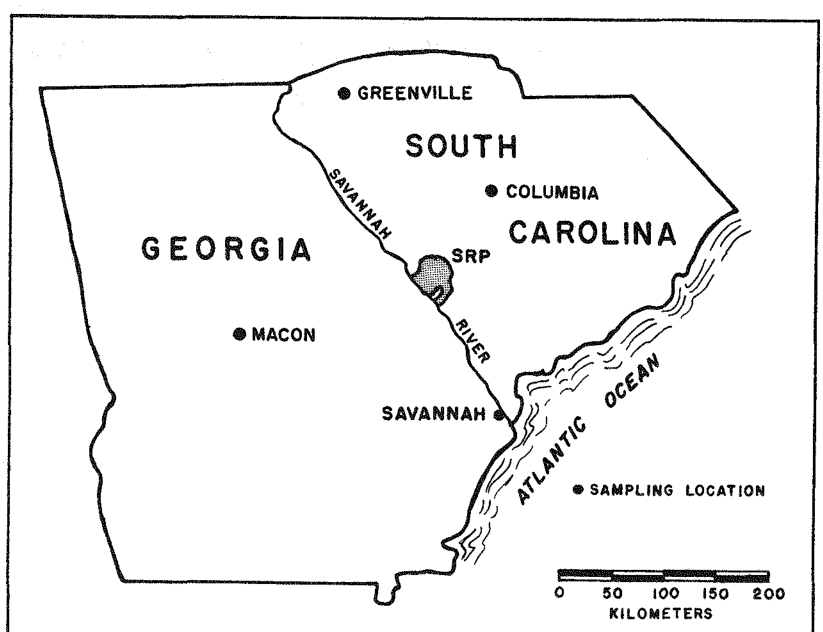


FIGURE 3. DISTANT AIR MONITORING STATIONS

Vegetation

Uranium/Plutonium and Strontium-90 analyses are the same as for farm produce.

Gamma-emitting Radionuclides are determined by counting dried, briquetted vegetation in cans using a 9-in. X 9-in. NaI(Tl) well detector and 400-channel gamma spectrometer.

Soil

The technique used for collection and preparation of soil samples generally follows that used by the ERDA Health and Safety Laboratory (HASL) [7].

Plutonium. Dried soil is blended in a Z-blender, pulverized in a hammer mill to size approximately 20 mesh. 50 grams of the soil is then leached with 8N HCl, passed through an anion-exchange resin. The resin column is eluted with 0.35N HCl - 0.01N HF and the plutonium in the eluate is electrodeposited on a platinum disk for alpha spectrometric analysis.

Gamma-emitting Radionuclides. Approximately 800 grams of the pulverized soil is bottled in a 500-ml plastic bottle and counted as described for vegetation.

Strontium-90. 300 grams of the pulverized soil is leached with 6N HCl. The strontium is precipitated from the leach solution as an oxalate. The precipitate is muffled and dissolved in 0.08N HCl and analyzed the same as water.

ATMOSPHERE MONITORING

Concentrations of radioactive materials in the atmosphere are measured by weekly analyses of air filter contents collected at thirteen monitoring stations near the plant perimeter and twelve stations around a circle of about 25 miles from the center of the plant (figure 2). Stations are spaced to permit continuous monitoring within every 30° sector on the plant perimeter and at 25-mile-radius points, thereby increasing the probability of detecting a significant release of airborne activity by SRP regardless of wind direction. Deposition rates of radioactive materials at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). Four additional air monitoring stations at Savannah and Macon, GA, and at Columbia and Greenville, SC, are so distant from SRP that the effect of SRP operations is negligible; they serve as reference points for determining background (figure 3). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between global fallout and SRP releases.

The small amount of particulate beta activity released to the atmosphere, primarily from the fuel separations areas, is obscured in the area surrounding the plant by worldwide fallout. The influence of nuclear tests, which were resumed in September 1961, is shown in figure 4. The slightly increasing trend (1967 through mid-1972 and again in 1974) is attributed to fallout from atmospheric testing by nonparticipants in the testing moratorium. Some increase occurs each spring as a result of the mixing of the stratosphere with the trophosphere. The beta activity for 1973, however, was relatively low and the characteristic spring maximum – noted in previous years and again in 1974, 1975, and 1976 – was absent. Radioactivity in air, determined from filter analysis and atmospheric moisture analysis of tritium, is shown in table B-1. Annual tritium oxide concentration in air at plant perimeter stations did not exceed 0.1% of the CG. The average of all plant perimeter stations was 50 pCi/m^3 (0.03% CG) compared with 18 pCi/m^3 at the 25-mile-radius stations.

A monthly particulate beta concentration in air of 0.5 pCi/m^3 (maximum weekly concentration of 2.0 pCi/m^3) was measured during October and was attributed to a Chinese atmospheric nuclear

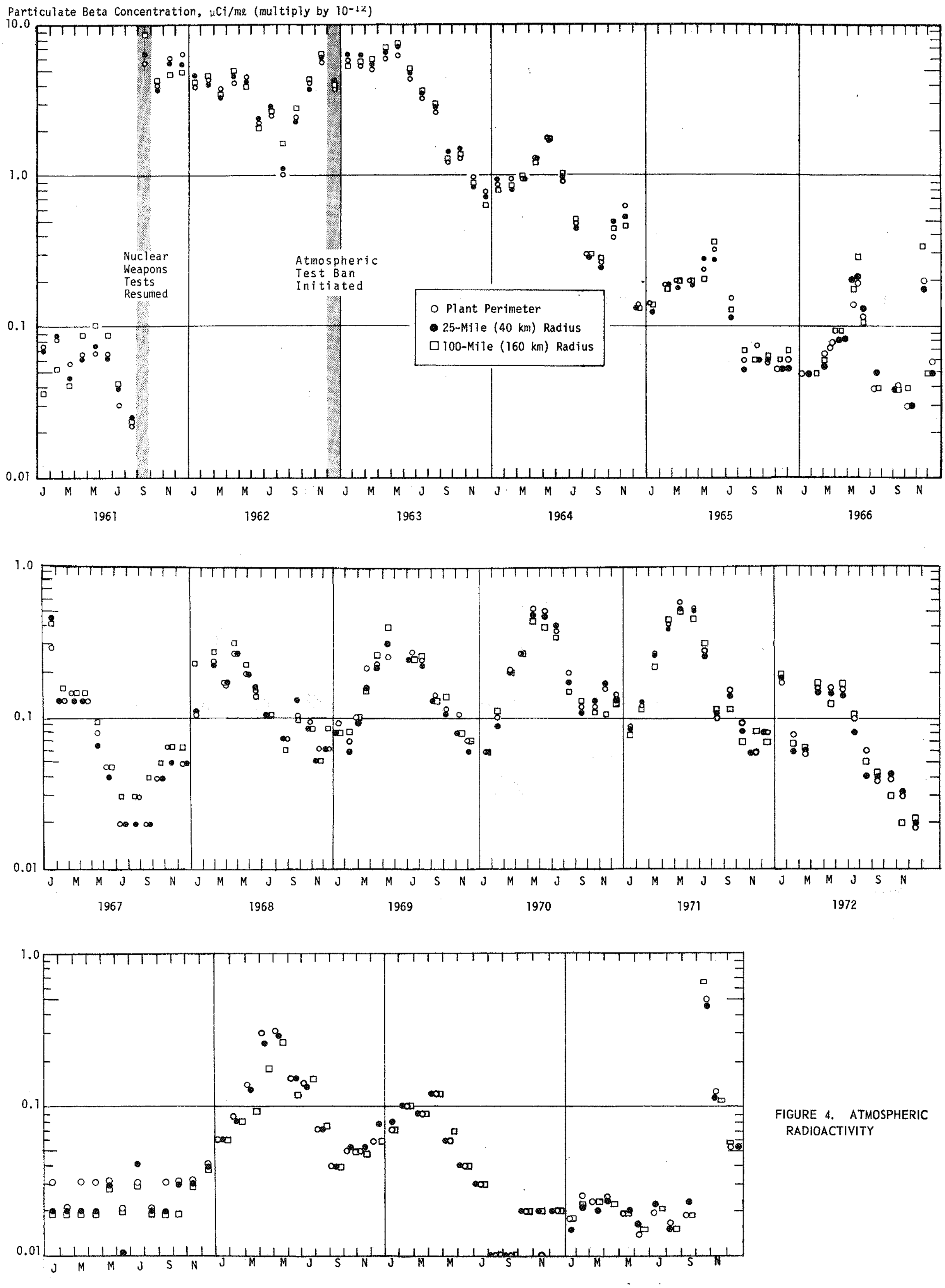


FIGURE 4. ATMOSPHERIC RADIOACTIVITY

weapons test in late September (see Chinese fallout monitoring, page 30). The increase in particulate beta concentration in air for the year, however, was only 40% (0.05 pCi/m^3 during 1975 compared to 0.07 pCi/m^3 during 1976). Alpha activity in air averaged 0.0008 pCi/m^3. The 1976 concentrations of beta and alpha activity in air are 0.07% and 4.0% of the respective CG's.

Radionuclides of global fallout origin were observed in air filters throughout the fourth quarter of 1976. During 1976 no gamma-emitting fallout radionuclides were identified in air samples before the September Chinese test. The major component, beryllium-7, in air filters is a naturally occurring radionuclide formed by interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. Plant releases of airborne beta or gamma activity, with the exception of tritium, are not detectable at the plant perimeter. Therefore, concentrations are calculated by standard meteorological dispersion equations, normalized to agree with measured dispersion of tritium. These calculated concentrations are listed in table 13 along with the yearly releases at the emission source and dose estimates.

After being measured for particulate alpha, beta, and gamma activities, weekly filters from each of the location groups (plant perimeter, 25-mile radius, and 100-mile radius) are combined and dissolved to produce three composite monthly samples for isotopic plutonium analyses. Plutonium is separated by ion exchange, electrodeposited, and counted for alpha emission. Many of the individual plutonium measurements, particularly those for plutonium-238, showed net values lower than the minimum detection level of the analyses. Plutonium-238 and -239 concentrations in air are listed in table B-1. The average concentrations of plutonium-239 in air were 6.5 aCi/m^3 at the plant perimeter, 5.7 aCi/m^3 at a 25-mile radius, and 7.4 aCi/m^3 at a 100-mile radius. The respective plutonium-238 concentrations were 1.7 aCi/m^3, 1.0 aCi/m^3, and 1.3 aCi/m^3.

Deposition rates of plutonium were also determined from rainwater ion exchange columns (fallout collectors). Monthly samples were composited according to two groups: plant perimeter and 25-mile radius (table B-2). Plutonium-239 deposition at the plant perimeter for 1976 was 0.62 pCi/m^2 and 0.60 pCi/m^2 at 25-mile radius. The respective plutonium-238 depositions were 0.60 pCi/m^2 and 0.15 pCi/m^2. Most plutonium-238 values were near or less than the sensitivity of analysis.

Deposition of other radionuclides from weapons test fallout during 1976 averaged 15.2 nCi/m^2 at the plant perimeter and 14.6 nCi/m^2 at 25-mile-radius locations (table B-2); comparable values for 1975 were 6.2 nCi/m^2 at the plant perimeter and 6.5 nCi/m^2 at 25-mile-radius locations. Naturally occurring beryllium-7 (deposition of 48.2 nCi/m^2 at plant perimeter and 37.7 at 25-mile radius), as in air filter samples, is the major fallout component. Radionuclides of worldwide fallout origin were detected in fallout collectors throughout the fourth quarter of 1976; no gamma-emitting radionuclides were identified during the first three quarters. Rainwater is analyzed biweekly for tritium. The average concentration during 1976 at the plant perimeter was 2.5 pCi/ml as compared with 0.6 pCi/ml at 25-mile-radius locations (table B-2).

Gamma radiation is measured quarterly with thermoluminescent dosimeters at the plant perimeter, 25- and 100-mile-radius air monitoring locations (figures 2 and 3). 1976 environmental gamma radiation data (table B-3) were characteristic of measurements observed at individual stations for the past several years (average 70 mR/yr). An environmental thermoluminescent dosimeter (TLD) monitoring program was initiated during 1973 to measure background radiation at 79 stations selected at one-mile intervals along the plant perimeter. Exposure rates at the 79 perimeter stations averaged 65.7 ± 18.3 mR/yr for the four 1976 quarterly cycles monitored. All measurements are taken at one meter above the ground. The contribution of cosmic radiation to the annual terrestrial and atmospheric radiation exposure rate was 29 ± 1.5 mR [DPSPU 76-30-1].

Atmospheric emissions of SO_2, NO_X, and fly ash are presently within applicable standards with the exception of fly ash from several steam power plants. There are eight coal-fired power plants at SRP, which burn about 500,000 tons of coal per year. Sulfur content of the coal averages 0.9%. At the largest plant, which uses 65% of the coal burned at SRP, atmospheric emissions of fly ash are now within applicable standards. Electrostatic precipitators, put into operation in November 1975, reduced fly ash emission from 2.75 to less than 0.03 lb/10^6 Btu input. At the remaining seven plants, fly ash and smoke emission exceeded South Carolina standards in 1976. Prototype two-stage dust collectors have been installed on each of the two boilers in 700-A Administration Area, and their performance was being evaluated at yearend. Dust collectors for the remaining six plants will be designed on the basis of test results in A Area.

VEGETATION AND FOOD MONITORING

Vegetation

Radioactive contamination of growing plants may result from sorption of radioactive materials from the soil or from foliar deposition. Bermuda grass is selected for analysis because of its importance as a pasture grass for dairy herds and its year-round availability.

Grass samples are routinely collected at seven locations on the plant perimeter and at seven other locations on a 25-mile radius (figure 5). Samples are analyzed individually for alpha, nonvolatile beta, and tritium and composited monthly for analyses for specific gamma emitters. Concentrations of gamma-emitting radionuclides from general fallout, as in the atmosphere, were detectable only during the fourth quarter of 1976. Radioisotopic concentrations found in vegetation are shown in table B-4. Naturally occurring beryllium-7 is the major component. Alpha emitters in vegetation collected at the plant perimeter, 25-mile radius, and 100-mile radius averaged 0.1 to 0.2 pCi/g, and beta emitter averages ranged from 30 pCi/g to 42 pCi/g.

Tritium is the only radionuclide of plant origin detected in vegetation. The average concentration in the free water from vegetation collected at the plant perimeter is 7 pCi/ml as compared with 3 pCi/ml at a 25-mile radius and 1 pCi/ml at a 100-mile radius.

Milk

Milk is sampled at two dairies (North Augusta, SC, and Waynesboro, GA) within a 25-mile radius of SRP. Samples are collected twice monthly and analyzed for tritium and radioiodine. Analyses are made quarterly for strontium-90 and monthly for cesium-137. Milk produced in the area and sold by a major distributor is also analyzed for these radionuclides. Results are summarized in table B-5.

Strontium-90 and cesium-137 in milk are attributed to fallout. Average concentrations of the radionuclides in milk were essentially the same as in 1975: 10 pCi/l for both cesium-137 and strontium-90. Iodine-131 in milk samples was less than the sensitivity of analysis (1 pCi/l) throughout the first three quarters of 1976. Fallout iodine-131 from the Chinese weapons test was detected in milk during the fourth quarter (see page 33). Strontium, cesium, and iodine (January – September) values represent 3.3, 0.05, and less than 0.3% of the respective CG's for water. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level (0.6 pCi/ml) is 0.02% of the CG for water.

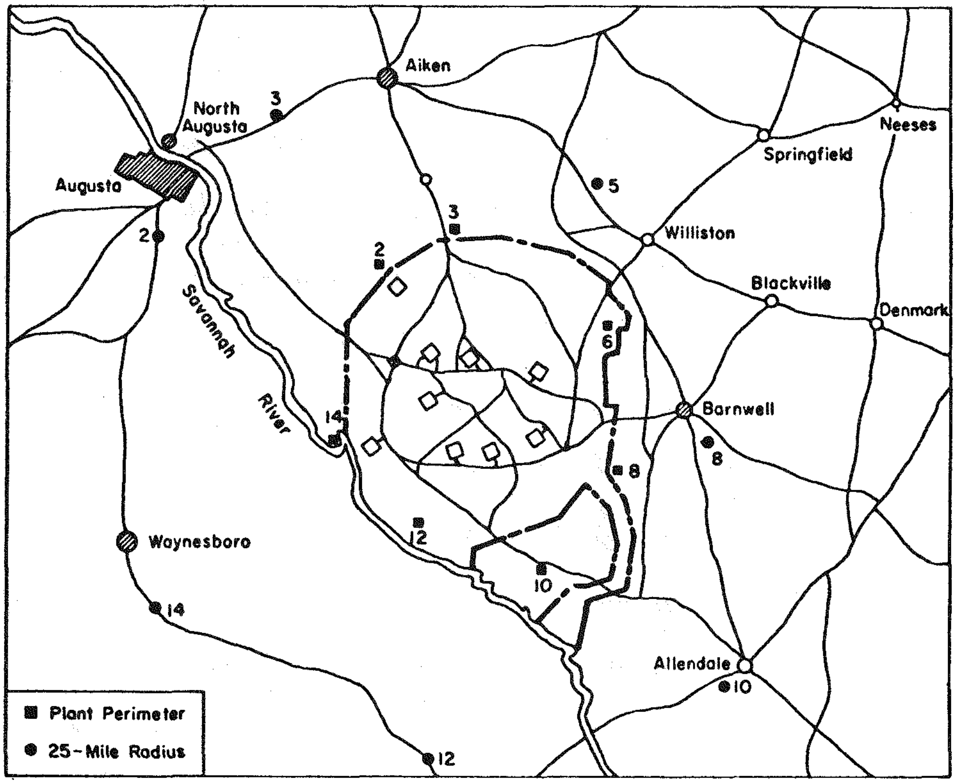


FIGURE 5. VEGETATION SAMPLE LOCATIONS AT
PLANT PERIMETER AND 25-MILE RADIUS

Farm Produce

Over 60 samples of farm produce representing five food categories (grain, fruit, leafy vegetables, poultry, and beef) are collected at 14 localities in the six counties surrounding SRP. Six locations are near the plant perimeter and eight at a distance of approximately 25 miles (figure 6). The samples of local beef were collected near Aiken and Ehrhardt, SC. All samples were analyzed by gamma spectrometry for gamma-emitting radionuclides. Radiochemical analyses are used for strontium-90 and alpha emitters (uranium and plutonium). Liquid scintillation counting is used for tritium. With exception of grains, all foods are prepared as though for human consumption. Peelings, seeds, and other nonedible parts are removed. Wheat containing the whole grains only and oats containing both grains and husks are processed unwashed. Results for 1976 are summarized in table B-6.

SRP contributions to the levels of radioactivity (excluding tritium) in farm produce were so low in 1976 that they were indistinguishable from fallout. All radionuclides in food were near or below the levels of detection. Collards, as during previous years, contained the highest concentration of strontium-90. Because the collards were collected after the arrival of fallout from the September Chinese weapons test, other low level fission product activity was also detected.

Fish

Fish are trapped in the Savannah River upstream, adjacent to, and downstream from the SRP effluents. Individual whole fish are analyzed by gamma spectrometry for cesium-137 and other gamma-emitting radionuclides; bone from each specimen is composited monthly for strontium-89,90 analysis. Fish analysis data for 1976 are presented in table B-7.

During 1976 the radioactivity in bone and flesh showed only minor contribution by SRP and concentrations are of minor significance from a radiation dose viewpoint. Thirty fish (6 collected above, 6 adjacent to, and 18 below the plant) were radioanalyzed, and with exception of three fish, none contained detectable cesium-137 activity (less than 0.1 pCi/g). Two fish collected adjacent to the plant contained 0.1 and 0.2 pCi/g cesium-137, and one fish collected downstream from the plant contained 0.2 pCi/g. An adult regularly consuming fish from the river adjacent to SRP (at a rate of 25 lb/yr) containing the maximum concentration of cesium-137 would receive a whole-body dose of only 0.1 mrem, compared to approximately 115 mrems from natural radiation [9].

Deer and Hogs

Concentrations of cesium-137 in 1357 deer and 177 hogs killed during the autumn 1976 hunts (figure 7) were estimated with a portable, single-channel scintillation instrument before release of the animals to hunters. The estimated cesium-137 content was verified by gamma spectrometric analysis of muscle tissue from 58 deer.

Cesium-137 concentrations in deer originated almost entirely from fallout deposits from nuclear weapons tests. Average cesium-137 concentration in deer was 11 pCi/g with a maximum in one deer of 41 pCi/g. Edible meat from that deer weighed about 63 lb and would therefore contain about 1.17 μCi of cesium-137. An adult eating all of this deer meat would receive a radiation dose of 70 mrems to the whole body – less than the annual dose South Carolina residents receive from natural radiation [9]. Deer and hog data are shown in table B-8. A summary of cesium-137 concentrations detected in deer during all of the public hunts, beginning in 1965, is summarized in table 4. Cesium-137 in SRP deer since 1968 is also compared with data of South Carolina Coastal Plain (SCCP) deer provided by the School of Forest Resources, University of Georgia, Athens, GA.

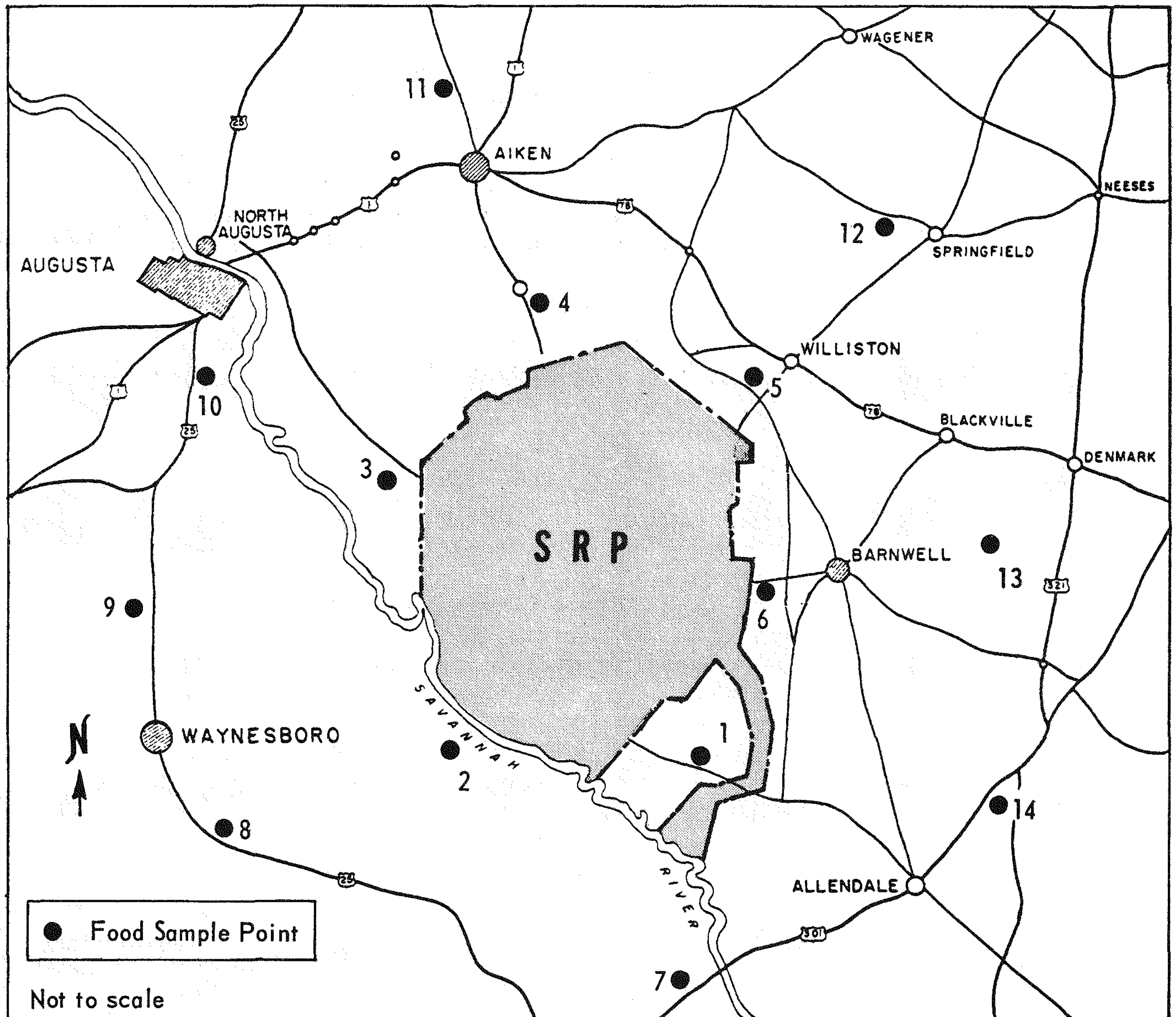


FIGURE 6. FOOD SAMPLE LOCATIONS

FIGURE 7. U.S. FOREST SERVICE PERSONNEL – PUBLIC DEER HUNT

Thyroids from 65 deer were analyzed for iodine-131. Concentrations averaged 150 pCi/g with a maximum of 670 pCi/g. The elevated iodine-131 concentrations are attributed to Chinese weapons test fallout. Bone from 15 deer were analyzed for radiostrontium; concentrations averaged less than 4.5 pCi/g with a maximum of 11 pCi/g.

TABLE 4

^{137}Cs IN DEER, pCi/g

Year	No. of Deer Killed SRP	No. of Deer Killed SCCP[a]	Average SRP	Average SCCP[a]	Maximum SRP	Maximum SCCP[a]
1965	198		<10		10	
1966	541		6		24[b]	
1967	1032		9		104[c]	
1968	699	34	11	23	74[c]	80
1969	889[d]	31	15	15	204[c]	72
1970	864	33	18	20	77[c]	57
1971	865	42	11	21	48	42
1972	808	72	8	11	38	32
1973	1158	78	6	16	31	49
1974	1551	89	5	9	52	23
1975	1391		9	e	36	e
1976	1357		11	e	41	e

a South Carolina Coastal Plains.
b Killed along Four Mile Creek.
c Killed near Steel Creek.
d Approximately 20% of deer monitored before 1969; each deer monitored since 1969.
e Data not available.

Game Birds

Waterfowl collected onplant for radioanalysis included 11 wood ducks, 3 coots, and 2 marsh hens from Par Pond, and 7 wood ducks from Steel Creek. Average concentrations of cesium-137 in Par Pond waterfowl were 2 pCi/g in wood ducks, 1 pCi/g in coots, and 0.5 pCi/g in marsh hens. Cesium-137 in Steel Creek ducks averaged 2 pCi/g. The maximum concentration of cesium-137 was 9 pCi/g, measured in a Par Pond wood duck.

One turkey trapped in the northern section of the plantsite showed less than 0.1 pCi/g of cesium-137.

WATER MONITORING

Savannah River – Radioactivity

The plantsite is drained by five streams that flow several miles through the reservation before reaching the river (figure 1). The primary sources of the very small amount of radioactivity that reaches the river are the reactor facilities. Tritium accounts for the largest quantity of radioactivity released by the reactors to the effluent streams. However, the contribution of tritium to the Savannah River amounts to only 0.14% of the concentration guide.

River water is sampled above and below the plant (sampling method described earlier) and is analyzed weekly. Concentrations of gross alpha and nonvolatile beta emitters in river water for 1976 are summarized in table B-9. The values represent the radioactivity associated with dissolved and suspended solids and are all near or less than the sensitivity of analysis. Upstream measurements are attributed to natural radioactivity and worldwide fallout from nuclear weapons tests. Downstream measurements reflect these sources plus releases from SRP.

Tritium, trace amounts of cesium-137, and strontium-90 were the only radionuclides of SRP origin detected in river water at the downstream location. Strontium-90 and tritium from worldwide fallout were also detected in river water upstream from SRP effluents. Average concentrations of all radionuclides found in river water during 1976 (table B-10) are only small fractions of the concentration guides.

Savannah River – Chemical Water Quality and General River Health

The water quality of the Savannah River (table B-11) is not adversely affected by the operation of the Savannah River Plant. More fecal coliform bacteria are found in the river water entering the plant than in the effluent water re-entering the river. With respect to thermal effect, several miles of onsite streams and a large swamp permit dissipation of almost all heat generated at SRP. The maximum temperature increase of river water is within South Carolina and Georgia standards. Results of temperature profile surveys also show compliance with NPDES Permit limitations as shown on page 23.

The Limnology Department of the Academy of Natural Sciences of Philadelphia (ANSP), under contract to Du Pont, has performed a continuing survey of aquatic biota and water quality of the Savannah River upstream and downstream from SRP since 1951. Collections are made of algae, protozoa, insects, other macroinvertebrates, and fish from four locations in the river: near Johnson's Landing, SC (river mile 124.3 from the Savannah, GA, harbor), Little Hell Landing (river mile 134.5), Brigham's Landing (river mile 141.6), and Shell Bluff Landing (river mile 161.9). In addition, chemical analyses are run at all four stations. The purpose of this survey is to determine the effect, if any, of SRP effluent discharges on general river health. The data generated to date all indicate that there are no significant differences in water quality among the four stations. The evidence suggests there is a source of enrichment and eutrophication upstream from the study area. The 1976 results indicate that this enrichment is not as heavy as it was in 1972.

Diatometers are positioned in the river at three locations (one above and two below the SRP site) to provide a continuous monitor of the effects of plant effluents on one major group of river organisms. The diatometers contain glass slides on which diatoms accumulate. The slides are replaced every two weeks, and the slides containing dried diatoms are sent to ANSP for analysis. In rivers adversely affected by pollution, the number of species will be reduced in varying amounts corresponding to the degree of pollution. The less tolerant species are eliminated while the more tolerant species proliferate. Thus, while total populations may increase in size, the number of different species will be reduced. Detailed readings and summaries of the diatometer surveys are issued quarterly by ANSP. There is no evidence that the operation of the Savannah River Plant affected the diatom flora of the Savannah River.

Quarterly surveys of other algae, insects, invertebrates, and fish are also conducted by ANSP. Specialists in entomology, algology, invertebrate zoology, and ichthyology sample river biota during times of the year most suitable to their specialty. An algologist or entomologist accompanies every survey to provide continuity of collecting and methodology and to observe environmental conditions. Results of the quarterly surveys are summarized and published annually. No detrimental effects upon aquatic life in the Savannah River results from operation of SRP.

Periodically, or as a result of major changes in the physiography of the river, ANSP makes comprehensive surveys of the biota and chemical water quality above, adjacent to, and below SRP to ascertain effects of SRP operations on river conditions. Determinations obtained from a comprehensive survey in 1976 show no marked changes in the number of species in the various classes of organisms studied. All indications are that the condition of the river was better at all stations than it was during the last comprehensive survey in 1972. For example, three species of fish, previously unrecorded at river stations, were collected during the 1976 survey. Although these species are represented by few individuals, their occurrence suggests water quality improvement. Also, the beds of rooted aquatic plants, which indicated degraded water quality, are no longer dominating the shallows in 1976 as in 1972.

Savannah River – Pesticides

Arrangements were made in 1971 for the United States Geological Survey (USGS) Water Quality Laboratory, Washington, DC (now located in Atlanta, GA), to analyze water and sediment from SRP streams and the Savannah River for pesticides. Water samples were previously analyzed for pesticides by the Federal Water Pollution Control Administration (now Environmental Protection Agency) at Athens, GA, and all results were less than sensitivity of analyses. Gas chromatographic water analyses in 1976 also show concentrations of pesticides in river water both upstream and downstream from the plant less than sensitivity of analyses (less than 0.05 μg/l). Previously, trace quantities of pesticides (approximately 0.05 μg/l, primarily dieldrin) have been detected in river water both upstream and downstream from SRP. Dieldrin is an agricultural pesticide and is not used at SRP. River sediment showed trace quantities of dieldrin, DDD, and DDE, but these pesticides are not used at SRP. Some pesticides and herbicides are used moderately in areas where insect and vegetation control is necessary for security and safety. Some herbicide and chemical treatment is also carried on by the US Forest Service in timber management. Quantities of pesticides detected in river sediment by the USGS laboratory are shown in table 5. The pattern of concentrations detected in sediment indicates that offplant sources are the primary contributors. Possible offsite sources for pesticides found in the river include industrial discharges and drainage from farm areas.

TABLE 5
PESTICIDES IN SAVANNAH RIVER SEDIMENT IN 1976, ug/kg

	River 2 (Upstream)	River 10 (Downstream)
DDD	4.6	2.1
DDE	2.2	2.3
Dieldrin	a	0.6

[a] Less than sensitivity of analyses.

Temperature Survey – National Pollutant Discharge Elimination System Permit (NPDES)

A temperature profile survey of the Savannah River made in August showed that heated waters discharged by SRP mix adequately with river water so that temperatures are in compliance with limitations established by the U.S. Environmental Protection Agency. The standard applicable to the Savannah River as stated in U.S. ERDA NPDES Draft Permit SC 00000175, 1976, is as follows.

During the period beginning on effective date and lasting through expiration, the permittee is authorized to discharge from outfalls-once-through cooling water.

Such discharges shall be limited and monitored by the permittee as specified below.

Effluent Characteristic	Discharge Limitations Instantaneous Maximums	Monitoring Requirements Measurement Frequency	Sample Type
Plume Temp, °C	32.2[a]	1/quarter	Grab
Plume Temp Rise Above ambient, °C	2.8[a]	1/quarter	Grab

[a] Measured at the edge of the approved mixing zone. The zone for mixing shall be limited to not more than 25% of the cross-sectional area and/or flow of the Savannah River and shall not include more than one-third of the surface area measured from shore to shore. Mixing zone lengths shall not exceed 100 yards below the mouth of Beaver Dam Creek, 300 yards below the mouth of Four Mile Creek, and 100 yards below the mouth of Steel Creek. Ambient temperature shall be determined upstream from Beaver Dam Creek. Monitoring shall be conducted for a period of one year, during the months of May, August, November, and February and shall include three-dimensional data collection and plots. Data collection should be at low river flow to the extent practicable.

Figures 8, 9, and 10 show cross-sectional temperature profiles in the Savannah River at the edge of the three approved mixing zone lengths: 100 yd below the mouth of Beaver Dam Creek, 300 yd below the mouth of Four Mile Creek, and 100 yd below the mouth of Steel Creek. The river flow on the days of the surveys was approximately 6700 cfs (1976 average, 14,300 cfs). The profiles at each location extended from the South Carolina shore, at 10-ft intervals for a distance of one-half the river width. No temperature measurement, at any depth, exceeded 2.8°C above the average ambient river temperature of 23.3°C measured 100 yd upstream from Beaver Dam Creek. The locations of the maximum temperatures in each of these profiles were as follows: 25.0°C below Beaver Dam Creek, 40 ft from SC shore at a depth of approximately 2 ft; 26.0°C below Four Mile Creek, 10 ft from SC shore at depths from 1 to 6 ft; and 25.9°C below Steel Creek, 120 ft from SC shore at a 1-ft depth.

Six additional cross-sectional temperature profiles were taken at the mouth and downstream of both Beaver Dam and Four Mile Creeks. These profiles, extending from the SC shore for a distance of one-third the river width (88 ft for Beaver Dam, 102 ft for Four Mile) showed maximum temperatures as follows: Beaver Dam Creek, 23.4°C (0.1° above ambient) at both the mouth and 50 yd downstream; and Four Mile Creek, 23.7°C (0.4° above ambient) at a 1-ft depth at the mouth, 25.3°C (2.0°C above ambient) at 50 yd downstream, 24.6°C (1.3°C above ambient) at a 1-ft depth at 100 yd downstream, and 23.6°C (0.3° above ambient) at various depths at 200 yd downstream. One additional temperature profile was taken 50 yd downstream from Steel Creek to a depth of 17 ft and extending for a distance of one-third the river width. The maximum temperature was 24.9°C (1.6° above ambient) at a 1-ft depth. Previous temperature profiles in the mouth of Steel Creek and Lower Three Runs Creek have shown temperatures within 1°C of unaffected upstream water. Based on extensive cross-section temperature profiles in the Savannah River below Beaver Dam and Four Mile Creeks in 1974, these 1977 temperature profiles show that limitations for the mixing zones are not exceeded and that the plant is in compliance with the NPDES Permit.

In June 1974, over 80 temperature profile cross sections (approximately 2000 temperature measurements) of the Savannah River were taken below Beaver Dam and Four Mile Creeks. Locations were selected to show maximum changes in temperatures and shape of the heated waters. The profiles for Beaver Dam Creek extended from the SC shore 120 ft and were repeated at approximately 10-ft intervals downstream for 360 ft. Four Mile Creek profiles extended from the SC shore 60 ft and were repeated at approximately 10-ft intervals downstream for 1280 ft. The plume of heated water from Beaver Dam Creek extends downstream through a mixing zone of approximately 370 ft and a maximum cross section of 60 ft. The mixing zone below Four Mile Creek is approximately 1200 ft long with a maximum cross section of approximately 50 ft. The width of the Savannah River is approximately 300 ft.

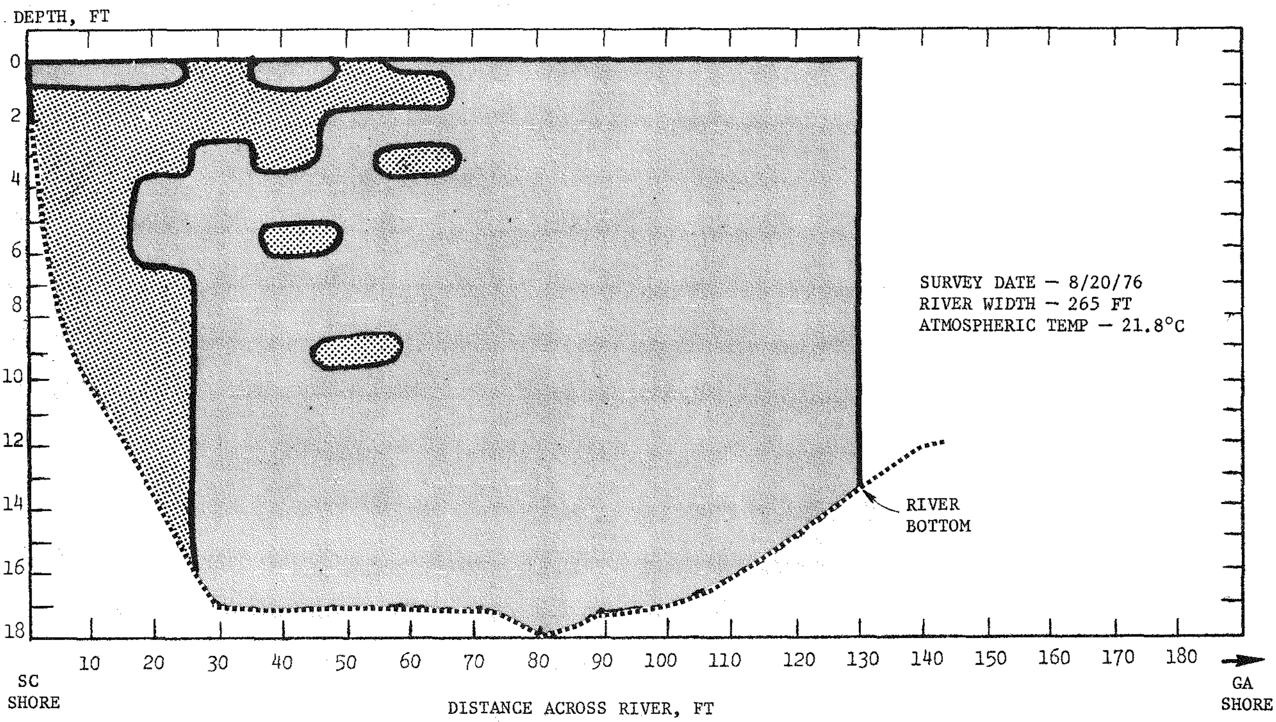
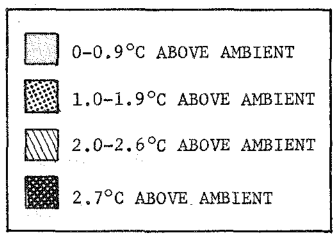


FIGURE 8. TEMPERATURES IN RIVER 100 YD BELOW BEAVER DAM CREEK



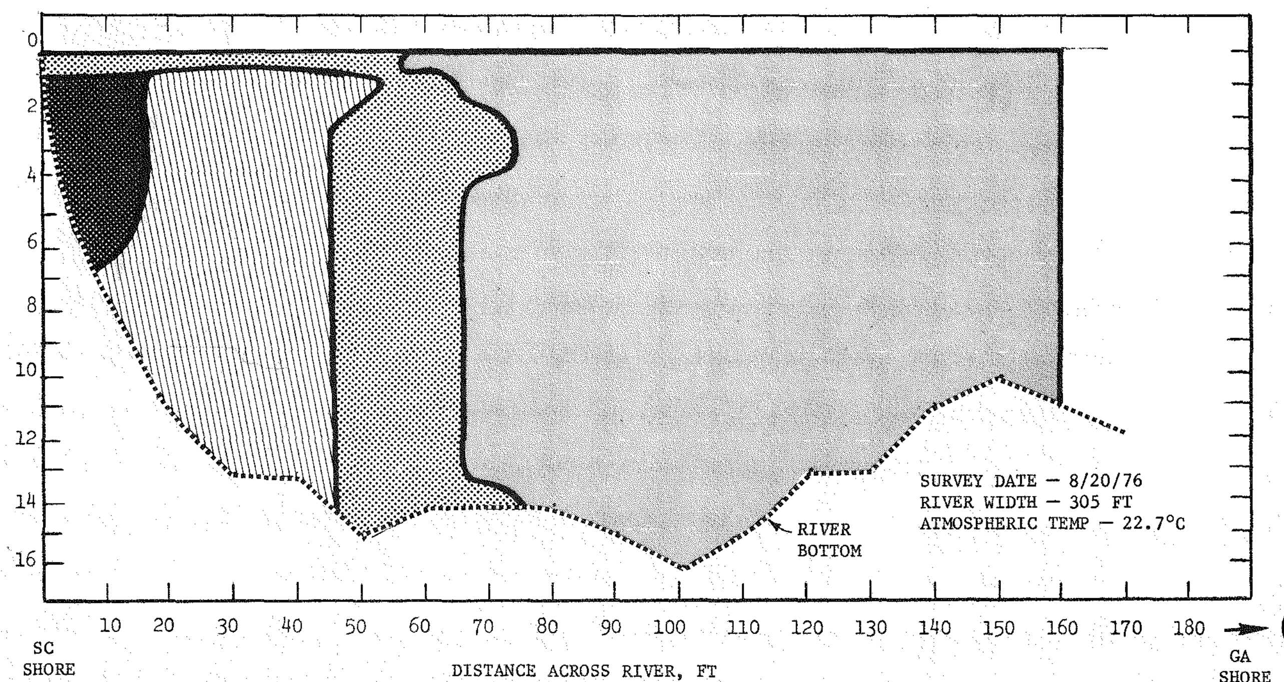


FIGURE 9. TEMPERATURES IN RIVER 300 YD BELOW FOUR MILE CREEK

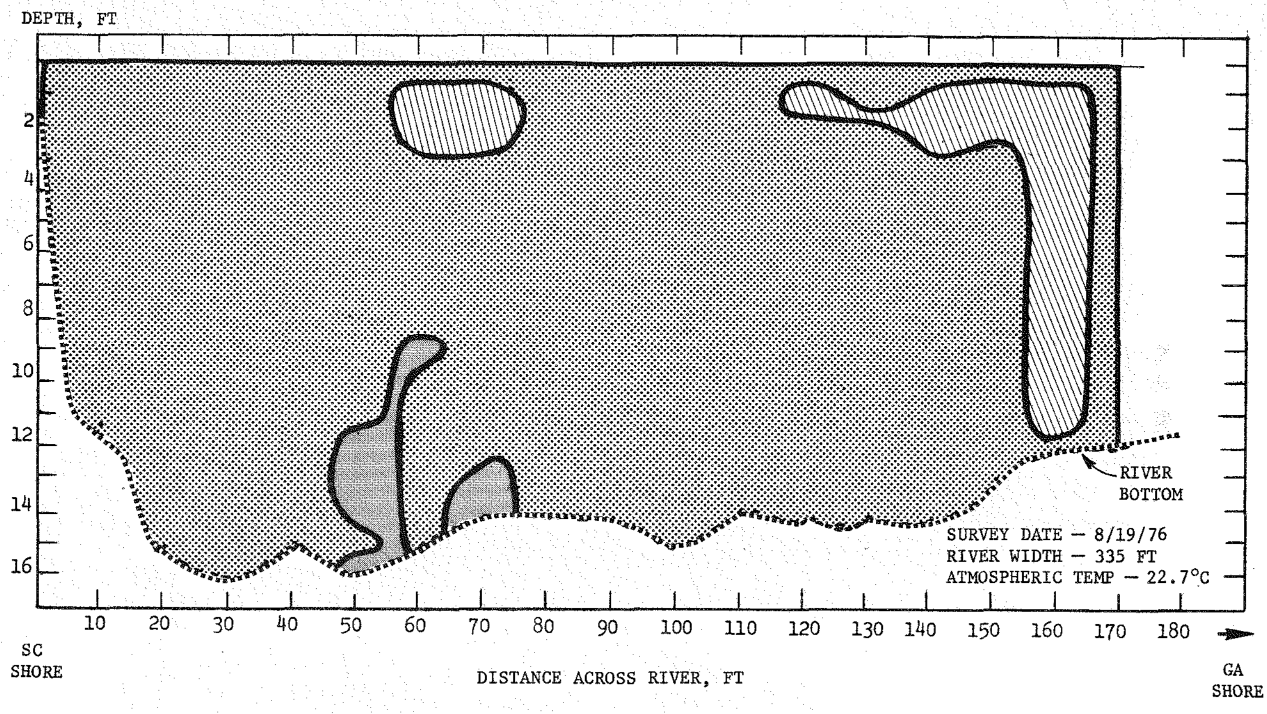
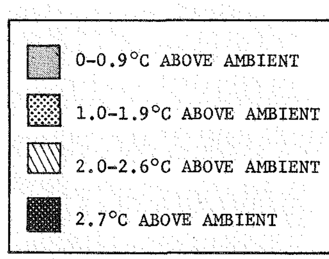


FIGURE 10. TEMPERATURES IN RIVER 100 YD BELOW STEEL CREEK



Drinking Water

Communities near SRP get drinking water from deep wells or surface streams. Public water supplies from 14 surrounding towns are collected semiannually. Data from analyses of all public water samples from the immediate vicinity of the plant are shown in table B-12. Drinking water wells onplant show concentrations of radioactivity similar to those offplant.

Average alpha activity (0.5 pCi/l) and beta activity (3 pCi/l) are essentially the same as those observed before plant startup. Very low levels of tritium are found in drinking water of several of the towns that use surface water (annual maximum 0.7 pCi/ml). Concentrations of tritium in water from deep wells are near or less than the sensitivity of the analyses (0.3 pCi/ml).

The Beaufort-Jasper Water Authority operates a treatment facility to furnish drinking water, partially obtained from the Savannah River, to most of Beaufort County, SC. Water is supplied through a canal from the river at a point about 90 miles below SRP. A water treatment plant at Port Wentworth, GA, supplies water to a business-industrial complex near Savannah. These two water supplies are analyzed monthly for tritium content.

Tritium concentrations in water collected from the Beaufort-Jasper plant averaged 2 pCi/ml (0.07% CG, as defined in the foregoing section on Applicable Standards) and 4 pCi/ml in water from the Port Wentworth plant (0.13% CG) during 1976.

SOIL MONITORING

Concentrations of radiocesium and plutonium in soils collected at four locations near the plant perimeter and two locations approximately 100 miles distant during 1976 are similar to the deposition values reported for previous years. The average concentration of cesium-137 in the top 5 cm at the plant perimeter is 0.8 pCi/g and at the 100-mile distance, 1.0 pCi/g. The total plutonium average in the top 5 cm at the plant perimeter is 0.018 pCi/g and at 100 miles, 0.015 pCi/g. Deposits of cesium and plutonium measured in soils for the past four years are summarized in table 6. Total plutonium deposition and cesium-137 deposition in all samples are within the range normally found in global fallout. Plutonium-238 in plant perimeter and 100-mile-radius soil samples did not exceed the sensitivity of the analysis (0.001 pCi/g). Soil data are shown in table B-13.

Soil samples from noncultivated areas were first collected for radioanalysis in 1973 at four locations along the plant perimeter (representing each quadrant) and at three locations up to 100 miles from the plant. In each successive year, samples have been collected at the plant perimeter locations and at two of the 100-mile-radius locations. At each site, 10 soil cores 5 cm deep are taken in a straight line 30 cm apart for plutonium analysis. Ten 15-cm soil cores were taken at each site for cesium-137 analysis prior to 1976. The soil cores were composited by location for radioanalysis.

TABLE 6
RADIOACTIVITY IN SURFACE SOIL, mCi/km^2

	Plant Perimeter			100-Mile Radius		
Year	^{239}Pu	^{238}Pu	^{137}Cs	^{239}Pu	^{238}Pu	^{137}Cs
1973	1.78	0.08	78	1.69	0.12	105
1974	1.19	.11	73	1.26	.13	59
1975	1.13	.07	88	0.68	.02	72
1976	1.30	0.07	63	1.09	0.06	74

SAVANNAH RIVER SWAMP MONITORING

During the 1960's, radioactive materials from SRP releases were deposited in about 1.7 square miles of offsite swamp downstream from SRP. Waterborne sediments settle in the swamp during periods of high flow in the river when the river overflows its natural banks into the swamp. When the swamp is flooded, the flow from SRP surface streams generally follows a path through the swamp paralleling the main river channel and bordering the north swamp margin. This swamp flow does not enter the main river channel until high ground is encountered at Little Hell Landing, approximately four miles from the SRP boundary (figure 11).

Associated with the deposit in the offsite swamp were approximately 25 Ci of cesium-137 and less than 1 Ci of cobalt-60. Most of the cesium-137 and cobalt-60 in the swamp were from releases from L- and P-Area reactor fuel basins to Steel Creek. The discharges to Steel Creek were substantially reduced in 1970 following modifications to one reactor and shutdown of the other reactor. Aerial radiological surveys and ground surveys conducted in 1974 [10,11] showed that approximately 4.8 Ci of cesium-137 and most of the cobalt-60 were deposited in a quarter-mile-long section of swamp (43 acres) immediately adjacent to the SRP boundary (figure 11). The remainder of detectable radioactivity was deposited in a four-mile-long band bordering the north swamp margin, terminating at the Little Hell Landing area. The 1976 radiation survey of the swamp showed no significant change in levels of radioactivity from those measured and reported for the past two years.

Fifty-two locations along ten trails transecting the swamp were selected for sampling vegetation and soil and radiation (TLD) measurements. The trails were established in 1974 and samples are collected annually as near as possible to locations used in the 1974 survey.

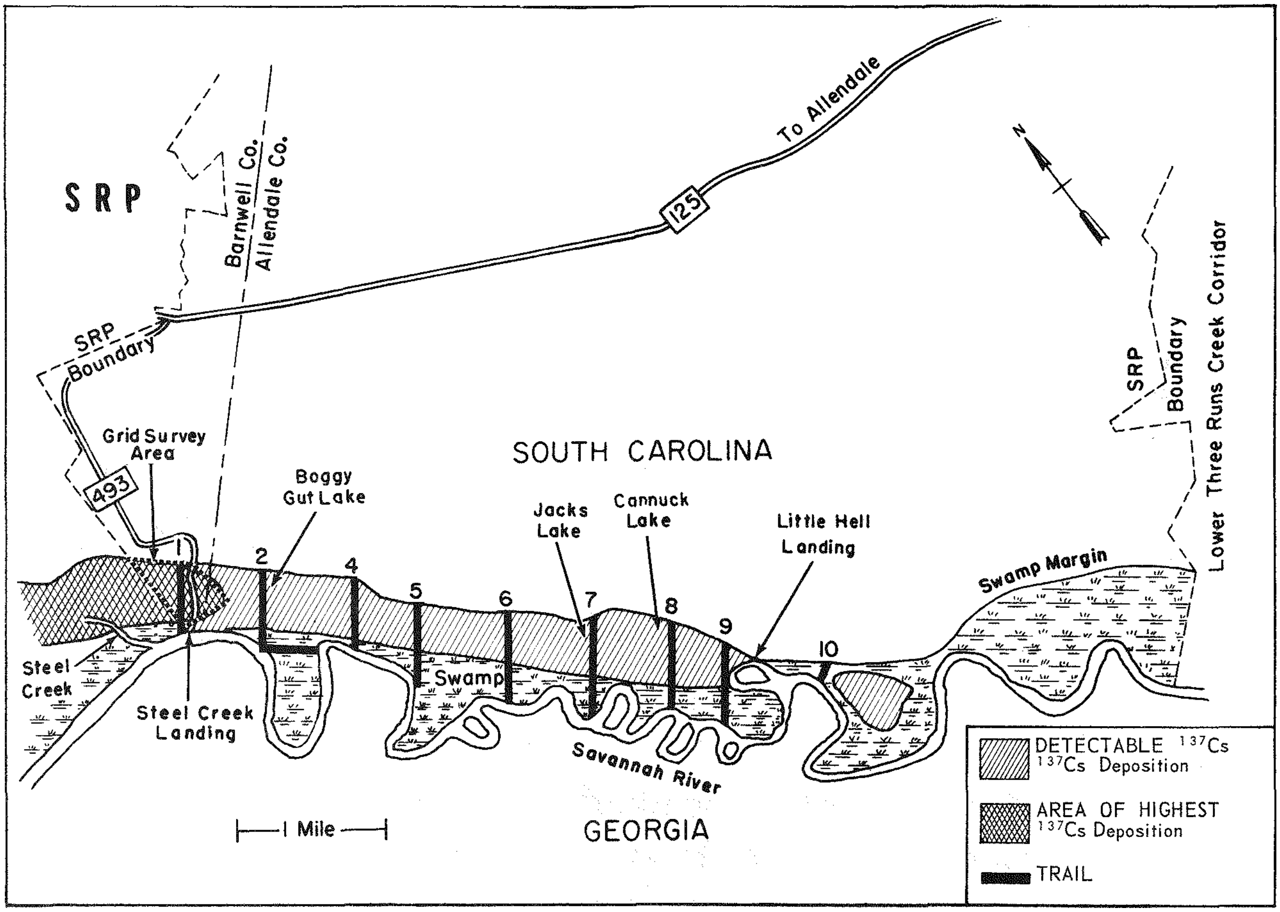


FIGURE 11. RADIOACTIVITY DEPOSITION IN THE SAVANNAH RIVER SWAMP

Maximum cesium-137 concentrations in 1976 are 119 pCi/g in vegetation, and 174 pCi/g in soil (5-cm depth). The maximum radiation exposure rate measured was 77 μR/hr (includes approximately 10 μR/hr background). The 1976 TLD measurements are slightly higher than in 1975. The lower 1975 measurements were attributed to higher water levels in the river that flooded the swamp and provided additional shielding. This shielding effect was substantiated by the similarity between the 1976 and 1974 measurements. Individual TLD data are shown in table B-14.

Sediment cores were collected along each of the trails at the location showing the highest observed radiation level. At each site, 10 sediment cores, approximately 8 cm deep, were taken in a straight line 30 cm apart. Soil cores are composited by location for radioanalysis. Concentrations of plutonium in soil samples during 1976 are compared with 1975 in table 7. The plutonium-238 alpha percentage (ratio of plutonium-238 to total plutonium) ranged from 10% to 30% and is indicative of some plant contribution. Individual survey results for the past several years are shown in tables B-14 through B-16.

Because slightly elevated plutonium activity was found along the swamp trails, a special sediment core along trail 1 was collected to analyze concurrently with eight control sediment samples. Four control samples were collected from flood plain areas of the Savannah River above the plant at Demier's Landing (river mile 160 from the Savannah harbor), above Upper Three Runs Creek (river mile 157.5), Flowery Gap Landing (river mile 155.5), and just above Beaver Dam Creek (river mile 153.5). The four other control samples were collected from flood plain areas of the Pee Dee River at 0.25 mi, 1 mi, 2 mi, and 3 mi below US Highway I-95 (Florence County, SC). The Pee Dee River drainage area is comparable to that of the Savannah River. Analysis results summarized in table 8 show elevated plutonium-238, plutonium-239, cesium-137, and strontium-90 along trail 1 as compared with the control samples. Sediment samples from other flood plain areas of the Savannah River showed plutonium-238, plutonium-239, cesium-137, and strontium-90 concentrations that are within global fallout levels. These samples were collected at strategic points between river mile 160.5 (3 mi above SRP) and river mile 118.7 (at US Highway 301, 10 mi below SRP). These data are summarized in table 9.

TABLE 7
SAVANNAH RIVER SWAMP SEDIMENT CORES
RADIOACTIVITY CONCENTRATION RANGES — 1975–1976

	Range, pCi/g	
	1975	1976
^{137}Cs	1–261	<1–174
^{238}Pu	0.003–0.052	<0.001–0.054
^{239}Pu	0.022–0.096	0.003–0.123

TABLE 8

RADIOACTIVITY IN SEDIMENT FROM RIVER FLOOD PLAINS, pCi/g

Locations	^{238}Pu	^{239}Pu	^{137}Cs	^{90}Sr
Savannah River				
Trail 1 - swamp below plant	0.039	0.080	205	0.63
Control				
Demier's Landing (river mile 160.4)	.005	.007	0.5	.12
Above Upper Three Runs (river mile 157.4)	.002	.029	1.7	-
Flowery Gap Landing (river mile 155.5)	.001	.018	1.4	.20
Above Beaver Dam Creek (river mile 153.6)	.002	.012	0.8	.06
Pee Dee River Controls				
0.25 mile below I-95	.001	.007	0.5	.12
1.0 mile below I-95	.003	.009	.4	.13
2.0 miles below I-95	.001	.003	.1	.10
3.0 miles below I-95	0.001	0.007	0.6	0.13

TABLE 9

RADIOACTIVITY IN SEDIMENT FROM RIVER FLOOD PLAINS, pCi/g

Location — Savannah River	^{238}Pu	^{239}Pu	^{137}Cs	^{90}Sr
3 miles above SRP (marker 78) (river mile 160.5)	0.0005	0.001	0.7	0.04
Below Four Mile Creek (river mile 150.2)	<0.0005	.003	.7	.10
Steel Creek (river mile 136.6)	0.0005	.001	.7	.08
Little Hell Landing (river mile 134.0)	0.0005	.004	0.6	.11
Lower Three Runs Creek (river mile 128.5)	<0.0005	.002	1.1	.10
Highway 301 (river mile 118.7)	0.0005	0.003	2.2	0.11

CHINESE FALLOUT MONITORING

There were two announced Chinese atmospheric nuclear detonations during 1976, on September 26 and November 17. The September test caused higher levels of fallout radionuclides in the environment than have been observed in recent years. Fallout levels in environmental samples in early October were several orders of magnitude higher than in September. The November test caused no detectable increase in radiation levels. Table 10 compares maximum levels measured in samples in October, after the arrival of fresh fallout, with the earlier September levels.

The predicted arrival of fallout from the November test for South Carolina was November 21, 4 days after detonation. Travel time of all detectable Chinese test fallout, with one exception, has ranged from 7 to 14 days, averaging 9.5 days. Fallout from a test in 1973 was not detected until four months later. At the time of the predicted arrival of fallout from the November test, radioactive debris was reported to have been carried along with high altitude winds and this, coupled with absence of heavy rain, prevented its detection. Residual radiation from the November test will most likely appear gradually over a period of several months and will be difficult to differentiate from weapons debris from the September test.

After the September 26 test an extensive special monitoring program, in addition to the routine program, was initiated to measure the fallout in the environment. The first detection of the arrival of fallout was observed in a high volume (45 cfm) air sample collected over a 24-hr period ending at 8 a.m. on October 4 (seven days after detonation). The maximum gamma activity in air (approximately 10 pCi/m^3) was measured on October 5, the eighth day after the detonation. Daily measurements of fallout air activity are shown in figure 12. The sharp decreases observed in air activity, notably October 7 - 14, October 19 - 21, and beginning on October 28, correspond to periods following heavy rainfall (approximately 5.4 inches over the entire period). On October 22, barium-140, which had been undetected for several days, reappeared along with increased iodine-131 and cerium-141. This indicated cycling of fallout around the earth in about 20 days. A second cycling peak occurred in about 17 days. These cycling periods correspond to those observed in earlier years. The increase observed on November 20 was too early for the arrival of fallout from the November 17 Chinese test. Also, no neptunium-239 or increased iodine-131 and barium-140, typical of fresh fallout, were seen.

Because of heavy rains occurring soon after the arrival of the fallout, deposition of radioactivity was larger than usual. Radionuclides deposited in rain are shown in figure 13. The first period, October 3 - 7 (rain occurring mostly on October 6 and 7), showed increased nonvolatile beta activity (too low for isotopic identification) and low level iodine-131 activity. The second rain sample, collected October 7 - 8, showed the maximum deposition of 57 nCi/m^2, with nine fresh fallout radionuclides identifiable. The third rain sample, collected on October 8 - 9 showed a reduction in deposition (4.5 nCi/m^2) with six radionuclides identifiable. Fallout activity was not detected in over two inches of rain during October 20 - 26 or in November and December rains.

Milk samples showed iodine-131 activity beginning October 6. The maximum concentration (778 pCi/l) was measured in a sample collected from a cow at Windsor, SC, on October 10. From observations of the drinking habits of the cows and analysis of surface water samples, it appeared that the Windsor cow used more surface water as a drinking supply and this contributed to the higher concentration of iodine-131. Only low level iodine-131 was measured in approximately 40 special vegetation samples. The maximum iodine-131 concentration in vegetation was 8 pCi/g in a sample collected 25 miles from the plant. Fallout data for milk and vegetation are summarized in tables 11 and 12.

TABLE 10
ENVIRONMENTAL RADIOACTIVITY BEFORE AND AFTER ARRIVAL
OF CHINESE FALLOUT, SEPTEMBER - OCTOBER 1976

Sample	During September	Maximum During October
Hi-vol air sample (daily) - gamma activity, pCi/m^3	<0.02	9.5
Rain deposition (daily) - gamma activity, nCi/m^2	<0.03	57.2
Routine air samples (weekly) - filterable beta, pCi/m^3	~0.02	0.07 to 1.11
Vegetation ^{131}I, pCi/g	<3	8
Milk ^{131}I, pCi/l	<1.5	780
Deer thyroids, killed in public hunts, ^{131}I, pCi/g	<0.2	670
River water above and below plant Ru, ^{131}I, pCi/l	None	Trace
Vegetables (collards collected 10/26) - gamma activity, pCi/g	<0.2	0.5 to 0.8

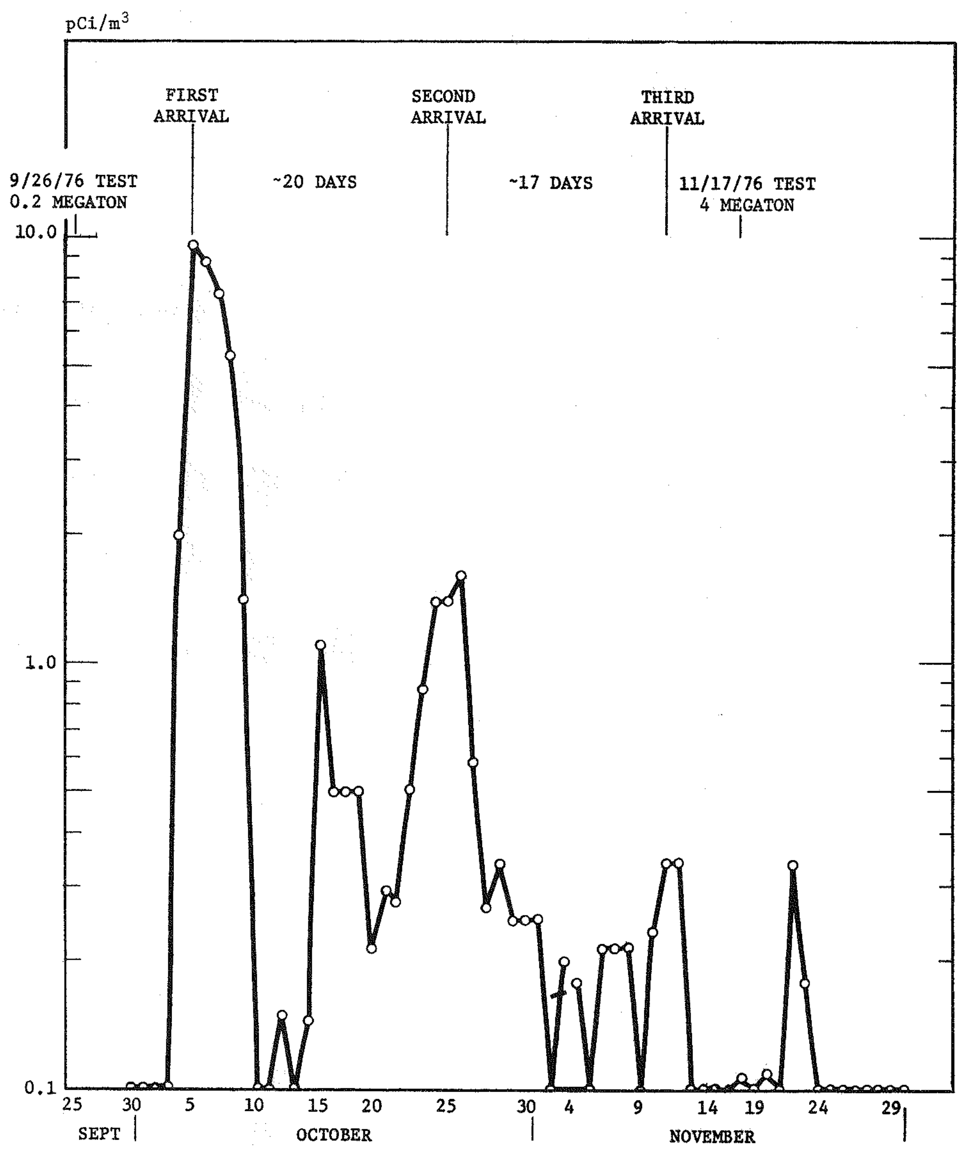


FIGURE 12. GAMMA ACTIVITY IN AIR – CHINESE FALLOUT

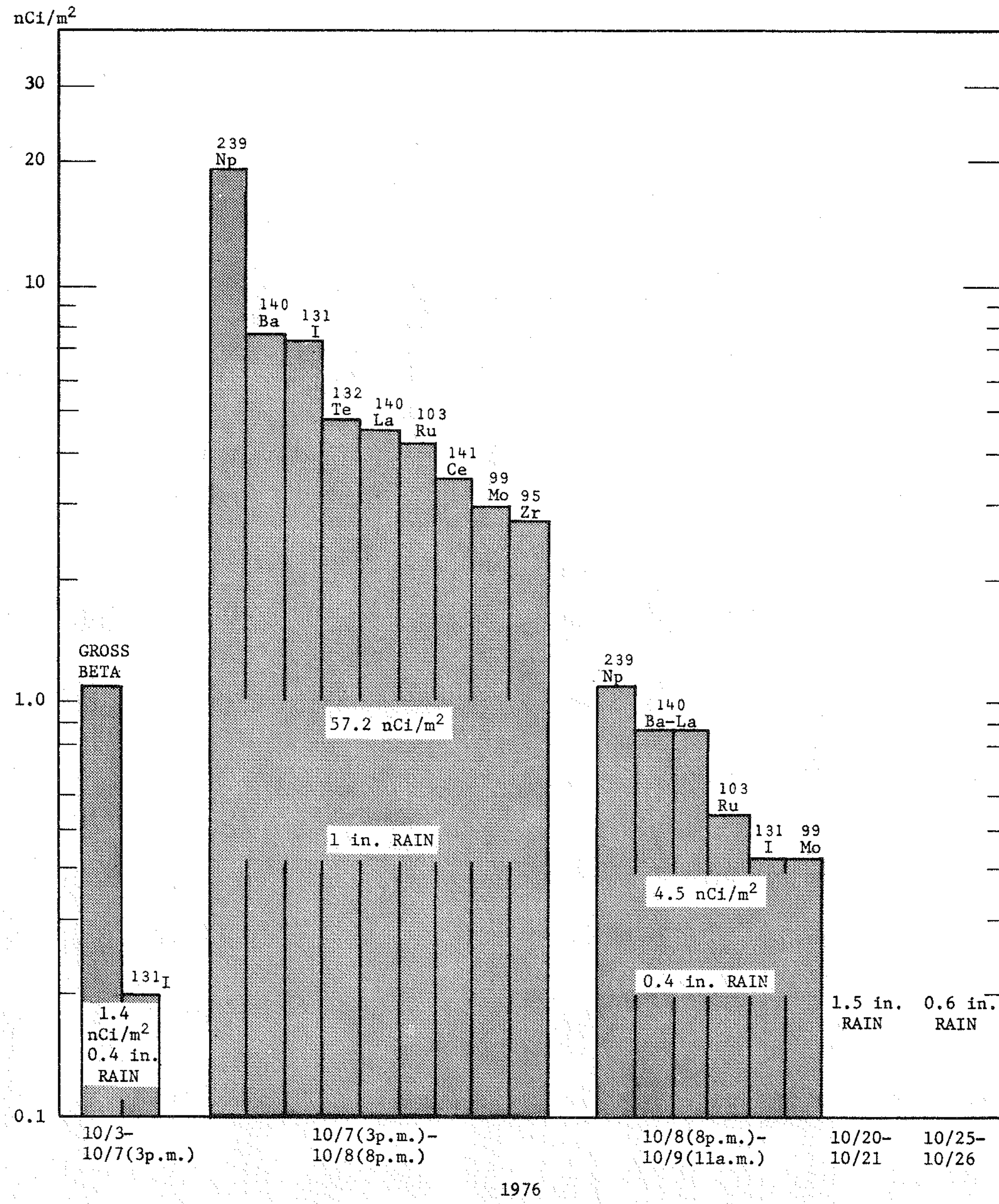


FIGURE 13. RADIONUCLIDES DEPOSITED IN RAIN – CHINESE FALLOUT

TABLE 11
^{131}I IN MILK — CHINESE FALLOUT

Source	Period	Sampling Location	No. of Samples	pCi/l[a] Max	Min	Avg
Farm cow	10/06 - 10/08	4	33	778	3	124
Small dairy	10/11 - 10/18	5	8	67	<2	8
Major distributor	10/11 - 10/18	1	3	6	<2	4

[a] No ^{131}I in routine milk samples on 10/28.

TABLE 12
^{131}I IN VEGETATION — CHINESE FALLOUT

Location	Period	Sampling Location	No. of Samples	pCi/g Max	Min	Avg
Onplant	10/6	4	4	0.8	0.4	0.6
Plant perimeter	10/6	2	2	0.8	0.8	0.8
25-mile radius	10/7 - 10/18	12	34	8.0	0.8	1.6
100-mile radius	10/8	1	1	-	-	6.3

RADIATION DOSE COMMITMENT – INDIVIDUAL AND POPULATION

As used in this report, "radiation dose" means "radiation dose equivalent" as defined by the International Commission on Radiological Protection [12]. Radiation dose commitment is the amount of radiation dose received from major pathways of exposure, internal and external, throughout the lifetime of an individual from direct first-pass exposure. (A brief description of dose calculational techniques is given in appendix C.) Population dose commitment is the sum of radiation dose commitment of individuals and is expressed in units of man-rem. (For example, if 1000 people each received a dose of 1 rem, their population dose would be 1000 man-rems.) The segments of the population that receive the highest radiation dose commitments from SRP releases of radioactive materials to the environment are described in the following sections.

Persons Living in the Area Surrounding the Savannah River Plant and Exposed to Radioactive Materials via Atmospheric Pathways

Radioactive materials released from exhaust stacks are diluted by the atmosphere and the concentration in air decreases with distance from point of release because of mixing by turbulent movements of the atmosphere. As a result of this dispersion, the average radiation dose commitment from SRP releases to individuals 50 miles from the center of the plant is only about 23% of that received by people living near the plant perimeter. The radiation dose received by people from atmospheric releases of radioactive materials from SRP is too low to permit direct measurement of all pathways of exposure; therefore, radiation dose commitments are calculated with mathematical models using known dispersive characteristics of the atmosphere and the known major pathways of exposure to man.

During 1976, the average dose commitment to an individual from atmospheric releases of radioactive materials from SRP was calculated to be 0.7 mrem at the plant perimeter (table 13). The major contributors to this dose were tritium (hydrogen-3), 69%; argon-41, 22%; and carbon-14, 7%. The remaining 2% was from krypton and xenon isotopes (chemically inert noble gases), iodine-129,131, and miscellaneous radioactive particles. The calculated population dose commitment from release of radioactive materials from SRP to the atmosphere in 1976 to people living within 80 km (50 miles) of the center of SRP (population: 465,000) is 95 man-rems. Table 13 shows the amount of each radionuclide released to the atmosphere from normal SRP operations and calculated whole-body radiation dose commitment.

Tritium (T), the major contributor to population dose from normal SRP releases in 1976, is a radioactive isotope of hydrogen with a radiological half-life of 12.33 years. The maximum energy of the beta particle emitted during decay is 0.0186 MeV; the average energy is about 0.006 MeV. At SRP, some tritium is unavoidably released during normal operations both as an elemental gas (T_2, HT, DT) and in combination with oxygen (T_2O, HTO, DTO). Both forms are readily dispersed in air and will enter into the same chemical and biological reactions as hydrogen or water vapor.

TABLE 13

ATMOSPHERIC TRANSPORT AND DOSE — 1976

Nuclide	Curies Released at Emission Source	Calculated Avg Conc at Plant Perimeter, μCi/ml	Calculated Whole Body Dose to Individual at Plant Perimeter, mrem		Calculated Population Dose Commitment, man-rem	
			Average	Maximum	80 km	100 km
Gases and Vapors						
^{3}H	3.0×10^{5}	8.1×10^{-11}	0.48	0.66	75.2	94.1
^{14}C	6.9×10^{1}	1.9×10^{-14}	.048	.066	7.5	9.4
^{41}Ar	8.3×10^{4}	1.1×10^{-11}	.15	.23	11.0	11.8
^{85m}Kr	3.8×10^{2}	7.3×10^{-14}	.00015	.00022	0.014	0.016
^{85}Kr	7.4×10^{5}	2.0×10^{-10}	.0026	.0036	.46	.59
^{87}Kr	4.2×10^{2}	4.4×10^{-13}	.00076	.0012	.045	.047
^{88}Kr	5.1×10^{2}	8.2×10^{-14}	.0022	.0032	.18	.20
^{131m}Xe	6.3×10^{2}	1.7×10^{-13}	.00031	.00045	.043	.053
^{133}Xe	2.5×10^{3}	6.6×10^{-13}	.00063	.00089	.085	.10
^{135}Xe	7.3×10^{2}	1.6×10^{-13}	.00049	.00071	.055	.064
^{129}I	1.5×10^{-1}	4.1×10^{-17}	.0015	.0020	.23	.28
^{131}I	1.6×10^{-1}	2.8×10^{-17}	0.00003	0.00004	0.0031	0.0035
Particulates						
^{60}Co	1.3×10^{-4}	7.5×10^{-21}	<0.00001	<0.00001	<0.00001	<0.00001
$^{89,90}Sr$	4.6×10^{-3}	2.7×10^{-19}	<0.00001	<0.00001	<0.00001	<0.00001
^{95}Zr	1.4×10^{-2}	8.1×10^{-19}	<0.00001	<0.00001	<0.00001	<0.00001
^{95}Nb	2.7×10^{-2}	1.6×10^{-18}	<0.00001	<0.00001	<0.00001	<0.00001
^{103}Ru	2.1×10^{-2}	1.2×10^{-18}	<0.00001	<0.00001	<0.00001	<0.00001
^{106}Ru	2.6×10^{-1}	1.5×10^{-17}	<0.00001	<0.00001	0.00003	0.00003
^{134}Cs	1.7×10^{-4}	9.8×10^{-21}	<0.00001	<0.00001	<0.00001	<0.00001
^{137}Cs	1.3×10^{-3}	7.5×10^{-20}	<0.00001	<0.00001	<0.00001	<0.00001
^{141}Ce	2.0×10^{-4}	1.2×10^{-20}	<0.00001	<0.00001	<0.00001	<0.00001
^{144}Ce	1.1×10^{-2}	6.4×10^{-19}	<0.00001	<0.00001	0.00003	<0.00003
U	5.0×10^{-3}	2.9×10^{-19}	<0.00001	<0.00001	0.00021	0.00024
$^{238,239}Pu$	1.7×10^{-2}	9.8×10^{-19}	0.0015	0.0021	0.14	0.16
		Total →	0.696	0.971	95.0	116.9

The low energy beta particle emitted by tritium during decay will penetrate human tissue only 0.013 cm. As an elemental gas, tritium constitutes little hazard because the weak beta is completely attenuated (absorbed) in the inert external skin layer (epidermis). Only 0.004% of the gas inspired is converted to the oxide and retained in the body. Almost all tritium oxide (water vapor) inhaled is absorbed in the lungs and enters the body water pool. In addition, almost as much tritium oxide is absorbed through the skin as is absorbed during inhalation. Because of the great difference between the biological assimilation of tritium gas and tritium oxide, the concentration guide [1] for tritium oxide is several hundred times more restrictive than for elemental gas. The environmental radiation dosimetry program used at SRP makes the conservative assumption that all normal SRP releases are in the oxide form and thus, there is an overestimation of individual and population dose commitment from tritium.

Persons Living Downstream from SRP and Consuming Savannah River Water Containing Low Concentrations of Radioactive Materials

Radioactive materials released to effluent streams on the SRP site flow to the Savannah River. There is no known use of river water for irrigation downstream from SRP. Fish from the river are not an important source of food for any large segment of the population. The most important pathway of exposure of a population segment to radioactive materials in the river is from consumption of river water. Two water treatment plants downstream from SRP supply treated river water to customers in Beaufort and Jasper Counties in South Carolina and Port Wentworth, GA. Of the radioactive materials released to effluent streams on SRP during 1976 (table 14), only tritium is measurable by routine water monitoring techniques of the water from the treatment plants. Data shown for other nuclides are calculated, based on dilution by known river flow rates. Of the radioactive materials in water, tritium is the source of 99% of the whole-body dose commitment to consumers. People who consume this water at a rate of 1.2 liters per day would receive a dose commitment from tritium of:

Beaufort-Jasper	0.18 mrem
Port Wentworth	0.36 mrem

The population dose commitment from tritium to these two groups from 1976 SRP tritium releases are 8.9 man-rems to consumers of Beaufort-Jasper water (population: 50,000) and 7.1 man-rems to consumers of Port Wentworth water (estimated consumer population: 20,000 – most of Port Wentworth water is used for industrial purposes), a total of 16 man-rems to river water consumers. Radionuclides other than tritium contribute an additional 0.1 man-rem population dose commitment as shown in table 14.

TABLE 14
RIVER TRANSPORT AND DOSE — 1976

Nuclide	Curies Released at Emission Source	Avg Conc in River, μCi/ml	Calculated Individual Dose Commitment, mrem: Whole Body	Bone	Lower Large Intestine	Thyroid	Testis	Calculated Population Dose Commitment, man-rem
^{3}H	6.0×10^{4}	2.0×10^{-6} [a]	0.178					8.9
		4.0×10^{-6} [b]	0.356					7.1
^{32}P	1.7×10^{-2}	1.3×10^{-12}	<0.00001	0.00011				0.0003
^{35}S	3.4×10^{-1}	2.7×10^{-11}	0.00003				0.00012	0.0021
^{51}Cr	3.6×10^{-1}	2.8×10^{-11}	<0.00001		0.00002			<0.0001
$^{58,60}Co$	2.0×10^{-3}	1.6×10^{-13}	<0.00001		<0.00001			<0.0001
^{89}Sr	4.0×10^{-3}	3.1×10^{-13}	<0.00001	<0.00001				<0.0001
^{90}Sr	9.1×10^{-1}	7.2×10^{-11}	0.00011	0.047				0.008
$^{89,90}Sr$	1.7×10^{-2}	1.3×10^{-12}	<0.00001	.00088				0.0002
^{91}Y	7.5×10^{-2}	5.9×10^{-12}	<0.00001		0.00019			<0.0001
$^{95}ZrNb$	1.7×10^{-2}	1.3×10^{-12}	<0.00001		.00002			<0.0001
$^{103,106}Ru$	1.0×10^{-3}	7.9×10^{-14}	<0.00001		.00001			<0.0001
^{131}I	2.0×10^{-3}	1.6×10^{-13}	<0.00001			0.00013		<0.0001
^{134}Cs	1.7×10^{-2}	1.3×10^{-12}	0.00006					0.004
^{137}Cs	2.8×10^{-1}	2.2×10^{-11}	.00059					.041
$^{134,137}Cs$	2.3×10^{-2}	1.8×10^{-12}	0.00008					0.0057
$^{141,144}Ce$	9.0×10^{-3}	7.1×10^{-13}	<0.00001		.00005			<0.0001
^{147}Pm	9.4×10^{-2}	7.4×10^{-12}	<0.00001		.00003			<0.0001
U	3.6×10^{-1}	2.8×10^{-11}	0.00001		.00074			0.0004
^{239}Pu	8.3×10^{-3}	6.5×10^{-13}	.00001	.00031				0.0004
		Total →	.18[c] 0.36[d]	0.048	0.0011	0.00013	0.00012	16.1

a Beaufort-Jasper. Concentrations are measured values.
b Port Wentworth. Concentrations are measured values.
c Summation for Beaufort-Jasper.
d Summation for Port Wentworth.

Comparison of Calculated Dose Commitment from Plant Releases with that from Other Sources

Population dose commitment (man-rem) can be used for comparison with radiation exposure from other sources, such as natural radioactivity and medical radiation exposure. The 1976 population dose commitment from SRP releases (95 man-rems from atmospheric releases to people within 80 km of the center of the plant and 16 man-rems from liquid releases to people consuming Beaufort-Jasper and Port Wentworth water) is compared with radiation dose from natural and medical sources in the following table.

Source of Exposure	Population Dose, man-rem
Natural	63,000
Artificial	
Medical diagnosis [13]	54,000
Weapons fallout [14]	2,700
SRP releases	111

Even though SRP contribution to population dose is very small (0.18% of that from natural sources), SRP has a continuing program to improve operating techniques and to develop new technology directed toward reducing releases of radioactive materials to the environment.

Tritium Quality Factor

Tritium doses were calculated using a quality factor of 1.7 for the low energy beta particle emission. The Concentration Guide (CG) for tritium published in the Code of Federal Regulations, Title 10, Part 20 (10CFR20) was derived with this same quality factor. In 1969 [15], the International Commission on Radiological Protection (ICRP), and in 1971, the National Council on Radiation Protection and Measurement (NCRP) recommended a quality factor of 1.0 as being appropriate within the degree of precision required for purposes of radiological protection. However, this recommendation has not yet been reflected in the federal regulations. A quality factor of 1.0 would have the effect of lowering the calculated population dose from tritium.

APPENDIX A.
DATA ANALYSIS AND QUALITY CONTROL

Data Analysis

The sensitivity of laboratory analyses (shown in table on page 41) refers to the minimum amount of radioactivity that can be detected by the radiochemical analytical technique in use. It is based on statistical counting error (95% confidence level) and is influenced by sample size, counter and procedure efficiencies, length of count, counter background, and decay. Where samples are analyzed by gamma spectrometry, the lower level of detection of a given radionuclide varies with the background of each individual channel grouping, with the geometry and volume of sample analyzed, and with number of radionuclides present in the sample. For this reason average sensitivities are given for only milk and vegetation.

Survey data (appendix B) show the arithmetic annual averages of individual measurements. Many of the individual measurements, after subtracting instrument background, showed net values lower than minimum detection level of analyses. For averaging purposes, however, these very small or zero values are included with larger, positive values.

Average values are usually accompanied by a plus or minus (±) limit value. This value, designated 2 Std Dev, is the standard deviation (95% confidence level) of the average and is a measure of the range in the concentration encountered at that location. When the average is given for groups of locations, the Std Dev is the measure of the range in concentration found at all locations. In some tables the standard deviation is not calculated because of the small number of sample results. When a ± figure accompanies an individual result, such as the maximum (max) or minimum (min), it represents the statistical counting error at the 95% confidence level, which in many cases exceeds the net value of the sample. Max and min refer to the greatest and smallest concentration found in a single sample collected during the year.

No self-absorption corrections have been applied to gross alpha and gross nonvolatile beta results. If activity appears unusual, and specific analyses are not routinely scheduled, further analyses are performed for verification.

Because of the voluminous amount of data and computer handling, the numbers presented in the tables are not rounded off to the significant digit.

Quality Control

An internal quality control program is maintained by (1) monthly calibration of counting instruments; (2) daily source and background counts; (3) routine yield determinations of radiochemical procedures; (4) duplicate analyses to check precision; (5) reagent blank analyses to check purity of all chemicals. Accuracy of radioactivity measurements is established by use of standards obtained from the National Bureau of Standards or their equivalent. The Environmental Monitoring Laboratories at SRP are also participating in the Interlaboratory Comparison program established with the Las Vegas Quality Assurance Branch of EPA. A number of different environmental samples (water, air filters, milk, and diet) containing a variety of radionuclides of interest are forwarded to all laboratories participating in the program. Three separate determinations are performed on each sample and the results returned to EPA for comparison with the known value and the results from the other laboratories. Comparisons of reported values with EPA values and those of other laboratories permit evaluation of precision and accuracy.

In 1976, participation in an ERDA-wide program of quality assurance was initiated. Samples are sent from the Health and Safety Laboratory (HASL) to various laboratories on a quarterly basis for analysis of a number of nuclides in various media. The first samples received were for September 1976 (samples dated July 1, 1976) and included soil, vegetation, animal bone, water, and air filters. The sample aliquots received were already prepared for radioanalysis; the soil pulverized and blended, the vegetation ashed and sieved, the bone ashed, ground, sieved, and blended, and the water acidified. The air filter samples consisted of two glass fiber filters; each had been moistened with solution, evenly distributed, and dried. The results are submitted to HASL and an intercomparison of data obtained by other participating laboratories (on split samples of the same media) is reported by HASL.

The quality control program in the water quality laboratory is designed to constantly evaluate results of the analyses. An intralaboratory quality control program is maintained by (1) routine calibration of instruments, (2) routine yield determinations of procedures, and analysis of standards furnished by the Environmental Protection Agency (EPA), (3) routine standardization of titrating solutions used in procedures, and (4) duplicate analyses.

Because spikes are not run for biochemical oxygen demand, pH, alkalinity and chloride analyses, the quality of these results is dependent on the standardization of standards and instrument calibration. Evaluations of the stability of reagents are determined. Some standards must be standardized daily; however, other standards are stable for varying but known amounts of time. Stability has been improved by storing in dark bottles or away from light. Standardization is done before significant changes occur.

Samples sometimes require digestion in order to break down organic compounds which may contain the element of interest in their chemical structure. Unless the organic molecule is fragmented by digestion, this element may not exhibit the chemical properties which indicate its presence. The efficiency of the digestion process for samples is evaluated by digesting prepared standard organic compounds.

TABLE A-1
SENSITIVITY AND STANDARD DEVIATIONS OF LABORATORY ANALYSES

Analysis	Sample Type	Length of Count, Minutes	Standard Aliquot	Sensitivity and Precision (95% Confidence Level)	Units
		Zinc Sulfide Alpha Counters			
Gross alpha	Water	20	1 ℓ	0.25 ± 0.13	pCi/l
	Vegetation	20	2 g	.12 ± .06	pCi/g
	Rain (collection pan)	20	0.37 m^2	.0007 ± .0004	nCi/m^2
	Air	20	∿800 m^3	.03 ± .02	pCi/m^3 ($\times10^{-2}$) (0.0003 ± 0.0002 pCi/m^3)
U or Pu (alpha)	Food	20	100 g	0.002 ± 0.001	pCi/g
		Gas Flow Proportional Beta Counters			
Gross beta	Water	10	1 ℓ	7.05 ± 0.39	pCi/l
	Air	10	∿800 m^3	0.88 ± .05	pCi/m^3 ($\times10^{-2}$) (0.0088 ± 0.0005 pCi/m^3)
Strontium-89,90	Bone	10	2 g	4.5 ± .25	pCi/g
	Rain	10	0.37 m^2	0.02 ± .001	nCi/m^2
	Air composites				
	Plant perimeter	10	∿19,500 m^3	0.10 ± 0.001	pCi/m^3 ($\times10^{-2}$) (0.0010 ± 0.00001 pCi/m^3)
	25-mile radius	10	∿18,000 m^3	.11 ± .001	pCi/m^3 ($\times10^{-2}$) (0.0011 ± 0.00001 pCi/m^3)
	100-mile radius	10	∿6,000 m^3	0.33 ± 0.02	pCi/m^3 ($\times10^{-2}$) (0.0033 ± 0.0002 pCi/m^3)
		Low Background Beta Counter			
Strontium-90	River water	50	20 ℓ	0.02 ± 0.002	pCi/l
	Milk	50	0.5 ℓ	1.10 ± .12	pCi/l
	Food	50	20 g	0.02 ± .002	pCi/g
	Rain	50	0.37 m^2	0.004 ± 0.0004	nCi/m^2
		Liquid Scintillation Counters			
Tritium	Drinking water	300	4 ml	300 ± 10	pCi/l (0.30 ± 0.01 pCi/ml)
	River water	300	4 ml	300 ± 10	pCi/l (0.30 ± 0.01 pCi/ml)
	Rainwater	300	4 ml	300 ± 10	pCi/l (0.30 ± 0.01 pCi/ml)
	Milk	300	4 ml	300 ± 10	pCi/l (0.30 ± 0.01 pCi/ml)
	Air (atmospheric moisture)	300	4 ml (water)	300 ± 10	pCi/l (0.30 ± 0.01 pCi/ml) (× avg abs humidity = ∿4 pCi/m^3 of air)
	Food	20	3 ml	1 ± 0.05	pCi/ml (free water)
	Vegetation	20	3 ml	1 ± 0.05	pCi/ml (free water)
		Solid-State Alpha Spectrometer			
Plutonium-238	Air composites				
	Plant perimeter	72[a]	∿19,500 m^3	0.36	aCi/m^3
	25-mile radius	72[a]	∿18,000 m^3	0.39	aCi/m^3
	100-mile radius	72[a]	∿6,000 m^3	1.18	aCi/m^3
	Rain composites				
	Plant perimeter	72[a]	4.81 m^2	0.0020	pCi/m^2
	25-mile radius	72[a]	4.44 m^2	.0022	pCi/m^2
	Soil	24[a]	50 g	0.0002	pCi/g
Plutonium-239	Air composites				
	Plant perimeter	72[a]	∿19,500 m^3	0.35	aCi/m^3
	25-mile radius	72[a]	∿18,000 m^3	0.38	aCi/m^3
	100-mile radius	72[a]	∿6,000 m^3	1.12	aCi/m^3
	Rain composites				
	Plant perimeter	72[a]	4.81 m^2	0.0019	pCi/m^2
	25-mile radius	72[a]	4.44 m^2	.0021	pCi/m^2
	Soil	24[a]	50 g	0.0002	pCi/g
		Na(I) Detector (9 in. × 9 in.)			
Iodine-131	Milk	200	3.8 ℓ	1.0 ± 0.5	pCi/l
	Vegetation	10	50 g	0.2 ± 0.01	pCi/g
Cesium-137	Milk	200	1.8 ℓ	3 ± 2	pCi/l

[a] Hours

APPENDIX B. SURVEY DATA

TABLE B-1

RADIOACTIVITY IN AIR

Location	No. of Samples	Max	CT Err 95% CL	Min	CT Err 95% CL	Arithmetic Mean	Arithmetic 2 Std Dev
				Alpha, pCi/m³ (×10⁻²)			
Plant Perimeter							
Allendale Gate	49	0.23	±0.10	0.01	±0.04	0.08	±0.10
A-14	45	.17	± .09	.00	± .08	.06	± .08
Barnwell Gate	52	.17	± .09	.00	± .06	.05	± .08
D Area	52	.38	± .24	.01	± .05	.09	± .12
Dark Horse	52	.19	± .09	.01	± .04	.06	± .06
East Talatha	52	.18	± .10	.00	± .04	.08	± .08
Green Pond	52	.22	± .10	.01	± .03	.08	± .08
Highway 21/167	51	.18	± .09	.00	± .01	.06	± .08
Jackson	50	.18	± .09	.00	± .02	.08	± .08
Pattersons Mill	52	.19	± .10	.00	± .04	.08	± .08
Talatha Gate	52	.19	± .09	.01	± .04	.08	± .10
West Jackson	37	.16	± .08	.02	± .04	.06	± .06
Windsor Road	51	0.13	±0.08	0.00	±0.04	0.07	±0.08
					Avg →	0.07	±0.09
25-mile Radius							
Aiken Airport	52	0.17	±0.08	0.00	±0.05	0.06	±0.08
Aiken State Park	51	.24	± .26	.00	± .00	.07	± .08
Allendale	50	.18	± .08	.00	± .03	.06	± .08
Augusta	52	.33	± .13	.00	± .00	.12	± .10
Highway 301	52	.19	± .09	.02	± .05	.07	± .08
Langley	52	.23	± .10	.02	± .04	.09	± .08
Lees	52	.25	± .10	.02	± .06	.10	± .10
Olar	52	.25	± .12	.01	± .06	.07	± .08
Perkins	52	.17	± .08	.02	± .04	.07	± .08
South Richmond	52	.27	± .11	.00	± .04	.10	± .10
Springfield	52	.27	± .11	.00	± .05	.10	± .10
Waynesboro	52	0.16	±0.08	0.00	±0.04	0.07	±0.08
					Avg →	0.08	±0.10
100-mile Radius							
Columbia	52	0.25	±0.11	0.00	±0.03	0.10	±0.12
Greenville	51	.20	± .10	.00	± .03	.08	± .08
Macon	47	.28	± .12	.00	± .03	.09	± .10
Savannah	50	0.24	±0.10	0.01	±0.04	0.07	±0.08
					Avg →	0.08	±0.10

TABLE B-1, Contd
RADIOACTIVITY IN AIR

Location	No. of Samples	Max	CT Err 95% CL	Min	CT Err 95% CL	Arithmetic Mean	Arithmetic 2 Std Dev
			Nonvolatile Beta, pCi/m^3 ($\times 10^{-2}$)				
Plant Perimeter							
Allendale Gate	49	104.83	±3.30	0.41	±0.97	8.34	±36.24
A-14	45	13.11	±1.11	.08	±0.66	2.69	± 5.40
Barnwell Gate	52	111.01	±3.05	.15	±0.81	7.87	±41.74
D Area	52	89.32	±2.61	.49	±1.13	7.29	±30.66
Dark Horse	52	67.84	±2.25	.00	±0.67	5.66	±22.28
East Talatha	52	71.45	±2.53	.00	±0.77	7.51	±30.88
Green Pond	52	61.42	±2.17	.01	±0.70	6.33	±24.60
Highway 21/167	51	86.14	±2.68	.08	±0.17	7.31	±30.88
Jackson	50	81.90	±2.52	.21	±2.47	7.87	±33.42
Pattersons Mill	52	93.63	±2.66	.13	±2.57	7.13	±31.88
West Jackson	37	151.98	±3.18	.68	±0.79	11.04	±53.50
Talatha Gate	52	66.74	±2.36	.00	±0.75	6.13	±26.32
Windsor Road	51	94.52	±2.66	0.78	±0.86	7.84	±33.74
					Avg →	7.15	±32.03
25-mile Radius							
Aiken Airport	52	83.16	±2.44	0.00	±0.70	5.49	±25.66
Aiken State Park	51	102.19	±2.55	.00	±2.23	6.63	±30.18
Allendale	49	32.64	±1.74	.00	±0.75	4.08	±12.46
Augusta	52	37.49	±1.93	.00	± .87	4.96	±16.84
Highway 301	52	69.00	±2.42	.66	± .82	6.75	±26.64
Langley	52	74.17	±2.45	.12	± .85	6.46	±25.88
Lees	52	154.38	±3.05	.68	± .85	7.80	±44.74
Olar	52	100.64	±2.69	.00	± .91	6.82	±31.32
Perkins	52	86.73	±2.51	.68	± .78	6.48	±27.28
South Richmond	52	88.99	±2.63	.52	±0.73	7.57	±30.96
Springfield	52	88.48	±2.44	.17	±1.02	6.57	±28.34
Waynesboro	52	63.47	±2.13	0.52	±0.75	6.53	±25.80
					Avg →	6.34	±28.07
100-mile Radius							
Columbia	52	174.59	±3.48	0.00	±0.73	7.74	±49.62
Greenville	51	209.42	±4.34	.22	±1.17	8.80	±58.88
Macon	47	126.31	±3.22	.00	±0.79	8.07	±41.46
Savannah	50	67.61	±2.21	0.26	±1.37	6.98	±28.64
					Avg →	7.89	±45.86

TABLE B-1, Contd
RADIOACTIVITY IN AIR

Location	No. of Samples	Tritium in Air, pCi/m³ Max	Min	Arithmetic Mean	2 Std Dev
Plant Perimeter					
Allendale Gate	26	52	<4	21	±27
A-14	23	130	<4	55	±68
Barnwell Gate	25	170	<4	53	±76
D Area	26	310	10	100	±126
Dark Horse	26	245	<4	53	±110
East Talatha	25	150	5	50	±73
Green Pond	24	140	<4	47	±79
Highway 21/167	26	140	<4	49	±82
Jackson	25	110	<4	43	±67
Pattersons Mill	25	93	<4	32	±43
Talatha Gate	25	170	5	58	±88
West Jackson	19	150	<4	45	±83
Windsor Road	24	190	<4	48	±88
			Avg →	50	±78
25-mile Radius					
Aiken Airport	26	120	4	23	±49
Aiken State Park	26	41	<4	18	±24
Allendale	24	100	<4	15	±40
Augusta	26	80	<4	19	±39
Highway 301	23	80	<4	17	±33
Langley	26	61	<4	22	±35
Lees	25	54	<4	19	±27
Olar	25	54	<4	16	±25
Perkins	25	60	4	13	±21
South Richmond	26	50	<4	15	±22
Springfield	23	80	<4	20	±38
Waynesboro	26	70	9	20	±29
			Avg →	18	±33
100-mile Radius					
Columbia	4	15	3	10	-
Greenville	3	10	<4	6	-
Macon	2	<4	<4	<4	-
Savannah	3	4	2	3	-
			Avg →	5	±10

\- Insufficient data.

TABLE B-1, Contd
RADIOACTIVITY IN AIR

SPECIFIC RADIONUCLIDES IN AIR

Radionuclide	No. of Samples[a]	Max	Min	Avg	2 Std Dev	No. of Samples[a]	Max	Min	Avg	2 Std Dev
	Plant Perimeter					25-mile Radius				
	Gamma Emitters, pCi/m^3 ($\times 10^{-2}$)									
^{7}Be	8	66.9	10.2	25.4	±39.0	7	62.7	11.6	25.9	±38.7
$^{89,90}Sr$	8	0.1	<0.1	<0.1	-	7	0.1	<0.1	<0.1	-
$^{95}Zr-^{95}Nb$	8	14.1	<0.1	2.9	±10.5	7	10.3	<0.1	2.2	±7.7
$^{103,106}Ru$	8	1.8	<0.4	0.6	±1.1	7	1.3	<0.4	0.5	±1.0
^{137}Cs	8	0.5	<0.1	0.2	±0.4	7	0.5	<0.1	0.2	±0.4
$^{141,144}Ce$	8	6.8	<0.1	1.3	±4.9	7	6.6	<0.1	2.0	±5.5
	Alpha Emitters, aCi/m^3									
^{238}Pu	12	4.2	0.5	1.7	±2.6	11	3.7	0.1	1.0	±2.0
^{239}Pu	12	18.7	2.0	6.5	±9.4	11	9.9	2.6	5.7	±4.6

Radionuclide	No. of Samples[a]	Max	Min	Avg	2 Std Dev
	100-mile Radius				
	Gamma Emitters, pCi/m^3 ($\times 10^{-2}$)				
^{7}Be	8	62.6	9.1	24.0	±40.1
$^{89,90}Sr$	8	1.6	<0.3	0.3	±1.1
$^{95}Zr-^{95}Nb$	8	15.0	<0.1	2.6	±10.5
$^{103,106}Ru$	8	<1.5	<1.5	<1.5	-
^{137}Cs	8	0.5	<0.2	<0.2	-
$^{141,144}Ce$	8	7.8	<0.5	2.1	±6.5
	Alpha Emitters, aCi/m^3				
^{238}Pu	12	6.7	<1.0	1.3	±5.0
^{239}Pu	12	13.5	3.0	7.4	±6.6

\- Insufficient data.

[a] Monthly composite of weekly samples.

TABLE B-2
FALLOUT AND RAINWATER ANALYSES

Location	No. of Samples	Gross Alpha	^{7}Be	^{89}Sr	^{90}Sr	^{95}Zr, ^{95}Nb	^{103}Ru	^{131}I	^{137}Cs	^{141}Ce
					Total Fallout Deposited, nCi/m^2					
Plant Perimeter										
Allendale Gate	13	0.02	81.90	4.09	0.37	2.73	0.64	12.35	0.75	4.99
Road A-14	12	.05	46.66	3.42	.39	1.88	.37	6.08	.20	1.95
Barnwell Gate	13	.03	42.78	2.24	.46	3.02	< .44	0.75	.29	4.20
D Area	13	.02	38.18	2.60	.60	2.56	< .44	9.45	.22	3.08
Dark Horse	13	.03	53.77	3.32	.24	2.12	.15	6.91	.28	2.77
East Talatha	13	.02	71.77	2.24	.57	1.97	0.13	14.14	.70	1.96
Green Pond	13	.02	15.04	0.58	.35	0.83	1.70	0.92	< .35	1.43
Highway 21/167	13	.04	63.90	3.48	.56	0.77	0.51	11.18	.25	3.13
Jackson	13	.02	44.67	3.15	.59	2.90	.18	1.31	.28	2.05
Pattersons Mill	13	.02	46.45	2.50	.27	1.92	.39	9.60	.32	2.38
Talatha Gate	13	.03	43.39	1.99	.49	3.84	.24	2.62	.24	4.13
West Jackson	10	.02	25.57	0.76	.16	0.97	< .40	0.73	.29	1.93
Windsor Road	13	0.02	51.91	1.95	0.33	2.44	0.10	8.08	0.40	2.23
	Avg →	0.03	48.15	2.49	0.41	2.15	0.44	6.47	0.35	2.86
	2 Std Dev →	±0.02	±35.42	±2.07	±0.29	±1.82	±0.83	±9.58	±0.35	±2.42
25-mile Radius										
Aiken Airport	13	0.04	75.21	4.89	0.40	3.09	0.58	15.43	0.51	4.11
Aiken State Park	13	.03	13.83	1.88	.29	1.16	< .30	0.42	< .30	1.06
Allendale	13	.03	10.92	0.99	.20	0.67	< .30	<4.42	< .30	0.94
Augusta	13	.08	37.45	7.61	.31	1.50	.22	0.82	.17	1.53
Highway 301	13	.03	34.64	4.60	.48	0.71	.14	3.93	< .30	0.93
Langley	13	.03	26.49	4.93	.32	1.65	.18	0.11	.13	1.05
Lees	13	.06	20.08	7.55	.29	1.38	.12	.81	.12	1.18
Olar	13	.04	29.43	10.07	.21	1.36	.13	.85	.19	2.03
Perkins	13	.06	18.82	2.05	.42	0.60	< .30	.73	< .30	1.01
South Richmond	13	.03	37.80	8.67	.27	1.96	.27	0.82	.13	2.56
Springfield	13	.03	50.66	4.11	.31	1.54	.21	1.45	.26	2.00
Waynesboro	13	0.02	96.47	5.38	0.62	6.64	0.83	23.31	0.89	7.25
	Avg →	0.04	37.65	5.23	0.34	1.86	0.30	4.42	0.30	2.14
	2 Std Dev →	±0.04	±51.12	±5.64	±0.24	±3.30	±0.49	±15.32	±0.54	±3.72

TABLE B-2, Contd
FALLOUT AND RAINWATER ANALYSES

TRITIUM IN RAINWATER

Location	No. of Samples	Tritium, pCi/ml Max	CT Err 95% CL	Min	CT Err 95% CL	Arithmetic Mean	2 Std Dev
Plant Perimeter							
Allendale Gate	25	3.03	±0.30	0.00	±0.30	0.78	±1.44
A-14	24	13.47	± .30	.00	± .30	4.21	±6.36
Barnwell Gate	25	9.17	± .30	.34	± .30	2.95	±4.10
D Area	24	13.46	± .30	.79	± .30	5.26	±7.46
Dark Horse	25	5.19	± .30	.00	± .30	1.55	±2.68
East Talatha	24	8.95	± .30	.00	± .30	2.42	±5.10
Green Pond	21	7.71	± .30	.00	± .30	2.30	±3.92
Highway 21/167	23	10.34	± .30	.00	± .30	2.43	±4.60
Jackson	26	6.55	± .30	.00	± .30	2.27	±3.56
Pattersons Mill	23	3.53	± .30	.00	± .30	1.31	±1.92
Talatha Gate	25	7.84	± .30	.00	± .30	2.36	±4.12
West Jackson	20	8.11	± .30	.00	± .30	2.49	±4.80
Windsor Road	24	10.84	±0.30	0.00	±0.30	2.13	±4.74
					Avg →	2.49	±4.95
25-mile Radius							
Aiken Airport	19	2.30	±0.30	0.00	±0.30	0.75	±1.20
Aiken State Park	27	3.73	± .30	.00	± .30	.74	±1.56
Allendale	23	1.58	± .30	.00	± .30	.52	±0.80
Augusta	24	2.27	± .30	.00	± .30	.51	±1.32
Highway 301	22	1.98	± .30	.00	± .30	.40	±0.98
Langley	24	1.64	± .30	.00	± .30	.65	±0.96
Lees	26	3.80	± .30	.00	± .30	.72	±1.66
Olar	26	1.55	± .30	.00	± .30	.48	±0.96
Perkins	24	3.00	± .30	.00	± .30	.67	±1.20
South Richmond	21	2.16	± .30	.00	± .30	.57	±1.36
Springfield	25	3.19	± .30	.00	± .30	.67	±1.66
Waynesboro	23	3.79	±0.30	0.00	±0.30	0.63	±2.14
					Avg →	0.60	±1.36

Plutonium in Deposition, pCi/m^2

Location	^{238}Pu	^{239}Pu	^{238}Pu Alpha %
Plant Perimeter	0.60 ± 0.04	0.62 ± 0.04	49.2
25-mile Radius	0.15 ± 0.03	0.60 ± 0.05	20.0

TABLE B-3
ENVIRONMENTAL GAMMA RADIATION

Location	No. of Samples	TLD, mR/24 Hr Max	CT Err[a] 95% CL	Min	CT Err[a] 95% CL	Arithmetic Mean	2 Std Dev	mR/Year Mean
Plant Perimeter								
Allendale Gate	3	0.13	±0.02	0.13	±0.02	0.13	-	47.5
A-14	3	.18	± .02	.16	± .02	.17	-	62.1
Barnwell Gate	3	.21	± .02	.17	± .02	.18	-	65.7
D Area	3	.19	± .02	.18	± .02	.19	-	69.4
Dark Horse	3	.17	± .02	.16	± .02	.16	-	58.4
East Talatha	3	.17	± .02	.16	± .02	.16	-	58.4
Green Pond	3	.17	± .02	.16	± .02	.17	-	62.1
Highway 21/167	3	.16	± .02	.14	± .02	.15	-	54.8
Jackson	3	.19	± .02	.18	± .02	.19	-	69.4
Pattersons Mill	3	.17	± .02	.16	± .02	.16	-	58.4
Talatha Gate	3	.19	± .02	.17	± .02	.18	-	65.7
West Jackson	1	.22	± .02	.22	± .02	.22	-	80.3
Windsor Road	3	0.17	±0.02	0.17	±0.02	0.17	-	62.1
					Avg →	0.17	±0.03	62.6
25-mile Radius								
Aiken Airport	3	0.19	±0.02	0.17	±0.02	0.18	-	65.7
Aiken State Park	3	.16	± .02	.14	± .01	.15	-	54.8
Allendale	3	.20	± .02	.17	± .02	.18	-	65.7
Augusta	3	.19	± .02	.17	± .02	.18	-	65.7
Highway 301	3	.24	± .02	.19	± .02	.22	-	80.3
Langley	3	.19	± .02	.18	± .02	.19	-	69.4
Lees	3	.22	± .02	.21	± .02	.21	-	76.7
Olar	3	.18	± .02	.16	± .02	.17	-	62.1
Perkins	3	.20	± .02	.16	± .02	.18	-	65.7
South Richmond	3	.19	± .02	.18	± .02	.19	-	69.4
Springfield	3	.22	± .02	.20	± .02	.21	-	76.7
Waynesboro	2	0.17	±0.02	0.15	±0.02	0.16	-	58.4
					Avg →	0.18	±0.04	67.6
100-mile Radius								
Columbia	1	0.19	±0.02	0.19	±0.02	0.19	-	69.4
Greenville	2	.33	± .03	.30	± .03	.32	-	116.8
Macon	2	.21	± .02	.19	± .02	.20	-	73.0
Savannah	2	0.16	±0.02	0.16	±0.02	0.16	-	58.4
					Avg →	0.21	±0.14	79.4

- Insufficient data.

[a] The error shown is the precision observed from known exposures of the same magnitude under similar conditions.

TABLE B-4
RADIOACTIVITY IN VEGETATION

pCi/g (dry weight)

Location	No. of Samples	Max	CT Err 95% Cl	Min	CT Err 95% Cl	Arithmetic Mean	2 Std Dev
			Alpha,				
Plant perimeter							
2	13	0.93	±0.38	0.00	±0.15	0.22	±0.52
3	13	.40	± .26	.00	± .20	.13	± .26
6	13	.83	± .37	.00	± .10	.23	± .50
8	13	.49	± .26	.00	± .07	.13	± .30
10	13	0.72	± .34	.00	± .12	.21	± .48
12	13	1.17	± .43	.00	± .14	.23	± .60
14	13	0.52	±0.27	0.00	±0.12	0.19	±0.32
					Avg →	0.19	±0.44
25-mile radius							
2	13	0.64	±0.32	0.00	±0.13	0.22	±0.42
3	13	.70	± .31	.00	± .12	.14	± .38
5	13	.40	± .27	.00	± .13	.18	± .30
8	13	.54	± .30	.00	± .13	.19	± .38
10	13	.77	± .33	.00	± .17	.15	± .42
12	13	0.52	± .27	.00	± .16	.19	± .32
14	13	1.00	±0.39	0.00	±0.18	0.22	±0.56
					Avg →	0.18	±0.39
100-mile radius							
Columbia	4	0.10	±0.15	0.00	±0.13	0.05	-
Greenville	4	.17	± .24	.03	± .15	.08	-
Macon	3	.20	± .19	.00	± .13	.11	-
Savannah	6	0.35	±0.22	0.00	±0.17	0.10	-
					Avg →	0.08	±0.19
			Nonvolatile Beta,				
Plant perimeter							
2	13	57.31	±4.96	7.41	±3.56	31.78	±25.24
3	13	59.47	±5.02	15.66	±3.78	35.35	±24.94
6	13	112.00	±5.84	17.94	±3.47	41.90	±54.10
8	13	56.32	±4.39	9.04	±3.54	35.73	±28.34
10	13	57.98	±5.07	9.11	±3.20	31.42	±23.66
12	13	78.21	±5.46	4.70	±3.11	31.52	±38.16
14	13	59.34	±4.47	2.49	±2.95	30.07	±29.94
					Avg →	33.96	±33.34
25-mile radius							
2	13	63.42	±4.77	8.11	±3.24	29.84	±29.62
3	13	62.86	±4.52	20.41	±3.88	37.61	±26.64
5	13	93.53	±5.84	18.85	±3.62	47.64	±51.14
8	13	63.14	±5.11	22.94	±3.75	39.56	±25.80
10	13	130.27	±6.73	18.85	±3.83	48.72	±62.68
12	13	61.13	±4.85	19.09	±3.63	40.04	±28.16
14	13	108.14	±6.16	18.09	±3.95	49.01	±44.68
					Avg →	41.77	±41.47
100-mile radius							
Columbia	4	41.18	±4.47	4.09	±3.19	24.46	-
Greenville	4	50.03	±4.47	15.66	±3.42	32.93	-
Macon	3	44.61	±4.61	11.65	±3.47	26.39	-
Savannah	6	51.33	±4.51	14.64	±3.48	36.00	-
					Avg →	29.94	±28.20

- Insufficient data.

TABLE B-4, Contd
RADIONUCLIDES IN VEGETATION

Location	No. of Samples	Max	CT Err 95% CL	Min	CT Err 95% CL	Arithmetic Mean	2 Std Dev
			Tritium, pCi/ml (free water)				
Plant perimeter							
2	13	25.01	±2.14	0.00	±1.39	4.71	±13.52
3	12	34.45	±2.66	.66	±1.52	7.22	±19.32
6	11	23.43	±2.10	.00	±1.40	6.95	±15.26
8	13	45.65	±2.83	.00	±1.37	7.17	±24.92
10	12	11.13	±1.83	.00	±1.35	2.88	± 8.28
12	12	52.31	±2.87	.00	±1.36	11.53	±30.06
14	12	46.04	±2.70	0.40	±1.41	9.38	±25.20
					Avg →	7.12	±20.73
25-mile radius							
2	10	8.12	±2.10	0.06	±1.39	3.87	±5.96
3	11	10.54	±2.13	.00	±1.99	3.10	±6.16
5	12	7.17	±2.06	.00	±1.37	2.45	±5.54
8	11	20.03	±2.05	.00	±1.61	4.16	±11.80
10	11	5.74	±1.87	.00	±1.60	1.45	±3.56
12	10	3.56	±1.81	.00	±1.50	0.67	±2.28
14	10	12.55	±2.21	0.00	±2.04	2.32	±7.74
						2.57	±6.91
100-mile radius							
Columbia	4	0.74	±1.46	0.00	±1.89	0.29	-
Greenville	3	7.39	±1.84	.00	±1.58	2.90	-
Macon	3	1.13	±1.42	.00	±1.41	0.38	-
Savannah	4	0.91	±2.07	0.00	±0.30	0.39	-
					Avg →	0.99	±3.85

\- Insufficient data.

pCi/g (dry weight)

Location	No. of Samples	Max	CT Err	Min	CT Err	Avg	2 Std Dev	Max	CT Err	Min	CT Err	Avg	2 Std Dev
				^{7}Be						^{95}Zr-^{95}Nb			
Plant perimeter[a]	12	38.6	±4.6	4.2	±5.2	12.6	±22.6	13.3	±0.7	0.0	±0.3	2.7	±9.4
25-mile radius[a]	12	42.7	±4.7	2.6	±4.5	12.1	±26.5	12.5	± .7	.0	± .3	2.7	±8.8
100-mile radius[b]	6	31.3	±4.1	0.1	±3.3	8.9	±17.9	15.0	±0.7	0.0	±0.3	2.0	±8.9
				$^{103,106}Ru$						^{137}Cs			
Plant perimeter[a]	12	2.5	±2.2	0.0	±2.8	0.7	±1.7	2.0	±0.3	0.1	±0.3	0.7	±1.1
25-mile radius[a]	12	2.8	±2.4	.0	±2.9	.5	±2.0	12.9	± .5	.1	± .4	2.4	±8.7
100-mile radius[b]	6	4.3	±2.6	0.1	±2.2	0.9	±2.8	0.7	±0.3	0.1	±0.3	0.2	±0.5
				$^{141,144}Ce$									
Plant perimeter[a]	12	19.5	±1.6	0.1	±1.2	5.6	±14.5						
25-mile radius[a]	12	21.0	±2.1	.2	±2.1	4.4	±14.2						
100-mile radius[b]	6	26.8	±1.7	0.0	±1.4	4.4	±16.4						

a Composite of seven locations.
b Composite of four locations.

TABLE B-5
RADIOACTIVITY IN MILK

pCi/ℓ

Local Dairies	No. of Samples	Tritium (CG: 3,000,000) Max	Min	Avg	2 Std Dev	Strontium-90 (CG: 300) Max	Min	Avg	2 Std Dev	Iodine-131 (CG: 300) Max	Min	Avg	Cesium-137 (CG: 20,000) Max	Min	Avg	2 Std Dev
North Augusta	23	3020	390	1240	±1200	30	8	17	±15	1	<1	<1	19	<3	13	±12
Waynesboro	19	1080	<300	350	±620	20	<1	6	±13	8	<1	<1	13	<3	7	±9
Major distributor[a]	22	1530	<300	260	±680	10	3	7	±5	9	<1	<1	15	<3	9	±7

[a] Milk produced in local dairies but sold by major distributor.

TABLE B-6
RADIOACTIVITY IN FOOD

pCi/g (wet weight)

	No. of Samples	Max	Min	Avg	2 Std Dev	Max	Min	Avg	2 Std Dev	Max	Min	Avg	2 Std Dev
		Alpha Emitters				^{90}Sr				$^{95}Zr-^{95}Nb$			
Collards	14	0.02	<0.01	0.01	±0.03	1.44	0.23	0.47	±0.72	1.24	0.15	0.58	±0.62
Plums	14	.04	< .01	.02	± .04	0.16	< .02	.03	± .10	<0.02	< .02	< .02	-
Oats, rye, & wheat	14	.06	< .01	.01	± .03	.14	< .02	.05	± .09	< .02	< .02	< .02	-
Corn	14	.03	< .01	.01	± .02	.24	< .02	.08	± .15	< .02	< .02	< .02	-
Chicken	4	.05	.01	.03	±0.06	.15	.04	.08	± .09	< .02	< .02	< .02	-
Beef	2	<0.01	<0.01	<0.01	-	0.03	<0.02	0.03	-	<0.02	<0.02	<0.02	-
		^{137}Cs				$^{141,144}Ce$				Tritium, pCi/ml, Free Water			
Collards	14	0.08	<0.04	0.04	±0.05	1.42	0.16	0.69	±0.71	36	<1	9	±23
Plums	14	< .04	< .04	< .04	-	<0.05	< .05	< .05	-	6	1	4	±5
Oats, rye, & wheat	14	.08	< .04	< .04	-	< .05	< .05	< .05	-	8	<1	2	±6
Corn	14	.04	< .04	< .04	-	< .05	< .05	< .05	-	2	<1	1	±2
Chicken	4	< .04	< .04	< .04	-	< .05	< .05	< .05	-	<1	<1	<1	-
Beef	2	<0.04	<0.04	<0.04	-	<0.05	<0.05	<0.05	-	a	a	a	-

[a] No analysis.
- Insufficient data.

TABLE B-7
RADIOACTIVITY IN SAVANNAH RIVER FISH
pCi/g (wet weight)

Location	No. of Fish Assayed: Bass	Bream	Catfish	^{137}Cs (Whole Fish) Bass Max	Min	Avg	Bream[a] Max	Min	Avg	Catfish[b] Max	Min	Avg	$^{89,90}Sr$ Bone[c] Max	Min	Avg
Above SRP Boundary	0	1	5	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<4.5	<4.5	<4.5
Adjacent to SRP	0	0	6	-	-	-	-	-	-	0.2	<0.1	<0.1	<4.5	<4.5	<4.5
Below SRP at Highway 301	2	8	8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<4.5	<4.5	<4.5

- No analysis.
[a] Shell cracker, bluegill, and redbreast (Leopomis).
[b] Predominantly yellow cat (Ictalurus).
[c] Bass, bream, and catfish composited monthly.

TABLE B-8

RADIOACTIVITY IN DEER AND HOGS

pCi/g (wet weight)

No. of Animals	Species	^{137}Cs in Flesh Average	^{137}Cs in Flesh Range	$^{89,90}Sr$ in Bone Average	$^{89,90}Sr$ in Bone Range
1357	Deer	11	<1-41	<4.5	<4.5-11
177	Hogs	12	<1-28	-	-

- No analysis.

TABLE B-9

RADIOACTIVITY IN SAVANNAH RIVER WATER

Location	No. of Samples	Max	CT Err 95% CL	Min	CT Err 95% CL	Arithmetic Mean	Arithmetic 2 Std Dev
			Alpha, pCi/l				
Savannah River[a]							
R-2 Dissolved	49	0.79	±0.49	0.00	±0.13	0.18	±0.36
R-2 Suspended	50	1.61	± .68	.00	± .19	.23	± .56
R-4 Above Four Mile Creek	52	0.84	± .52	.00	± .26	.19	± .38
R-8 Below Steel Creek	50	1.12	± .58	.00	± .19	.22	± .50
R-9 Below Lower Three Runs Creek	46	1.25	± .60	.00	± .19	.20	± .46
R-10 Dissolved	48	1.26	± .63	.00	± .19	.25	± .54
R-10 Suspended	50	1.36	±0.64	0.00	±0.19	0.28	±0.52
Control							
Edisto River	49	1.78	±0.71	0.14	±0.44	0.70	±0.64
			Nonvolatile Beta, pCi/l				
Savannah River[a]							
R-2 Dissolved	49	6.82	±6.28	0.00	±6.66	1.76	±3.92
R-2 Suspended	50	6.61	±5.99	.00	±6.62	1.23	±3.60
R-4 Above Four Mile Creek	52	12.03	±6.27	.00	±5.94	2.32	±5.38
R-8 Below Steel Creek	50	5.58	±6.01	.00	±6.66	2.22	±3.72
R-9 Below Lower Three Runs Creek	46	25.58	±6.71	.00	±6.58	2.90	±8.68
R-10 Dissolved	48	8.23	±6.52	.00	±6.15	1.98	±3.38
R-10 Suspended	50	6.32	±6.20	0.00	±6.74	1.07	±3.32
Control							
Edisto River	49	13.26	±6.71	0.00	±6.64	2.98	±5.88
			Tritium, pCi/ml				
Savannah River[a]							
R-2 Above Plant	11	1.55	±0.30	0.00	±0.30	0.46	±0.98
R-4 Above Four Mile Creek	11	3.73	± .30	0.69	±1.63	1.88	±2.12
R-10 Highway 301	11	7.77	±0.30	2.49	±0.30	4.75	±3.82

[a] R-2 One mile upstream from Upper Three Runs Creek.
R-10 Eight miles downstream from Lower Three Runs Creek.

TABLE B-10

RADIONUCLIDES IN SAVANNAH RIVER WATER

Radionuclide	Sensitivity of Analysis	Concentration, pCi/ℓ: 1 Mile Upstream from Upper Three Runs Creek R-2 (control)	Concentration, pCi/ℓ: 8 Miles Downstream from Lower Three Runs Creek at Highway 301 R-10	% of CG at Highway 301
^{3}H	300	460	4750	0.16
^{35}S	5.0	ND	ND	<.01
^{51}Cr	4.3	ND	ND	<.001
^{54}Mn	0.4	ND	ND	<.0004
^{60}Co	1.4	ND	ND	<.005
^{65}Zn	1.1	ND	ND	<.001
^{89}Sr	0.3	ND	ND	<.001
^{90}Sr	0.02	0.5	0.5	.17
^{95}Zr-^{95}Nb	0.5	ND	ND	<.001
$^{103,106}Ru$	3.2	ND	ND	<.03
^{131}I	0.2	ND	ND	<.07
^{137}Cs	<0.01	ND	0.015	<.001
^{140}Ba-^{140}La	1.6	ND	ND	<.01
$^{141,144}Ce$	2.5	ND	ND	<.02
^{239}Np	2.2	ND	ND	<0.002

ND = Less than sensitivity of analysis.

TABLE B-11

SAVANNAH RIVER WATER QUALITY

Parameter	River 2 Above Plant: No. of Analyses	Max	Min	Arithmetic Mean	2 Std Dev	River 10 Below Plant: No. of Analyses	Max	Min	Arithmetic Mean	2 Std Dev
Water volume, liters		1.069×10^{13} (total)					1.247×10^{13} (total)			
Temperature, °C	12	24.3	9.0	17.1	±10.1	12	25.8	8.3	17.3	±10.8
pH	12	7.6	6.5			12	7.0	6.4		
Dissolved oxygen, mg/l	12	11.7	8.5	9.8	±2.0	12	11.2	8.5	9.6	±1.8
Alkalinity, mg/l	12	22.8	3.1	13.3	±9.7	12	17.0	10.4	14.3	±4.1
Hardness, mg/l	12	17.5	6.2	11.7	±7.0	12	18.0	6.2	11.8	±7.4
Conductivity, μmhos	12	60	39	52	±12	12	77	41	54	±21
Suspended solids, mg/l	12	54	2	20	±30	12	87	7	19	±43
Volatile solids, mg/l	12	32	1	21	±10	12	38	5	21	±18
Total dissolved solids, mg/l	12	57	6	40	±17	12	59	7	39	±27
Fixed residue, mg/l	12	27	5	18	±11	12	26	<1	16	±17
Biological oxygen demand, mg/l	12	12	<1	2	±6	12	2	<1	1	±1
Lignin, mg/l	12	2.1	<1	<1	±1	12	3.0	<1	<1	±1
Surfactant, mg/l	7	0.03	<0.02	<0.02	±0.025	7	0.08	<0.02	0.02	±0.05
Fecal coliform, c/100 ml	50	3800	40	480[a]		50	640	0	150[a]	
Chloride (Cl), mg/l	12	5.6	1.5	4.0	±2.0	12	6.0	2.5	4.0	±1.7
Nitrite (N), mg/l	12	0.18	<0.02	0.03	±0.11	12	0.30	<0.02	0.05	±0.18
Nitrate (N), mg/l	11	1.10	<0.02	0.32	±0.69	11	1.1	0.02	0.33	±0.64
Sulfate (SO_4), mg/l	12	6.4	2.6	4.6	±1.9	12	7.4	2.6	4.5	±2.7
Sulfide (S), mg/l	12	0.5	<0.1	<0.1	±0.1	12	0.7	<0.1	<0.1	±0.4
Total phosphate (PO_4), mg/l	12	3.90	<0.02	0.85	±2.77	12	1.50	<0.02	0.36	±0.92
Aluminum (Al), mg/l	12	1.0	<1	<1	±0.6	12	1.0	<1	<1	±0.5
Ammonia (NH_4), mg/l	12	0.2	<0.1	<0.1	±0.1	12	0.2	<0.1	<0.1	±0.1
Calcium (Ca), mg/l	12	2.5	1.5	1.9	±0.5	12	2.8	1.7	2.1	±0.5
Sodium (Na), mg/l	12	7.7	4.1	5.8	±2.1	12	7.6	4.2	5.5	±2.2
Total iron (Fe), mg/l	12	1.2	<0.1	.3	±0.7	12	1.3	<0.1	0.3	±0.7

[a] Average of monthly geometric means.

TABLE B-12
RADIOACTIVITY IN DRINKING WATER

	No. of Samples	Max	CT Err 95% Cl	Min	CT Err 95% Cl	Arithmetic Mean	2 Std Dev
Alpha, pCi/l							
Location (source)							
Aiken (stream & well)	2	1.07	±0.60	0.87	±0.52	0.97	-
Allendale (deep well)	2	0.94	± .57	.33	± .35	.64	-
Augusta (river)	2	.47	± .40	.07	± .30	.27	-
Barnwell (deep well)	2	.13	± .27	.00	± .23	.07	-
Bath (deep well)	2	.87	± .52	.00	± .27	.44	-
Blackville (deep well)	2	.60	± .48	.40	± .38	.50	-
Clearwater (lake)	2	0.07	± .23	.00	± .27	0.04	-
Jackson (deep well)	2	1.34	± .63	.74	± .52	1.04	-
Langley (deep well)	2	0.20	± .30	.07	± .30	0.14	-
New Ellenton (deep well)	2	1.27	± .64	0.33	± .35	0.80	-
North Augusta (river)	2	1.88	± .73	1.21	± .63	1.55	-
Sardis (deep well)	2	0.20	± .35	0.00	± .19	0.10	-
Waynesboro (stream)	2	.27	± .33	.07	± .30	.17	-
Williston (deep well)	2	0.94	±0.54	0.60	±0.48	0.77	-
					Avg →	0.53	±1.01
Treatment Plants							
Savannah treated	11	0.77	±0.50	0.00	±0.19	0.20	±0.44
Beaufort treated	11	1.61	±0.68	0.00	±0.24	0.33	±0.90
Nonvolatile Beta, pCi/l							
Aiken (stream & well)	2	2.47	±6.21	1.65	±5.76	2.06	-
Allendale (deep well)	2	5.55	±5.92	5.17	±5.57	5.36	-
Augusta (river)	2	3.07	±5.82	0.00	±5.35	1.54	-
Barnwell (deep well)	2	2.73	±6.22	1.06	±5.74	1.90	-
Bath (deep well)	2	2.86	±6.23	1.30	±5.75	2.08	-
Blackville (deep well)	2	2.83	±5.81	0.00	±6.10	1.42	-
Clearwater (lake)	2	1.69	±6.18	0.00	±5.58	0.85	-
Jackson (deep well)	2	5.72	±6.35	3.07	±5.82	4.40	-
Langley (deep well)	2	4.55	±6.30	2.71	±5.80	3.63	-
New Ellenton (deep well)	2	1.77	±5.77	0.65	±6.14	1.21	-
North Augusta (river)	2	7.20	±5.98	5.20	±6.33	6.20	-
Sardis (deep well)	2	5.07	±6.32	1.06	±5.74	3.07	-
Waynesboro (stream)	2	4.29	±6.29	0.00	±5.68	2.15	-
Williston (deep well)	2	6.11	±6.36	0.47	±5.71	3.29	-
					Avg →	2.79	±4.25
Treatment Plants							
Savannah treated	11	16.12	±6.52	0.00	±5.71	8.21	±11.24
Beaufort treated	11	10.61	±7.19	0.00	±5.59	3.45	±6.40
Tritium, pCi/ml							
Aiken (stream & well)	2	0.68	±0.36	0.44	±0.30	0.56	-
Allendale (deep well)	2	.06	± .36	.00	± .30	.03	-
Augusta (river)	2	.52	± .36	.24	± .30	.38	-
Barnwell (deep well)	2	.15	± .36	.00	± .30	.08	-
Bath (deep well)	2	.55	± .36	.30	± .30	.43	-
Blackville (deep well)	2	.62	± .36	.00	± .30	.31	-
Clearwater (lake)	2	.57	± .36	.53	± .30	.55	-
Jackson (deep well)	2	.46	± .36	.00	± .30	.23	-
Langley (deep well)	2	.75	± .36	.32	± .30	.54	-
New Ellenton (deep well)	2	.39	± .36	.22	± .30	.31	-
North Augusta (river)	2	.29	± .36	.24	± .30	.27	-
Sardis (deep well)	2	.43	± .36	.35	± .30	.39	-
Waynesboro (stream)	2	.45	± .36	.19	± .30	.32	-
Williston (deep well)	2	0.12	±0.36	0.08	±0.30	0.20	-
					Avg →	0.36	±0.49
Treatment Plants							
Savannah treated	11	7.72	±0.30	0.90	±0.30	3.84	±3.72
Beaufort treated	11	3.54	±0.30	0.30	±0.30	1.62	±2.00

- Insufficient data.

TABLE B-13

CONCENTRATION AND DEPOSITION OF RADIOACTIVITY IN SOIL

(0.5-cm depth)

	Concentration, pCi/g (Dry Weight)				Deposition, mCi/km^2			
	^{90}Sr	^{137}Cs	^{238}Pu	^{239}Pu	^{90}Sr	^{137}Cs	^{238}Pu	^{239}Pu
Plant perimeter								
NE quadrant	0.12 ± 0.02	1.0 ± 0.03	0.001 ± 0.001	0.018 ± 0.002	8.9 ± 1.4	76.2 ± 2.3	0.07 ± 0.04	1.38 ± 0.18
NW quadrant	.05 ± .01	0.8 ± .03	.001 ± .001	.016 ± .002	3.4 ± 0.8	61.0 ± 2.3	.05 ± .03	1.23 ± .15
SE quadrant	.08 ± .01	.8 ± .03	.001 ± .001	.014 ± .002	6.1 ± 1.0	61.0 ± 2.3	.06 ± .06	1.06 ± .19
SW quadrant	.08 ± .01	0.7 ± .03	.001 ± .001	.020 ± .002	5.8 ± 1.0	53.3 ± 2.3	.10 ± .05	1.53 ± .18
100-mile radius								
Clinton, SC	.41 ± .04	0.74 ± .05	.001 ± .001	.009 ± .002	31.1 ± 3.4	56.4 ± 3.8	.06 ± .06	0.70 ± .18
Savannah, GA	0.25 ± 0.02	1.2 ± 0.04	.001 ± 0.001	0.020 ± 0.002	19.4 ± 1.1	91.4 ± 3.0	0.07 ± 0.04	1.49 ± 0.16

TABLE B-14
SAVANNAH RIVER SWAMP — STEEL CREEK TO LITTLE HELL LANDING
RADIATION MEASUREMENTS (TLD, 1 METER ABOVE GROUND)

Location		Distance	mR/Day				
River Mile	Trail Number	From River Meters	1972	1974	(June, July) 1975	(Sep,[a] Oct) 1975	(Aug, Sep) 1976
141.5	1	0	0.27	0.30	0.23	0.21	0.26
		178	.35	.35	.29	.17	.36
		358	0.58	0.51	0.44	.31	0.60
		550	-	-	-	.76	-
		656	1.47	1.60	1.56	.94	1.85
		805	0.17	0.18	0.15	.20	0.20
140.8	2	0	.19	.22	.20	.22	.28
		207	.21	.26	.20	.24	.28
		406	.19	.24	.22	.22	.27
		598	.23	.28	.22	.24	.26
		798	.29	.37	.28	.27	.35
		945	-	.59	.63	.54	.58
		975	.14	.19	.20	.15	.20
139.5	3	0		.22		.19	.23
to		281		.23		.17	-
140.8		627		.23		.23	.23
139	4	0		.30		.27	.31
		293		.31		.25	.33
		380		.49		.32	.46
		515		.45		.26	.40
		580		.99		.79	.91
		729		.22		.20	.25
135.5	5	0		.19		.20	.22
		534		.36		.30	.35
		573		0.61		0.55	0.62
		640		1.09		1.03	1.22
		773		0.24		0.21	0.24
137	6	0		.22		.18	.30
		549		.30		.29	.33
		701		.84		.43	.65
		772		.85		.62	.77
		817		.26		.21	.29
136.3	7	0		.20		.19	.21
		579		.19		.16	.21
		793		.90		.91	.96
		823		.24		.24	.23
135.7	8	0	.20	.22	.19	.19	.20
		168	.21	.25	.22	.21	.26
		279	.23	.24	.20	.15	.23
		445	.21	.24	.22	.22	.28
		612	.23	.24	.22	.20	.24
		814	.34	.36	.35	.28	.39
		884	-	.64	.63	.57	.62
		915	0.22	.22	0.23	.22	.23
135.5	9	0		.22		.20	.23
		512		.46		.36	.44
		621		.54		.29	.57
		671		-		.47	.75
		769		.18		.18	.20
134.4	10	0		-		.18	-
		30		-		.28	-
		73		.20		.18	-
Green Pond, near 700 Area (Control)				0.16		0.18	0.17 (1st quarter)

[a] Lower results are attributed to shielding from higher water levels at some locations.
- No measurement.

TABLE B-15
SAVANNAH RIVER SWAMP — STEEL CREEK TO LITTLE HELL LANDING
RADIOACTIVITY IN SOIL

Location		Distance	Concentration, pCi/g (dry wt)						
			^{137}Cs			^{238}Pu		^{239}Pu	
River Mile	Trail Number	From River Meters	1974 0-6, cm	1975 0-8, cm	1976 0-8, cm	1975 0-8, cm	1976 0-8, cm	1975 0-8, cm	1976 0-8, cm
141.5	1	0	31	41					
		178	23	14	21				
		358	126	46					
		550	345	261	174		0.054 ± 0.006		0.123 ± 0.010
		656	194	75		0.052 ± 0.016		0.096 ± 0.028	
		805	3	1	1				
140.8	2	0	1	1					
		207	2	3	2				
		406	4	3					
		598	9	4					
		798	47	18					
		945	122	73	5				
		975	3	1	1	0.012 ± 0.001	<0.001	0.036 ± 0.003	0.025 ± 0.006
139.5	3	0	<1	2	<1				
to		281	5	2	2	0.003 ± 0.006		0.022 ± 0.001	
140.8		627	1	1			<0.001		0.005 ± 0.002
139	4	0	1	2					
		293	13	19	18				
		380	86	61					
		515	72	55					
		580	187	98		0.026 ± 0.012	0.001 ± 0.002	0.067 ± 0.015	0.003 ± 0.003
		729	2	2	44				
135.5	5	0	1	1					
		534	34	13	<1				
		573	140	86					
		640	260	141	<1	0.026 ± 0.014	<0.001	0.090 ± 0.047	0.004 ± 0.003
		773	1	2	<1				
137	6	0	1	2					
		549	50	29	27				
		701	160	124					
		772	300	123	93	0.027 ± 0.010		0.088 ± 0.41	
		817	4	1	3		0.002 ± 0.002		0.032 ± 0.005
136.3	7	0	2	1					
		579	6	3	3				
		793	527	26	159	0.005 ± 0.004	0.026 ± 0.005	0.036 ± 0.008	0.081 ± 0.008
		823	3	2	2				
135.7	8	0	12	1					
		168	4	1	2				
		279	1	2					
		445	5	2					
		612	6	2					
		814	63	37	32				
		884	114	5		0.010 ± 0.006		0.033 ± 0.003	
		915	5	2	4		0.001 ± 0.004		0.040 ± 0.009
135.5	9	0	2	1					
		512	120	57					
		621	134	111	74				
		671	1	92	117	0.019 ± 0.005	0.024 ± 0.006	0.044 ± 0.004	0.073 ± 0.011
		769		1	2				
134.4	10	0		24	28				
		30	51	36	34				
		73	5	2	4	0.010 ± 0.003	0.002 ± 0.002	0.089 ± 0.007	0.036 ± 0.006
Control (100 mi from plant)			0.8	0.3	1	0.003 ± 0.003	0.001 ± 0.001	0.009 ± 0.001	0.010 ± 0.002

Blank space indicates no sample or analysis.

TABLE B-16
SAVANNAH RIVER SWAMP — STEEL CREEK TO LITTLE HELL LANDING
RADIOACTIVITY IN VEGETATION

Location		Distance	Vegetation, pCi/g (dry wt)			
			^{137}Cs			Alpha
River Mile	Trail Number	From River, meters	1974	1975	1976	1976
141.5	1	0	2	<1		
		178	20	13	52	0.3
		358	3	2		
		550	122	103	100	0.4
		656	22	189		
		805	2	<1	<1	<0.1
140.8	2	0	<1	<1		
		207	3	<1	<1	<0.1
		406	1	<1		
		598	<1	<1		
		798	2	<1		
		945	144	54	3	<0.2
		975	1	<1	<1	<0.1
139.5	3	0	<1	<1	<1	<0.2
to		281	<1		<1	0.2
140.8		627	<1	<1	<1	<0.2
139	4	0	2	<1		
		293	2	<1	7	<0.2
		380	15	2		
		515	19	30		
		580	98	15	<1	<0.1
		729	1	<1	1	0.3
135.5	5	0	1	<1		
		534	1	<1	<1	0.2
		573	15	3		
		640	36	6	<1	<0.1
		773	<1	<1	<1	0.3
137	6	0	1	<1		
		549	47	15	9	.3
		701	18	26		
		772	235	2	119	.4
		817	1	<1	1	.2
136.3	7	0	1	2		
		579	1	<1	1	.3
		793	76	24	35	.3
		823	<1	<1	<1	0.3
135.7	8	0	4	1		
		168	1	<1	<1	<0.2
		279	<1	<1		
		445	1	2		
		612	1	<1	<1	
		814	11	6	8	<0.1
		884	43	19		
		915	1	3	<1	<0.1
135.5	9	0	<1	<1		
		512	3	1		
		621	1	1		<0.1
		671	1	6	2	<0.1
		769		1	<1	<0.1
134.4	10	0		3	11	0.2
		30	1	2	<1	.2
		73	<1	<1	1	.3
(Control) Plant perimeter and 100-mile radius vegetation			1	1	<1	0.1

Blank space indicates no sample or analysis.

APPENDIX C. METHODS FOR CALCULATING ENVIRONMENTAL RADIATION DOSE

Releases to the Atmosphere

Radiation dose to man in the vicinity of SRP is calculated for the radioactive gases and particulates unavoidably released to the atmosphere from the Savannah River Plant operations. Although SRP has an extensive environmental monitoring system, a mathematical model is needed to estimate potential radiation dose commitment from the atmospheric releases. The mathematical model is needed because the majority of releases lead to very low concentrations not detectable (exception: tritium oxide) by current monitoring techniques.

The model is based on measured and calculated releases and on dispersion by measured meteorology. The meterorological data were obtained over a two-year period (1966-1968) from instrumentation installed at eleven elevations on a 1200-foot television transmitting tower 30 kilometers (18.8 miles) northwest of the geometric center of SRP. Data collected at three-minute intervals over the two-year period provided information on wind speed, wind direction, wind variability, and thermal stability. Sufficient data were collected to include meteorological variations typical of the SRP site. Adequacy of this meteorological data base and calculational model is verified annually with measured dispersion of tritium released during normal operations to the atmosphere at SRP.

Annual averaged concentration factors in air and external gamma dose rate factors from a plume were calculated for each radionuclide individually by processing the meteorological data assuming a 1-curie release for each data period (15-minute averages). Ground level concentrations and external gamma dose were accumulated for each azimuth (16 sectors) and radial distance from the point of release for each meteorological data period according to a polar grid overlay of SRP and environs (see figure 14).After all meteorological data for the two-year period had been processed, the accumulated concentrations and gamma doses were divided by the total number of data periods represented. The result was a quantity representing a yearly integrated concentration (curie-seconds per cubic meter) and gamma dose associated with each grid point for a curie release over the year. These quantities were corrected for decay according to radionuclide and measured meteorology for each data period. For each of the 320 grid points, the integrated air concentration and gamma dose factor for a curie release is multiplied by the number of curies of each radionuclide released in a year to obtain integrated air concentrations and gamma cloud dose for subsequent calculations of dose commitment to individuals (and to the population).

The grid overlay was divided into sixteen 22.5° sectors and twenty 5-kilometer radial increments. Population distribution for each sector and radial increment was determined from the 1970 census and is shown in figure 1'. Integrated air concentration and gamma plume dose is calculated at the center of each areal increment and is assumed to be representative of average conditions for the increment. The integrated air concentration and gamma dose are used for calculating radiation dose commitment to all persons within the areal increment.

Major pathways of radiation exposure from radioactive materials released to the atmosphere are:

- o External dose from radioactive materials in the atmosphere
- o External dose from radioactive materials deposited on earth's surface
- o Internal dose from inhalation of radioactive materials in the air
- o Internal dose from ingestion of food and water containing radioactive materials deposited from the atmosphere.

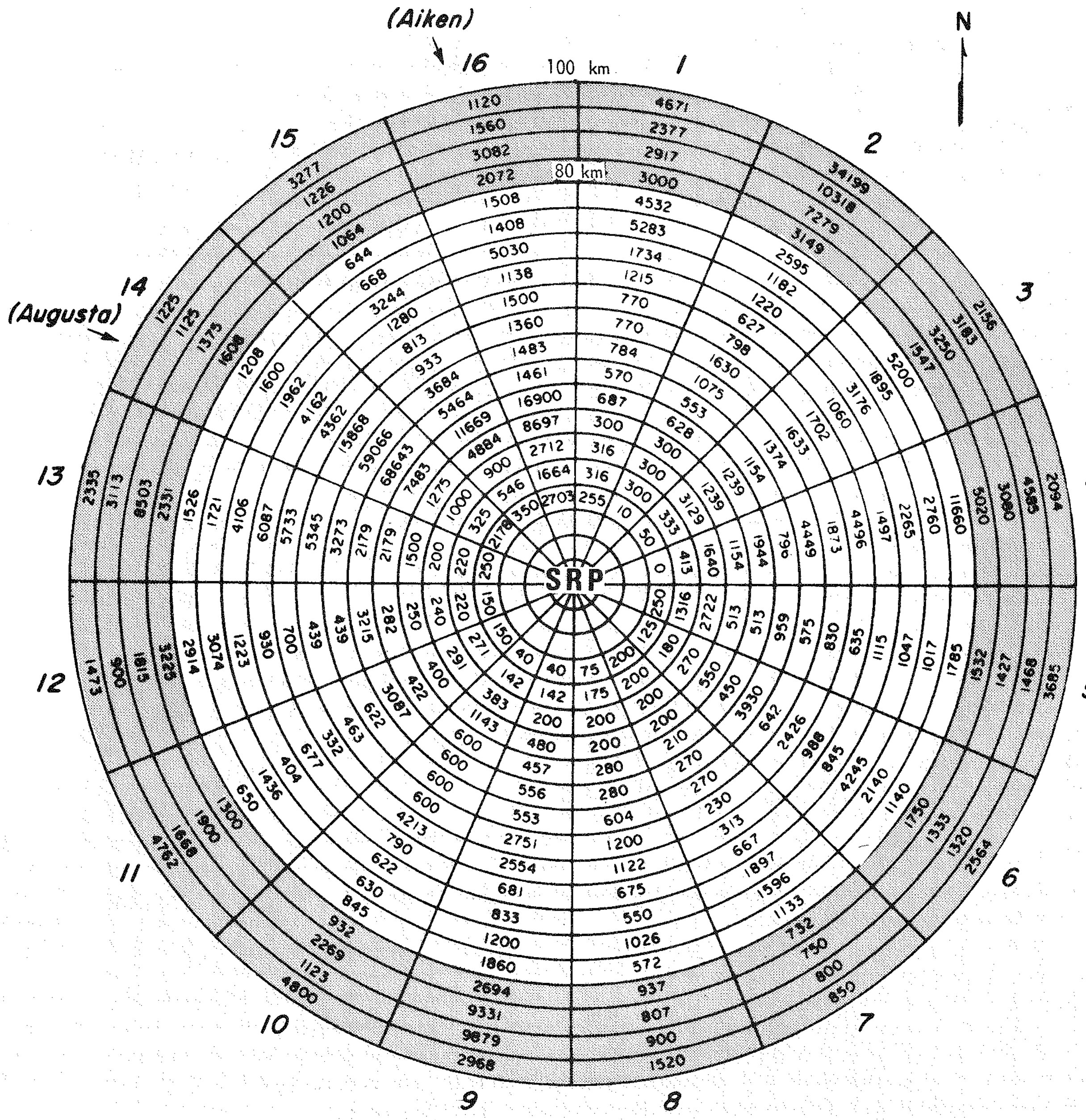


FIGURE 14. DISTRIBUTION OF POPULATION IN REGION SURROUNDING SRP
(Radial Increments = 5 km, 22.5° Sector)
1970 Census

Factors were calculated for converting integrated air concentrations of each radionuclide to a 70-year lifetime dose commitment via each exposure pathway. Techniques for calculating dose were patterned after methods used by the ICRP [2,12,16]. Standard man data were used for deriving dose factors for the general population; factors are also provided for calculating dose to infants when they are critical members of the population for specific pathways of exposure (example: iodine-131 in air → pasture grass → cow → milk → infant thyroid gland). Body dose, as calculated with dose factors, is summarized with gamma plume dose to obtain whole body dose.

Recycling of noble gases, carbon-14, and tritium oxide in the global invironment is not included in the mathematical dose model. If noble gases and carbon-14 are assumed to be diluted by the world's atmosphere and tritium oxide is diluted by the world hydrological cycle, subsequent 70-year dose commitment to the population groups considered in this report will be a small fraction of 1% of the first pass dose from release of all radionuclides.

The external dose from gamma-emitting radionuclides deposited on the earth's surface are calculated assuming the nuclides are on the surface of soil and on surfaces of vegetation during the first year following release, and in succeeding years are distributed exponentially with depth in the soil as a result of washoff and infiltration into the soil with rainwater. Lifetime dose from these deposited nuclides is calculated with the assumption that each person is exposed throughout life only at the location of his residence. No corrections are made for surface runoff, surface roughness factors, or shielding by buildings.

Releases to the Savannah River

Radionuclides in liquid effluents from SRP are analyzed at the point of release, in surface streams on the SRP site before entry into the Savannah River swamp, and in the Savannah River upstream and downstream from SRP. Many radionuclides that are measurable at the point of release are below the analytical limit of sensitivity after being diluted with river water; only tritium oxide and trace amounts of cesium-137 and strontium-90 are routinely measurable in the river, and only tritium oxide at the two downstream water treatment plants. Dose commitments to downstream consumers of river water are based on the release inventory and the following assumptions.

- o All radionuclides, as measured at the point of release, move down the Savannah River during the year of release.
- o No depletion in the quantity of radionuclides occurs except for natural radioactive decay. Approximately five days elapse between time of release of radionuclides and entry into the two water treatment plants approximately 100 miles downstream. For the radionuclides released in 1976, no decay corrections were made.
- o The flow rate of the river at the water treatment plants in 1976 averaged about 14,300 cubic feet per second (annual flow = 1.3×10^{16} ml).
- o No allowance is made for removal of radionuclides in the water treatment plants.
- o Dose commitment from tritium is based on measured concentrations at the water treatment plants.
- o Individuals served by the water treatment plants consume an average of 1200 ml of water per day (standard man).

Dose factors were calculated for converting concentration of each radionuclide in water to a 70-year lifetime dose commitment. Techniques for calculating dose were patterned after methods used by the ICRP [2,12,16].

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