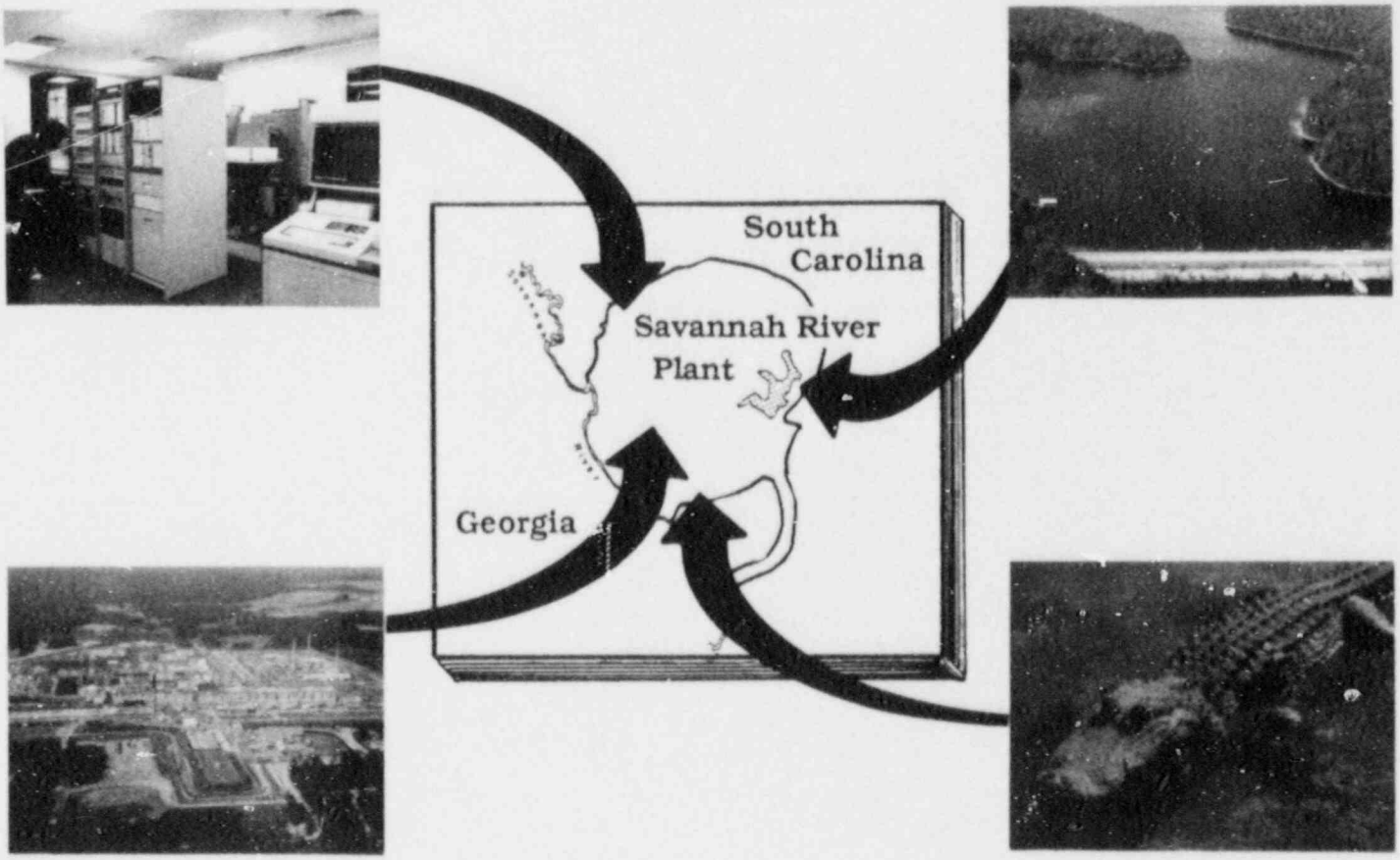
DPSPU-88-30-1

Volume I
Text

U. S. DEPARTMENT OF ENERGY

SAVANNAH RIVER PLANT ENVIRONMENTAL REPORT FOR 1987



E. I. du Pont de Nemours & Co.
Savannah River Plant
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
UNDER CONTRACT DE-AC09-76SR00001

FRACTIONS AND MULTIPLES OF UNITS

Multiple	Decimal Equivalent	Prefix	Symbol
10^{6}	1,000,000	mega-	M
10^{3}	1,000	kilo-	k
10^{2}	100	hecto-	h
10	10	deka-	da
10^{-1}	0.1	deci-	d
10^{-2}	0.01	centi-	c
10^{-3}	0.001	milli-	m
10^{-6}	0.000001	micro-	μ
10^{-9}	0.000000001	nano-	n
10^{-12}	0.000000000001	pico-	p
10^{-15}	0.000000000000001	femto-	f
10^{-18}	0.000000000000000001	atto-	a

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

DISCLAIMER

DPSPU-88-30-1
Volume I
Text

U.S. DEPARTMENT OF ENERGY

SAVANNAH RIVER PLANT ENVIRONMENTAL REPORT

Annual Report for 1987

By

Sue C. Mikol
Laurie T. Burckhalter
James L. Todd
Donna K. Martin

Prepared for the United States Department of Energy by the
Health Protection Department of
E. I. du Pont de Nemours & Co.
Savannah River Plant, Aiken, South Carolina

ACKNOWLEDGMENTS

The authors acknowledge with appreciation the efforts of a number of individuals and groups who contributed technical data and reviewed the draft report. The authors express gratitude to the following groups:

Environmental Monitoring Group, Health Protection Department, SRP
Environment and Energy Department, SRP
Power Technology Department, SRP
Custodians of Groundwater Monitoring Sites
Environmental Sciences Division, SRL
Environmental Transport Division, SRL
Savannah River Ecology Laboratory
Savannah River Forest Station
Department of Energy
Academy of Natural Sciences of Philadelphia

The authors are indebted to the following individuals who were instrumental in the preparation and review of the report:

S. P. Boynton
C. L. Cummins
E. M. Heath
J. D. Heffner
R. L. Kump
W. L. Marter
A. S. Morrison

W. M. Fay, Exploration Software
M. R. Rainer, Exploration Software
M. A. Harper, Exploration Software

J. E. Till, Radiological Assessments Corporation
G. G. Killough, Radiological Assessments Corporation

Special thanks go to R. A. Childers, Information Industries, Inc., for editing and preparing the copy for publication and to the Publications Group at SRP.

Contents

ABBREVIATIONS AND ACRONYMS

ACWS	Alternate Cooling Water System
ANSP	Academy of Natural Sciences of Philadelphia
APHA	American Public Health Association
BDC	Beaver Dam Creek
BG	Burial Ground
BP	biomass production
BWHP	Backwash Holding Pond
CAAC	Clean Air Act Code
CCWS	Comprehensive Cooling Water Study
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CL	confidence level
CSRA	Central Savannah River Area
DCG	Derived Concentration Guide
DEL	deleted version
DM	Dry Monitoring (Wells)
DOE	Department of Energy
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
ECS	Environmental and Chemical Services
E & E	Environment and Energy Department (SRP)
EEI	Envirodyne Engineers, Inc.
EID	environmental information document
EIP	Environmental Implementation Plan
EIS	Environmental Impact Statement
EML	Environmental Measurements Laboratory (DOE)
EOC	Emergency Operating Center
EPA	Environmental Protection Agency
ETF	Effluent Treatment Facility
ETI	Environmental Testing, Inc.
ETP	Effluent Treatment Plant
FDA	Food and Drug Administration
FEIS	Final Environmental Impact Statement
FMC	Four Mile Creek
GDNR	Georgia Department of Natural Resources
GIS	Geographic Information System
HEP	Habitat Evaluation Procedures
HP	Health Protection Department (SRP)
HPGe	high purity germanium
HQ	Headquarters (DOE)
ICRP	International Commission on Radiological Protection
IDMS	isotope dilution mass spectrometric
IGB	Indian Grave Branch
IT	International Technology Corporation
ITAS	IT Analytical Services
LANDSAT	Land Resources Observatory Satellite
LEPC	local emergency planning commission
LETF	Liquid Effluent Treatment Facility
LLD	lower limit of detection
LSC	liquid scintillation counter
L3R	Lower Three Runs Creek
MCL	maximum contaminant level
MDC	Minimum Detectable Concentration
MSDS	Material Safety Data Sheet
MSS	multispectral scanner
MTF	Memorandum-to-File
NBS	National Bureau of Standards
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
PB	Pen Branch
PCB	polychlorinated biphenyl
PHA	pulse height analysis
POC	point-of-compliance
QA	quality assurance
QAD	Quality Assurance Division (EPA)
QAP	Quality Assessment Program (DOE)
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RWHP	Raw Water Holding Pond
SARA	Superfund Amendments and Reauthorization Act
SBL	stable boundary layer
SCB	standing crop biomass
SCCP	South Carolina Coastal Plain
SCDHEC	South Carolina Department of Health and Environmental Control
SEFES	Southeastern Forest Experiment Station
SMCC	Subsurface Microbiological Culture Collection
SREL	Savannah River Ecology Laboratory

SRFS	Savannah River Forest Station
SRL	Savannah River Laboratory
SRP	Savannah River Plant
STABLE	Stable Atmospheric Boundary Layer Experiment
SWMU	solid waste management unit
TB	Tims Branch
TLD	thermoluminescent dosimeter
TRAC	Tracking Radioactive Atmosphere Contaminants
TSP	total suspended particulates
TSS	total suspended solids
TRU	transuranic
USFS	U. S. Forest Service
USFWS	U. S. Fish and Wildlife Service
USGS	U. S. Geological Survey
U3R	Upper Three Runs Creek
VOC	volatile organic compound
WCAL	Weather Center Analysis Laboratory
WIND	Weather Information and Display
WSCTF	Waste Site Closure Task Force

ABSTRACT

In 1987, as in previous years, the radiological impact of Savannah River Plant operations on public health was insignificant. The maximum radiation dose commitment to a hypothetical individual on the SRP boundary from 1987 SRP atmospheric releases of radioactive materials was 0.6 millirem (mrem) (0.006 mSv). To obtain the maximum dose, an individual would have had to reside on the SRP boundary at the location of highest dose for 24 hours per day, 365 days per year. The average radiation dose commitment to the hypothetical individual on the SRP boundary was 0.3 mrem (0.003 mSv).

The maximum radiation dose commitment to an individual downriver of SRP who consumed Savannah River water was 0.1 mrem at both the Cherokee Hill water treatment plant at Port Wentworth, GA (near Savannah) and the Beaufort-Jasper water treatment plant near Beaufort, SC. This assumes the individual drinks two liters (approximately one-half gallon) of water each day, 365 days per year.

These radiation doses from SRP operations are small when compared to the dose from natural radiation, which averages 295 mrem (2.95 mSv) per year [NCRP87]. The largest part of this natural dose is 200 mrem (2.00 mSv) from natural radon gas in homes. The maximum dose from SRP atmospheric releases of 0.6 mrem is only 0.2% of the average annual dose from natural radiation.

This 1987 report contains monitoring data from routine radiological and nonradiological environmental surveillance activities, summaries of environmental protection programs in progress, a summary of National Environmental Policy Act (NEPA) activities, and a listing of environmental permits issued by regulatory agencies and their status. The environmental surveillance activities at and in the vicinity of SRP comprise one of the most comprehensive and extensive environmental monitoring programs in the United States.

PREFACE

The purpose of this report is to provide information to the public about the impact of SRP operations on the public and the environment. This report, *U. S. Department of Energy Savannah River Plant Environmental Report for 1987*, describes environmental surveillance and monitoring activities conducted at and around the Savannah River Plant (SRP) during the calendar year 1987. The SRP Environmental Report is published annually and is widely distributed to government officials, U. S. Congressmen, universities, and other interested parties. Copies of the report are placed in public reading rooms. Preparation and publication of the report is mandated by Order DOE 5484.1, with a publication deadline of May of the following year.

The objectives of this report are to:

- provide detailed information about the SRP site and environmental monitoring activities,
- report 1987 monitoring data for the SRP and surrounding environs,
- provide radiation dose estimates for surrounding populations and describe how the estimates are derived,
- summarize all significant environmental activities at SRP in one report,
- provide a historical document for reference and trending,
- show trend analyses, when possible, to indicate increases and decreases in concentrations and/or discharges.

Ensuring the radiation safety of the public in the vicinity of SRP was a foremost consideration in the design of the plant and has continued to be a primary objective during the 33 years of SRP operations. An extensive environmental surveillance program has been maintained continuously since 1951 (before SRP startup) to determine the concentrations of radionuclides in the environment of the plant. Data generated by the onsite surveillance program have been recorded in SRP documents since 1951. A public report, in which data from offsite environmental monitoring activities were published and issued to the public, was initiated in 1959. Dual reporting of SRP environmental monitoring activities continued until 1985 when data from both onsite and offsite surveillance programs were merged into a single publication. In 1985, the report expanded to two volumes. A listing of past onsite and offsite reports is presented in Appendix A.

The scope of the environmental monitoring program at SRP has increased significantly during the years since plant startup. The change is reflected in annual reports. Prior to the mid-1970s, the reports contained primarily radiological monitoring data. Beginning in the mid-1970s, the reports included increased amounts of nonradiological monitoring data as those programs increased. The nonradiological monitoring program is now as extensive as the radiological monitoring program.

Volume I of the report summarizes environmental surveillance and monitoring activities at SRP and contains key figures and summary tables. Volume II contains figures (maps and diagrams) and detailed monitoring data tables.

Previous reports were categorized by radioactive and nonradioactive monitoring with subdivisions by media (air, water, etc.). The format of the 1987 report has been reversed: monitoring programs are presented first by media type and then subdivided by type of monitoring.

The 1987 report is written for a broad audience with a variety of environmental interests. Readers may selectively read different sections of the report according to their specific interests. The abstract gives an overall picture of what the report contains, while the executive summary provides a short digest of the entire report. A brief summary is presented at the beginning of each chapter, and highlights appear at the end of the chapter. More detailed information is found in the chapters.

EXECUTIVE SUMMARY

The environmental surveillance activities at and in the vicinity of the Savannah River Plant comprise one of the most comprehensive and extensive environmental monitoring programs in the United States. This 1987 report contains monitoring data from routine radiological and nonradiological environmental surveillance activities, summaries of environmental protection programs in progress, a summary of National Environmental Policy Act (NEPA) activities, and a listing of environmental permits issued by regulatory agencies and their status. The report consists of two volumes. Text, major figures, and summary data tables are presented in Volume I; Volume II is comprised of figures and comprehensive data tables. The purpose of this report is to provide information to the public about the impact of SRP operations on the public and the environment.

SRP occupies a large area of approximately 300 square miles along the Savannah River, principally in Aiken and Barnwell Counties of South Carolina. SRP's primary function is the production of plutonium, tritium, and other special nuclear materials for national defense, for other governmental uses, and for some civilian purposes. SRP is operated for the Department of Energy (DOE) by E. I. du Pont de Nemours & Co.

ASSESSMENT OF RADIOLOGICAL IMPACT OF SRP OPERATIONS ON THE PUBLIC

Radiation Dose Terms

As used in this report, the term *dose* normally means "effective dose equivalent." It is defined by the International Commission on Radiological Protection [ICRP77, ICRP79] as "the sum of the external dose equivalent plus the committed dose equivalents to specific organs of the body, times a weighting factor appropriate for each organ." The term *dose commitment*, as it is applied to an individual, means "committed effective dose equivalent," which is a measure of the amount of radiation dose received by the individual over a lifetime as a result of exposure to all radiation pathways during the year being considered. In this report, the individual's lifetime is assumed to extend 50 years beyond the time of exposure.

The terms, *dose* and *dose commitment*, are sometimes used interchangeably in this report. The dose commitment to an individual is usually expressed in units of millirem (abbreviated "mrem") or millisievert (abbreviated "mSv") (1 mrem = 1/1000 rem; 1 mSv = 1/1000 Sv; 1 Sv = 100 rem).

Population dose commitment is the sum of individual dose commitments in a population group and is expressed in units of person-rem (person-sievert). For example, if each person in a population of 1,000 receives a dose commitment of 1 rem (0.01 Sv), the population dose commitment would be 1,000 person-rem (10 person-Sv).

Applicable Dose Standards

The DOE radiation standards for the protection of the public in the vicinity of SRP are given in Order DOE 5480.1A. These standards are based on recommendations of the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP).

In 1985, a draft DOE order was issued that contained revised interim standards incorporating the recommendations and dose models contained in ICRP Publications 26 and 30 [ICRP77, ICRP79]. (The previous standards had been based on ICRP Publications 2 and 10 [ICRP59, ICRP68]. The previous guides were based on a maximum annual dose of 500 mrem (5 mSv) to an offsite individual. The draft DOE order changed the maximum allowable offsite dose to 100 mrem (1 mSv). The revised interim standards, which also include Environmental Protection Agency (EPA) limits for the atmospheric pathways contained in 40 CFR 61, Subpart H [EPA85], are given in Table ES-1 p. xii.

EPA drinking water standards which apply at downriver water treatment plants are based on an annual whole body dose of 4 mrem (0.04 mSv)

Table ES-1. DOE Revised Interim Radiation Dose Limits

All Pathways. The effective dose equivalent for any member of the public from all routine DOE operations[a] (natural background and medical exposures excluded) shall not exceed the values given below:

	Effective dose equivalent[b]	
	mrem/year	**(mSv/year)**
Occasional annual exposures	500	(5)
Prolonged period of exposure[c]	100	(1)

No individual organ shall receive a committed dose equivalent of 5 rem/year (50 mSv/year) or greater.

Air Pathway Only (Limits of 40 CFR 61, Subpart H)

	Dose equivalent	
	mrem/year	**(mSv/year)**
Whole body dose	25	(0.25)
Any organ	75	(0.75)

Liquid Pathway Only (Limits of 40 CFR 141 [Drinking Water])

	Dose equivalent	
	mrem/year	**(mSv/year)**
Whole body dose	4	(0.04)

[a] "Routine DOE operations" means normal planned operations and does not include additional planned or unplanned releases.
[b] Effective dose equivalent is expressed in rem (or mrem) with the corresponding value in Sv (or mSv) in parentheses.
[c] For the purpose of these standards, a prolonged exposure is one that lasts, or is predicted to last, longer than 5 years.

from the annual consumption of two liters of water per day [EPA75,EPA87]. Periodically in this report, radioactivity concentrations are compared with EPA drinking water standard concentrations. While this is a convenient reference, it should be noted that the current EPA standard concentrations for tritium (20,000 pCi/L) and ^{90}Sr (8 pCi/L) correspond to a whole body dose less than 4 mrem. EPA is considering a change to these concentrations to reflect the actual 4 mrem dose [EPA86].

Calculational Models

With few exceptions, most of the radioactive materials released from SRP are of such low concentrations that when dispersed in the environment they are not detectable by conventional monitoring procedures. Therefore, radiation doses to offsite populations are calculated with mathematical models that use known transport mechanisms for atmospheric and liquid releases and known major pathways of exposure to man. Environmental measurements of tritium oxide released from production areas in small quantities are used to verify atmospheric dispersion in the transport models [Ma84].

Dose Commitment from Atmospheric Releases

The maximum radiation dose commitment to a hypothetical individual on the SRP boundary from 1987 SRP atmospheric releases of radioactive materials was 0.6 mrem (0.006 mSv). The 0.6 mrem (0.006 mSv) is 0.6% of the DOE guide of 100 mrem/yr (1 mSv) for a prolonged exposure to an individual in the public zone. The assumptions used in calculating the maximum public zone dose commitment are conservative; that is, they tend to overestimate the dose commitment. Therefore, it is very likely that the actual maximum individual

dose commitment was less than 0.6 mrem (0.006 mSv). This maximum individual dose commitment from SRP operations was approximately 0.2% of the average dose of 295 mrem (2.95 mSv) per year received in the vicinity of SRP from natural radiation. The radiation dose commitment to the average individual at the plant perimeter was 0.3 mrem (0.003 mSv), which is 0.1% of the average dose of 295 mrem (2.95 mSv) from natural radiation sources.

The population dose commitment from SRP atmospheric releases to the 555,100 people who live within 50 miles (80 km) of the center of the plant was 29 person-rem (0.29 person-Sv) with an average dose of 0.00005 rem (0.0000005 Sv) per person. During 1987, this same population received an estimated annual radiation dose of 164,000 person-rem from natural radiation and an additional dose of 29,400 person-rem from medical procedures. Most of the natural radiation dose comes from radon in homes. The individual radiation dose from natural radioactivity, medical procedures, and consumer products averages 360 mrem per person, which is 7200 times the dose from SRP operations.

Releases of tritium account for ~50% of the offsite population dose from SRP atmospheric releases. Tritium from SRP is released in two forms to the atmosphere. The HT or elemental gas form is not readily absorbed in the human body while the HTO or oxide form (tritiated water) is readily assimilated. The dose from the elemental form is therefore significantly less than from the oxide form. (The dose per unit of intake is 25,000 times less for elemental tritium than for tritium oxide.)

Before 1985, all tritium released from SRP to the atmosphere was considered to be in the oxide form because the methodology to distinguish between the two forms had not been perfected to the extent that reliable continuous measurements could be made. Techniques to measure the two forms of tritium were perfected in 1985. Measurements of the forms of tritium in 1987 showed that approximately 54% of the tritum released to the atmosphere from SRP was in the elemental form.

Dose Commitment from Liquid Releases

Consumption of water from the two water treatment plants on the Savannah River below SRP also contributes to the offsite dose commitment. The Cherokee Hill water treatment plant at Port Wentworth, GA (near Savannah) provides water for industrial and manufacturing purposes. The 20,000 consumers of this water are primarily adults working in industrial facilities. The Beaufort-Jasper Counties, SC, water treatment plant provides water to 50,000 consumers of all ages living in Beaufort and Jasper Counties, SC. Approximately 94% of the radiation dose at the water treatment plants from SRP operations is due to tritium.

The radiation dose commitment to an individual downriver of SRP who consumed Savannah River water at a maximum rate of two liters a day was 0.1 mrem (0.001 mSv) at both the Cherokee Hill water treatment plant at Port Wentworth, GA, and the Beaufort-Jasper water treatment plant. The dose commitment for an individual consuming the water at an average rate of one liter per day was 0.05 mrem (0.0005 mSv) for Beaufort-Jasper and 0.06 mrem (0.0006 mSv) for Port Wentworth.

The dose commitment to a hypothetical individual who could receive the highest offsite doses from releases of radioactivity from SRP to the Savannah River was 0.9 mrem (0.009 mSv). This *maximum individual* would consume an average amount of water and a large amount of fish from the river just downriver from SRP and would also spend many hours in shoreline activities, swimming, and boating. This dose commitment of 0.9 mrem is only 0.3% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources.

The population dose commitment from liquid releases in 1987 was 6 person-rem (0.06 person-Sv). The dose commitments from the water consumption pathway (Beaufort-Jasper and Port Wentworth) occur to discrete population groups; however, the dose commitments from other exposure pathways (i.e., fish and shellfish consumption and recreational activities) occur to a diffuse population that cannot be described as being in a specific geographical location.

Perspective

These radiation doses from SRP operations are small when compared to the dose from natural radiation, which averages 295 mrem (2.95 mSv) per year [NCRP87a]. The largest part of this

natural dose is 200 mrem (2.00 mSv) from natural radon gas in homes. The maximum dose from SRP atmospheric releases of 0.6 mrem (0.006 mSv) is only 0.2% of the average dose from natural radiation. Fig. ES-1 below graphically shows the sources of an individual's radiation dose, the percentage each source contributes, and SRP's maximum atmospheric contribution from releases. Table ES-2 (shown as ES-1 in Volume II) summarizes the individual and population doses from SRP and from other sources.

The population dose commitment (person-rem) from SRP releases can be compared with the population doses from natural radioactivity (cosmic radiation, terrestrial radioactivity, internal radioactivity, and radon in homes) and medical radiation exposure. The 1987 population dose commitment from SRP releases (29 person-rem from atmospheric releases and 6 person-rem from liquid releases) is compared with annual population dose from natural and medical sources in Table ES-2. Even though the SRP contribution to population dose commitment is very small (0.02% 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.

The radiation dose the public receives from nuclear operations at SRP can be viewed from several perspectives. From the viewpoint of regulatory standards, the maximum radiation dose to consumers of water treated by the Port Wentworth and Beaufort-Jasper water treatment

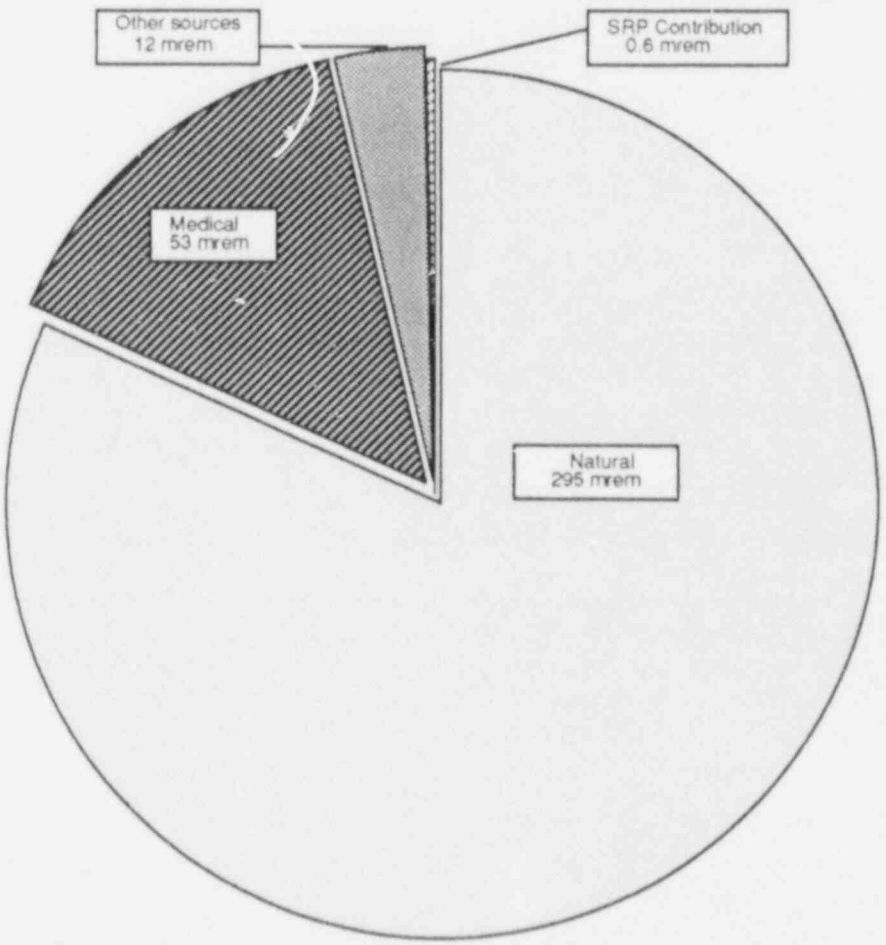


Fig ES-1. Sources of radiation dose vs. SRP's contribution

Table ES-2. INDIVIDUAL AND POPULATION DOSES - 1987

Location/Source	Calculated Individual Dose, mrem[a]		Population Size	Calculated Population dose, person-rem[a]
SRP Boundary	Average	Maximum		
SRP Atmospheric Releases	0.26	0.65[b]	-	-
SRP Liquid Releases	-	0.93[c]	-	-
Within 80 km of SRP				
Dose From Atmospheric Releases	0.05[d]	-	555,100	29.3
Water Treatment Plants Downstream of SRP				
Using Water From Beaufort-Jasper Treatment Plant	0.05	0.11	51,000	2.5
Using Water From Port Wentworth Treatment Plant	0.06	0.11	20,000	1.1
River Fish and Recreation				
Consuming River Fish	-	-	555,100	2.3
Recreation	-	-	555,100	<0.1
SRP Releases Total				35.3

Other Sources	Annual Dose,mrem	Pop. Dose, person-rem	
Natural Radioactivity[a]			
Cosmic Radiation	27		
External Terrestrial	28		
Internal Terrestrial	40		
Radon in Homes	200		
		555,100(within 80km)	164,000
		71,000(water plants)	20,900
Subtotal (Natural)	295		185,000
Medical Radiation[a,f]	53		
		555,100(within 80km)	29,400
		71,000(water plants)	3,800
Subtotal (Medical)	53		33,200
Consumer Products	10		
		555,100 (within 80km)	5,600
		71,000 (water plants)	700
Subtotal (Consumer Products)	10		6,300
Weapons Test Fallout	<1.0		
		555,000(within 80km)	600
		71,000(water plants)	100
Subtotal (Weapons Tests)	<1.0		700
Other	<1.0		
		555,000 (within 80km)	600
		71,000 (water plants)	100
Subtotal (Other)	<1.0		700
Other Sources Total	360		225,000

[a] Committed effective dose equivalent.
[b] Based on a hypothetical individual with maximum dietary habits located on the plant perimeter at locations of highest exposure. No such individual is known to exist.
[c] Based on a hypothetical individual with maximum dietary habits who lives on the shore of the Savannah River. No such individual is known to exist.
[d] Based on atmospheric dispersion of SRP releases as described in Table 2-2 (Vol. II).
[e] Average values for the United States.
[f] Dose is prorated over the U. S. population. This is a means of arriving at an average dose, which when multiplied by the population size, produces an estimate of population exposure. It does not mean that every member of the population received a radiation exposure from these sources.
- Not applicable.

plants was 2.5% of the EPA standard. In comparison to the EPA standard pertaining to atmospheric releases, the maximum individual dose at the SRP perimeter was 2.4% of the EPA limit. Compared to the exposure from natural radiation (average is about 300 mrem/year in the SRP area), the dose contributed by SRP operations is miniscule. Even the variation in the natural radiation dose in this area far exceeds the maximum offsite dose resulting from the Savannah River Plant. In the context of the recommendations of the National Committee on Radiation Protection [NCRP 87b], any radiation dose less than 1 mrem (0.01 mSv) per year is so low that further effort to reduce radiation exposure to the individual is unwarranted.

OVERVIEW OF 1987 MONITORING RESULTS

Magnitude of Program

The environmental monitoring program conducted at SRP is one of the largest and most comprehensive in the United States. A total of 177,000 analyses (89,000 radiological and 88,000 nonradiological) were performed in 1987. In addition, over 1.6 million nonradioactive measurements were made at ambient air quality monitoring stations and over 460,000 water quality readings were made in Beaver Dam Creek and Steel Creek.

While the radiological monitoring program has continued to experience some growth from year to year, the most pronounced growth has occurred in the nonradiological program. This program began expanding in the mid-1970s and has continued to escalate so that it is now as large as the radiological program. The major growth has occurred in groundwater monitoring.

Presentation of Units

It is intended to use the most practical units of measure when presenting data in this report. Most data are presented in picocuries per liter (pCi/L) or picocuries per gram (pCi/g). [1 pCi = 10^{-12} Ci (curie).] Fractions and multiples of units are shown on the inside front cover of this report. In some cases, data are presented in femtocuries (fCi). [1 fCi = 10^{-15} Ci.] A few data are presented in attocuries (aCi). [1 aCi = 10^{-18} Ci.] Tritium concentrations are usually expressed in picocuries per milliliter (pCi/mL) but are sometimes shown in pCi/L. [1pCi/mL = 1,000 pCi/L.] Statistical errors are not presented with data shown in Volume I but are included in the comprehensive data tables in Volume II.

Air Monitoring

Extensive monitoring for radioactivity in air is performed at six onplant stations, 13 plant perimeter stations, 12 stations at the 25-mile radius of SRP, and four stations at the 100-mile radius. The small amount of particulate alpha and beta-gamma radioactivity released to the atmosphere from SRP facilities is generally obscured in the area surrounding SRP by worldwide fallout. Tritium, the only radionuclide of plant origin routinely detected in offsite air, showed a decreasing trend with distance from the site. The average tritium concentration at the plant perimeter was 81 pCi/m^3, compared to 25 pCi/m^3 at the 25-mile radius and 3.9 pCi/m^3 at the 100-mile radius. The average onsite tritium concentration was 1,000 pCi/m^3.

Continuous measurements of the intensity of gamma radiation levels at 350 locations at and around SRP were made with thermoluminescent dosimeters (TLDs). In the unlikely event of a significant unplanned release of radioactivity, these TLDs would provide a quick and reliable method to determine external gamma radiation doses to population groups within an 8,000-square-mile area in the vicinity of SRP. Significant variability in environmental radiation is seen from one location to the other because of variable radioactivity in soil, rocks, and building material. As observed in previous years, there were no significant differences in 1987 between measurements taken at the site boundary and those taken as far as 100 miles away from SRP.

Atmospheric emissions of sulfur dioxide, oxides of nitrogen, and total suspended particulates from the five onsite coal-fired power plants were within applicable standards in 1987. All SRP stacks met the 40% opacity standard at all times except for the 291-F stack, which occasionally exceeded the standard. A number of renovations are under way to ensure 100% compliance by the 291-F stack. The quality of air at SRP was monitored at several locations around the site that measure total suspended particulates, sulfur dioxide, oxides of nitrogen, and ozone. The states of South Carolina and Georgia performed additional ambient air monitoring. All SRP monitoring results were within state standards.

Surface Water Monitoring

The Savannah River and all plant streams located on the SRP site are continuously sampled to monitor radioactivity released in effluent water from SRP facilities. Radioactivity in the liquid effluents is diluted by stream water, reactor heat exchanger cooling water, and Savannah River water. In 1987, no measurable differences were detected between upriver and downriver alpha and nonvolatile beta concentrations in the Savannah River. The release of tritium accounted for greater than 99% of the total radioactivity introduced into the Savannah River from SRP activities during 1987. After dilution by SRP streams and the Savannah River, tritium concentrations averaged 3.3 pCi/mL in the river below SRP at Highway 301 compared to 3.9 pCi/mL in 1986. The only radionuclide other than tritium detected in river water by routine analytical techniques was ^{90}Sr in trace quantities.

Using a special low-level analysis technique, the Savannah River Laboratory (SRL) detected ^{137}Cs both upriver and downriver of SRP. In 1987, the average ^{137}Cs concentrations determined by this technique were 0.010 pCi/L upriver and 0.057 pCi/L downriver of SRP. The difference between the upriver and downriver concentrations is attributed to releases from SRP operations. The maximum ^{137}Cs concentration detected was 2,000 times less than the EPA drinking water standard of 200 pCi/L.

Located approximately 20 miles from SRP, the Edisto River is minimally affected by SRP operations and is sampled for radioactivity as a measure for comparison to concentrations in SRP streams. The maximum radioactivity concentrations detected in the Edisto River in 1987 were 1.5 pCi/L alpha, 2.9 pCi/L nonvolatile beta, and 940 pCi/L (0.9 pCi/mL) tritium.

The primary SRP stream with the highest concentration of radionuclides in 1987 was Four Mile Creek (FMC), which receives effluents from F- and H-Separations Areas, C-Reactor Area (although C-Reactor was not operating in 1987) and migration from F- and H-Separations Areas seepage basins and the Solid Waste Storage Facility (Burial Ground). Alpha and nonvolatile beta concentrations in FMC were elevated with maximum activities of 15 and 140 pCi/L, respectively. Tritium concentrations were also elevated with a maximum concentration of 3,300 pCi/mL.

A comparison of the amount of tritium released from SRP facilities in 1987 with the amount of tritium measured in transport in SRP streams and in the Savannah River continued to show relatively good agreement. Sources of tritium in liquid effluents include direct releases from plant facilities (20% in 1987 compared with 26% in 1986) and migration of tritium from the Burial Ground, F-, H-, and P-Area seepage basins, and K-Area Containment Basin (80% in 1987 compared with 74% in 1986).

SRP liquid effluents are regulated by the South Carolina Department of Health and Environmental Control (SCDHEC) under the National Pollutant Discharge Elimination System (NPDES). In 1987, 68 active, permitted outfalls were monitored. SRP had a 99.7% NPDES compliance rate in 1987, compared to a 99.4% compliance rate in 1986. Only 18 of the 6,560 analyses performed exceeded permit limits.

The Savannah River is extensively monitored for chemicals, physical properties, and metals. Chemical and biological quality standards for the Savannah River are specified in the requirements of the state of South Carolina for Class B streams. All indications are that SRP operations do not have a deleterious effect on the Savannah River aquatic environment.

The Division of Environmental Research of the Academy of Natural Sciences of Philadelphia (ANSP) continued surveys of the aquatic environment and water quality of the Savannah River. Studies in 1987 included diatometer studies, aquatic insect surveys, and algal and aquatic macrophyte surveys. In addition, a comprehensive survey was conducted in the Savannah River in the vicinity of the Vogtle 1 Nuclear Power Plant.

Extensive monitoring of SRP streams indicates that, except for temperature in Pen Branch, the water quality is not adversely affected by SRP operations. Temperature profile surveys were conducted at the mouths and upriver of Beaver Dam Creek and Steel Creek as part of a comprehensive study of the thermal effects of SRP operations upon the waters of the state of South Carolina as stated in consent order 84-4-W between SCDHEC and DOE. Temperature measurements in both Beaver Dam Creek and Steel Creek exceeded the ambient river temperatures but were within the consent order limits.

Groundwater Monitoring

SRP monitors groundwater quality to identify any contamination that may occur as a result of plant operations. The purposes of monitoring groundwater are:

- to identify sources of contamination as soon as possible
- to measure concentrations of contaminants that may enter groundwater, and
- to provide data that can be used to design any needed cleanup projects.

The SRP Health Protection Department maintains the primary responsibility for installing monitoring wells, and for collecting and analyzing groundwater samples.

Monitoring of groundwater for radioactivity began in 1957. Monitoring of groundwater for possible chemical or nonradioactive contaminants began in 1975.

Approximately 75 waste sites, operating facilities, and spill sites have monitoring wells. About 800 wells were monitored in 1987, and around 100 new monitoring wells are being added to the monitoring system each year. Many of these wells have been installed to comply with environmental regulations.

Groundwater in the M-Fuel Fabrication Area was found to be contaminated with metal degreasing solvents in 1981. Followup sampling indicated trichloroethylene and tetrachloroethylene (chlorocarbons) in Wells 20A and 53A in the A-Administration Area. Upon confirmation of the presence of chlorocarbons, these drinking water wells were shut down and drinking water was supplied from Well 82A. New drinking water supply wells 112-G and 113-G were placed in service in late 1986.

No confirmed positive concentrations of chlorocarbons were detected in drinking water samples from the A-Administration/M-Fuel Preparation Areas or in other drinking water supplies at SRP in 1987. Occasional low concentrations of trichloroethylene and tetrachloroethylene continued to be detected at the wellhead of Well 31A. The maximums for 1987 were 13 µg/L and 4µg/L respectively. Process water wells 20A and 53A continued to show elevated chlorocarbon analysis results. The maximum concentration was 123 µg/L of trichloroethylene.

Environmental Monitoring of Other Media

Air and water are the principal dispersal media for SRP radioactive releases. However, the SRP environmental surveillance program also includes samples representing other segments of the environment that may be affected by these releases or that might provide pathways of radiation exposure to people.

Concentrations of radioactivity routinely detected in milk, food, drinking water, wildlife, rainwater, soil, sediment, and vegetation in 1987 were within ranges observed during the last several years. Except for tritium, the concentrations observed were similar to those reported by other agencies in parts of the country not affected by SRP operations [EPA82,EPA83]. Therefore, the occasional trace amounts of radioactivity detected in these samples are attributed to worldwide fallout from atmospheric nuclear weapons tests. Tritium, when present, is attributed to SRP operations.

Annual hunts are conducted at SRP to control the deer and hog populations and to reduce animal-vehicle accidents. All animals are monitored for radioactivity before being released to the hunters. The 1987 hunts yielded 606 deer and 123 hogs, as compared with 944 deer and 127 hogs in 1986.

Concentrations of ^{137}Cs in the deer and hogs were within ranges observed over the last several years. Consumption of the meat from these animals presents no radiation hazard. For example, an adult consuming all of the meat (12 kg) from the deer with the maximum ^{137}Cs concentration (45 pCi/g) would receive a 50-year radiation dose commitment of 27 mrem (0.27 mSv) or 9% of the average local resident's annual dose from naturally occurring radiation. Average ^{137}Cs concentrations in SRP deer and offsite deer were 5 and 9 pCi/g, respectively.

Special Surveys and Studies

Special radiological surveys were conducted in the environment when short-term tritium releases occurred on three occasions in 1987. The maximum calculated dose to an individual at the site boundary from the largest release was 0.02 mrem (0.0002 mSv) when 172,000 Ci of tritium was released to the atmosphere on July 31, 1987.

Special surveys were conducted on two other occasions in 1987 when short-term radioactivity releases occurred. An estimated 1.5 Ci of mixed radionuclides were inadvertently released to Upper Three Runs Creek on January 1, 1987. The maximum alpha and nonvolatile beta concentrations in Upper Three Runs Creek in 1987 (which were due to this release) were 1.5 and 2.6 pCi/L, respectively. These concentrations are within the ranges of radioactivity observed in the Edisto River. On November 24, 1987, 1 Ci of ^{137}Cs and 33 mCi of ^{134}Cs were released to the atmosphere from an H-Area facility. The maximum ^{137}Cs concentrations detected onplant and at the plant perimeter were 0.70 and 0.79 pCi/m^3, respectively. The maximum concentration of 0.79 pCi/m^3 detected at the site boundary was 0.2% of the DCG for ^{137}Cs.

Savannah River Swamp Survey. Monitoring of five square miles of swamp bordering the Savannah River below the SRP boundary continued to indicate radioactivity (previously identified as ^{60}Co and ^{137}Cs) above natural background levels. The offsite swamp area is uninhabited and inaccessible except for possible occasional hunting or fishing. A comprehensive survey along 10 sampling trails that traverse the swamp was conducted in 1985 before the startup of L-Reactor. Cursory surveys performed in 1986 and 1987 indicated the following radiological conditions:

- Gamma radiation measurements were within ranges observed in previous years. The maximum radiation measurement was 0.94 mR/day.
- Radionuclide concentrations in soil and vegetation samples were within ranges observed in previous data.
- Concentrations of ^{137}Cs in fish collected from two lakes near the swamp trails were within ranges observed in previous years.

Special Creek Plantation Well Survey. Wells on the offsite Creek Plantation below SRP were sampled and analyzed for radioactivity in 1987 to confirm these wells have not been impacted by SRP operations. All results were below EPA drinking water standards and were within ranges observed for other offsite drinking water wells routinely sampled.

Comprehensive Surveys at the Beaufort-Jasper and Port Wentworth Water Treatment Plants. Comprehensive surveys were conducted at the Beaufort-Jasper and Port Wentworth water treatment plants following the 1985 startup of L-Reactor. The surveys were conducted quarterly beginning in June 1986, and ending in April 1987. Surveys were conducted to meet environmental impact statement requirements and to determine if the L-Reactor startup impacted the water treatment plants below SRP. Similar surveys were conducted in 1983 to provide baseline data of environmental conditions prior to L-Reactor startup in October 1985. In addition to radioactivity measurements, water quality measurements were also performed. Monitoring results showed no significant impact to the water treatment plants from L-Reactor startup.

Special Atmospheric Radon Study. An atmospheric radon study conducted at SRP and at residences in the region indicated doses from radon were equivalent to those in other areas of the United States. According to the study, the annual average effective dose equivalent to residents in the Savannah River region from radon exposure probably lies between 100 and 300 mrem/year. A comprehensive assessment of radiation exposure of the U. S. population reported by the National Council on Radiation Protection and Measurements (NCRP) in 1987 estimated the radon contribution at 200 mrem/year [NCRP87a].

Spills. A site-wide procedure requires prompt reporting of oil and chemical spills to a spill coordinator who ensures spills are reported to the Department of Energy (DOE), Environmental Protection Agency (EPA), and South Carolina Department of Health and Environmental Control (SCDHEC) as appropriate to satisfy regulatory requirements. In 1987, there were 145 spills reported to the spill coordinator. Most of these were minor spills of petroleum products. None of the spills were reportable under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). SRP has not had a CERCLA reportable spill in over two years.

ENVIRONMENTAL MANAGEMENT AND RESEARCH PROGRAMS

A wide variety of environmental management and research programs are conducted at the SRP site each year by the Savannah River Plant (SRP), Savannah River Laboratory (SRL), Savannah River Ecology Laboratory (SREL), and the Savannah River Forest Station (SRFS). Summaries of

programs conducted during 1987 are included in Chapter 12 of this report. Highlights of a few of the programs are discussed in the succeeding paragraphs.

Savannah River Plant Environmental Management Programs

Environmental Audits and Appraisals. From the third quarter of 1986 into 1987, the Environmental Protection Agency (EPA) conducted the largest environmental audit ever at SRP. This audit, known as a multimedia audit, encompassed seven areas: hazardous waste (RCRA), solid waste management units (SWMUs), wastewater (NPDES), drinking water, groundwater, toxic substances, and air quality. No major problems were found; there were 98 minor administrative findings which SRP corrected during and after the audit.

As part of a commitment to Congress to perform a baseline environmental survey of all DOE facilities, the Department of Energy Headquarters (HQ) conducted a comprehensive environmental survey at SRP in January 1987.

Operations Under Hazardous Waste RCRA Part B Permit. On September 30, 1987, SCDHEC issued to SRP a RCRA Part B Permit for operation of the Hazardous Waste Storage Facilities (Buildings 709-G, 709-2G, 709-4G, and 710-U) and post-closure maintenance of the M-Area Settling Basin and vicinity (overflow ditch, seep area, and Lost Lake). The EPA issued the federal portion of the permit covering the requirements of 3004 (u) and 3005 (h) of the 1984 RCRA Amendments. This portion of the permit identified 65 solid waste management units at SRP that will require a RCRA Facility Investigation (RFI).

Preparation of Environmental Impact Statements. During 1987, the following two environmental impact statements (EISs) were issued:

Waste Management Activities for the Protection of Groundwater at the Savannah River Plant, DOE/EIS-0120, December 1987. (The Record of Decision was issued in March 1988.)

Alternative Cooling Water Systems, SRP, DOE/EIS-0121, October 1987. (The Record of Decision was delayed until early 1988 pending a decision on an EPA and SCDHEC recommendation to install a recirculating cooling tower for K Area. The Record of Decision was issued on February 12, 1988, and recommended installation of the tower.)

Savannah River Laboratory Environmental Management and Research Programs

Comprehensive Cooling Water Study. The Comprehensive Cooling Water Study (CCWS) was initiated in 1983 to evaluate environmental effects associated with SRP cooling water withdrawals and discharges, and to determine the significance of these effects on the onsite and downriver environments. The CCWS was published in October 1987. Some observations discussed in the report include the following:

- The water quality of onsite streams at SRP has been influenced primarily by the elevated temperatures and flow rates associated with reactor operation.
- In the vicinity of SRP, the Savannah River contains an abundant, diverse fish population. There is no evidence that river populations are adversely affected by SRP cooling water discharges.
- Reactor operations have no adverse impact on the Par Pond system.
- Four threatened or endangered species use areas that could be affected by SRP cooling water withdrawal or release.

Waste Management and Groundwater Protection Environmental Impact Statement (EIS). An environmental impact statement (EIS) on waste management activities for groundwater protection at the SRP was issued in December 1987. Seventy-seven waste sites at 45 distinct geographical locations around SRP were analyzed for impacts on human health and the ecology resulting from postulated closure actions. The results of the environmental analysis of waste disposal sites at SRP indicate that the risk to human health and the ecology is quite low. For many sites, no remedial action is needed. For others, backfilling and capping the waste site provides the required protection. At one site and possibly two, removal of the waste may be required to reduce the calculated risk to the human population.

National Environmental Research Park Program

During 1987, approximately 15 NERP program research projects were conducted at the SRP. The site was surveyed for plants listed by state or federal agencies as endangered, threatened, or of special concern. Other scientists surveyed soil organisms, shallow pond protozoa, stream insects, and forest vines. In 1987, NERP sponsored an SRP meeting at which scientists from across the country learned about opportunities to study microorganisms found in the sedimentary rocks hundreds of feet beneath the SRP.

Savannah River Ecology Laboratory Programs

Wood Storks at Kathwood Artificial Foraging Ponds. When the Department of Energy (DOE) decided to restart the L-Reactor, there was concern that reactor cooling water would increase the water level in the Steel Creek delta and make this area unavailable to wood storks that nest in a rookery near Millen, GA, and fly to the SRP to feed on fish. (In 1984, the U. S. Fish and Wildlife Services classified the wood stork population as endangered.) To replace the potentially lost foraging habitat, DOE created ponds at the site of Kathwood Lake on the National Audubon Society's Silver Bluff Plantation Sanctuary in 1985. In 1986, wood storks foraged on the ponds for over two months, and 97 storks were counted feeding at one time; this number increased to 150 in 1987. The patterns of numbers of storks at the ponds suggest that the artificial ponds do indeed present appropriate foraging habitat.

U. S. Forest Service Savannah River Forest Station Programs

Timber cut during 1987 brought the Federal Government nearly $2.3 million for 27 million board feet. Pine seedlings were planted on over 2,200 acres during FY 1987.

Southern bald eagles returned to SRP to nest in 1987. For the second year, two eaglets were raised to fledging.

In an effort to reduce genetic inbreeding, two red cockaded woodpecker chicks were removed from a nest at Francis Marion Forest, transported to SRP, and substituted for two chicks of the same age in an SRP nest. The SRP chicks were then placed in the nest at Francis Marion Forest. All of the swapped chicks were accepted and reared by their foster parents. In 1987, all three pairs of red cockaded woodpeckers at SRP nested successfully. They produced seven fledgings, increasing the known SRP population to 14 birds.

1
Introduction and Program Overview

SUMMARY — An overview of the environmental monitoring program at Savannah River Plant (SRP) is given in this introductory chapter, along with a description of the SRP site and facilities. SRP occupies approximately 300 square miles along the Savannah River in a predominantly rural section of South Carolina, principally in Aiken and Barnwell Counties. SRP's primary function is the production of plutonium, tritium, and other special nuclear materials for national defense, other governmental uses, and some civilian purposes. Major operating facilities include three nuclear reactors, a fuel target fabrication plant, a naval fuel materials facility, two chemical separations plants, and the Savannah River Laboratory (SRL), which is a process development laboratory that supports production operations. Exclusion of the public from the plant site (except for controlled public hunts for deer and hogs) creates a refuge for many terrestrial and aquatic animals. The extensive environmental program at SRP encompasses both radioactive and nonradioactive monitoring. The program intensively surveys a 2,000-square-mile area in the immediate vicinity of SRP and analyzes representative samples collected from an additional 30,000-square-mile area. Both radiological and nonradiological analyses are carried out for air, surface water, groundwater, drinking water, sediment, and fish. In addition, radiological analyses are carried out on samples of milk, food, wildlife, rainwater, soils, and vegetation. SRP streams and the Savannah River are extensively monitored for chemicals, metals, organics and numerous other constituents and physical properties. Drinking water is analyzed for total coliform, residual chlorine, and a variety of chemicals, including chlorocarbons. River and stream water and sediment are analyzed for pesticides, herbicides, and polychlorinated biphenyls (PCBs). In addition to the monitoring programs, a significant amount of environmental research is conducted each year at SRP by organizations that include SRL, the Savannah River Ecology Laboratory (University of Georgia), and the Savannah River Forest Station.

DESCRIPTION OF THE SRP SITE AND FACILITIES

The Savannah River Plant (SRP) occupies an area of approximately 300 square miles along the Savannah River, principally in Aiken and Barnwell Counties of South Carolina. Most of the plant's environs are rural. Average population density in the counties surrounding SRP ranges from 23 to 560 people per square mile with the largest concentration in the Augusta, GA metropolitan area, which has a population greater than 250,000. The countryside is predominantly forested. Farming is diversified; the main crops are cotton, soybeans, corn, and small grains. Production of beef cattle continues to expand.

The climate is mild, with an average frost-free season of approximately 246 days. The annual average rainfall at SRP is about 48 inches and is fairly evenly distributed throughout the year. The SRP and surrounding area are described in more detail in "The Savannah River Plant Environment" [Du84].

SRP's primary function is the production of plutonium, tritium, and other special nuclear materials for national defense, for other governmental uses, and for some civilian purposes. Major operating facilities in 1987 included three nuclear reactors, a fuel and target fabrication plant, a naval fuel materials facility, two chemical separations plants, and the Savannah River Laboratory (SRL), a process development laboratory which supports production

operations. Many other facilities necessary to support operations are located on the SRP site. The heavy water production plant, which began operation in 1953, was shut down in 1981. The three operating reactors are the P-, K-, and L-Reactors. L-Reactor was restarted in October 1985 after an extensive upgrade. A fourth reactor, C-Reactor, operated until 1986, when it was shut down for repairs. The fifth reactor, R-Reactor, was permanently shut down in 1964. Reactors and separations plants are located near the center of the site; other facilities are located near the perimeter.

Nuclear fuels and targets, together with other reactor components, are manufactured in the fuel and target fabrication facility. The reactors at SRP are fueled with uranium, moderated and cooled by heavy water circulated in a closed system through heat exchangers. Water from the Savannah River and Par Pond, a manmade cooling water impoundment covering 2,640 acres, is used as a coolant in the heat exchangers.

Because heat exchanger cooling water does not pass directly through the reactors, it is not subject to direct neutron activation. The heat exchanger cooling water from P-Reactor is returned to Par Pond, some of which overflows to Lower Three Runs Creek. L- and K-Reactors use Savannah River water as heat exchanger coolant. The water is discharged via different waterways. L-Reactor heat exchanger cooling water is discharged to L Lake, which overflows to Steel Creek. K-Reactor heat exchanger cooling water is discharged to Pen Branch.

Reactor produced products are recovered in the chemical separations areas. Plutonium-238, ^{238}Pu, and uranium are separated from each other and from fission products by complex chemical processes. These areas also have facilities for purification and packaging of tritium and for storage of fission product wastes. SRP production areas and effluent streams are shown on the facing page in Fig. 1-1.

A major facility is currently under construction on the SRP site. The Defense Waste Processing Facility (DWPF) will immobilize high-level radioactive waste in a solid, unleachable glass. The facility will be the first of its type in the nation.

Another process waste facility under construction at SRP is the F/H Effluent Treatment Facility (ETF). The ETF will treat wastewater generated by the chemical separations facilities before it is discharged to the Savannah River via Upper Three Runs Creek. The wastewater is currently discharged to seepage basins. Operation of the facility is expected to begin in late 1988.

Construction of a Naval Reactor Fuel Materials Facility to produce nuclear fuel for the U.S. Navy was completed in 1986 and the facility is undergoing startup tests.

Exclusion of the public from the plant site creates a refuge for many terrestrial and aquatic animals. The deer population is limited by controlled public hunts to prevent range deterioration and to minimize deer/vehicle accidents. More than 700 deer and hogs were harvested in the 1987 hunts.

SRP is committed to reforestation

In 1972, SRP was designated as the first National Environmental Research Park (NERP). This designation opened the site for investigators from universities and other research organizations to design and conduct research studies of man's impact on the environment. In addition to environmental research programs normally con-

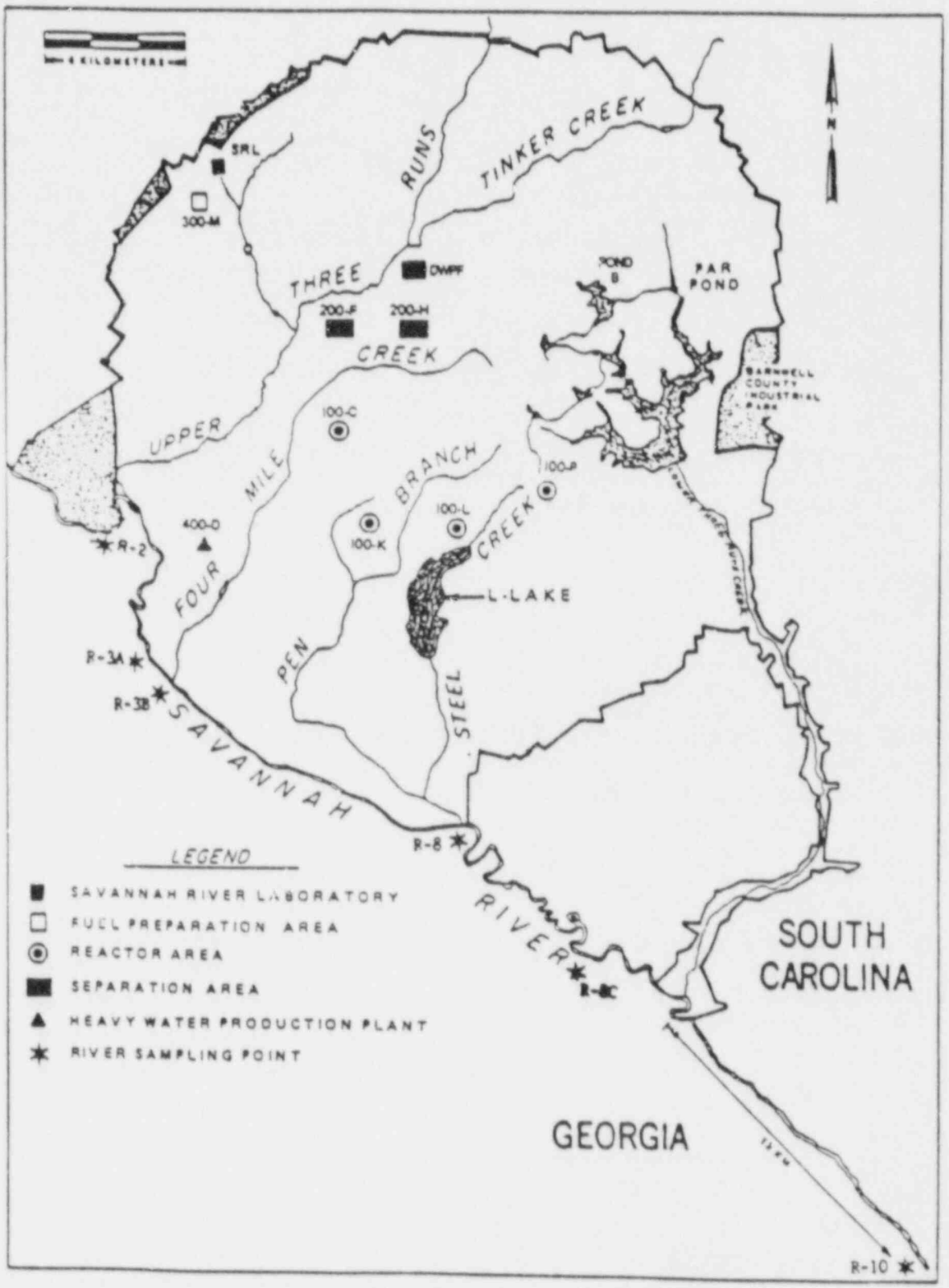


Fig. 1-1. Production areas and effluent streams.

ducted at the site that are funded by the Department of Energy (DOE), approximately 15 research projects were conducted at the SRP site under the NERP program in 1987.

The U.S. Forest Service has planted over 99 million pine seedlings on nearly 91,000 acres of the plant site since 1952. Significant quantities of pine, hardwood saw timber, and pulpwood have been harvested during this same period.

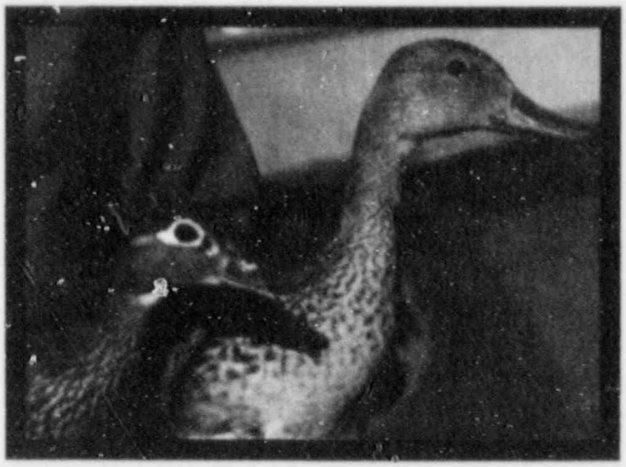
OVERVIEW OF ENVIRONMENTAL PROGRAMS

Environmental Monitoring and Regulatory Compliance

The environmental monitoring program at SRP is one of the largest and most comprehensive in the United States. Extensive programs are conducted in both radioactive and nonradioactive monitoring. A total of 177,000 analyses (89,000 radiological and 88,000 nonradiological) were performed in 1987. In addition, over 1.6 million nonradioactive measurements were made at ambient air quality monitoring stations and over 460,000 water quality readings were taken from monitors in Beaver Dam Creek and Steel Creek. Monitoring programs are coordinated by the Health Protection (HP) Department at SRP. Regulatory compliance is coordinated by the Environment and Energy (E & E) Department at SRP. Research programs are conducted by the Savannah River Laboratory (SRL) and the Savannah River Ecology Laboratory (SREL).

E & E is responsible for the oversight and coordination of site programs to protect the environment and ensure regulatory compliance. A staff of nearly 30 professionals in engineering, chemistry, geology, biology, toxicology, and health physics provides support to the site environmental programs.

Radiological Programs	Departments Involved
■ Environmental Monitoring (Air, Surface Water, Groundwater, Food, Drinking Water, Wildlife, Rainwater, Soil, Sediment, Vegetation)	Health Protection Dept
Nonradiological Programs	**Departments Involved**
■ Air Monitoring	Health Protection Dept Environment and Energy Dept Operating Depts
■ Water Quality Monitoring	Health Protection Dept Laboratories Dept Environment and Energy Dept
■ Drinking Water	Health Protection Dept Power Technology Dept Environment and Energy Dept
■ Surface Water Monitoring (NPDES)	Health Protection Dept Environment & Energy Dept Operating Depts
■ Groundwater Monitoring (Nonregulatory & Regulatory)	Health Protection Dept Environment & Energy Dept Operating Depts SRL Interim Waste Technology Div



Wildlife is monitored

Monitoring programs at SRP and departments involved are shown on the facing page.

The Health Protection Department performs most radiological and nonregulatory water quality analyses. HP facilities include sample receiving areas, radiochemical preparation laboratories, nonradiochemical analytical laboratories, and radioanalytical counting rooms. Nearly 30 laboratory analysts and technicians collect, prepare, and analyze environmental samples. In addition to the laboratory supervisors who supervise sample collection, preparation, and analysis, a staff of over 15 professionals in biology, chemistry, geology, health physics, and computer science provides technical support to the monitoring program. A large portion of the regulatory monitoring programs is contracted to commercial laboratories.

Each year, extensive radioactive monitoring is performed in a 2,000-square-mile area in the immediate vicinity of SRP and representative samples are collected from an additional 30,000-square-mile area. In this 30,000-square-mile area, many different types of samples are collected routinely and analyzed for radioactivity. The radioactive monitoring program generated approximately 23,800 samples and 89,000 analyses in 1987. Approximately 504,000 samples and 1,859,000 analyses have been generated since the program began in 1951. Types of samples collected and analyzed for radioactivity are shown at the bottom of the page.

The nonradioactive ambient air monitoring program is coordinated by HP, and routine operation of the program is contracted to an offsite company. Onsite stations house instruments which monitor for sulfur dioxide, oxides of nitrogen, ozone, and total suspended particulates. Over 1.6 million measurements were made in 1987.

SRP has monitored site stream wastewater discharges and their effects on Savannah River water quality since the early 1960s. The inhouse nonregulatory water quality program, conducted by the Health Protection Department, monitors plant streams and the Savannah River for chemicals, metals, and organics. Six to 33 constituents are analyzed at each sample location. The SRP Laboratories Department performs coliform bacteria analyses for this program. Each year, approximately 200 samples are collected and 5,500 analyses performed. In addition, water quality parameters are

Types of Samples Analyzed in the Radioactive Monitoring Program

Air
Thermoluminescent Dosimeters
Surface Water
- rivers
- streams
- seepage basins

Groundwater
Milk
Food
- (i.e., eggs, chickens, meats, fruits, grains, collards)

Drinking Water
Wildlife
- fish
- crabs and oysters
- deer and hogs
- furbearers (i.e., oppossums, foxes, raccoons)
- turtles
- ducks

Rainwater
Soil
Sediment
Vegetation

measured in Steel Creek and Beaver Dam Creek to comply with consent order 84-4-W between the South Carolina Department of Health and Environmental Control (SCDHEC) and the DOE. Temperature and dissolved oxygen measurements are taken daily in Steel Creek, and readings for temperature, conductivity, pH, oxidation/reduction potential and dissolved oxygen are made every five minutes in Beaver Dam Creek. In 1987, over 460,000 measurements were made.

Analyses for the regulatory National Pollutant Discharge Elimination System (NPDES) liquid effluent monitoring program coordinated by HP are contracted to commercial laboratories certified by SCDHEC. HP handles sample collection and administration of analytical contracts. E & E reviews and reports data to SCDHEC via the DOE. Approximately 6,600 routine analyses were performed on 68 active outfalls in 1987. An additional 10,000 analyses were performed for NPDES permit renewal.

Sample collection, laboratory analysis, and data handling for the groundwater monitoring program (nonregulatory and regulatory) are contracted to offsite companies. Contracts are administered by HP. E & E reviews and reports groundwater data to SCDHEC to fullfill regulatory requirements. Approximately 61,000 analyses of groundwater were performed in 1987.

Drinking water analyses for residual chlorine and a variety of chemicals are subcontracted to offsite laboratories by the Power Technology Department. Total coliform analysis of drinking water is performed onsite by the Laboratories Department. Chlorocarbon analyses are performed on duplicate drinking water samples by both the Laboratories Department and an offsite laboratory. E & E reviews and reports the regulatory required data to SCDHEC via DOE. Approximately 4,200 analyses were performed on drinking water in 1987.

River and stream water and sediment are analyzed for pesticides, herbicides, and polychlorinated biphenyls (PCBs) by an offsite laboratory. There were 576 analyses performed in 1987. In addition, mercury analyses in fish are normally conducted each year. Types of routine samples analyzed in the nonradiological monitoring programs are shown in the table at the top right hand column of the page.

Types of Samples Analyzed in the Nonradiological Monitoring Programs

- **Air**
- **Surface Water**
  - Rivers
  - Streams
  - Seepage Basins
- **Groundwater**
- **Drinking Water**
- **Sediment**
  - Rivers
  - Streams
- **Fish**

Environmental Research

A significant amount of environmental research is conducted each year at SRP. Many of these activities are described in Chapter 12 of this report. Groups involved in these efforts include the following:

- Savannah River Laboratory
  - Environmental Sciences Division
  - Environmental Transport Division
  - Interim Waste Technology Division
- Savannah River Ecology Laboratory (University of GA)
- Savannah River Forest Station

PROGRAM REVIEWS

External Review of Nonradiological Monitoring Program

At the Health Protection Department's request, International Technology Corporation (IT) performed a comprehensive review of the SRP nonradiological environmental monitoring program during the fourth quarter of 1986. A similar audit of the radiological programs was reported in the 1986 SRP Environmental Report [Ze87]. Five areas were audited: (1) surface and ground water quality sampling; (2) air quality sampling; (3) well installation; (4) laboratory analysis; and (5) biological studies. Each area was separately audited. Written checklists developed by IT were followed during the audit.

The general objective of the audit was to evaluate procedures and the effectiveness of their implementation, to evaluate work areas and activities, to review documentation, and to recommend methods to improve the program. The scope of the audit included the following:

- subcontractor capability and performance
- field operations, records, and procedures
- laboratory testing and records
- equipment calibration and records
- identification and control of samples
- numerical analyses and designs
- information reporting
- record control and retention
- personnel training

The analytical laboratories were audited according to requirements of the IT Analytical Services (ITAS) Quality Assurance Manual and appropriate SRP QA procedures. Items examined by the auditor included availability and implementation of approved laboratory procedures, equipment calibration and records, control and storage of samples, QC sample program, performance documentation and checking, and nonconformance documentation. Two Du Pont laboratories and five subcontractor laboratories were audited:

- Du Pont Lab 772-D (SRP)
- Du Pont Lab 735-A (SRP)
- Environmental and Chemical Services, Inc. (New Ellenton, SC)
- Environmental Testing, Inc. (Charlotte, NC)
- Envirodyne Engineers, Inc. (St. Louis, MO)
- Academy of Natural Sciences (Philadelphia, PA)
- Zedek Corporation (Durham, NC)

The audit findings and recommendations were documented in a report issued in December 1986. The report evaluated the programs as technically strong and presented a favorable view of the programs. The report also identified several areas where the programs could be strengthened to improve quality.

The major recommendations pertained to written plans for monitoring objectives and criteria of each monitoring program. These plans will document why monitoring is performed and provide technical justification. Other methods to improve the quality of programs include chain-of-custody and minor modifications to procedures.

DOE - Headquarters Environmental Survey

In 1987, DOE performed a comprehensive environmental survey at SRP to identify environmental problems and areas of associated environmental risk. The multimedia survey was conducted on the SRP site in two phases. During the first phase from January 5-23, 1987, the survey team developed a sampling and analysis plan to assist in further assessing certain of the environmental problems identified during the visit. The second phase was conducted from September 14-December 17, 1987. The preliminary report from the first phase was published in August 1987 and included 65 findings, none of which identified any environmental problems at SRP that represent an immediate threat to human health or the environment. When analyses of samples collected during phase two are completed, the results will be incorporated into an SRP Environmental Survey Interim Report, which will reflect the final determinations of the SRP survey.

Environmental Advisory Committee

A committee composed of four consultants meets quarterly to review SRP/SRL environmental programs and make recommendations. The four consultants are nationally recognized experts in their respective fields of biology, ecology, hydrogeology, and health physics.

1987 HIGHLIGHTS

- The Defense Waste Processing Facility (DWPF), a major facility that will immobilize high-level radioactive waste in a solid, unleachable glass, is under construction on the SRP site. The facility will be the first of its type in the nation.
- The F/H Effluent Treatment Facility (ETF), another process waste facility under construction on the SRP site and expected to be in operation in 1988, will treat wastewater generated by the chemical separations facilities before it is discharged to the Savannah River via Upper Three Runs Creek.
- Approximately 15 research projects were conducted at the SRP site under the National Environmental Research Park (NERP) program in 1987.
- The environmental monitoring program expanded with 89,000 radiological and 88,000 nonradiological analyses performed in 1987.
- Approximately 6,600 routine analyses were performed on 68 active outfalls for the regulatory National Pollutant Discharge Elimination System (NPDES) liquid effluent monitoring program during 1987; an additional 10,000 analyses were performed for NPDES permit renewal.
- During 1987, approximately 61,000 analyses were performed for the groundwater monitoring program. This is twice the number performed in 1986.
- Drinking water analyses for 1987 totaled approximately 4,200.
- River and stream sediment were sampled for pesticides, herbicides, and polychlorinated biphenyls (PCBs); 576 analyses were performed during 1987.
- An audit of the nonradiological programs evaluated them to be technically strong.
- DOE conducted a comprehensive multimedia survey in 1987. The preliminary report included 65 findings, none of which identified any environmental problems at SRP that represent a threat to human health or the environment.

2
Air Monitoring Program

SUMMARY — Results of radiological and nonradiological monitoring of atmospheric emissions, environmental gamma radiation measurements made with TLDs, and ambient air quality measurements of total suspended particulates, sulfur dioxide, oxides of nitrogen, and ozone are presented in this chapter. Airborne radioactive materials are measured by analysis of filter papers, charcoal filters, and tritium desiccants located at monitoring stations on the site, around the plant perimeter, and at distances of 25 and 100 miles. The major gamma-emitting radionuclide routinely detected in air was naturally occurring ^{7}Be. The offsite radiation dose commitments from radioactivity released to the atmosphere from SRP facilities during normal operations were calculated for individuals closest to the plant site by potential pathways, and for populations out to a distance of 80 km (50 miles) from the center of the site. The highest potential dose commitment from atmospheric releases of radioactivity to a hypothetical person at the plant boundary was 0.6 mrem which is 0.2% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources. Atmospheric emissions from the five coal-fired power plants located at SRP that burned a total of 452,980 tons of coal in 1987 were within applicable standards. A comparison of data from SRP ambient air monitoring stations with Georgia and South Carolina standards clearly shows that air quality in the SRP area is good and well within the EPA standards.

RADIOACTIVE MONITORING

Atmospheric Emissions

Description of Monitoring Program. Concentrations of radioactive materials in the air are measured at six monitoring stations on the plant site, 13 monitoring stations around the plant perimeter, and 12 stations at distances of approximately 25 miles from the center of the plant (called "25-mile-radius" stations). The stations at the plant perimeter and the 25-mile-radius stations are spaced to permit continuous monitoring within each 30 degree sector. This spacing enhances the probability of detecting a significant release of airborne radioactivity from SRP regardless of wind direction. Air filters are collected weekly for analysis (see Chapter 10). The locations of the air monitoring stations are shown in Fig. 2-1, on p. 10.

Additional air monitoring stations located at Savannah and Macon, GA, and at Columbia and Greenville, SC ("100-mile-radius" stations), are so distant from SRP that the effect of SRP operations at these locations is negligible. They serve as reference points for determining background radioactivity levels from natural sources and from worldwide fallout. Distant air monitoring stations are shown in Fig. 2-2, Vol. II.

Airborne radioactive materials are measured by analysis of filter papers, charcoal filters, and tritium desiccants placed at the monitoring stations for specified periods. The filter papers and charcoal filters remain in place for one week; the tritium desiccants are changed every two weeks.

Applicable Standards. The guides for concentrations of radionuclides in air are given in Chapter XI of order DOE 5480.1A (Rev. 8/5/85). These guides are based on recommendations in Publications 26 and 30 of the International Commission on Radiological Protection [ICRP77; ICRP 79].

The guides are designated as Derived Concentration Guides (DCGs). The DCG for a radionuclide is defined as the air concentration of that radionuclide that will give a 50-year dose commitment of 100 mrem if breathed continuously for one year. The DCGs for radionuclides released to the atmosphere from SRP are listed in Table 2-1 at the top of p. 11.

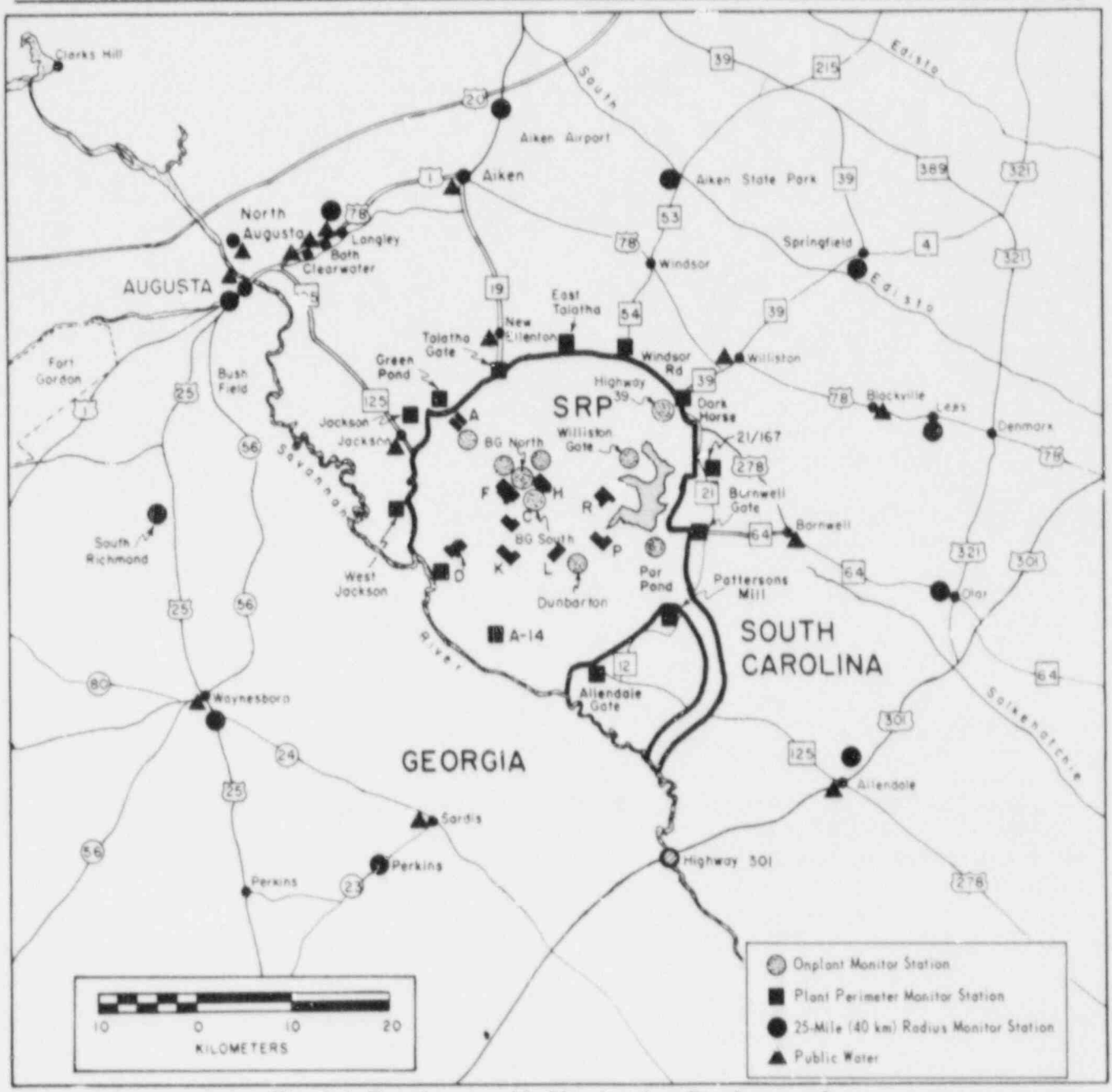


Fig. 2-1. Continuous Air Monitoring Stations and Public Water Sample Locations

The revised DOE interim standards also include the EPA National Emission Standards for Hazardous Air Pollutants (NESHAPS): Standards for Radionuclides (40 CFR 61), which apply to federal facilities. The NESHAPS standards state that radioactive air emissions shall not result in a whole body dose of greater than 25 mrem/year to any member of the public.

Monitoring Results. Atmospheric monitoring results are presented in Table 2-1, Vol II. The small contribution of particulate radioactivity from releases at SRP was not detectable at any of the site

Average activity concentration (fCi/m³)*		
Location	**Alpha**	**Beta**
Onplant	1.1	28
Plant Perimeter	1.0	17
25-Mile Radius	1.0	16
100-Mile Radius	1.2	15

* 1,000 fCi/m³ = 1 pCi/m³

Table 2-1. DOE Derived Concentration Guides for Air (pCi/m³)*

H-3	100,000	Nb-95	3,000	Ce-141	1,000
C-14	6,000	Ru-103	2,000	Ce 144	30
Co-58	2,000	Ru-106	30	U-235	0.1
Co-60	80	I-129	70	U-238	0.1
Kr-85m	100,000	I-131	400	Pu-238	0.03
Kr-85	300,000	Xe-131m	400,000	Pu-239	0.02
Kr-87	20,000	Xe-133	300,000	Am-241	0.02
Kr-88	20,000	Cs-134	200	Cm-242	0.7
Sr-89	300	Xe-135	100,000	Am-243	0.02
Sr-90	9	Cs-137	400	Cm-244	0.04

* Department of Energy draft order 5480.1A (Chapter XI) for soluble forms.

boundary monitoring stations. Tritium was the only radionuclide of plant origin that was routinely detected in offsite air. The concentrations of all particulate radioactivity and tritium were only small percentages of the DCGs for air.

The small amount of particulate alpha and beta-gamma radioactivity released to the atmosphere, primarily from the F- and H-Separations Area facilities, is generally obscured in the area surrounding SRP by worldwide fallout levels. The plant perimeter, 25-mile-radius, and 100-mile-radius sample groups had essentially the same average particulate alpha and nonvolatile beta concentrations as shown in the table at the bottom right column on p. 10.

These results indicate a slightly higher nonvolatile beta average for the "onplant" location group but are within ranges observed in previous years. The maximum onplant alpha concentration of 3.7 fCi/m³ occurred at A Area, and the maximum onplant nonvolatile beta concentration of 290 fCi/m³ occurred at H Area. Both maximum values were detected in November 1987.

The historical influence of fallout from weapons tests on particulate nonvolatile beta activity in air is shown in Fig. 2-2 on p. 12. Elevated nonvolatile beta concentrations were observed at all locations after atmospheric testing was resumed in the United States in September 1961, and after atmospheric testing of nuclear weapons by nonparticipants in the 1962 atmospheric testing moratorium.

Some increase in nonvolatile beta in air has also generally occurred at all locations in the spring as a result of the mixing of the stratosphere with the troposphere. This phenomenon is generally observed between January and June depending on prevailing meteorological conditions.

The major gamma-emitting radionuclide routinely detected in air was ^{7}Be, which is naturally formed by the interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. In 1987, concentrations of naturally occurring ^{7}Be ranged from 1.6 to 1,400 fCi/m³.

No significant difference was noted between average measurements of plutonium in air at the site boundary and offsite locations as shown in the following table:

Average plutonium concentrations (aCi/m³)* in the SRP vicinity

Location	Pu-238	Pu-239
Onplant	28	11
Plant Perimeter	0.31	1.3
25-Mile Radius	0.31	1.0
100-Mile Radius	0.70	1.5

* 1,000,000 aCi/m³ = 1 pCi/m³

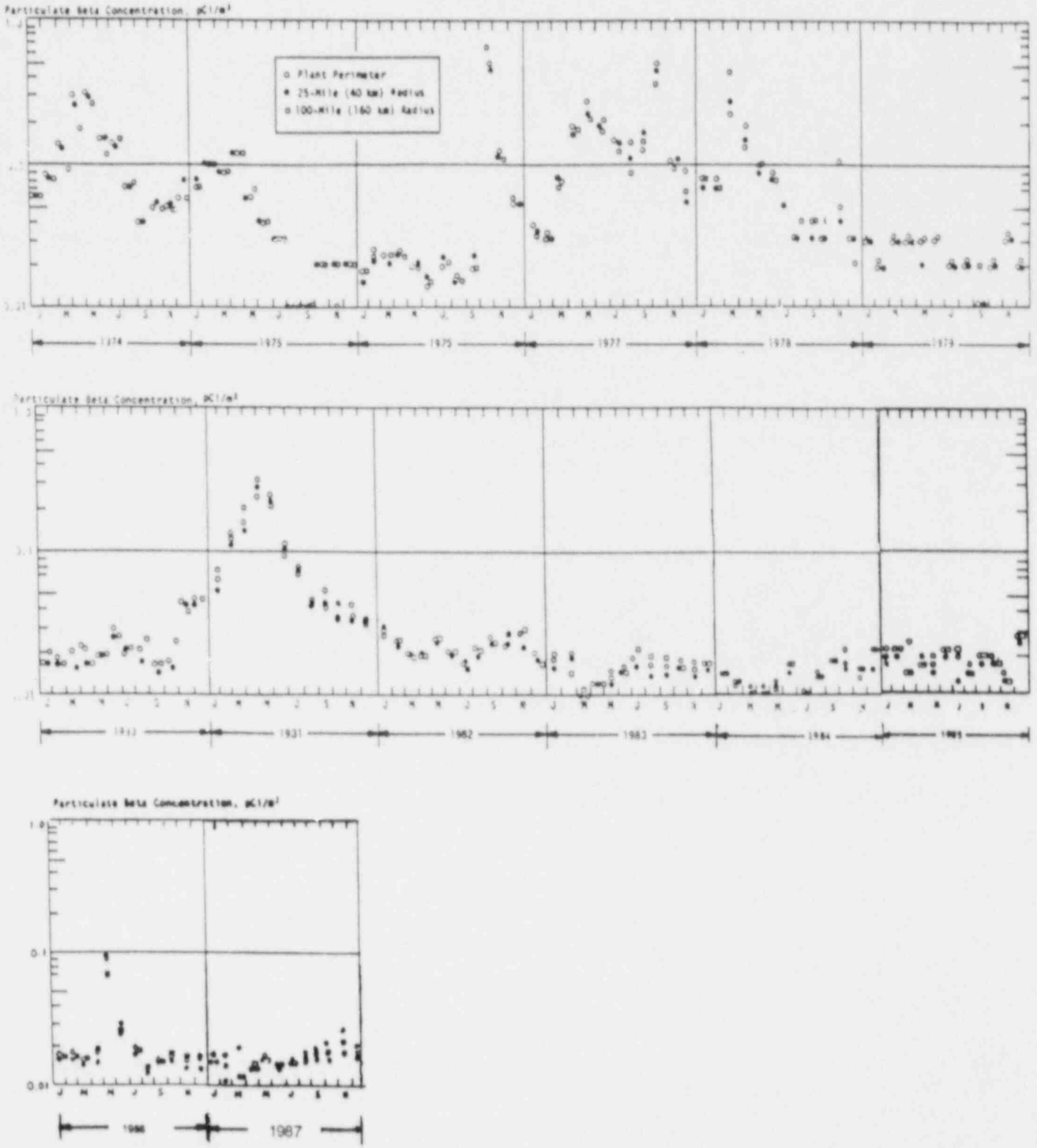


Fig. 2-2. Beta radioactivity in air

TABLE 2-2. 1987 RADIOACTIVE ATMOSPHERIC RELEASES AND CONCENTRATIONS

Nuclide	Curies Released at Emission Source	Calculated Avg. Conc. at Plant Perimeter, pCi/m³
Gases and Vapors:		
H-3 (oxide)	2.70E+05	8.1E+01
H-3 (elemental)	3.20E+05	9.6E+01
H-3 (total)	5.90E+05	1.8E+02
C-14	4.10E+01	1.2E-02
Ar-41	8.77E+04	1.4E+01
Kr-85m	1.69E+03	3.9E-01
Kr-85	3.95E+05	1.2E+02
Kr-87	1.16E+03	1.4E-01
Kr-88	2.01E+03	4.0E-01
Xe-133	5.32E+03	1.6E+00
Xe-135	3.48E+03	9.2E-01
I-129	7.20E-02	2.0E-05
I-131	1.26E-02	3.4E-06
Particulates:		
Co-60	1.30E-05	3.6E-09
Se-75	<4.00E-04	<1.1E-08
Sr-89,90	1.35E-03	3.7E-07
Zr-95	1.67E-03	4.6E-07
Nb-95	3.29E-03	9.0E-07
Ru-103	1.37E-03	3.7E-07
Ru-106	4.53E-02	1.2E-05
Cs-134	2.20E-03	6.0E-07
Cs-137	1.07E+00	2.9E-04
Ce-141	6.00E-06	1.6E-09
Ce-144	3.15E-02	8.6E-06
Os-185	<7.00E-05	<1.9E-08
Total U	8.52E-03	2.3E-06
Pu-238	1.96E-03	5.4E-07
Pu-239	4.07E-04	1.1E-07
Cm-242,244	2.04E-04	5.6E-08
Am-241,243	3.22E-04	8.8E-08

Higher values were detected at the onsite monitoring stations near the F- and H-Separations Areas. Concentrations of ^{238}Pu ranged up to 220 aCi/m³ and ^{239}Pu ranged up to 93 aCi/m³ at these locations.

SRP-released tritium was detected at offsite monitoring stations and shows a decreasing trend with distance from the site as shown in the table at right:

Onsite tritium oxide concentrations in air ranged from 6.5 to 7,200 pCi/m³. The maximum value was detected at the H-Area monitoring station.

TABLE 2-3. AVERAGE INDIVIDUAL DOSES AT THE PLANT PERIMETER FROM ATMOSPHERIC RELEASES

By Pathway

Pathway	Avg. Individual Dose, mrem*	Percent of Total Dose
Plume	9.54E-02	36.18
Ground	1.77E-02	6.71
Inhalation	6.72E-02	25.48
Vegetation	5.32E-02	20.17
Milk	1.49E-02	5.65
Meat	1.53E-02	5.80
Total	2.64E-01	

By Radionuclide

Radionuclide	Avg. Individual Dose, mrem*	Percent of Total Dose
Gases and Vapors:		
H-3	1.08E-01	40.91
C-14	6.85E-03	2.59
Ar-41	8.75E-02	33.14
Kr, Xe isotopes	7.91E-03	3.00
I-129	1.75E-02	6.63
I-131	3.54E-05	0.01
Particulates:		
Ru-106	1.46E-03	0.55
Cs-137	2.82E-02	10.68
U-235,238	2.66E-03	1.01
Pu-238	2.07E-03	0.78
Pu-239	4.78E-04	0.18
Am-241,243	4.64E-04	0.18
Cm-242,244	1.51E-04	0.06
Total	2.64E-01	

* Committed effective dose equivalent.

Average tritium concentrations in the SRP vicinity

Location	Tritium (pCi/m³)
Onplant	1,000
Plant Perimeter	81
25-Mile Radius	25
100-Mile Radius	9.9

TABLE 2-4. MAXIMUM INDIVIDUAL DOSES AT THE PLANT PERIMETER FROM ATMOSPHERIC RELEASES

By Pathway

Pathway	Average Consumption Maximum Individual Dose, mrem*	Average Consumption Percent of Total Dose	Maximum Consumption Maximum Individual Dose, mrem*	Maximum Consumption Percent of Total Dose
Plume	1.70E-01	37.98	1.70E-01	26.34
Ground	2.90E-02	6.48	2.90E-02	4.49
Inhalation	1.11E-01	24.80	1.11E-01	17.20
Vegetation	8.77E-02	19.59	2.35E-01	36.42
Milk	2.47E-02	5.52	7.03E-02	10.89
Meat	2.52E-02	5.63	3.00E-02	4.65
Total	4.48E-01		6.45E-01	

By Radionuclide

Radionuclide	Average Consumption Maximum Individual Dose, mrem*	Average Consumption Percent of Total Dose	Maximum Consumption Maximum Individual Dose, mrem*	Maximum Consumption Percent of Total Dose
Gases and Vapors:				
H-3	1.79E-01	39.96	2.85E-01	44.16
C-14	1.13E-02	2.52	2.74E-02	4.25
Ar-41	1.57E-01	35.05	1.57E-01	24.33
Kr,Xe isotopes	1.36E-02	3.04	1.36E-02	2.11
I-129	2.88E-02	6.43	7.39E-02	11.45
I-131	5.82E-05	0.01	1.30E-04	0.02
Particulates:				
Ru-106	2.39E-03	0.53	3.04E-03	0.47
Cs-137	4.62E-02	10.31	7.41E-02	11.48
U-235,238	4.40E-03	0.98	5.21E-03	0.81
Pu-238	3.43E-03	0.77	3.71E-03	0.57
Pu-239	7.90E-04	0.18	8.56E-04	0.13
Am-241,243	7.67E-04	0.17	1.03E-03	0.16
Cm-242,244	2.50E-04	0.06	3.34E-04	0.05
Total	4.48E-01		6.45E-01	

* Committed effective dose equivalent.

Summary of 1987 Atmospheric Releases and Concentrations

Radioactivity released to the atmosphere from SRP facilities during normal operations is monitored at the source of release for all atmospheric effluents. Releases of radioactive materials to the atmosphere in 1987 are shown in Table 2-2 on p. 13 (also in Vol. II). Gases and vapors are the major constituents of the releases and also contribute most of the offsite dose.

Tritium is the only radionuclide of SRP origin which is detected routinely in offsite air. The maximum concentration of tritium oxide measured at the plant perimeter in 1987 was 286,000 pCi/m^3 due to the tritium release which occurred on July 31, 1987 (see Chapter 8). Tritium concentrations were also

TABLE 2-5. 80-KM POPULATION DOSE - 1987 ATMOSPHERIC RELEASES

By Pathway

Pathway	Population Dose person-rem*	Percent of Total Dose
Plume	4.17E+00	14.25
Ground	4.18E+00	14.29
Inhalation	8.64E+00	29.53
Vegetation	8.48E+00	28.98
Milk	2.06E+00	7.04
Meat	1.73E+00	5.91
Total	2.93E+01	

By Radionuclide

Radionuclide	Population Dose person-rem*	Percent of Total Dose
Gases and Vapors:		
H-3	1.50E+01	51.28
C-14	9.79E-01	3.35
Ar-41	3.63E+00	12.41
Kr,Xe isotopes	5.37E-01	1.84
I-129	2.62E+00	8.96
I-131	8.56E-03	0.03
Particulates:		
Ru-106	1.42E-01	0.49
Cs-137	5.56E+00	19.01
U-235,238	3.82E-01	1.31
Pu-238	2.57E-01	0.88
Pu-239	5.92E-02	0.20
Am-241-243	5.89E-02	0.20
Cm-242,244	1.92E-02	0.07
Total	2.93E+01	

* Committed effective dose equivalent.

calculated using computer codes and standard meteorological dispersion equations [USNRC73]. The average concentration of tritium oxide measured at plant perimeter monitoring stations was 81 pCi/m^3, which is the same as the calculated value shown in Table 2-2 on p. 13. Thus, it appears that the calculated concentrations in the table are a reasonable estimation of the offsite effect of releases of radioactive materials.

Offsite Radiation Doses from Atmospheric Releases

Offsite radiation dose commitments from atmospheric releases during 1987 were calculated for individuals closest to the plant site and for cumulative population dose out to a distance of 80 km (50 miles) from the center of the site using meteorological data for the period 1982 through 1986. Table 2-3 on p. 13 (also in Vol. II) shows the calculated dose commitments to the average individual at the plant perimeter by pathway. Dose commitments, based on annual releases, were calculated for persons with normal living habits residing at 320 locations equidistantly spaced along the plant perimeter. These dose commitments were then averaged over the 320 locations to give the values in Table 2-3.

The dose commitment of 0.3 mrem (0.003 mSv) to the average individual was 0.09% of the normal average dose of about 295 mrem (2.95 mSv) from natural radiation sources in the Central Savannah River Area [NCRP87a].

Table 2-4 on p. 14 (also in Vol. II) shows the dose by pathway to a hypothetical individual located at the plant perimeter at the point of maximum exposure. With an assumed average dietary intake, the dose to this individual is 0.4 mrem (0.004 mSv). If the maximum intake of all types of food (milk, meat, and vegetables) is assumed, the dose is 0.6 mrem (0.006 mSv) which is 2.4% of the NESHAPS standard of 25 mrem/year to a member of the public.

Doses were calculated for individuals within 80 km (50 miles) of the SRP site at normal places of residence, and the individual doses were summed to obtain the population doses shown in Table 2-5 (also in Vol. II). The population dose commitment calculated in this manner for the population of 550,000 within 80 km of the plant site in 1987 was 29.3 person-rem (0.29 person-Sv). This dose is equivalent to an average dose of 0.05 mrem (0.0005 mSv) and is 0.02% of the dose of 295 mrem received annually by the 80-km-radius population from natural radiation sources.

Environmental Gamma Radiation

Continuous measurements of the intensity of gamma radiation levels at and around SRP were made with thermoluminescent dosimeters (TLDs).

In the unlikely event of a significant unplanned radioactivity release, these 350 monitoring stations would provide a quick and reliable method to determine external gamma radiation doses to population groups within an 8,000-square-mile area in the vicinity of SRP. Five Panasonic TLDs are placed at each station with a 90-day collection cycle. The TLDs are placed at stations up to a 100-mile radius from SRP. The number of stations and their locations are shown in the table below:

Location	No. of TLD Stations
Onplant	100
Plant Perimeter	174
SC Cities and Towns	48
GA Cities and Towns	30

Changes to 1987 Monitoring Program. During 1987, the environmental TLD program changed from using SRP-designed TLDs to using Panasonic-801 TLDs (described in Chapter 8). Both types of TLDs were used through the third quarter of 1987, with a complete conversion to the Panasonic TLDs in the fourth quarter.

Monitoring Results. Environmental gamma radiation fields vary significantly from one location to another because of differences in the terrestrial and cosmic components of the natural background radiation. The differences are influenced by the decay products of radium and thorium in the soil. The table below provides a comparison of 1987 TLD results with 1986 results. Summaries of all TLD results are presented in Tables 2-6 and 2-7 of Vol. II, and locations are shown in Figs. 2-4 and 2-5, Vol. II.

Radiation levels above background were detected at the fences around operating facilities. The maximum was 1.6 mR/day around H Area which reflected radiation from process equipment or work being performed inside the area. The F-Area Separations maximum was 0.55 mR/day.

Plant Perimeter Radioactivity Stations. In addition to the monitoring stations described on p. 9, there are 12 plant perimeter stations which monitor gamma radiation levels and tritium concentrations. These stations supplement the plant's emergency response capability by continuously measuring and periodically reporting gamma radiation levels and tritium concentrations from each 30° sector around SRP. The gamma monitors are capable of detecting radiation levels from 10 μR/hr to 1,000 R/hr. The tritium ion chambers can detect tritium concentrations from 1×10^{-6} μCi/mL to 1×10^{-2} μCi/mL.

The monitors are housed in temperature-controlled buildings. Using a U.S. Geological Survey satellite telemetry system, each monitoring station transmits data at least once per day. Should an emergency occur, the monitors can be set to transmit data at six-minute intervals. The data are transmitted to the WIND (Weather INformation and Display) system computers and integrated into the overall emergency response system.

Comparison of 1987 TLD Gamma Radiation Measurements with 1986 Results

Identification	No. of Locations	Maximum (mR/yr) 1986	Maximum (mR/yr) 1987	Minimum (mR/yr) 1986	Minimum (mR/yr) 1987	Average (mR/yr) 1986	Average (mR/yr) 1987
Plant Perimeter Stations							
Air Sampling Locations	13	84	135	47	47	73	73
1-Mile Intervals	79	106	135	29	40	44	69
25-Mile Radius	12	84	113	47	51	58	77
100-Mile Radius	4	204	124	40	62	84	95
Cities and Towns (South Carolina and Georgia)							
Inside Buildings	62	803*	219	37	47	113	113
Outside Buildings	62	226	164	33	47	100	102

* Result of one unexplainably high value at the inside location in Columbia, SC - "Shandon." Other measurements during the year at this location were within normal ranges.

Power Plant Location	No. of Boilers	Capacity of Each Boiler 10^6 Btu/hr Input
A-Administration Area	2	71.7
D-Powerhouse Area	4	396
H-Separations Area	3	71.7
K-Reactor Area	2	194.5
P-Reactor Area	2	194.5

Monitoring Results. Atmospheric emissions of sulfur dioxide, oxides of nitrogen, and total suspended particulates from power plants at SRP were within applicable standards in 1987. Compliance with the sulfur dioxide (SO_2) emissions standard at power plants is determined by analysis of the coal received. The sulfur content of coal burned at SRP in 1987 averaged 1.0%, which yielded an average of 1.73 lb $SO_2/10^6$ Btu input. This is 49% of the South Carolina standard.

NONRADIOACTIVE MONITORING

Atmospheric Emissions

Description of Monitoring Program. Five coal-fired power plants located at SRP burned a total of 452,980 tons of coal in 1987. The location, number of boilers and capacity of each boiler for each of these plants are listed in the table above.

The four D-Powerhouse Area boilers use pulverized coal; all of the other boilers are stoker fed. The D-Powerhouse also burns waste oil. The content of the coal delivered to the site for burning is determined by analyses for sulfur, carbon, ash, water and Btu output.

There are six other onsite process stacks with major emissions of nonradioactive materials. They include three 313-M stacks and one 321-M stack in the M-Fuel Fabrication Area and the two 291 stacks in the F- and H-Separations Areas.

Applicable Standards. Nonradioactive atmospheric emissions from SRP stacks are regulated by permits issued by the South Carolina Department of Health and Environmental Control (SCDHEC). Air Emissions Standards are listed below.

Sulfur dioxide	3.5 lb/10^6 Btu input
Total suspended particulates	0.6 lb/10^6 Btu input
Opacity	40%*

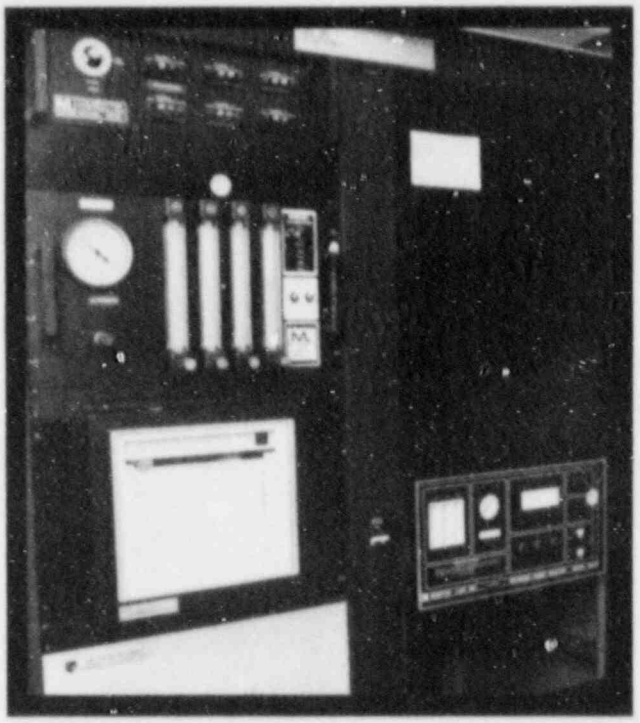
* Applicable for process stacks in existence prior to January 1, 1986, and powerhouse stacks built before February 11, 1971, when these standards become effective. For stacks that came on line after these dates, the standard is 20%.

The day-to-day control of total suspended particulates and oxides of nitrogen is maintained by use of opacity meters in all SRP powerhouse stacks. These measurements indicated that SRP boilers were within limits more than 99% of the time in 1987.

Compliance with standards for oxides of nitrogen and total suspended particulates is determined by periodic air compliance tests conducted every two years by specialists in air emissions testing under contracts issued by SRP. All SRP boilers were within compliance limits during the latest series of tests conducted in the second half of 1987.

A new regulation limiting opacity of oxides of nitrogen went into effect in February 1986. As indicated in the table at the bottom of the page, the new standard is 20%, except for stacks that existed before January 1, 1986, and powerhouse stacks built before February 11, 1971; these existing stacks are subject to a 40% opacity limit. All SRP process stacks, including the four 300-M stacks and 291-F and -H stacks, are subject to the 40% limit. In 1987, all stacks met the 40% opacity requirement except for the 291-F stack, which occasionally exceeded the limit. Rework of the deteriorating acid absorption column in 291-F stack reduced the opacity of the stack to borderline compliance. A number of programs (including a multi-million dollar absorber column control project) are being pursued to ensure that the opacity is below 40% on all occasions. The absorber column project is scheduled for completion in December 1989.

In December 1987, SCDHEC conducted an compliance inspection of all permitted air emission sources. All emissions were within applicable standards.



Ambient air monitor

Ambient Air Quality

Description of Monitoring Program. The quality of air at SRP is monitored at several locations around the site that measure total suspended particulates, sulfur dioxide, oxides of nitrogen, and ozone. The operation of these stations is consistent with requirements of the EPA and SCDHEC. Additional monitoring of ambient air quality near SRP is performed by the states of South Carolina and Georgia as part of the network associated with the Clean Air Act Amendments of 1970.

Changes in 1987 Monitoring Program. Changes in the 1987 monitoring program were as follows:

- Two ambient monitoring stations were discontinued on June 30, 1987, bringing the total number of monitoring stations to four. The two stations, 614-37G and 614-36G, were discontinued as the result of a technical reevaluation of the program.
- Existing samplers for total suspended particulates were modified by installing PM_{10} size selective inlets. These inlets allow only particulates of 10μ and smaller to impact the filter paper.
- During the second quarter, barometers were installed in all air monitoring stations to make current barometric data available throughout the day.
- Data management computer software was upgraded to provide automatic creation of database space for the upcoming year.

	Air Quality Standard			
	South Carolina[b]	Georgia	SRP Maximum	Percent[a] Standard
Sulfur dioxide (μg/m³)				
3 hour	1300[c]	1300	146	11
24 hour	365[c]	365	53	14
Annual	80	80	6	8
Total suspended particulates (μg/m³)				
24 hour	250	150	120	80
Annual geometric mean	60	75	38	63
Ozone (ppm)				
1 hour	0.12[d]	0.12	0.100	83
Nitrogen dioxide (μg/m³)				
Annual	100	100	7	7

[a] Compared to the most restrictive standard.
[b] Lead, carbon monoxide and gaseous fluorides are not monitored because the potential release is insignificant compared to the standard.
[c] Not to be exceeded more than once a year.
[d] Not to be exceeded more than one day a year.

Applicable Standards. Georgia and South Carolina air quality standards are shown in the comparison table on the bottom of p. 18.

Monitoring Results. Listed in the same table is a comparison of monitoring data from the SRP ambient air monitoring stations with Georgia and South Carolina standards.

The locations of the SRP monitoring stations and analyses performed at each station are shown in Fig. 2-6, Vol. II, and monitoring data are presented in Table 2-8, Vol II.

The latest available air quality measurements of the South Carolina and Georgia network monitored by the states in the vicinity of SRP are presented in Tables 2-9 and 2-10 of Vol II. The measurements indicate that the air quality near SRP is good and well within the EPA standards.

1987 HIGHLIGHTS

- Onsite tritium concentrations in air ranged from 6.5 to 7,200 pCi/m^3. The maximum value was detected at the H-Area monitoring station. Tritium was the only radionuclide of plant origin routinely detected offsite in air.
- No significant difference was noted between average measurements of plutonium in air at the site boundary and offsite. The highest values were detected onsite near the F- and H-Separations Areas, but were within ranges observed in previous years.
- The maximum dose commitment to a hypothetical individual at the SRP boundary from atmospheric releases was 0.6 mrem (0.006 mSv), or 0.2% of the normal average dose of about 295 mrem (2.95 mSv) from natural radiation sources. The average dose commitment to a hypothetical individual at the SRP boundary from atmospheric releases was 0.3 mrem (0.003 mSv), or 0.09% of the normal average dose from natural radiation sources.
- Continuous measurements from 350 monitoring stations provide a quick and reliable method to determine external gamma radiation doses to population groups within an 8,000-square-mile area in the vicinity of SRP.
- The 12-station plant perimeter radioactivity monitoring system is capable of continuously measuring gamma radiation from 10 μR/hr to 1,000 R/hr, and tritium levels from 1×10^{-6} μCi/mL to 1×10^{-3} μCi/mL.
- The sulfur content of coal burned at SRP in 1987 averaged 1.0%, which yielded an average of 1.73 lb $SO_2/10^6$ Btu input. This is 49% of the South Carolina standard.
- Two ambient air monitoring stations were discontinued on June 30, 1987, bringing the total number of monitoring stations to four.

3
Surface Water Monitoring Program

SUMMARY — This chapter describes the radioactive and nonradioactive monitoring of surface waters on and around SRP, summarizes the results of these surveys, and compares the results to the applicable standards. The Savannah River and all streams located on the SRP site are continuously sampled to monitor radioactivity released in effluent water from SRP facilities. This comprehensive program consists of monitoring at 35 SRP stream locations and six Savannah River locations for alpha, nonvolatile beta, tritium, and a variety of specific radionuclides. Water samples from seepage basins in the F, H, P, K, L, and C Areas, which generally reflect concentrations observed in the wastewater released to the basins, were also monitored. Liquid releases and concentrations of radioactive materials, including an inventory of tritium released, are summarized, and offsite radiation doses from these liquid releases are calculated. The highest potential dose commitment from releases of radioactivity from SRP to the Savannah River to a hypothetical individual is 0.9 mrem (0.009 mSv), which is 0.3% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources. Surface water is monitored nonradiologically for chemicals, metals, temperature, and other physical and biological properties. Operational effluents from SRP facilities discharge through 68 active point-source outfalls under a SCDHEC permit. River quality surveys conducted by the Academy of Natural Sciences of Philadelphia are described, and results of river and stream temperature profile surveys are reported.

RADIOACTIVE MONITORING

Savannah River

Description of Monitoring Program. The Savannah River is continuously sampled with paddlewheel samplers at strategic locations above, adjacent to, and below SRP in order to monitor radioactivity released to the Savannah River via SRP streams. The river sampling locations are presented in Fig. 3-1 on p. 22 (also in Vol. II). River flow is measured with United States Geological Survey (USGS) flow recorders at sampling stations R-2 above SRP and R-10 below SRP. The sampling program consisted of six sampling locations in 1987.

The continuous river paddlewheel samples are generally collected weekly for analyses of alpha, nonvolatile beta, tritium, and a variety of specific radionuclides. The frequency and type of analysis varies from location to location and is based upon the potential quantity and type of radioactivity likely to be present. The sample locations and frequencies of analysis change from time to time to accommodate changes in SRP operations and variations in radiological conditions.

Applicable Standards. DOE derived concentration guides (DCGs) for surface water apply to SRP releases to the Savannah River (Table 3-1 on p. 23). EPA drinking water standards apply at the downriver water treatment plants.

Monitoring Results. In 1987, no measurable differences were detected between upriver and downriver alpha and beta concentrations in the Savannah River. Alpha and nonvolatile beta concentrations in river water samples at stations R-2 (upriver) and R-10 (downriver) were determined in both dissolved and suspended portions of the samples. Average concentrations of alpha activity were near or less than the minimum detectable concentration of approximately 0.3 pCi/L. Maximum nonvolatile beta concentrations for 1987 (excluding tritium) ranged from 0.88 to 4.1 pCi/L, compared to a range of 1.3 to 6.0 pCi/L in 1986. River monitoring data are presented in Table 3-1, Vol. II.

The release of tritium accounted for more than 99% of the total radioactivity introduced into the Savannah River from SRP activities during 1987. Fig. 3-2 on p. 23 (also in Vol. II) shows tritium releases at the source for the years 1983 through 1987. Tritium

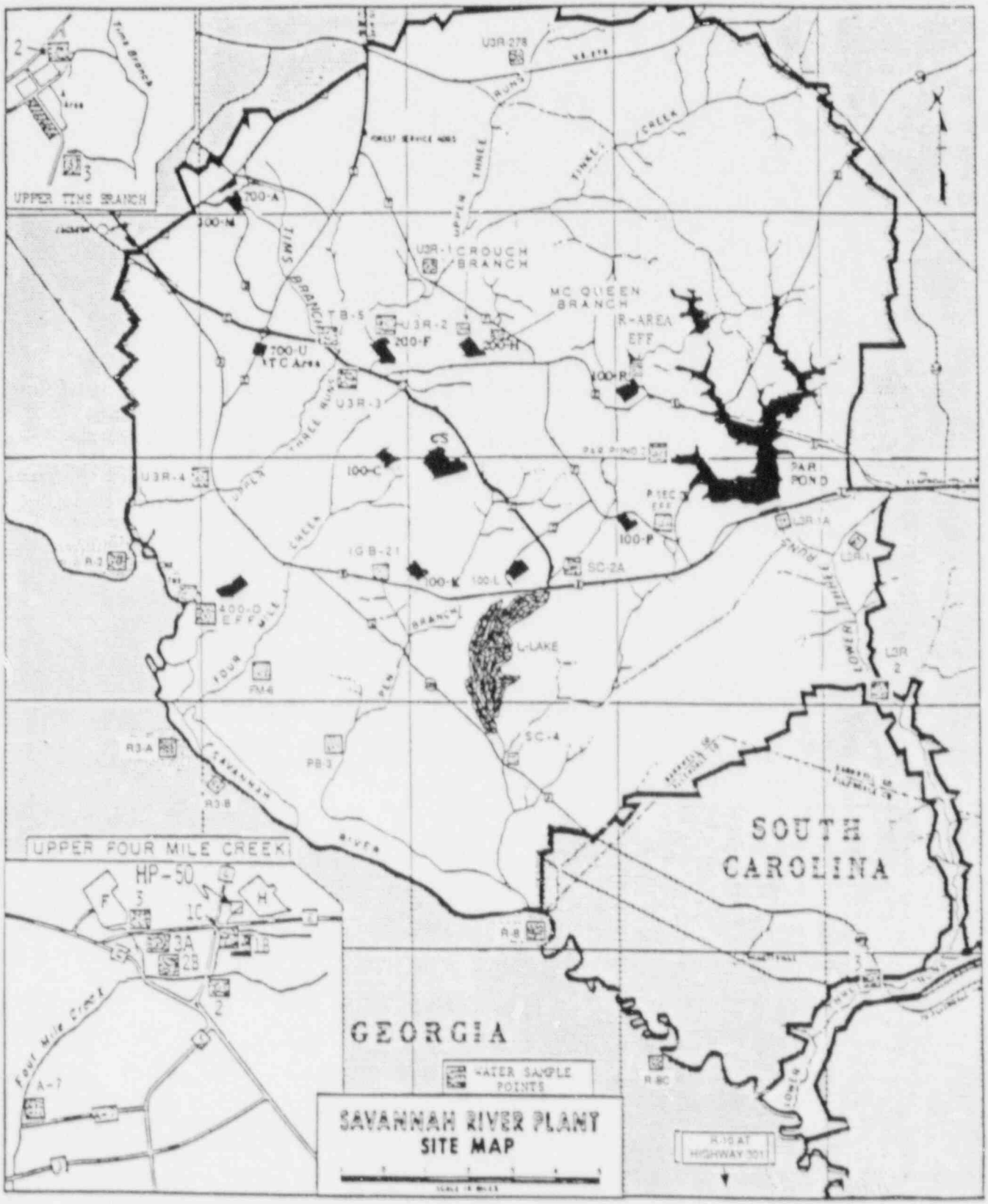


Fig. 3-1. Stream and river sample locations

measured in transport in the river was 26,145 Ci in 1987, compared to 22,120 Ci in 1986. The average river flow in 1987 was about 10,328 ft^3/sec, which is 146% of the 1986 flow rate of 7,070 ft^3/sec. After dilution by SRP streams and the Savannah River, tritium concentrations in 1987 averaged 3.3 pCi/mL in the river below SRP at Highway 301 compared to 3.9 pCi/mL in 1986. The higher river flow rate in 1987 accounts for the fact that the average tritium concentration in the river in 1987 was lower than in 1986 even though the amount of tritium released to the river was greater.

Savannah River water is routinely monitored for gamma-emitting radionuclides by concentrating the radioactivity in about 20 liters of water on ion exchange columns. Ion columns are counted directly for gamma emitters and then chemically analyzed for radiostrontium. The only radionuclide other than tritium detected in river water by routine analytical techniques was ^{90}Sr in trace quantities. Routine analytical techniques are described in Chapter 10. Other radionuclides may be detected by ultra-low-level analysis techniques.

The quantity measured in transport in the river was 2.2 Ci of ^{90}Sr in 1987. This amount of ^{90}Sr corresponds to concentrations in the river below SRP that are indistinguishable from worldwide fallout levels of ^{90}Sr detected upriver of SRP. The average concentrations of ^{90}Sr both upriver and downriver of SRP were less than the minimum detectable concentration of 0.3 pCi/L (averages of data include zeros for observations below lower limits of detection and negative values that sometimes result from instrument background corrections; see Chapter 11).

Table 3-1. DOE Derived Concentration Guides For Surface Water (pCi/L)[a]

H-3	2,000,000	Cs-134	2,000
C-14	70,000	Cs-137	3,000
Co-58	40,000	Ce-141	50,000
Co-60	5,000	Ce-144	7,000
Sr-89	20,000	U-235	600
Sr-90	1,000	U-238	600
Zr-95	40,000	Pu-238	40
Nb-95	60,000	Pu-239	30
Ru-103	50,000	Am-241	30
Ru-106	6,000	Cm-242	1,000
I-129	500	Am-243	30
I-131	3,000	Cm-244	60

[a] Department of Energy draft order DOE 5480.XX for soluble forms.

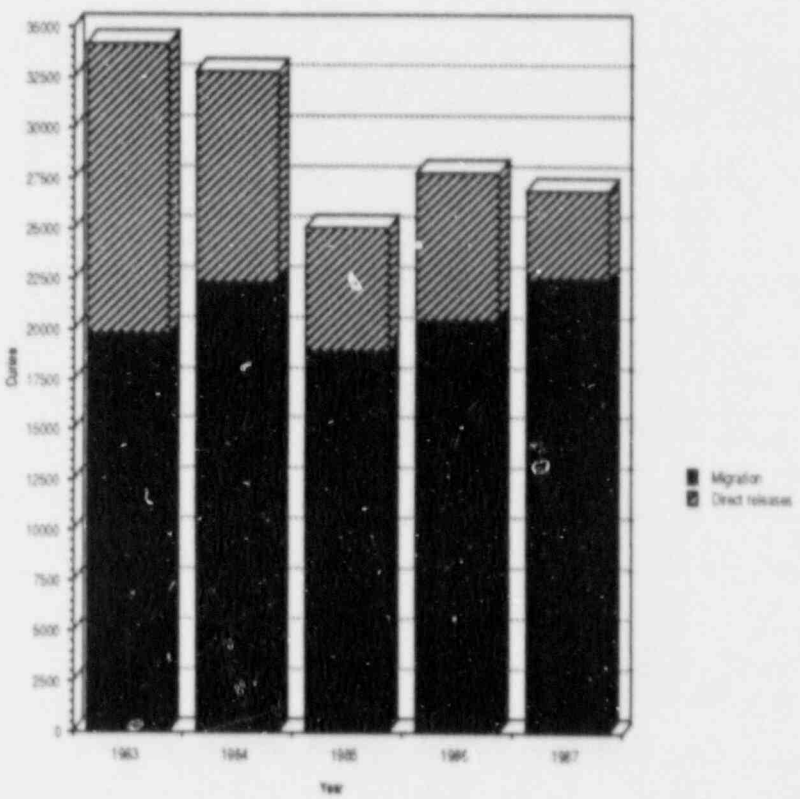


Fig. 3-2. Tritium releases at source

SRP Streams

Description of Monitoring Program. All streams located on the SRP site are continuously sampled at

Savannah River

strategic locations to monitor radioactivity released in effluent water from SRP facilities. This comprehensive program consists of monitoring at 35 SRP stream locations. Stream sample locations are presented in Fig. 3-1. At most locations stream flows are determined with USGS flow recorders. Sampling is maintained on all major streams near Road A (Highway 125), a convenient monitoring location before the streams exit the SRP site.

The continuous samples are generally collected weekly for analyses of alpha, nonvolatile beta, tritium and numerous specific radionuclides. The analyses vary in frequency and type from one location to another and are generally based upon the potential quantity and type of radioactivity. The sample locations and frequencies of analyses are sometimes changed in accordance with changes in SRP operations and variations in radiological conditions.

Changes in 1987 Program. During March 1987, a continuous sampler was installed in Crouch Branch to monitor stormwater runoff from the northeast side of the H-Separations Area. Crouch Branch is a tributary of Upper Three Runs Creek (see Fig. 3-1).

Applicable Standards. The DOE DCGs (Table 3-1) apply at the site boundary, which is the Savannah River. DCGs, however, are reasonable references for gauging the impact of radioactivity in stream water. In addition, offsite surface water was sampled to provide background data (i.e., data from comparable waterways that are unlikely to have been significantly influenced by SRP operations). A good indication of background radioactivity concentrations in offsite surface water similar to SRP streams is provided by radioactivity measurements in the Edisto River, a small river that is similar in many characteristics to SRP streams. The maximum concentrations detected in the Edisto River during 1987 are shown in Table 3-2 at the bottom of the page.

Monitoring Results. Stream monitoring data are presented in Table 3-2, Vol. II. The use of background values and DCGs provide references for evaluating stream data. Table 3-3 at the bottom of the facing page presents maximum, average, and minimum radioactivity values for plant streams and the Edisto River. Direct liquid tritium releases to plant streams for the years 1983 through 1987 are represented in the top right column of p. 25 in Fig. 3-3 (also in Vol. II).

Tims Branch (TB) received effluents from the M-Fuel Fabrication Area and SRL. SRL releases were negligible. The M-Area effluent contained small quantities of uranium. The average alpha and nonvolatile beta concentrations in the M-Area effluent were 3.3 and 7.2 pCi/L, respectively. M-Area releases to TB flow downstream and enter Upper Three Runs Creek (U3R). Average alpha and nonvolatile beta concentrations in TB, before entering U3R, were 0.41 and 1.4 pCi/L, respectively. These concentrations are within the ranges observed in control samples from the Edisto River.

Table 3-2. Background Radioactivity Levels in Offsite Streams[a]

Radiation type	Maximum concentration in 1987 (pCi/L)
Alpha	1.5
Nonvolatile beta	2.9
Tritium	940

[a] Based on measurements taken in the Edisto River, a small river that is similar to SRP streams.

Upper Three Runs Creek (U3R) also receives stormwater runoff from parts of the F- and H-Separations Areas. During January 1987, elevated alpha and nonvolatile beta concentrations were detected in samples from U3R at Road C. These concentrations were attributed to a solvent release that occurred when a solvent sump area in the H-Separations Area overflowed. The maximum concentrations of alpha and nonvolatile beta for 1987 in U3R (due to this release) were 1.5 and 2.6 pCi/L, respectively. These concentrations are within the ranges observed in the Edisto River.

Beaver Dam Creek (BDC) received effluents from the heavy water rework and laboratory facilities in 400-D Area. Tritium oxide was the principal radionuclide released. Tritium concentrations in BDC ranged to a maximum of 360 pCi/mL. The average tritium concentration in BDC for 1987 was 19 pCi/mL. Average alpha and nonvolatile beta concentrations in BDC for 1987 were 0.08 and 1.9 pCi/L respectively, within the ranges observed in the Edisto River.

Four Mile Creek (FMC) received effluents from fuel reprocessing facilities in the F- and H-Separations Areas and from the C-Reactor Area. C Reactor was not in operation in 1987 and released only 3.8 Ci of tritium in liquid effluent releases for the entire year. Four Mile Creek also received tritium and ^{90}Sr migrating from the F- and H-Separations Area seepage basins and the Solid Waste Storage Facility (Burial Ground).

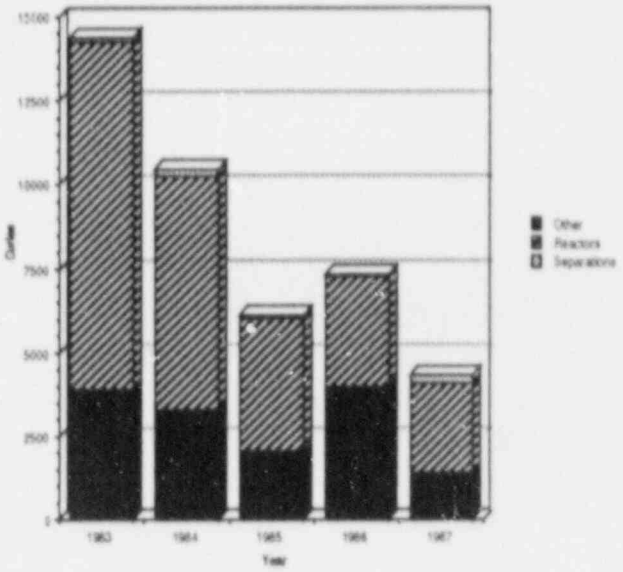


Fig. 3-3. Direct tritium releases to streams excluding seepage basin migration

Tritium concentrations in FMC ranged to a maximum of 5,200 pCi/mL at FM-1C which contains releases from H-Separations Area. This maximum concentration, which occurred in February 1987, was attributed to a release from the tritium facilities. A thermal diffusion column wall failed, contaminating process cooling water that was subsequently released to FMC. This event resulted in a release of 156 Ci of tritium to FMC.

The maximum of the averaged concentrations at the FMC sampling points was 2,400 pCi/mL. After dilu-

Table 3-3. Radioactivity in Plant Stream Water

	Alpha (pCi/L)			Nonvolatile Beta (pCi/L)			Tritium (pCi/mL)		
Location*	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Tims Branch	1.7	-0.08	0.37	4.6	-0.85	1.6	2.8	-0.38	1.1
Upper Three Runs	1.7	0.00	0.56	11	-0.58	3.0	3.3	1.6	2.4
Beaver Dam Creek	0.54	-0.23	0.08	3.4	0.42	1.9	360	-0.01	19
Four Mile Creek	15	-0.16	0.72	140	8.7	35	3,300	34	1,020
Indian Grave Branch	0.41	0.00	0.18	1.8	-0.26	0.82	9,600	62	5,371
Pen Branch	0.38	-0.08	0.07	2.8	0.49	1.6	66	7.9	13
Steel Creek	0.69	-0.08	0.16	11	0.95	5.1	70	1.6	26
Lower Three Runs	0.91	-0.16	0.09	7.1	0.58	4.1	12	0.77	6.6
Control									
Edisto River	1.5	0.00	0.51	2.9	-0.06	1.0	0.94	-0.42	0.41

*Does not include effluent sampling points.

Steel Creek Monitoring Data						
	1985		1986		1987	
Analysis	Max	Avg	Max	Avg	Max	Avg
Alpha, pCi/L	0.69	0.14	0.78	0.15	0.41	0.10
Nonvolatile Beta, pCi/L	8.9	4.0	6.3	2.4	3.5	2.0
Tritium, pCi/mL	17	8.6	4.7	2.5	4.5	2.8
Sr-89,90, pCi/L	0.94	0.33	0.75	0.13	0.51	0.11
Cs-134, 137, pCi/L	9.3	3.5	3.7	0.87	3.2	0.32

tion by other water in FMC, the average concentration of tritium in FMC before entering the river (Road A) was 590 pCi/mL.

Indian Grave Branch (IGB) receives tritium migration from the K-Reactor containment basin. IGB flows into Pen Branch (PB) which also receives heat exchanger cooling water from K-Reactor Area. The maximum tritium concentration was 9,600 pCi/mL at sampling location IGB-21, which is downgradient from the containment basin. After dilution, the maximum tritium concentration measured in PB at Road A was 66 pCi/mL. Alpha and nonvolatile beta concentrations in PB at Road A were at or near background ranges.

Steel Creek received radioactive releases from the migration of tritium from P-Reactor Area seepage basin and from effluents from L-Reactor Area. These releases enter L Lake, which overflows to Steel Creek near Road A. Most radionuclide concentrations in Steel Creek below L Lake represent notable decreases from their 1985 levels. The decreases likely resulted from the increased flow of river water used in L-Reactor. Maximum and average concentrations for Steel Creek are presented in the table at the top of the page.

Par Pond receives P-Reactor heat exchanger cooling water and other effluents from P Area. Par Pond also receives all storm sewer outfalls from the deactivated R Area and from a few storm sewers from P Area. The average concentrations detected in Par Pond water in 1987 were 0.32 pCi/L of alpha, 5.9 pCi/L of nonvolatile beta, and 9.3 pCi/mL of tritium.

The overflow from Par Pond goes to Lower Three Runs Creek (L3R). Maximum concentrations in L3R at Road A were 0.23 pCi/L of alpha, 5.7 pCi/L of nonvolatile beta, and 4.1 pCi/mL of tritium. These concentrations for 1987 were essentially unchanged from 1986.

There were no radioactive releases from TNX Area. Radioactivity concentrations in the TNX-Area outfalls were at or near background ranges.

Seepage Basins

Description of Monitoring Program. Seepage basins are shallow, earthen excavations used to receive wastewater containing low concentrations of chemicals and radionuclides. The waste water seeps downward through the sides and floor of a basin to

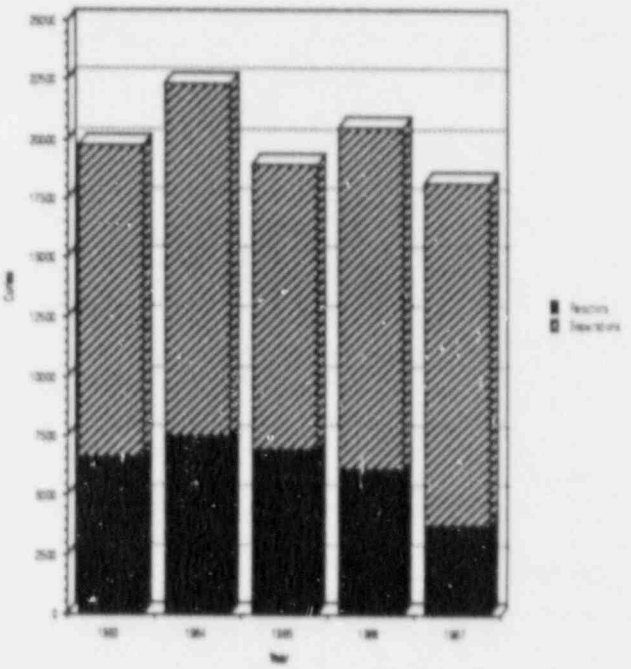


Fig. 3-4. Tritium migration from seepage basins

the shallow groundwater. After mixing with the groundwater it generally flows slowly in a horizontal direction, eventually outcropping into a surface stream. During its slow travel through the soil, the wastewater loses some of its contaminants by precipitation, filtration, adsorption, ion exchange, and radioactive decay [St83].

Water samples from seepage basins located in F, H, P, K, L, and C Areas generally reflect concentrations observed in the wastewater released to the basins. The settling basin at 300-M Area was taken out of service in July 1985, when the Liquid Effluent Treatment Facility (LETF) was placed in operation. Wastewater is released to Tims Branch after treatment in the LETF. The results of seepage basin sample analyses are presented in Table 3-3, Vol. II, and the seepage basin locations are shown in various figures in Vol. II. Fig. 3-4 at the bottom of p. 26 (and in Vol. II) shows tritium migration from seepage basins for the years 1983 through 1987.

Migration of Radioactivity from F- and H-Area Seepage Basins and K-Area Containment Basin. Tritium was the only radionuclide detected migrating from the K-Area containment basin to Pen Branch. Weekly flow measurements combined with tritium concentrations measured in Indian Grave Branch (a tributary of Pen Branch) indicated migration of 3,600 Ci in 1987. This quantity represents a 41% decrease from 1986. This migration is subsequently diluted by heat exchanger cooling water from K-Reactor Area before entering the river.

Migration of radioactivity from F-and H-Separations Area seepage basins was measured with continuous samplers and flow recorders in Four Mile Creek. Groundwater from the F-Separation Area seepage basins outcrops into Four Mile Creek (FMC) between sampling locations FM-3A, FM-2B, and FM-A7. Most of the H-Area seepage basin outcropping from basins 1 through 3 occurs between FM-1C and FM-2B. Flow measurements at FM-2B were estimated from FM-2, because beaver dams periodically backed up the water near FM-2B, causing false flow measurements. Additional outcropping from H-Area seepage basin 4 and the Solid Waste Storage Facility occurs between FM-3 and FM-3A. The radioactivity from these two sources mixes, and radioactivity from the two sources cannot be distinguished. Four Mile Creek sample locations are shown in Fig. 3-1 (also in Vol. II).

Measured migration of tritium in 1987 was 2,760 Ci from F-Area seepage basins (56% increase from 1986), 6,150 Ci from H-Area seepage basin 4 and the Solid Waste Storage Facility (18% increase from 1986), and 5,630 Ci from the other H-Area seepage basins (24% decrease from 1986).

The quantity of tritium migrating from all seepage basins to SRP streams was 18,266 Ci in 1987, compared with 20,627 Ci in 1986, an 11% decrease. The tritium migrating from seepage basins represents 80% of the total SRP tritium released to streams.

The amount of ^{90}Sr migration was 0.19 Ci from F-Area seepage basins and 0.08 Ci from H-Area seepage basins. Cesium-137 migration, if it occurs, cannot be measured because of the desorption of ^{137}Cs in the stream bed from previously released ^{137}Cs. Desorption is calculated by subtracting the F- and H-Separations Area contributions (sampling locations FM-3, FM-1C, FM-1B) from the total curies of ^{137}Cs at FM-A7. On May 1, 1987, FM-1B showed elevated nonvolatile beta and ^{137}Cs concentrations. This sampling point receives stormwater runoff from the H-Waste Management Facilities and the 288-H Ash Basin, and water from the H-Area powerhouse. The ^{137}Cs concentration in this sample was 1.0 pCi/mL. Sample points downstream of FM-1B did not show elevated ^{137}Cs concentrations. Since this result affects the transport calculation, it was assumed that the ^{137}Cs was deposited in the stream bed. Cesium-137 was not detected in the effluent (HP-52) from H-Separations Area, and thus this release was most likely due to stormwater runoff from a contaminated area. Measurements of radioactivity in transport at sample points on Four Mile Creek indicate an estimated desorption of 0.02 Ci of ^{137}Cs.

Migration of radionuclides from seepage basins is presented in Table 3-4, Vol. II. Radioactivity in transport at sample points on Four Mile Creek and desorption of ^{137}Cs from Four Mile Creek are shown in Table 3-5, Vol. II.

Migration from P- and C-Area Seepage Basins. Liquid purges from the P- and C-Reactor area disassembly basins have been released to their respective seepage basins since 1978. Purge water is released to the seepage basins so that a significant part of the tritium can decay before the water outcrops to surface streams and flows to the Savannah River. The delaying action of the basins reduces the dose that

users of water from downriver treatment plants receive from SRP tritium releases.

During the period between 1970 and 1978, disassembly basin purge water was released to SRP streams, but the seepage basins had been previously used for purging the disassembly basins (from the 1950s to 1970). The earlier experience with seepage basins indicated that the extent of radioactive decay during the holdup was sufficient to recommend their reinstatement in the P and C Areas.

Equipment was installed at locations downgradient from each basin to measure tritium migration from the P-and C-Area seepage basins. Results from paddlewheel samplers installed on Twin Lakes and Castor Creek at C Area indicated no measurable tritium that could be attributed to migration from the C-Area seepage basin in 1987. Results from a paddlewheel sampler installed on Steel Creek, above L Lake, indicated 130 Ci of tritium migrating from the P-Area seepage basin during 1987.

Inventory of Tritium Released

A comparison of the amount of tritium released from SRP facilities in 1987 with the amount of tritium measured in transport in SRP streams and in the Savannah River continued to show relatively good agreement. Point-of-release measurements are calculated from known concentrations contributed to the streams. Stream transport is measured at the last sampling point before entry into the river. Results showed that point-of-release and stream transport measurements agreed within 9% and that the point-of-release measurements were less than the river transport measurements by 16%. The cause of small differences is due to statistical uncertainties associated with measurements. Tritium inventory in the streams and in the Savannah River is summarized in Table 3-6, Vol. II.

Sources of tritium in liquid effluents include direct releases from plant facilities (20% in 1987 compared with 26% in 1986) and migration of tritium from the

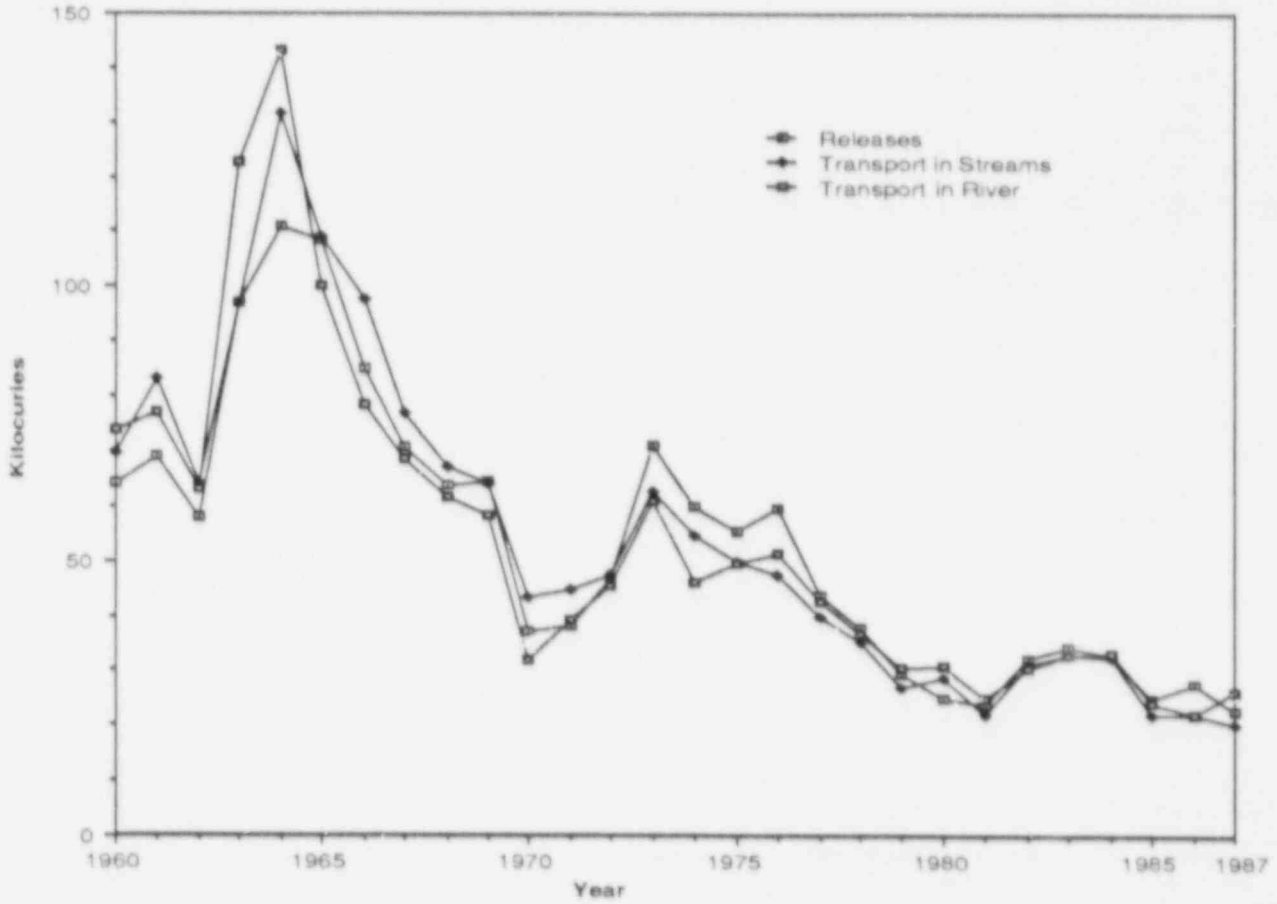


Fig. 3-5. Tritium balance summary 1960-1987

Liquid scintillation counter

Burial Ground, F-, H-, and P-Area seepage basins, and K-Area Containment Basin (80% in 1987 compared with 74% in 1986). Migration occurs when tritium released to the seepage basins in previous years reaches SRP streams via groundwater outcropping into the streams.

Relatively good agreement in the inventory of tritium measured at three locations (the point of release, plant streams before entry into the river, and the river below SRP) has been achieved each year since the statistics have been compiled (1960) as shown in Fig. 3-5 at the bottom of p. 28 (also in Vol. II). A tritium inventory summary from 1960 to 1987 is presented in Table 3-7 of Vol. II.

Before 1959, low-level measurement techniques needed for routine measurements of tritium concentrations in streams and the river were not available. The minimum detectable concentration for the vibrating reed electrometer, used at that time, was 1,000 pCi/ml. Liquid scintillation counters, developed in the late 1950s, made low-level measurements practical (the minimum detectable concentration is now 1 pCi/mL).

SRP began routine use of liquid scintillation counting in 1959 and made river and stream measurements beginning in the last half of that year. During some of the early years (1960–1964), noticeable differences occurred between releases and the amount of tritium measured in streams and the river. This discrepancy led to additional effluent monitoring points where small amounts of tritium were released (miscellaneous reactor releases), and the measurement of leakage from reactor heat exchangers to accomplish further sampling refinements.

As shown in Fig. 3-5, tritium releases to the Savannah River have decreased significantly since 1964, when the maximum tritium releases occurred. Process control improvements that have led to this decrease are:

- Change from continuous purge of reactor area disassembly basins to periodic purges in the late 1960s, allowing longer holdup time for decay, some evaporation, and a larger inventory of tritium in the basins.
- Development of equipment and techniques to flush and contain tritium-bearing moderator present on fuel and target

TABLE 3-4. 1987 RADIOACTIVE LIQUID RELEASES AND CONCENTRATIONS

Nuclide	Curies Released At Emission Source	Below SRP[a] Conc. µCi/mL	Beaufort-Jasper[b] Conc. µCi/mL	Port Wentworth[c] Conc. µCi/mL
H-3	2.0E+04[d]	3.3E-06[e]	2.2E-06[e]	2.3E-06[e]
Sr-90	4.0E-01	5.6E-10[e]	3.8E-11	4.0E-11
I-129	2.2E-02	3.2E-12	2.1E-12	2.2E-12
Cs-137	3.3E-01	3.0E-11[e]	3.7E-11	3.8E-11
U-235,238	5.5E-03	8.0E-13	5.3E-13	5.5E-13
Pu-239	1.8E-02	2.6E-12	1.8E-12	1.8E-12

[a] Savannah River just downriver from SRP.
[b] Beaufort-Jasper drinking water.
[c] Port Wentworth drinking water.
[d] Includes releases to streams and groundwater migration from seepage basins.
[e] Measured concentrations. All other concentrations were calculated using models that were verified using tritium measurements.

TABLE 3-5. MAXIMUM INDIVIDUAL DOSES - LIQUID RELEASES

By Pathway

Pathway	Maximum Individual[a] mrem[b]	Percent of Total Dose
Fish	8.48E-01	90.96
Water	8.34E-02	8.95
Shoreline	8.68E-04	0.09
Swimming	1.64E-06	0.00
Boating	4.91E-06	0.00
Total	9.32E-01	

By Radionuclide

Radionuclide	Maximum Individual[a] mrem[b]	Percent of Total Dose
H-3	8.32E-02	8.93
Sr-90	1.03E-02	1.11
I-129	7.86E-04	0.08
Cs-137	8.37E-01	89.81
U-235,238	8.01E-05	0.01
Pu-239	5.54E-04	0.06
Total	9.32E-01	

[a] Hypothetical person just downstream of SRP. There are no known persons who meet the hypothetical situation.
[b] Committed effective dose equivalent.

housings during discharge from the reactor.

- Diversion of periodic disassembly basin purges from streams to seepage basins in P and C Areas in 1978, allowing some radioactive decay of tritium before migration to streams via groundwater.

In addition, releases were reduced by the shutdown of K- and L-Area reactors in 1964 and 1968, respectively.

Summary of 1987 Liquid Releases and Concentrations

Releases of radioactive materials to the river in 1987 are shown in Table 3-4 on p. 29 (shown as Table 3-8 in Vol. II). Tritium constitutes the major release of radioactive material to liquid effluents. The average concentrations of radioactive materials in water are shown at three locations, i.e. just below SRP after complete mixing, in Beaufort-Jasper drinking water, and in Port Wentworth drinking water (both drinking water plants are approximately 100 miles downriver from SRP).

The majority of the concentrations shown in Table 3-4 are calculated, rather than measured; the calculated values are based on dilution of radioactivity entering the Savannah River with a known flow rate of water. However, measured concentrations are shown in those cases where the radionuclides are measurable by conventional analytical techniques.

As shown in Table 3-4, the maximum concentrations occur in the Savannah River just below SRP. Tritium was the radionuclide having the highest offsite concentration.

TABLE 3-6. INDIVIDUAL DOSES FROM PUBLIC WATER SUPPLIES AT BEAUFORT-JASPER

Average Consumption

Radionuclide	Individual Dose, mrem[a]	Percent of Total Dose
H-3	5.13E-02	94.48
Sr-90	1.83E-03	3.37
I-129	2.20E-04	0.41
Cs-137	6.79E-04	1.25
U-235,238	4.51E-05	0.08
Pu-239	2.79E-04	0.51
Total	5.43E-02	

Maximum Consumption

Radionuclide	Individual Dose, mrem[a]	Percent of Total Dose
H-3	1.01E-01	94.37
Sr-90	3.61E-03	3.37
I-129	4.33E-04	0.40
Cs-137	1.34E-03	1.25
U-235,238	8.88E-05	0.08
Pu-239	5.50E-04	0.51
Total	1.07E-01	

[a] Committed effective dose equivalent.

TABLE 3-7. INDIVIDUAL DOSES FROM PUBLIC WATER SUPPLIES AT PORT WENTWORTH

Average Consumption

Radionuclide	Individual Dose, mrem*	Percent of Total Dose
H-3	5.36E-02	94.38
Sr-90	1.91E-03	3.36
I-129	2.30E-04	0.41
Cs-137	7.10E-04	1.25
U-235,238	4.71E-05	0.08
Pu-239	2.92E-04	0.51
Total	5.68E-02	

Maximum Consumption

Radionuclide	Individual Dose, mrem*	Percent of Total Dose
H-3	1.06E-01	94.40
Sr-90	3.77E-03	3.36
I-129	4.54E-04	0.40
Cs-137	1.40E-03	1.25
U-235,238	9.30E-05	0.08
Pu-239	5.76E-04	0.51
Total	1.12E-01	

* Committed effective dose equivalent.

Offsite Radiation Doses from Liquid Releases

Table 3-5 on the facing page (shown as Table 3-9 in Vol. II) shows the calculated dose commitments to a hypothetical individual who could receive the highest offsite doses from releases of radioactivity from SRP to the Savannah River. The *maximum individual* is described as a person who consumes an average amount of water and a large amount of fish from the river just downriver from SRP. This person also spends many hours in shoreline activities, swimming, and boating. The highest potential dose commitment was 0.9 mrem (0.009 mSv). This dose commitment is only 0.3% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources.

Table 3-6 on p. 30 and Table 3-7 at the top of the page (shown as Tables 3-10 and 3-11 in Vol. II) show calculated dose commitments to individuals who consume their entire daily intake of water from water supplied by the Beaufort-Jasper and Port Wentworth water treatment plants, respectively. The dose commitments for average water consumption were 0.05 mrem (0.0005 mSv) for Beaufort-Jasper and 0.06 mrem (0.0006 mSv) for Port Wentworth; the dose commitments for maximum water consumption rates for both Beaufort-Jasper and Port Wentworth were 0.1 mrem (0.001 mSv). Doses for maximum water consumption are included for comparison with the EPA standard for public water supplies of 4 mrem to the body or any organ. EPA standards are based on a maximized water consumption of two liters per day.

Population dose commitments from liquid releases of radioactivity in 1987 are shown by exposure pathway in Table 3-8 below (shown as Table 3-12 in Vol. II). Dose commitments from the water consumption pathway (Beaufort-Jasper and Port Wentworth) occur to discrete population groups;

TABLE 3-8. POPULATION DOSE FROM LIQUID RELEASES

By Pathway

Pathway	Population Dose person-rem*	Percent of Total Dose
Sport Fish	2.22E+00	37.26
Cml. Fish	9.38E-02	1.57
Beaufort-Jasper	2.51E+00	42.12
Port Wentworth	1.13E+00	18.96
Salt Water Invert.	5.28E-05	0.00
Recreation-River	4.72E-03	0.08
Total	5.96E+00	

By Radionuclide

Radionuclide	Population Dose person-rem*	Percent of Total Dose
H-3	3.45E+00	57.89
Sr-90	1.43E-01	2.40
I-129	1.60E-02	0.27
Cs-137	2.32E+00	38.93
U-235,238	3.06E-03	0.05
Pu-239	1.91E-02	0.32
Total	5.96E+00	

* Committed effective dose equivalent.

TABLE 3-9. POTENTIAL DOSES FROM IRRIGATION PATHWAY

Food Type	Effective Dose Equivalent Maximum Individual mrem
Vegetation	1.74E-01
Leafy Veg.	2.14E-02
Milk	7.76E-02
Meat	2.43E-02
Total	2.97E-01

however, the dose commitments from other exposure pathways (i.e., fish and shellfish consumption and recreational activities) occur to a diffuse population that cannot be described as being in a specific geographical location. As shown in Table 3-8, the population dose commitment from liquid releases was 6.0 person-rem (0.06 person-Sv).

Radiation dose commitments are not routinely calculated for the irrigation exposure pathway because there is no known use of Savannah River water for farm irrigation downstream of SRP. But capability for calculating offsite dose from the irrigation-food pathways has been developed to provide potential dose from irrigation for information purposes. Potential doses from the irrigation pathway are shown above in Table 3-9 (shown as Table 3-13 in Vol. II).

The maximum individual dose commitment from the irrigation pathway was 0.3 mrem (0.003 mSv). This dose value is one-third of the maximum individual dose of 0.9 mrem (0.009 mSv) calculated for all other pathways (fish consumption, water consumption, and recreation).

NONRADIOACTIVE MONITORING

Surface water is monitored for nonradioactive materials at effluent outfalls from site facilities, at locations along the six site streams, and at three locations in the Savannah River. Operational effluents from SRP facilities discharge through 68 active SCDHEC-permitted, point source outfalls. These outfalls are monitored to ensure applicable permit limits are met. SRP also maintains an extensive network of stormwater outfalls. The stream and river monitoring programs serve as a backup to outfall monitoring to ensure that materials that could adversely affect the environment are detected if released.

Liquid Effluent Monitoring (NPDES)

Description of Monitoring Program. Measurements of physical properties and concentrations of chemicals and metals in SRP effluents are regulated by SCDHEC under the National Pollutant Discharge Elimination System (NPDES). The NPDES program at SRP included monitoring at 68 active outfalls in 1987. In addition, new permits were requested for the F-Area Effluent Treatment Facility (ETF) Holding Basin, the H-Area ETF Holding Basin, and the new Fuel Production Facility.

Changes in 1987 Monitoring Program. Updates on existing permits included the following:

- Request for deletion of Biochemical Oxygen Demand (BOD) (5-day) for K-Reactor Cooling Water Outfall;
- mercury limit added for TNX Effluent Treatment Facility;
- frequency change from weekly to monthly for Power Sanitary Waste Treatment;
- frequency change from monthly to annually for Par Pond stormwater.

Applicable Standards. Standards applicable to nonradioactive materials and physical properties in SRP wastewater discharges are contained in SRP's NPDES permit administered by SCDHEC. Monitoring requirements and standards can be found in permit SC 0000175 [SCDHEC85].

Analysis	No. of Exceptions	No. of Outfalls
Total Nonfilterable Residue	6	6
Fecal Coliform	3	3
pH	7	6
Oil and Grease	2	2
Totals	18	17

NPDES outfall

Monitoring Results. NPDES outfall locations are listed in Table 3-14, Vol. II, and a summary of monitoring results is presented in Table 3-15, Vol. II. SRP had a 99.7% NPDES compliance rate in 1987, as compared to a 99.4% compliance rate in 1986. Only 18 of the 6,560 analyses performed exceeded permit limits. Listed at the bottom of p. 32 is a summary of the 18 limits exceeded.

Savannah River

Description of Monitoring Program. The Savannah River is extensively monitored for chemicals, metals, and physical and biological properties. Monitoring of the river above and below the site provides a means of determining concentrations of pollutants that may be discharged by offsite industrial facilities upriver of SRP. Measurements confirm that the impact of SRP operations is minimal. All indications are that SRP operations do not have a deleterious effect on the Savannah River aquatic environment.

Applicable Standards. Chemical and biological quality standards for the Savannah River are specified in the requirements of the State of South Carolina for Class B streams, which are: "Freshwaters suitable for secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with requirements of the Department (SCDHEC). Suitable for fishing, survival, and propagation of fish, and other fauna and flora. Suitable also for industrial and agricultural uses" [SCDHEC81]. Specifications are summarized in the table at the bottom of the page.

Monitoring Results. A comparison of Savannah River water quality analyses upriver and downriver of SRP showed no significant differences except for fecal coliform. Fecal coliform levels were higher upriver of SRP than downriver. The average of the

South Carolina Water Quality Standards (for Class B Waters)

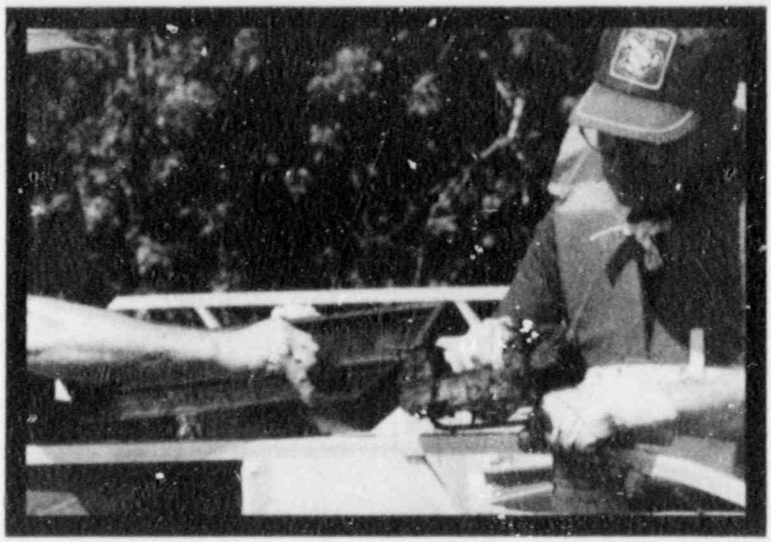
Fecal Coliform. (The count is) not to exceed a geometric mean of 1000 colonies/100 mL based on five consecutive samples during any 30-day period; not to exceed 2000 colonies/100 mL in more than 20% of the samples examined during such period.

pH. Range between 6.0 and 8.5, except that specified waters may range from pH 5.0 to 8.5 due to natural conditions.

Temperature. Shall not exceed a weekly average temperature of 90 degrees F (32.2 degrees C) after adequate mixing as a result of heated liquids, nor shall a weekly average temperature rise of more than 5 degrees F (2.8 degrees C) above temperatures existing under natural conditions be allowed as a result of the discharge of heated liquids unless an appropriate temperature criterion or mixing zone has been established.

Dissolved Oxygen. Daily average not less than 5.0 mg/liter with a low of 4.0 mg/L, except that specified waters may have an average of 4 mg/L due to natural conditions.

monthly geometric mean of fecal coliform measurements was 600 colonies/100 mL upriver and 196 colonies/100 mL downriver of SRP. The decrease is attributed to removal of fecal coliform by the heating of river water as it is passed through SRP reactor heat exchangers before it is returned to the river. Savannah River water quality data are presented in Tables 3-16 and 3-17 of Vol. II. Sampling locations are shown in Fig. 3-6 on the facing page (also in Vol. II).



Changing diatom slides

Academy of Natural Sciences of Philadelphia - River Quality Surveys

Description of Monitoring Program. The Division of Environmental Research of the Academy of Natural Sciences of Philadelphia (ANSP), under contract to Du Pont, has carried out continuing surveys of the aquatic environment and water quality of the Savannah River upriver (Station 1) and downriver (Station 6) from SRP since 1951. Survey locations are shown in Fig. 3-7, Vol. II. These studies were expanded in 1982 to include Station 5, below Steel Creek. The purpose of these studies is to determine the effect, if any, of SRP effluent discharges on general river health.

Three types of studies have been undertaken:

- **detailed surveys** (every four years): these surveys study algae and rooted aquatic plants, protozoa, macroinvertebrates, insects, fish, and water chemistry;
- **continuous cursory studies of aquatic life** (quarterly): these studies focus on algae, insects, and fish;
- **continuous surveys of diatom communities** (semi-monthly).

Monitoring Results. Diatometers are positioned in the river at three locations (one above and two below the SRP site). They provide continuous monitoring of the effects of SRP effluents on diatoms, one major group of river organisms. The diatometers contain glass slides on which diatoms accumulate. The slides were replaced every two weeks and sent to ANSP for diatom community analysis.

In rivers adversely affected by pollution, the number of species is reduced in varying amounts corresponding to the degree of pollution. The less tolerant species are eliminated, while the more tolerant species become dominant. While the total population may increase in size in a polluted river, the number of different species will be reduced. A summary of the results of the diatometer studies conducted in 1987 by ANSP will be issued in 1988.

Quarterly surveys of aquatic insects were also conducted by ANSP in 1987, during March, June, September, and November. In addition, algal and aquatic macrophyte surveys were conducted during the first (March) and fourth (November) insect trap collection periods, and fish were collected during the third (September) insect collection period. Data from these continuous cursory surveys constitute a chronological characterization of biological conditions in the vicinity of the SRP. Results of the 1987 cursory surveys will be issued during 1988.

Studies of the Savannah River in 1987 included a September comprehensive survey of the river in the vicinity of Vogtle Nuclear Power Plant, which became operational in 1987. These studies encompassed protozoa, algae, rooted aquatic plants and macrophytes, non-insect macroinvertebrates, insects, fish and water chemistry. Stations surveyed were located above (reference) and below (impact) the Vogtle Plant site discharge. Results of this study will be compared to results of previous preoperational baseline studies conducted by ANSP in 1985 and 1986, and will be issued as a report in 1988.

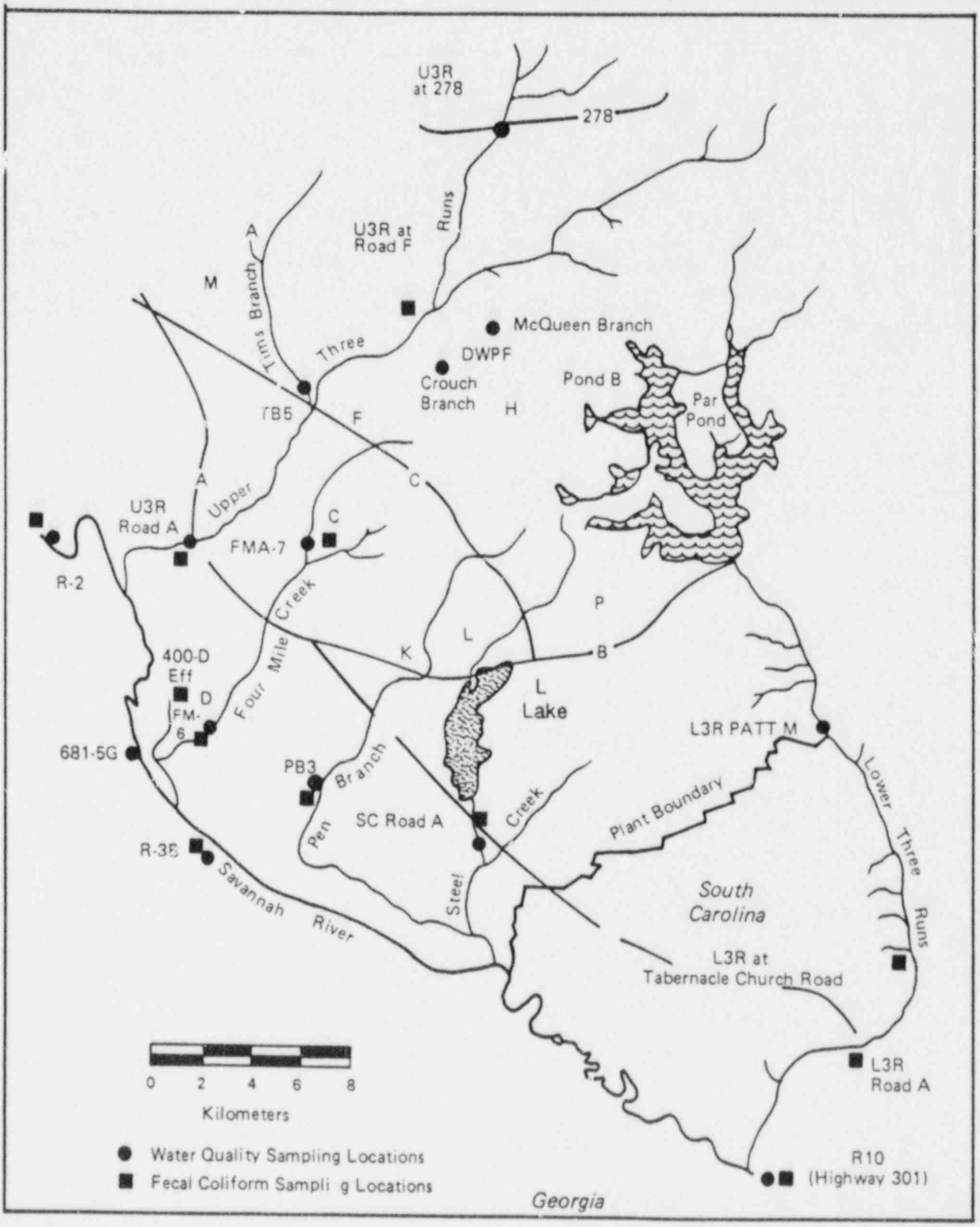


Fig. 3-6. Water quality sampling locations

SRP Streams

Description of Monitoring Program. SRP streams are extensively monitored for chemicals, metals, and physical and biological properties. The stream monitoring program helps ensure that materials are not inadvertently released from sources other than routine release points. Five principal streams traverse the SRP site and a sixth stream, Beaver Dam Creek, contains primarily water from the D-Area powerhouse. D Area also has heavy-water rework facilities and a process control laboratory. The streams receive varying amounts of wastewater and rainwater runoff from SRP facilities.

In addition to SRP monitoring, SCDHEC collects monthly samples from Tims Branch near Road C, Upper Three Runs Creek at Road A, Four Mile Creek at Road A-7, and Steel Creek at Road A. Duplicate samples are collected at these locations for analysis at SRP.

Applicable Standards. South Carolina water quality standards for Class B waters apply to SRP streams (shown on p. 33).

Monitoring Results. Analyses of SRP stream samples and measurements in the streams indicate that, except for temperature in Pen Branch, the water quality is not adversely affected by SRP operations. This stream receives heated water from K-Reactor Area. The heated water from L-and P-Reactor Areas is cooled by L Lake and Par Pond, respectively. The C-Reactor Area, which formerly discharged heated water to Four Mile Creek, was out of service in 1986 and 1987.

During 1987, fecal coliform counts increased in Pen Branch at Road A. The maximum count was 14,000 colonies/100 mL, and the geometric mean was 684 colonies/100 mL. The K-Area sanitary outfall, upstream of the sample point, did not show elevated counts. The laboratory noticed a red overgrowth on the Pen Branch samples that interfered with the analysis. As a result, the analytical procedure was changed to another EPA approved procedure. At this time, the cause of the elevated counts has not been determined.

Except for temperature and fecal coliform in Pen Branch, all stream analyses were generally within the South Carolina standards for a Class B stream. Stream water quality data are summarized in Tables 3-17 and 3-18 in Vol. II, and sampling locations are shown in Fig. 3-6 (also in Vol. II).

River and Stream Temperature Surveys

Description of Monitoring Program. Temperature profile surveys are conducted on the Savannah River and SRP streams as part of a comprehensive study of the thermal effects of SRP operations upon the waters of the state of South Carolina as stated in consent order 84-4-W between SCDHEC and DOE.

Measurements in the creek mouths are taken at 2-ft. intervals across the creeks. At each of these intervals, stream temperatures are measured at 1-ft.

Temperature Data

Month	Location	Maximum Temperature Above Ambient (°C)	Consent Order Daily Maximum Allowable Above Ambient (°C)
March	Steel Creek	2.6	16.6
	Beaver Dam Creek	9.9	17.5
May	Steel Creek	2.0	16.6
	Beaver Dam Creek	5.8	17.5
Sept.	Steel Creek	2.2	16.6
	Beaver Dam Creek	4.4	17.5
Dec.	Steel Creek	0.0	16.6
	Beaver Dam Creek	10.0	17.5

depth intervals from the surface to the bottom. River measurements are taken at 10-20 ft. intervals from the South Carolina bank to the Georgia bank. At each of these intervals, temperature measurements are taken at one-ft. depth intervals from the surface to the bottom.

The reference ambient temperature for the river and the streams is determined from a temperature profile 100 yards above the point where the first heated SRP effluent (Beaver Dam Creek) enters the river. In addition to the temperature profile surveys conducted by SRP, the USGS has established continuous monitoring stations for temperature measurements at the mouth of each SRP stream.

Monitoring Results. During 1987, quarterly temperature profile surveys were made in the mouths and upriver of Beaver Dam Creek and Steel Creek. Surveys were not made in the mouth and downriver of Four Mile Creek, because C-Reactor was not operating. Temperature measurements in both Beaver Dam Creek and Steel Creek exceeded the ambient river temperatures but were within the consent order limits shown at the bottom of p. 36.

Data from this survey, together with past data, indicated that subsurface river temperature measurements would also be significantly less than the limits set by consent order 84-4-W, which states that "the temperature should not exceed 2.8 C° above ambient at the edge of 25% of the cross sectional area and over 33% of the surface area." Therefore, additional measurements for plume definition in the Savannah River were not necessary.

The elevated temperatures in Pen Branch mentioned in a previous section are not reported in this survey. The mouth of Pen Branch is poorly defined swamp area and was not monitored under this program.

1987 HIGHLIGHTS

- In 1987, no measurable differences were detected between upriver and downriver alpha and beta concentrations in the dissolved or suspended portions of Savannah River samples.
- In 1987, tritium measured in transport in the Savannah River was 26,145 Ci, compared to 22,120 Ci in 1986. After dilution by streams and the Savannah River, tritium concentrations in 1987 averaged 3.3 pCi/mL in the river below SRP at Highway 301, compared to 3.9 pCi/mL in 1986.
- Radioactivity in plant streams reflected contributions from SRP operations. Alpha, beta, and tritium concentrations in plant streams were comparable to values observed in past years.
- Most radionuclide concentrations in Steel Creek below L Lake represent notable decreases from their 1985 levels.
- The quantity of tritium migrating from all seepage basins to SRP streams was 18,266 Ci in 1987, compared with 20,627 Ci in 1986, an 11% decrease. The tritium migrating from seepage basins represents 80% of the total SRP tritium released to streams, and direct release of tritium from plant facilities accounts for the remaining 20%.
- The maximum radiation dose commitment to an individual downriver of SRP who consumed Savannah River water was 0.1 mrem, or 0.03% of the average annual radiation dose from natural sources. The population dose commitment from liquid releases of radioactivity was 6 person-rem (0.06 person-Sv).
- SRP had a 99.7% NPDES compliance rate in 1987, as compared to a 99.4% compliance rate in 1986. Only 18 of 6,560 analyses performed exceeded permit limits.
- Except for temperature and fecal coliform in Pen Branch, all stream analyses were within the South Carolina standards for a Class B stream.

4
Groundwater Monitoring Program

SUMMARY — This chapter examines the results of groundwater monitoring of both radioactive and nonradioactive constituents at the Savannah River Plant (SRP). In addition the hydrogeology of the area is described, and geologic terminology applicable to the SRP vicinity is given. The current groundwater monitoring program uses several programs already in operation. These programs are managed by the SRP Health Protection Department, which has radioactive and nonradioactive monitoring programs; the SRP Raw Materials Engineering and Technology Department, which monitors for volatile organics in the A and M Areas of the site; and the Interim Waste Technology Division of the Savannah River Laboratory, which monitors selected wells within the Burial Ground. For both radioactive and nonradioactive constituents, drinking water standards were used as a convenient reference for comparison. In this chapter, activities of gross alpha, ^{90}Sr, tritium, and total radium are reported for wells having levels higher than the drinking water standards. In addition, wells with nonradioactive constituent levels above their respective federal primary drinking water standards are identified.

DESCRIPTION OF MONITORING PROGRAM

The operating policy at the Savannah River Plant is to prevent or minimize degradation of natural resources and to take restorative action should such degradation occur. The purpose of the groundwater monitoring program is to detect and quantify any degradation in groundwater quality at the Savannah River Plant. The program also supports research efforts and performs leak monitoring at selected sites.

The current groundwater monitoring program at SRP is a combination of several programs. The SRP Health Protection Department conducted both a radioactive monitoring program and a nonradioactive monitoring program. The radioactive monitoring program began in the early 1950s and has primarily monitored for gross alpha and nonvolatile beta activities and tritium concentrations at selected sites. The samples are collected by either pumping or bailing wells, and the analyses are conducted by the Health Protection Department's laboratory at the SRP site.

Groundwater monitoring for nonradioactive materials began in 1975 with four wells at the Sanitary Landfill. The scope of monitoring expanded rapidly, and the nonradioactive groundwater monitoring program was established in 1982. Most of the wells are sampled by pumping, and the analyses are conducted by contract laboratories. All wells are sampled quarterly for field measurements of pH, temperature, conductivity, and water level. Other analyses are performed according to the sampling schedule, which is generated using criteria that include applicable regulatory requirements, previous analytical results, potential constituents, and ongoing research.

Two other organizations monitor the groundwater. The SRP Raw Materials Engineering and Technology Department monitors for volatile organics in A and M Areas, and the Interim Waste Technology Division of the Savannah River Laboratory monitors selected wells within the Burial Grounds.

A description of each site and its hydrology and a listing of the sources and types of materials known to exist at the site are presented in Appendix B.

CHANGES IN THE PROGRAM DURING 1987

Three new well series were constructed in 1987. Four MCB Series wells were installed around the

Miscellaneous Chemical Basin, three RSF Series wells were installed around the kaolinite diked areas of R-Area Reactor Seepage Basins 1 and 3, and three ZBG Series wells were constructed in Z Area to serve as background monitoring wells.

Fifty-nine new wells were added to existing well series in 1987. Seven additional DCB wells were constructed around the D-Area Coal Pile Runoff Containment Basin. At the F-Area Seepage Basins, 30 Resource Conservation and Recovery Act (RCRA) point-of-compliance wells were installed. These FSB cluster wells are screened in the water-table, McBean, and Upper Congaree aquifers. In S Area one additional background well was constructed, and two RSE wells were added to the R-Area Reactor Seepage Basins monitoring network. Nineteen plume definition wells were added to the MSB well series.

Several ions were added for analysis during 1987 to determine all of the major ions present in the groundwater. The added analyses are calcium, potassium, magnesium, silica, and phosphate.

HYDROGEOLOGY AT SRP

The Savannah River Plant is located in the Upper Atlantic Coastal Plain, approximately 30 km southeast of the Fall Line separating the Piedmont and Coastal Plain provinces. The SRP is on the Aiken Plateau, a comparatively flat surface that slopes southeastward but is dissected by several tributaries to the Savannah River. The SRP stratigraphy comprises about 300 m of unconsolidated sands, clayey sands, and sandy clays, which in turn are underlain by dense crystalline metamorphic rock or consolidated red mudstone. The geologic terminology applicable to the SRP vicinity is as follows:

Cretaceous System: Cape Fear, Middendorf, Black Creek, and Steel Creek member of Pee Dee formations (formerly all called Tuscaloosa Formation). Sands in the lower and upper part of this section are important water producers.
Paleocene Series: Ellenton, Williamsburg, and unnamed formations. Very few clean sands occur in this part of the section, which constitutes a regional aquitard.
Lower Middle Eocene Stage: Lower Claibornian rocks are generally sandy and are capable of producing several hundred gallons of water per minute to good wells. The name Congaree Formation is generally applied.
Upper Middle Eocene Stage: Upper Claibornian Lisbon or Santee equivalents are generally marine formations of low permeability. Provisionally these units are assigned to the Santee Formation with a McBean sandy micritic member; a Warley Hill sandy, often glauconitic, member; and a basal Caw-Caw glauconitic and/or lignitic shale member. The Caw-Caw member has been called "the green clay" in SRP hydrologic writings.
Upper Eocene Stage: The lower portion, the Dry Branch Formation, comprises near-shore sands, clays, and oyster-shell-bearing limestones. A persistent clay in this formation is the "tan clay" of SRP hydrologic literature. The Irwinton Sand member overlies the tan clay. The upper portion, the "Tobacco Road Formation," is predominantly clayey sands with a few clean sands or clays. These two formations make up the Barnwell Group. In some SRP literature the Jacksonian Dry Branch Formation has been included in the "McBean Formation."
Post-Jacksonian Sediments: Gravels, clays, and arkosic sands of fluvial origin cap many interfluve areas of the SRP region and are included in an informal stratigraphic unit called the "upland unit." These gravels, together with a reticulate-mottled "B" soil horizon, were mapped as the "Hawthorn Formation" in early SRP area publications.
Flood Plain Deposits: These deposits are significant but generally occur along the Savannah River and its major tributaries.

A generalized view of these formations is shown in Fig. 4-1 in Vol. II. The two aquifers in the Cretaceous Formations are used separately and in combination to obtain yields of greater than 1,000 gal/min in properly designed and constructed wells. The lower middle Eocene Section also contains sands that yield a few hundred gallons per minute in many locations. Apart from these aquifers, most of the rest of the Coastal Plain sediments transmit water on a local scale but do not yield water to wells in sufficient quantity to be classified as primary aquifers. A few excavated wells and some low-yield drilled wells exist in the shallow formations; thus, these formations could marginally be classified as aquifers. The confining beds retard the interchange of water between formations but do not totally prevent it.

The direction of groundwater movement is governed largely by the depth of incision of the creeks that dissect the Aiken Plateau. Small creek valleys govern the groundwater flow directions in the shallow sediments. The valleys of major tributaries to the Savannah River govern flow direction in the

sediments of intermediate depth, and the flow in the deep sediments is governed by the valley of the Savannah River. Groundwater in the Cretaceous Formations flows toward the Savannah River, and that in the Lower Middle Eocene flows toward Upper Three Runs Creek or the Savannah River, depending on its location. In several locations, dissection by creek valleys creates groundwater subunits or islands in some formations.

In the northwest part of SRP, groundwater head decreases with depth, providing the potential for recharge from the surface to penetrate to the deeper formations. However, in the vicinity of the valleys of Upper Three Runs Creek and the Savannah River, the water levels above the Paleocene confining units are drawn down by natural discharge to a greater extent than those in the deeper formations. Thus, there is a head reversal so that the vertical groundwater gradients in the central part of SRP are upward.

Water levels in wells sampling the Cretaceous sands do not respond quickly to rainfall; however, a long-term relationship probably exists between water level and recharge by rainfall. Water levels have fallen to a degree that cannot be totally correlated with rainfall during the past several years. Pumping for irrigation in Allendale and Barnwell Counties has increased greatly during this period. In addition, the pumping at SRP has also increased during this period. The head reversal near the central part of the plant has not disappeared due to the falling water levels, but it has decreased.

RADIOACTIVE MONITORING

Applicable Standards

Analytical results of groundwater from onsite monitoring wells are compared with federal drinking water standards in this report. Although drinking water standards do not apply to monitoring wells, they are a convenient reference for comparison. For radioactive constituents the National Primary Drinking Water Regulations (CFR, 1987) lists standards for gross alpha, total radium, ^{90}Sr, and tritium (Table 4-1 at the top right-hand column of the page). Only wells with constituents above their respective drinking water standards are discussed in the following sections. Tables 4-2 through 4-4 summarize radioactive results from selected well series that are representative of groundwater monitoring in the various areas. Table 4-26 in Vol.II gives a complete summary of maximum constituent levels in groundwater.

Table 4-1. Drinking Water Standards (pCi/L) For Radioactive Constituents[a]

Gross alpha	15
Total radium	5
Strontium-90	8
Tritium	20,000

[a] CFR (Code of Federal Regulations), 1987. *National Primary Drinking Water Regulations*, 40 CFR 141.

Separations Areas

Maximum levels of radioactive constituents found in selected well series that are representative of groundwater monitoring in the separations areas are summarized in Table 4-2 on p. 42. The higher than expected levels of radium at several sites are under investigation.

Solid Waste Storage Facilities. The *Solid Waste Storage Facilities* (Burial Grounds) are monitored

Wells monitor Burial Ground perimeter

TABLE 4-2. MAXIMUM RADIOACTIVITIES IN SELECTED SEPARATIONS AREA WELLS

Constituent	DWS/units	Burial Grounds (BG)	(MGA)	(MGC)	(MGE)
Gross Alpha	15 pCi/L	7	9.7	7	4
Nonvol. Beta	NA	748	82	3,700	1,430
Tritium	20 pCi/mL	902,000	482,000	20,900,000	9,930,000

Constituent	DWS/units	F Area Seepage Basins (F)	Canyon Building (FCA)	Seepage Basins (FSB)	Tank Farm (FTF)
Gross Alpha	15 pCi/L	192	1,530	1,850	59.4
Nonvol. Beta	NA	2,420	2,230	9,960	34,600
Radium	5 pCi/L	-	120	155	-
Strontium-90	8 pCi/L	231	13.7	-	-
Tritium	20 pCi/mL	67,200	482	67,200	282

Constituent	DWS/units	H Area Seepage Basins (H)	Canyon Building (HCA)	Seepage Basins (HSB)	Tank Farm (HTF)
Gross Alpha	15 pCi/L	46.6	5.2	711	7.37
Nonvol. Beta	NA	14,200	16.7	9,150	73.2
Radium	5 pCi/L	-	4.9	48.6	-
Strontium-90	8 pCi/L	6.4	-	-	-
Tritium	20 pCi/mL	37,600	204	89,600	173

Constituent	DWS/units	S and Z Areas S Area (SBG)	Z Area (ZBG)
Gross Alpha	15 pCi/L	3.2	2.0
Nonvol. Beta	NA	10.4	3.4
Radium	5 pCi/L	1.3	1.1
Tritium	20 pCi/mL	23.2	16.5

DWS = Drinking water standard (EPA)

by wells along the perimeter fence line, within the fence, and outside the perimeter north of the 643-7G Burial Ground (Fig. 4-2, Vol. II). Results of the groundwater monitoring are presented in Table 4-1, Vol. II.

The perimeter is monitored by wells BG 26 through BG 67. The maximum gross alpha activity level in these wells was 3.66 pCi/L in well BG 32, and the maximum nonvolatile beta activity was 9.61 pCi/L in well BG 52. Tritium concentrations were above the drinking water standard in all but four of these wells, with most of the concentrations less than 50 pCi/mL.

Since 1978, high tritium concentrations have been found in two areas of the perimeter. A tritium plume has been migrating to the southwest from the south-

west end of the original Burial Ground (643-G) toward Four Mile Creek. The elevated tritium concentrations have in the past extended from well BG 53 through BG 58. These wells are downgradient of the western third of the 643-G Burial Ground. The tritium concentrations in these wells have varied widely from year to year, with the maximum value generally occurring in well BG 56 and occasionally in BG 54. In 1987, the highest tritium concentration recorded for this plume (53,900 pCi/mL) was found in well BG 56. The 1987 tritium concentration in well BG 56 is similar to the 1986 concentration but is higher than the concentrations observed from 1976 through 1985. The tritium concentrations in wells BG 53, 54, 57, and 58 declined in 1987. These wells are at the margins of the plume.

Another plume of tritium has been migrating to the northwest from the north end of the Burial Ground addition (643-7G) toward Upper Three Runs Creek. This plume extends from perimeter wells BG 33 through BG 35. Wells BG 68 through BG 90 were installed north of the perimeter fence to monitor this plume. Most of these wells had elevated tritium concentrations, with a maximum of 18,000 pCi/mL detected in well BG 77. The leading edge of this plume is apparently near wells BG 77, 79, and 83. The tritium concentrations in most of these wells changed during 1987, generally decreasing in wells to the south and generally increasing in wells to the north.

The 70 wells of the MGA, MGC, MGE, MGG, and MGI series monitor the groundwater beneath the *643-G Burial Ground* for gross alpha and nonvolatile beta activities and for tritium. As in 1986, the maximum activity levels for gross alpha (618 pCi/L) and nonvolatile beta (12,600 pCi/L) were found in well MGG 21. Elevated tritium concentrations were found in all wells, with the highest values recorded for wells MGC 5 (20,900,000 pCi/mL), MGE 3 (9,930,000 pCi/mL), MGG 13 (6,690,000 pCi/mL), MGG 34 (118,000,000 pCi/mL), and MGG 21D (4,410,000 pCi/mL). The maximum value recorded for well MGG 34 is considered spurious because it is two orders of magnitude higher than any of the other results from preceding and succeding quarterly analysis of the well.

Twenty-one wells of the BG series within the Burial Ground (identified with numbers in previous annual reports) monitor the groundwater beneath the *643-7G Burial Ground*. Elevated tritium concentrations (up to 114,000 pCi/mL) were detected at the southeastern end of 643-7G in well BG 408GR. Elevated tritium (up to 902,000 pCi/mL) was detected near the northern fence in well BG 822GR. A single excursion of nonvolatile beta (748pCi/L) was reported in well BG 822GR.

F Area. Nine facilities in F Area are monitored by groundwater wells: the F-Area A Line, the F-Area Acid/Caustic Basin, the F-Area Burning/Rubble Pits, the F-Area Canyon Building, the F-Area Coal Pile Runoff Containment Basin, the F-Area Seepage Basins, the Old F-Area Seepage Basin, the F-Area Tank Farm, and the Naval Fuels Facility background wells. The groundwater monitoring results from F Area are presented in Tables 4-2 and 4-3, Vol. II.

The *F-Area A Line* and the *F-Area Canyon Building* are monitored by the wells of the FAL and FCA series (Fig. 4-3, Vol. II). Wells FAL 1, FAL 2, and FCA 2D are between the southeast end of the Canyon Building and the A-Line Building. Of these wells only FCA 2D showed elevated levels of radionuclides, with activities up to 1,530 pCi/L for gross alpha, 2,230 pCi/L for nonvolatile beta, 13.7 pCi/L for ^{90}Sr, 34.1 pCi/mL for tritium, and 56.5 pCi/L for total radium. The values for these constituents declined in this well in the fourth quarter. In the past, alpha and gamma spectroscopy analyses of samples from well FCA 2D indicated that the radioactivity was due primarily to ^{238}U, with some ^{235}U and decay daughters. High nitrate levels from this well indicate the source of this activity is uranyl nitrate. If the contamination resulted from uranyl nitrate, a likely source would be the A-Line Building, which processes uranium in the uranyl nitrate form. The remaining wells of the FCA series had activities of up to 51.2 pCi/L gross alpha, 48.4 pCi/L nonvolatile beta, 120 pCi/L total radium, and 482 pCi/mL tritium.

The *F-Area Acid/Caustic Basin* is monitored by the wells of the FAC series (Fig. 4-4, Vol. II). Wells FAC 1 and 2 were dry during 1987. Upgradient well FAC 3 had the highest levels of gross alpha (36.5 pCi/L), nonvolatile beta (38.4 pCi/L), and total radium (23.1 pCi/L).

The *F-Area Burning/Rubble Pits* are monitored by the FBP wells (Fig. 4-5, Vol. II). The only elevated radioactive constituents reported for waters from these wells were nonvolatile beta (up to 98.2 pCi/L) in upgradient well FBP 1A and an excursion of radium (6.3 pCi/L) in well FBP 4.

The *F-Area Coal Pile Runoff Containment Basin* is monitored by the FCB wells (Fig. 4-6, Vol. II). The only measurement of radioactivity above drinking water standards was a total radium activity of 6.7 pCi/L in downgradient well FCB 3.

The *F-Area Seepage Basins* are monitored by the wells of the F and FSB series (Fig. 4-7, Vol. II). All of the F series wells and most of the FSB series wells had elevated tritium concentrations. Tritium and nonvolatile beta activities were elevated in all zones monitored except the lower portion of the Congaree Formation. The highest tritium values (67,200 pCi/mL) were found in wells F 10 and FSB 78. Well F 10 is located adjacent to Basin 3 and monitors the perched water zone. Well FSB 78 monitors the water table downgradient of Basin 3. Well F 10 also contained ^{90}Sr activity of 231 pCi/L. The highest nonvolatile beta value was 9,960 pCi/L in well FSB 92D. Wells with elevated gross alpha activity (up to 1,850 pCi/L) were F 10, 15, 16, and 18A and FSB 77, 78, 78C, 79, 79C, 87D, 88D, 89D, 90D, 91D, 92D, 94C, 97D, 98C, 98D, and 99D. Total radium activities (up to 155 pCi/L) were detected at levels above the drinking water standard in wells FSB 77, 78, 78C, 79, 79C, 87D, 89D, 90D, 91C, 91D, 92D, 97D, 98C, and 99D.

The *Old F-Area Seepage Basin* is monitored by the FNB well series (Fig. 4-8, Vol. II). Downgradient well FNB 2 had the highest radioactivity levels with maximums of 61.4 pCi/L for gross alpha, 701 pCi/L for nonvolatile beta, 9.5 pCi/L for total radium, and 657 pCi/mL for tritium. Sidegradient wells FNB 1 and 3 had elevated levels of tritium activity, and FNB 3 had elevated nonvolatile beta and total radium activities.

The water table at the *F-Area Tank Farm* is monitored by the 27 wells of the FTF series (Fig. 4-9, Vol. II). Elevated nonvolatile beta activity was found in wells FTF 3 through 12, 19, 20, 21, 24A, 25A, 26, and 27. Well FTF 6 had the maximum nonvolatile beta value (34,600 pCi/L), the highest tritium concentration (282 pCi/mL), and the highest elevated gross alpha value (59.4 pCi/L) at the site. All of the values in FTF 6 represent increases from 1986 levels. The source of the elevated values in wells FTF 5 through 7 is a spill that occurred in 1961 when Tank 8 was overfilled. Tritium was above the drinking water standard in wells FTF 5, 6, 7, 11, 12, 19, 24A, 25A, 26, and 27.

The *F-Area Naval Fuels Facility* (Fig. 4-3, Vol. II) is monitored by wells NBG 1 through 5. Wells NBG 1 and 2 had tritium levels in excess of the drinking water standard. The highest 1987 tritium concentration (897 pCi/mL), recorded for well NBG 2, represents an increase from 1986, when all tritium concentrations were under 250 pCi/mL. Well NBG 2 also contained elevated nonvolatile beta activity in 1987 (26.5 pCi/L), a level similar to the one recorded there in 1986.

H Area. Five facilities in H Area are monitored by groundwater wells: the H-Area Canyon Building, the H-Area Coal Pile Runoff Containment Basin, the H-Area Retention Basins, the H-Area Seepage Basins, and the H-Area Tank Farm. Tables 4-4 and 4-5 in Vol. II show the H-Area groundwater monitoring results.

The *H-Area Canyon Building* is monitored by the four wells of the HCA series (Fig. 4-10, Vol. II). Tritium concentrations (up to 204 pCi/mL) were above the drinking water standard in all four wells, and nonvolatile beta activity (up to 16.7 pCi/L) was elevated in wells HCA 1 and 2.

The *H-Area Coal Pile Runoff Containment Basin* is monitored by wells in the HCB series (Fig. 4-11, Vol. II). Results from all of the wells showed elevated levels of tritium. The highest concentration (42.8 pCi/mL) was recorded at upgradient well HCB 3. Well HCB 2 contained elevated gross alpha activities (27.7 pCi/L) and elevated nonvolatile beta activities (34.9 pCi/L). The total radium activity in this well was equal to the drinking water standard. These 1987 concentrations are considerably lower than those recorded in 1986.

The wells monitoring the *H-Area Retention Basins* are the HR3 and HR8 series (Fig. 4-12, Vol. II). Results for 1987 indicate that virtually no change in the concentrations in any of the wells has occurred since they were sampled in 1985. Well HR8 14, which is downgradient from the old retention basin, was the only well with elevated gross alpha (44.6 pCi/L), nonvolatile beta (21.4 pCi/L), and total radium (13.3 pCi/L) results. Tritium concentrations exceeded the drinking water standard in all wells except HR8 14. The maximum tritium concentration (70.3 pCi/mL) was found in sidegradient well HR8 11. Of the remaining wells, the second highest tritium value (54 pCi/mL) was in upgradient well HR3 13.

The *H-Area Seepage Basins* are monitored by the wells of the H and HSB series (Fig. 4-13, Vol. II). Most of the water-table wells and wells monitoring the lower Dry Branch Formation had elevated nonvolatile beta activities and tritium concentrations that exceeded the drinking water standard. The maximum tritium concentration was found in well HSB 86D (89,600 pCi/mL). The highest nonvolatile beta activity (14,200 pCi/L) occurred in well H 6, which is at the edge of Basin 2. Gross alpha activities were elevated in some of the water-table wells, with the maximum value of 711 pCi/L recorded in well HSB 68. Total radium activity was elevated in several of the water-table wells, with a maximum reported concentration of 48.6 pCi/L in well HSB 69. Well HSB 84A is screened in the upper portion of the Congaree Formation and had elevated levels of all of the measured radioactive constituents.

The *H-Area Tank Farm* is monitored by the wells of the HTF series (Fig. 4-14, Vol. II). Elevated levels of nonvolatile beta activity were detected in wells HTF 1 through 6, 9, and 27 and 241 H. The highest nonvolatile beta activity (73.2 pCi/L) was found in well HTF 5. This represents a decrease from the 1986 maximum of 190 pCi/L in the same well. Tritium concentrations were above the drinking water standard for all of the wells except HTF 7, 19, 27, 28, 31, and 32. As in 1986, well 241 H had the highest tritium concentration in the area (635 pCi/mL). The next highest tritium value (173 pCi/mL) was found in well HTF 25 and represents a substantial increase from the 1986 maximum for this well. Significant decreases in maximum tritium concentrations from 1986 levels were seen in wells HTF 1, 6, and 12. Otherwise, tritium levels were similar to those in 1986. Gross alpha activities were not elevated in the wells monitoring this site.

S Area. *S Area* and the *Defense Waste Processing Facility* are monitored by the SBG well series (Fig. 4-15, Vol. II). Analytical results from these wells are presented in Table 4-6, Vol. II. Tritium levels above the drinking water standard were detected in well SBG 1, with a maximum concentration of 23.2 pCi/mL.

Z Area. *Z Area* is monitored by wells in the ZBG series. These background wells are the only wells that have been installed in Z Area to date. Table 4-7 in Vol. II gives the monitoring results from these wells. No radioactive constituents were detected above drinking water standards.

Z and ZW Wells. The Z and ZW wells were installed in the separations areas (Fig. 4-16, Vol. II) as piezometers. Monitoring results from these wells are presented in Table 4-8, Vol. II. Gross alpha and nonvolatile beta activities were not elevated in the ZW wells except for 12.8 pCi/L of nonvolatile beta activity reported for well ZW 7. Tritium concentrations in excess of the drinking water standard were found in wells Z 3, Z 15, ZW 2, and ZW 5 through 10. The highest tritium value found in these wells (282 pCi/mL) was at well Z 3, which is approximately 150 m east of the F-Area Seepage Basins. The other wells with elevated tritium levels are in or around the F- or H- area operating fence lines. Tritium decreased from 1986 levels in wells Z3, ZW 2, and ZW 5.

Reactor Areas

Maximum levels of radioactive constituents occurring in selected well series that are representative of groundwater monitoring in the reactor areas are summarized in Table 4-3 on p. 46.

C Area. The following locations, shown in Fig. 4-17, Vol. II, are monitored by groundwater wells: the C-Area Burning/Rubble Pit, the C-Area Coal Pile Runoff Containment Basin, the C-Area Disassembly Basin, and the C-Area Reactor Seepage Basins. The monitoring results from these wells are presented in Tables 4-9 and 4-10, Vol. II.

The *C-Area Reactor Seepage Basins* are monitored by the wells of the CSB series, all of which had tritium levels above the drinking water standard. The 1987 tritium concentrations in these wells were similar to those of past years. Wells CSB 3A, 4A, and 5A, which are downgradient from Basins 1 and 2, had the highest tritium levels measured in the series (up to 120,000 pCi/mL). Overall, the tritium concentrations in the C-Area Reactor Seepage Basins wells declined during 1987. Well CSB 6A had one excursion (6.3 pCi/L) of total radium.

Elevated levels of tritium were found in wells CRP 1 and 2, which are upgradient and sidegradient, respectively, of the *C-Area Burning/Rubble Pit*. The maximum tritium value recorded for these wells was 294 pCi/mL in CRP 2.

Elevated levels of tritium were detected in both of the wells (CDB 1 and 2) monitoring the *C-Area Disassembly Basin*. The maximum concentration of 368 pCi/mL occurred in well CDB 2.

TABLE 4-3. MAXIMUM RADIOACTIVITIES IN SELECTED REACTOR AREA WELLS

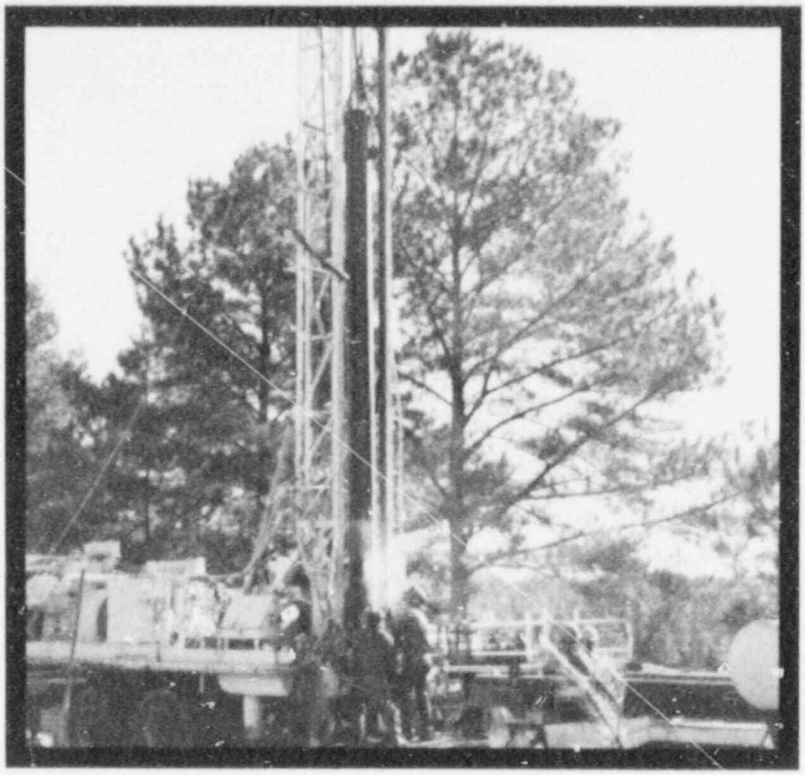
Constituent	DWS/units	C Area: Coal Pile Runoff Basin (CCB)	C Area: Disassembly Basin (CDB)	C Area: Burning/Rubble Pit (CRP)	C Area: Reactor Seepage Basins (CSB)
Gross Alpha	15 pCi/L	1.4	5.4	<3.0	1.8
Nonvol. Beta	NA	2.8	18.7	11.0	5.4
Radium	5 pCi/L	0.8	2.7	0.9	4.3
Tritium	20 pCi/mL	10.5	368	167	120,000

Constituent	DWS/units	K Area: Acid/Caustic Basin (KAC)	K Area: Disassembly Basin (KDB)	K Area: Retention Basin (KRB)	K Area: Reactor Seepage Basin (KSB)
Gross Alpha	15 pCi/L	42.2	18.3	6.6	1.45
Nonvol. Beta	NA	3.1	27.6	96.5	2.8
Radium	5 pCi/L	5.3	5.0	2.6	0.7
Tritium	20 pCi/mL	12.5	4,380	238,000	1,120

Constituent	DWS/units	L Area: Acid/Caustic Basin (LAC)	L Area: Disassembly Basin (LDB)	L Area: Burning/Rubble Pit (LRP)	L Area: Reactor Seepage Basin (LSB)
Gross Alpha	15 pCi/L	2.2	<3.0	1.6	<3.0
Nonvol. Beta	NA	5.0	3.0	4.0	2.7
Radium	5 pCi/L	0.9	1.2	1.1	<1.0
Tritium	20 pCi/mL	17.0	5.10	3.79	1,290

Constituent	DWS/units	P Area: Acid/Caustic Basin (PAC)	P Area: Disassembly Basin (PDB)	P Area: Burning/Rubble Pit (PRP)	P Area: Reactor Seepage Basin (PSB)
Gross Alpha	15 pCi/L	<3.0	4.2	5.2	1.54
Nonvol. Beta	NA	3.0	1.8	7.6	13.7
Radium	5 pCi/L	<1.0	0.9	1.8	1.3
Tritium	20 pCi/mL	12.9	342	82.9	272,000

Constituent	DWS/units	R Area: Acid/Caustic Basin (RAC)	R Area: Burning/Rubble Pits (RRP)	R Area: Reactor Seepage Basins (RSD)	R Area: Reactor Seepage Basins (RSF)
Gross Alpha	15 pCi/L	6.1	<3.0	10.5	8.3
Nonvol. Beta	NA	3.0	3.4	4,460	11.5
Radium	5 pCi/L	1.0	<1.0	-	1.6
Tritium	20 pCi/mL	4.60	3.57	6.78	20.4



Installing surface casing for well

K Area. Seven facilities have groundwater monitoring wells installed: the K-Area Acid/Caustic Basin, the K-Area Ash Basin, the K-Area Burning/Rubble Pit, the K-Area Coal Pile Runoff Containment Basin, the K-Area Disassembly Basin, the K-Area Reactor Seepage Basin, and the K-Area Retention Basin. The locations of these facilities are shown in Fig. 4-18, Vol. II, and the groundwater monitoring results are given in Tables 4-11 and 4-12, Vol. II.

The five wells of series KRB monitoring the *K-Area Retention Basin* contained elevated tritium concentrations. The maximum concentration for well KRB 1 was 252 pCi/mL. Measurements from the other wells were above 7,000 pCi/mL, with a maximum concentration of 238,000 pCi/mL in upgradient well KRB 8. Elevated nonvolatile beta activity (up to 91.0 pCi/L) was recorded for well KRB 15.

The three wells of series KDB, which monitor the *K-Area Disassembly Basin*, had elevated levels of tritium. The highest tritium value (4,380 pCi/mL) was recorded in sidegradient well KDB 1. Sidegradient well KDB 3 also contained elevated activities of gross alpha (18.3 pCi/L) and nonvolatile beta (27.6 pCi/L). Total radium activity (5.0 pCi/L) was equal to the drinking water standard.

K-Area Acid/Caustic Basin monitoring well KAC 1 contained elevated gross alpha levels up to 42.2 pCi/L and elevated total radium levels up to 5.3 pCi/L.

At the *K-Area Ash Basin*, wells KAB 1, 2, and 4 contained elevated levels of nonvolatile beta activity. The highest concentration (35.8 pCi/L) was reported for well KAB 1. Wells KAB 3 and 4 contained elevated total radium activities, with the highest concentration (13.6 pCi/L) found in well KAB 4 and the concentration in well KAB 3 equal to the drinking water standard. Wells KAB 2 and 4 contained elevated gross alpha activities, with the highest value (36.4 pCi/L) recorded for upgradient well KAB 2. Elevated calcium and conductivity values indicate that wells KAB 2 and 4 may be affected by leaching of well grout.

Groundwater from wells KCB 2 and 3, which monitor the *K-Area Coal Pile Runoff Containment Basin*, contained elevated levels of radioactive constituents. Well KCB 3 contained elevated gross alpha activities up to 32.8 pCi/L, nonvolatile beta activity at 27.0 pCi/L, total radium activity up to 14.5 pCi/L, and tritium activity at 27.4 pCi/mL. Well KCB 2 had elevated tritium concentrations (34.5 pCi/mL) only.

Elevated tritium concentrations were detected in all the *K-Area Reactor Seepage Basin* wells. The highest value (1,120 pCi/mL) was recorded for upgradient well KSB 1. The 1987 tritium concentrations in wells KSB 3 and 4A increased somewhat from their 1986 levels.

L Area. Groundwater monitoring wells have been installed at the following sites: the L-Area Acid/Caustic Basin, the L-Area Burning/Rubble Pit, the L-Area Disassembly Basin, the L-Area Oil and Chemical Basin, and the L-Area Reactor Seepage Basin (Fig. 4-19, Vol. II). Table 4-13 in Vol. II presents the groundwater monitoring results from these wells for 1987.

At the *L-Area Oil and Chemical Basin*, wells LCO 1 and 4 had elevated tritium concentrations and

nonvolatile beta activities similar to those that have been recorded since 1985. For 1987, the maximum values for tritium (1,040 pCi/mL) and nonvolatile beta (79.8 pCi/L) were from well LCO 1.

At the *L-Area Reactor Seepage Basin*, wells LSB 1 and 4 had elevated tritium concentrations up to 1,290 pCi/mL (in upgradient well LSB 4). These 1987 concentrations represent an increase from the 1986 maximum concentration of 207 pCi/mL. The elevated levels of these constituents are probably related to the reactivation of L-Reactor in 1985.

P Area. Five sites are monitored by groundwater wells (Fig. 4-20, Vol. II): the P-Area Acid/Caustic Basin, the P-Area Burning/Rubble Pit, the P-Area Coal Pile Runoff Containment Basin, the P-Area Disassembly Basin, and the P-Area Reactor Seepage Basins. The groundwater monitoring results are shown in Tables 4-14 and 4-15, Vol. II.

All wells monitoring the *P-Area Reactor Seepage Basins* contained elevated tritium concentrations. Most of the tritium values recorded for wells PSB 4A and 5A were below 500 pCi/mL. The values in the other wells were generally above 50,000 pCi/mL, and the highest value (272,000 pCi/mL) occurred in well PSB 1A. These 1987 concentrations are similar to those recorded in past years.

At the *P-Area Burning/Rubble Pit*, results from wells PRP 1A and 3 showed elevated levels of tritium. The highest tritium value recorded (82.9 pCi/mL) was for well PRP 1A. The tritium concentration in well PRP 3 was equal to the drinking water standard.

Both wells monitoring the *P-Area Disassembly Basin* (PDB 2 and 3) had elevated levels of tritium. The highest tritium value (342 pCi/mL) was recorded for well PDB 2.

R Area. The R-Area Acid/Caustic Basin, the R-Area Burning/Rubble Pits, and the R-Area Reactor Seepage Basins are monitored by groundwater wells. Tables 4-16 and 4-17 in Vol. II contain the monitoring data from these wells.

Nonvolatile beta activity was elevated in wells monitoring the *R-Area Reactor Seepage Basins* (Fig.

TABLE 4-4. MAXIMUM RADIOACTIVITIES IN SELECTED GENERAL AREA WELLS

		A/M Areas			
Constituent	DWS/units	Metals Burning Pit (ABP)	SRL Seepage Basins (ASB)	Misc. Chemical Basin (MCB)	M-Area Settling Basin (MSB)
Gross Alpha	15 pCi/L	1.9	5.7	3.1	259
Nonvol. Beta	NA	3.0	6.2	4.9	166
Radium	5 pCi/L	4.6	5.3	1.3	121
Tritium	20 pCi/mL	2.3	25.1	2.4	8.8

		Miscellaneous Areas	
Constituent	DWS/units	Fire Dept. Training Facility (CSO)	Sanitary Landfill (LFW)
Gross Alpha	15 pCi/L	<3.0	28.6
Nonvol. Beta	NA	<2.0	23.4
Radium	5 pCi/L	<1.0	6.7
Tritium	20 pCi/mL	11.1	96.1

4-21, Vol. II). Elevated levels were found in wells RSD 1 through 2C, 4 through 8, 10, 11, and RSE 1A, 3A through 7, 11, 12, 13, and 19. The highest nonvolatile beta value (14,000 pCi/L) and the only elevated gross alpha value (30.1 pCi/L) were found in well RSE 6. This well is adjacent to Basin 1 and is within the perimeter of the kaolinite dike. Most of the nonvolatile beta contamination in this area is probably due to ^{90}Sr from fuel element failure in 1957. The elevated nonvolatile beta values are similar to those recorded in past years. A single excursion of tritium (20.4 pCi/mL) was reported for well RSF 1.

General Areas

Table 4-4 on the facing page summarizes maximum activity levels of radioactive constituents in selected well series that that are representative of groundwater monitoring in the general areas.

A/M Area. Ten sites, as shown in Figs. 4-22 and 4-23, Vol. II, have groundwater monitoring wells: the A-Area Background Well, the A-Area Burning/Rubble Pits, the A-Area Coal Pile Runoff Containment Basin, the A-Area Metals Burning Pit, the M-Area Settling Basin and Lost Lake, the Metallurgical Laboratory Seepage Basin, the Miscellaneous Chemical Basin, the Motor Shop Oil Basin, the Savannah River Laboratory (SRL) Seepage Basins, and the Silverton Road Waste Site. The analytical results from the monitoring wells for these sites are presented in Table 4-18, Vol. II.

At the *A-Area Coal Pile Runoff Containment Basin*, well ACB 4A had elevated levels of total radium up to 7.9 pCi/L.

Wells MSB 1A through 8A are adjacent to the *M-Area Settling Basin* and *Lost Lake*. Total radium activity higher than the drinking water standard was detected (up to 29.2 pCi/L) in wells MSB 2A, 3A, 4A, and 8A. Gross alpha activity was above the drinking water standard in wells MSB 3A, 4A, and 8A (up to 97.2 pCi/L). Nonvolatile beta activity was elevated in wells MSB 3A, 4A, 5A, and 8A (up to 157 pCi/L).

The remaining MSB wells are used as plume definition wells, some of which were analyzed for radioactive constituents. Total radium activity (up to 121 pCi/L) was elevated in wells MSB 9C, 11C, 11F, 17B, and 29D. Gross alpha activity (up to 136 pCi/L) was elevated in wells MSB 9C and 11F. Nonvolatile beta activity (up to 47.7 pCi/L) was elevated in wells MSB 9C, 11F, 12C, 13B, and 17A.

The ASB series wells monitor the *Savannah River Laboratory (SRL) Seepage Basins*. Total radium levels above the drinking water standard occurred in wells ASB 2A (5.2 pCi/L) and ASB 3A (5.3 pCi/L). Tritium levels up to 25.1 pCi/mL were observed in well ASB 8C, which is approximately 120 m from the SRL Seepage Basins and adjacent to the A-001 outfall.

Central Shops. The following sites have groundwater monitoring wells installed: the Central Shops Burning/Rubble Pits, the Central Shops Hydrofluoric Acid Spill Area, the Fire Department Training Facility, the Ford Building Seepage Basin, and the Hazardous Waste Storage Facility (Fig. 4-24, Vol. II). Table 4-19 in Vol. II shows the analytical results from these wells. No elevated levels of radioactive constituents were detected in this area.

CMP Pits. The only radioactive constituent elevated at the *CMP Pits* (Fig. 4-25, Vol. II) was nonvolatile beta in well CMP 15B, with concentrations up to 20.4 pCi/L (Table 4-20, Vol. II).

D Area. The D-Area Burning/Rubble Pits, the D-Area Coal Pile Runoff Containment Basin, and the D-Area Oil Disposal Basin are monitored by groundwater wells, as shown in Figs. 4-26 and 4-27, Vol. II. The groundwater monitoring results from these wells are presented in Table 4-21, Vol. II.

The only elevated radioactive constituents detected in this area were in the DCB wells, which monitor the *D-Area Coal Pile Runoff Containment Basin*. Elevated gross alpha activities (up to 92.1 pCi/L) were reported in wells DCB 1A, 6, and 11. Elevated nonvolatile beta activities (up to 85.2 pCi/L) were reported in wells DCB 6, 10, and 11. Elevated total radium activities (up to 21.3 pCi/L) were reported in wells 1A, 6, and 10. The only well with an elevated tritium concentration was well DCB 12 (216 pCi/mL).

Sanitary Landfill. *The Sanitary Landfill* is monitored by the LFW series wells (Fig. 4-28, Vol. II). The monitoring data for these wells are presented in Table 4-22, Vol. II. Elevated tritium concentrations (up to 96.1 pCi/mL) were detected in wells LFW 6, 7, 8, 18, and 38. Elevated activities for gross alpha (28.6 pCi/L), for nonvolatile beta (23.4 pCi/L), and for total radium levels (6.7 pCi/L) were reported for

well LFW 7. A single elevated nonvolatile beta value of 11 pCi/L was reported for well LFW 25.

TNX Area. Two seepage basins have groundwater monitoring wells: the Old TNX Seepage Basin and the New TNX Seepage Basin. Fig. 4-29 in Vol. II, shows the location of the basins and their monitoring wells; Table 4-23, Vol. II, gives the monitoring data from these wells.

Old TNX Seepage Basin wells XSB 2, 4, and 5A contained elevated gross alpha activity and nonvolatile beta activity. Wells XSB 2 and 4 also contained elevated total radium activities. The highest values for gross alpha (125 pCi/L) and total radium (95 pCi/L) were recorded in upgradient well XSB 2. The highest value for nonvolatile beta (153 pCi/L) was found in well XSB 4.

Other Sites

One analysis of total radium activity (5.9 pCi/L) that exceeded the drinking water standard was reported for well BRD 3 monitoring the *Road A Chemical Basin* (Fig. 4-30, Vol. II). No elevated levels of radioactivity were detected in the GBW 1 well at the *Hawthorne Fire Tower*. Table 4-24, Vol. II, presents monitoring data for these wells.

NONRADIOACTIVE MONITORING

Applicable Standards

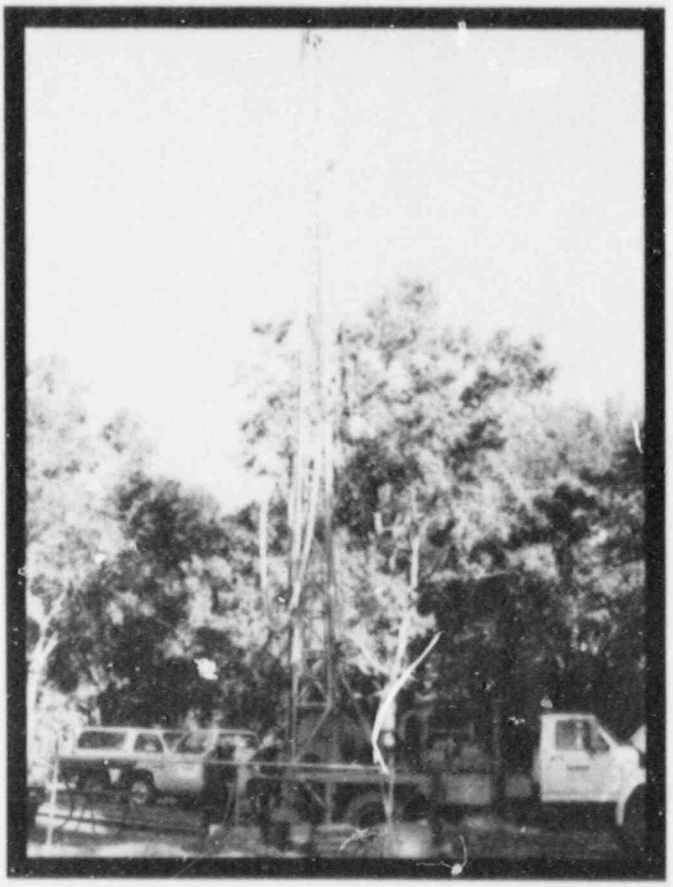
Analytical results of groundwater monitoring are compared to federal primary drinking water standards in this report. Although drinking water standards do not apply to monitoring wells, they are a convenient reference for comparison. Only wells with constituent levels above their respective drinking water standards are discussed in the following section. Table 4-5 on the facing page lists the standards for this comparison and the reference for each standard. Tables 4-6 through 4-9 present a sampling of nonradioactive results from selected well series that are representative of groundwater monitoring in the various areas. Table 4-26 in Vol. II gives a complete summary of maximum constituent levels in groundwater.

Separations Areas

A sampling of maximum levels of nonradioactive constituents found in selected well series monitoring separations areas is included in Tables 4-6 through 4-9.

F Area. Eight facilities in F Area are monitored by groundwater wells: the F-Area A Line, the F-Area Acid/Caustic Basin, the F-Area Burning/Rubble Pits, the F-Area Canyon Building, the F-Area Coal Pile Runoff Containment Basin, the F-Area Seepage Basins, the Old F-Area Seepage Basin, and the Naval Fuels Background Wells. The groundwater monitoring results from F Area are presented in Table 4-3, Vol. II.

The *F-Area A Line* and *F-Area Canyon Building* are monitored by the FAL and FCA wells, respectively (Fig. 4-3, Vol. II). Elevated concentrations of trichloroethylene were reported in the water of both FAL wells (up to 0.037 mg/L). Well FCA 2D, between the two buildings, had elevated conductivity, low pH, and elevated levels of cadmium (up to 0.022 mg/L), lead (up to 0.110 mg/L), nitrate (up to 173 mg/L), and trichloroethylene (up to 0.570 mg/L). Nitrate (up to 11.1 mg/L) was above the drinking water standard in wells FCA 9D and 16D. Trichloroethylene concen-



Thirty wells were installed in F Area in 1987

Table 4-5. Federal Primary Drinking Water Standards for Nonradioactive Constituents

Analyte	Level	Units	Reference*
Arsenic	0.05	mg/L	CFR, 1987
Barium	1.0	mg/L	CFR, 1987
Cadmium	0.01	mg/L	CFR, 1987
Chromium	0.05	mg/L	CFR, 1987
Fluoride	4	mg/L	CFR, 1987
Lead	0.05	mg/L	CFR, 1987
Mercury	0.002	mg/L	CFR, 1987
Nitrate (as N)	10	mg/L	CFR, 1987
Selenium	0.01	mg/L	CFR, 1987
Silver	0.05	mg/L	CFR, 1987
Endrin	0.0002	mg/L	CFR, 1987
2,4-D	0.1	mg/L	CFR, 1987
Lindane	0.004	mg/L	CFR, 1987
Methoxychlor	0.1	mg/L	CFR, 1987
Silvex	0.01	mg/L	CFR, 1987
Toxaphene	0.005	mg/L	CFR, 1987
Benzene	0.005	mg/L	EPA, 1987
Carbon Tetrachloride	0.005	mg/L	EPA, 1987
Chloroform*	0.1	mg/L	CFR, 1987
Trichloroethylene	0.005	mg/L	EPA, 1987
1,1,1-TCE	0.2	mg/L	EPA, 1987

* The level for trihalomethanes is set at 100 µg/L. Because no bromated methanes have been detected in SRP groundwater, Health Protection has made the assumption that most of the trihalomethanes present in plant water are chloroform.

• CFR (Code of Federal Regulations), 1987. *National Primary Drinking Water Regulations*, 40 CFR 141.

EPA (U.S. Environmental Protection Agency), 1987. *National Primary Drinking Water Regulations; Volatile Synthetic Organic Chemicals, U.S. Environmental Protection Agency*, Federal Register, July 8, 1987, pp. 25690-25717.

trations were elevated in wells FCA 16A and 16D, with a maximum reported concentration of 0.323 mg/L.

At the *F-Area Burning/Rubble Pits* (Fig. 4-5, Vol. II), elevated levels of nitrate (up to 16.9 mg/L) and trichloroethylene (up to 0.053 mg/L) were reported in upgradient well FBP 1A and downgradient well FBP 2A. Well FBP 2A also had elevated levels of carbon tetrachloride (up to 0.15 mg/L) and tetrachloroethylene. One elevated lead value (0.072 mg/L) was reported in sidegradient well FBP 3A.

At the *F-Area Coal Pile Runoff Containment Basin* (Fig. 4-6, Vol. II), lead concentrations in excess of the drinking water standard were detected in upgradient well FCB 1. The maximum lead concentration in this well was 0.163 mg/L. The elevated pH, conductivity, and calcium concentrations reported for this well indicate that it has been affected by well grout leaching

The *F-Area Seepage Basins* are monitored by the wells of the FSB series (Fig. 4-7, Vol. II). Nonradioactive constituents with concentrations detected above drinking water standards in these wells were nitrate, lead, and cadmium, with isolated cases of barium and trichloroethylene. Nitrate was the pervasive contaminant, occurring at elevated levels (up to 472 mg/L) in most of the wells above the green clay. Nitrate was also present in wells FSB 78B and 97A in the upper portion of the Congaree Formation. Elevated conductivity was found in the waters with elevated nitrate levels. Lead (up to 0.169 mg/L) was elevated in wells FSB 76, 78, 78C, 79, 79C, 87D, and 92D. Cadmium (up to 0.071 mg/L) was elevated in wells FSB 78, 78C, 79C, 87D, 92D, and 98C. Trichloroethylene (0.51 mg/L) was above the drinking water standard in well FSB 109D. Barium levels (up to 8.96 mg/L) were above the drinking water standard in wells FSB 91D, 92D, and 98C, possibly as a result of well construction. Isolated excursions of arsenic (0.192 mg/L) and selenium (0.02 mg/L) were recorded for well FSB 91D. No nonradioactive constituents with concentrations above drinking water standards were detected in

TABLE 4-6. A SAMPLING OF MAXIMUM NONRADIOACTIVE CONSTITUENT CONCENTRATIONS (MG/L) IN SELECTED SEEPAGE BASIN WELLS

Constituent	DWS (mg/L)	F-Area Seepage Basins (FSB)	H-Area Seepage Basins (HSB)	K-Reactor Seepage Basin (KSB)	M-Area Settling Basin (MSB)
Cadmium	0.01	0.071	0.007	<0.002	0.002
Lead	0.05	0.169	0.027	<0.006	0.072
Mercury	0.002	0.0020	0.0082	<0.0002	<0.0002
NO_3 (as N)	10	472	118	1.84	238
Endrin	0.0002	<0.0001	-	-	0.0005
Triclene	0.005	0.051	<0.005	-	125

the wells monitoring the lower portion of the Congaree Formation.

The FNB wells monitor the *Old F-Area Seepage Basin* (Fig. 4-8, Vol. II). Elevated levels of trichloroethylene (up to 0.099 mg/L) were reported in downgradient wells FNB 1 and 2. Elevated nitrate levels (up to 31.1 mg/L), elevated conductivity (up to 320 µmhos/cm), and low pH (3.4 to 4.3) were reported in downgradient well FNB 2 and downgradient well FNB 3. One elevated lead value (0.052 mg/L) was reported for well FNB 2.

Three wells (NBG 1, 2, and 3) monitoring the *F-Area Naval Fuels Facility* (Fig. 4-3, Vol. II) contained elevated levels of trichloroethylene. The highest trichloroethylene concentration (0.059 mg/L) was recorded for well NBG 1. Well NBG 2 contained concentrations of nitrate up to 31.7 mg/L.

At the *F-Area Tank Farm* (Fig. 4-9, Vol. II) nitrate concentrations above the drinking water standard were detected in wells FTF 6 (12.2 mg/L), FTF 25A (120 mg/L), and FTF 26 (42.6 mg/L). Elevated pH and conductivity in wells FTF 12 and 21 indicate that these wells have been affected by well grout leaching.

H Area. The H-Area Canyon Building, the H-Area Coal Pile Runoff Containment Basin, the H-Area Retention Basins, the H-Area Tank Farm, and the H-Area Seepage Basins have groundwater monitoring wells. Table 4-5 in Vol. II shows the H-Area groundwater monitoring results.

Trichloroethylene (up to 0.008 mg/L) in well HCA 4 was the only nonradioactive constituent detected above its drinking water standard in the groundwater at the *H-Area Canyon Building* (Fig. 4-10, Vol. II). Tetrachloroethylene was also detected in this well.

Results from sidegradient well HCB 2 monitoring the *H-Area Coal Pile Runoff Containment Basin* (Fig. 4-11, Vol. II) showed a lead concentration (0.054 mg/L) above its drinking water standard. The conductivity (240 to 2,080 µmhos/cm) and sulfate concentrations (150 to 760 mg/L) were elevated and variable in this well during 1987, as they were in 1986.

Of the HR3 and HR8 series wells, which monitor the *H-Area Retention Basins* (Fig. 4-12, Vol. II), only well HR8 14 had elevated levels of nonradioactive constituents. This well is downgradient of the old retention basin and had elevated conductivity (380 to 420 µmhos/cm) and nitrate concentrations (up to 38.7 mg/L).

The *H-Area Seepage Basins* are monitored for nonradioactive constituents in groundwater by the HSB well series (Fig. 4-13, Vol. II). Nitrate (up to 118 mg/L) was the most common nonradioactive constituent detected above the drinking water standard at this site. Wells HSB 67, 68, 69, 71, 83D, 84D, and 86D, which are screened in the water table, and wells HSB 68C and 86C, which are screened in the lower portion of the Dry Branch Formation, had elevated nitrate levels. Water-table wells HSB 67 and 83D had mercury levels (up to 0.0082 mg/L) that exceeded the drinking water standard. Well HSB 84A is screened in the upper portion of the Congaree Formation and had elevated levels of nitrate.

TABLE 4-7. A SAMPLING OF MAXIMUM NONRADIOACTIVE CONSTITUENT CONCENTRATIONS (MG/L) IN SELECTED COAL PILE RUNOFF BASIN WELLS

Constituent	DWS (mg/L)	F-Area Coal Pile Runoff Basin (FCB)	C-Area Coal Pile Runoff Basin (CCB)	P-Area Coal Pile Runoff Basin (PCB)	A-Area Coal Pile Runoff Basin (ACB)	D-Area Coal Pile Runoff Basin (DCB)
Cadmium	0.01	<0.002	<0.002	0.012	<0.002	0.032
Lead	0.05	0.163	0.015	0.062	0.020	0.310
Mercury	0.002	<0.0002	<0.0002	<0.0002	0.0009	0.0009
NO_3 (as N)	10	1.97	1.37	0.53	1.50	2.15
Endrin	0.0002	-	-	-	-	<0.0001
Triclene	0.005	-	-	<0.005	<0.001	0.034

Water samples from the HTF series wells at the *H-Area Tank Farm* (Fig. 4-13, Vol. II) were analyzed for sodium and nitrate in the third and fourth quarters of 1987. An elevated sodium concentration (460 mg/L) was found in a sample from well HTF 8, but this result is questionable because of the low conductivity result for the sample. The nitrate concentration (25 mg/L) in well HTF 22 was above the drinking water standard.

S Area. Analytical results from the *S-Area Background Wells* (Fig. 4-15, Vol. II) are presented on the facing page in Table 4-6, Vol. II. Trichloroethylene (0.111 mg/L) in well SBG 4 was the only nonradioactive constituent level above the drinking water standard that was detected in the groundwater. Low levels of mercury were detected in well SBG 1, but they did not exceed the drinking water standard.

Z Area. The *Z-Area Background Wells* are the only wells that have been installed in Z Area to date. Table 4-7 in Vol. II gives the monitoring results from these wells. No constituents were detected above the drinking water standards.

Reactor Areas

A sampling of maximum levels of nonradioactive constituents found in selected well series monitoring reactor areas is included in Tables 4-6 through 4-9.

C Area. The following locations are monitored by groundwater wells (Fig. 4-17, Vol. II): the C-Area Burning/Rubble Pit, the C-Area Coal Pile Runoff Containment Basin, the C-Area Disassembly Basin, and the C-Area Reactor Seepage Basins. The monitoring results from these wells are presented in Table 4-10, Vol. II.

At the *C-Area Disassembly Basin*, results from well CDB 1 showed one elevated measurement of lead (0.076 mg/L).

Elevated trichloroethylene levels, up to 5.2 mg/L in well CRP 3, were reported for wells CRP 1, 3, and 4, which monitor the *C-Area Burning/Rubble Pit*. Water from well CRP 3 had high pH, conductivity, and high calcium concentrations, indicating the effects of leaching of well grout. Elevated lead levels (up to 0.418 mg/L) and elevated chromium levels (up to 0.108 mg/L) were also reported for this well.

The CSB wells, which monitor the *C-Area Seepage Basins*, had elevated trichloroethylene concentrations. Well CSB 4A had the maximum trichloroethylene concentration (0.330 mg/L), which is similar to the maximum value recorded in 1986. Well CSB 5A had one elevated tetrachloroethylene result (0.203 mg/L). Upgradient well CSB 1A contained elevated chromium concentrations (up to 0.066 mg/L) and one elevated lead concentration (0.199 mg/L). High pH, conductivity, and calcium concentrations in the water from wells CSB 1A, 5A, and 6A indicate that these wells have been affected by well grout leaching.

K Area. Seven facilities have groundwater monitoring wells installed: the K-Area Acid/Caustic Basin, the K-Area Ash Basin, the K-Area Burning/Rubble

TABLE 4-8. A SAMPLING OF MAXIMUM NONRADIOACTIVE CONSTITUENT CONCENTRATIONS (MG/L) IN SELECTED MISCELLANEOUS WELLS

Constituent	DWS (mg/L)	Naval Fuels (NBG)	H-Area Canyon Building (HCA)	Z Area (ZBG)	Central Shops Hazardous Waste Storage (HWS)	Sanitary Landfill (LFW)
Cadmium	0.01	<0.002	<0.002	<0.002	<0.002	0.021
Lead	0.05	0.038	0.013	0.010	0.007	0.022
Mercury	0.002	0.0003	<0.0002	<0.0002	<0.0002	0.0005
NO_3 (as N)	10	31.7	1.69	1.75	0.90	1.95
Endrin	0.0002	-	<0.0001	<0.0001	-	<0.00005
Triclene	0.005	0.059	0.008	<0.005	-	0.044

Pit, the K-Area Coal Pile Runoff Containment Basin, the K-Area Disassembly Basin, the K-Area Reactor Seepage Basin, and the K-Area Retention Basin. The locations of these facilities are given in Fig. 4-18, Vol. II, and the groundwater monitoring results are given in Table 4-12, Vol. II.

The KAC wells monitor the *K-Area Acid/Caustic Basin*. No nonradioactive constituents with levels above drinking water standards were detected in these wells; however, elevated levels of sulfate and TDS and elevated conductivity were observed in downgradient well KAC 1 and to a lesser extent in wells KAC 2 and 3.

At the *K-Area Burning/Rubble Pit*, sidegradient well KRP 1 and upgradient well KRP 2 contained concentrations of lead in excess of the drinking water standard. The highest lead concentration (0.099 mg/L) was reported for well KRP 1. Downgradient well KRP 4 contained elevated trichloroethylene levels (up to 0.043 mg/L).

No nonradioactive constituents with levels above drinking water standards were detected in the KCB wells monitoring the *K-Area Coal Pile Runoff Containment Basin*. Downgradient well KCB 3 and to a lesser extent well KCB 4 had elevated conductivity levels.

Well KDB 1, which monitors the *K-Area Disassembly Basin*, contained elevated lead concentrations up to 0.142 mg/L. Well KDB 3 had elevated levels of calcium and conductivity, possibly indicating leaching of well grout.

Lead concentrations in excess of the drinking water standard were reported in wells KRB 1, 8, and 13, monitoring the *K-Area Retention Basin*. The highest lead concentration (0.189 mg/L) was detected in well KRB 1.

L Area. Groundwater monitoring wells have been installed around the following sites: the L-Area Acid/Caustic Basin, the L-Area Burning/Rubble Pit, the L-Area Disassembly Basin, the L-Area Oil and Chemical Basin, and the L-Area Reactor Seepage Basin (Fig. 4-19, Vol. II). Table 4-13 in Vol. II presents the groundwater monitoring results from these wells for 1987.

Elevated levels of tetrachloroethylene were found in wells LAC 1, 2, and 3 monitoring the *L-Area Acid/Caustic Basin*. Trichloroethylene levels were above the drinking water standard in all of the L-Area Acid/Caustic Basin wells, with a maximum value of 0.124 mg/L, which occurred in well LAC 2.

At the *L-Area Burning/Rubble Pit*, well LRP 2 contained elevated lead concentrations up to 0.061 mg/L.

L-Area Disassembly Basin wells LDB 1 and 2 contained lead levels above the drinking water standard, although these levels were substantially lower than those recorded for 1986. The 1987 maximum lead concentration (0.160 mg/L) was found in well LDB 1. In 1986 the maximum lead concentration was 0.718 mg/L.

L-Area Oil and Chemical Basin well LCO 4 had elevated levels of lead and mercury that exceeded the levels of these constituents found in this well in 1985 and 1986. The 1987 maximum lead value (0.069 mg/L) exceeded the drinking water standard; the 1987 maximum mercury value (0.002 mg/L) was equal to the drinking water standard. Well LCO 3 had elevated trichloroethylene concentrations, up to 0.015 mg/L. The trichloroethylene levels in well LCO 3 are possibly attributable to the influence of the nearby L-Area Acid/Caustic Basin because of the presence of trichloroethylene in wells monitoring that upgradient facility. Tetrachloroethylene was detected in wells LCO 2, 3, and 4.

P Area. Five sites (Fig. 4-20, Vol. II) are monitored by groundwater wells: the P-Area Acid/Caustic Basin, the P-Area Burning/Rubble Pit, the P-Area Coal Pile Runoff Containment Basin, the P-Area Disassembly Basin, and the P-Area Reactor Seepage Basins. The groundwater monitoring results are shown in Table 4-15, Vol. II.

At the *P-Area Burning/Rubble Pit,* sidegradient well PRP 3 had a single excursion of lead (0.065 mg/L) and elevated levels of tetrachloroethylene (up to 0.043 mg/L), trichloroethylene (up to 0.252 mg/L), and 1,1,1-TCE (up to 0.494 mg/L).

Well PCB 3A, downgradient from the *P-Area Coal Pile Runoff Containment Basin,* had single excursions of cadmium (0.012 mg/L), lead (0.062 mg/L), and selenium (0.011 mg/L) above their respective drinking water standards. This well also had elevated conductivity (952 to 1,450 µmhos/cm), calcium (59.4 mg/L), and sulfate concentrations (up to 831 mg/L).

Lead concentrations in excess of the drinking water standard were reported in well PDB 3, which monitors the *P-Area Disassembly Basin*. The highest concentration reported was 0.103 mg/L.

Four wells monitoring the P-Area Reactor Seepage Basins (PSB 3A, 4A, 5A, and 6A) contained elevated lead levels. The highest lead value reported was 0.077 mg/L in well PSB 4A. The elevated lead levels may be attributable to the P-Area Coal Pile Runoff Containment Basin, which is upgradient of the seepage basin. This well also contained one elevated nitrate level (13.7 mg/L).

R Area. The R-Area Acid/Caustic Basin, the R-Area Burning/Rubble Pits, and the R-Area Reactor Seepage Basins are monitored by groundwater wells. Table 4-17 in Vol. II contains the monitoring data from these wells.

At the *R-Area Reactor Seepage Basins* (Fig. 4-21, Vol. II), five wells (RSE 24 and 25 and RSF 1, 2, and 3) were monitored for nonradioactive constituents. One nitrate concentration (12.7 mg/L) above the drinking water standard was detected in well RSE 25. High pH and conductivity and high calcium concentrations in the water from well RSF 1 indicate that it was affected by the leaching of well grout.

General Areas

A sampling of maximum levels of nonradioactive constituents found in selected well series monitoring general areas is included in Tables 4-6 through 4-9.

A/M Area. Ten sites, as shown in Figs. 4-22 and 4-23, Vol. II, have groundwater monitoring wells: the A-Area Background Well, the A-Area Burning/Rubble Pits, the A-Area Coal Pile Runoff Containment Basin, the A-Area Metals Burning Pit, the M-Area Settling Basin, the Metallurgical Lab Seepage Basin, the Miscellaneous Chemical Basin, the Motor Shop Oil Basin, the Savannah River Laboratory (SRL) Seepage Basins, and the Silverton Road Waste Site. The analytical results from the monitoring wells are presented in Table 4-18, Vol. II.

Trichloroethylene levels up to 0.006 mg/L were detected in the *A-Area Background Well* (ABW 1), but these elevated levels may be due to contamination from the A-001 outfall, which is upgradient from the well site. All other constituents were below drinking water standards.

At the *A-Area Metals Burning Pit*, trichloroethylene levels above the drinking water standard were reported in wells ABP 2A, 3, and 4. The maximum concentration of 0.088 mg/L was reported in well ABP 3. Tetrachloroethylene was detected in the wells at this site.

At the *A-Area Burning/Rubble Pits,* trichloroethylene was elevated in wells ARP 1A and 3, with a maximum 1987 value of 0.248 mg/L in upgradient well ARP 3, representing an increase from the 1986 maximum of 0.067 mg/L. Well ARP 3 also showed a single tetrachloroethylene excursion.

TABLE 4-9. A SAMPLING OF MAXIMUM NONRADIOACTIVE CONSTITUENT CONCENTRATIONS (MG/L) IN SELECTED ACID CAUSTIC BASIN WELLS

Constituent	DWS (mg/L)	F-Area Acid/Caustic Basin (FAC)	K-Area Acid/Caustic Basin (KAC)	L-Area Acid/Caustic Basin (LAC)	P-Area Acid/Caustic Basin (PAC)	R-Area Acid/Caustic Basin (RAC)
Cadmium	0.01	0.002	0.004	0.002	0.002	0.002
Lead	0.05	0.029	0.012	0.029	0.006	0.044
Mercury	0.002	0.0002	0.0004	0.0002	0.0002	0.0002
NO_3 (as N)	10	0.20	0.63	1.22	1.23	3.76
Endrin	0.0002	-	-	-	-	-
Triclene	0.005	-	0.005	0.124	-	-

At the *Motor Shop Oil Basin*, well AOB 1 contained up to 0.112 mg/L of trichloroethylene. These elevated levels of trichloroethylene may originate from the nearby A-014 outfall, although the outfall is sidegradient of the basin. Tetrachloroethylene was detected in the wells at this site.

Wells MSB 1A through 4A are adjacent to the *M-Area Settling Basin*, and wells 5A through 8A are near *Lost Lake*. These wells are the designated RCRA point-of-compliance (POC) monitoring wells for the M-Area Hazardous Waste Management Facility. Wells MSB 3A and 4A were the most affected at the site. Trichloroethylene (up to 125 mg/L), tetrachloroethylene (up to 271 mg/L), and nitrate (up to 238 mg/L) were the most common contaminants. Levels of carbon tetrachloride (up to 0.072 mg/L), chromium (up to 0.056 mg/L), 1,1,1-trichloroethane (up to 0.589 mg/L), and chloroform (up to 0.3 mg/L) were also reported above the drinking water standards. Elevated levels of lead, nitrate, trichloroethylene, tetrachloroethylene, and chloroform were reported in some of the POC wells.

Trichloroethylene (up to 0.058 mg/L) was the only constituent above the drinking water standard detected in the AMB wells monitoring the *Metallurgical Laboratory Seepage Basin*.

Elevated trichloroethylene levels (up to 0.129 mg/L) were detected in the MCB wells at the *Miscellaneous Chemical Basin*.

Trichloroethylene (up to 0.096 mg/L) was detected above the drinking water standard in wells ASB 4 and 5A adjacent to the *Savannah River Laboratory Seepage Basins*. Higher concentrations of trichloroethylene (up to 3.2 mg/L) and concentrations of tetrachloroethylene (up to 0.146 mg/L) were detected in three wells (ASB 8, 8B, and 8C) downgradient from the A-001 outfall and approximately 120 m from the seepage basins.

Concentrations of two organic compounds were elevated in the SRW wells monitoring the *Silverton Road Waste Site*. Wells SRW 5, 6, 7, 8, and 11 contained carbon tetrachloride levels above the drinking water standard (up to 0.011 mg/L). Trichloroethylene levels (up to 0.011 mg/L) were above the drinking water standard in wells SRW 6, 7, 8, 11, and 16A.

Central Shops. The following sites have groundwater monitoring wells: the Central Shops Burning/Rubble Pits, the Central Shops Hydrofluoric Acid Spill Area, the Fire Department Training Facility (previously called the Central Shops Burnable Oil Basin), the Ford Building Seepage Basin, and the Hazardous Waste Storage Facility (Fig. 4-24, Vol. II). Table 4-19 in Vol. II shows the analytical results from these wells.

In well CSA 4, monitoring the *Hydrofluoric Acid Spill Area*, cadmium was detected at a concentration equal to the drinking water standard.

CMP Pits. The CMP Pits (Fig. 4-25, Vol. II) are monitored by the wells of the CMP series (Table 4-20, Vol. II). The only nonradioactive constituents with elevated levels were trichloroethylene in well CMP 13 (up to 0.009 mg/L), elevated carbon tetra-

chloride results in wells CMP 13 (0.007 mg/L) and CMP 14B (0.009 mg/L), and a single excursion for lead (0.272 mg/L) in well CMP 11.

D Area. The D-Area Burning/Rubble Pits, the D-Area Coal Pile Runoff Containment Basin, and the D-Area Oil Disposal Basin are monitored by groundwater wells, as shown in Figs. 4-26 and 4-27, Vol. II. The groundwater monitoring results from these wells are presented in Table 4-21, Vol. II. At the *D-Area Burning/Rubble Pits*, one trichloroethylene analysis from well DBP 4 was equal to the drinking water standard.

The DCB well series monitors the *D-Area Coal Pile Runoff Containment Basin*. Most of the wells had elevated sulfate concentrations, elevated conductivity, and low pH. Constituents with levels above the drinking water standards were cadmium in wells DCB 1A and 11 (up to 0.032 mg/L), chromium in wells DCB 6, 10, and 11 (up to 0.488 mg/L), fluoride in well DCB 6 (4.50 mg/L), lead in well DCB 1A (0.310 mg/L), and trichloroethylene in wells DCB 1A and 3A (up to 0.034 mg/L).

Metals analysis on groundwater samples

Sanitary Landfill. The data for the LFW wells, which monitor the *Sanitary Landfill* (Fig. 4-28, Vol. II), are presented in Table 4-22, Vol. II. Trichloroethylene levels (up to 0.044 mg/L) were reported above the drinking water standard in wells LFW 7, 8, 17, 36, 37, and 38. Similarly, tetrachloroethylene levels (up to 0.655 mg/L) were reported in wells LFW 21, 38, and 39. Elevated cadmium results (up to 0.021 mg/L) were reported in wells LFW 6, 17, and 26, and elevated chromium results were reported for wells LFW 8 and 17.

TNX Area. Two seepage basins have groundwater monitoring wells: the Old TNX Seepage Basin and the New TNX Seepage Basin. Fig. 4-29 in Vol. II shows the location of the basins and their monitoring wells; Table 4-23, Vol. II, gives the monitoring data from these wells.

The *Old TNX Seepage Basin* is monitored by the XSB well series. Four wells (XSB 1, 2, 4, and 5A) contained lead and nitrate levels in excess of their respective drinking water standards. The highest values for nitrate (220 mg/L) and lead (5.0 mg/L) were found in upgradient well XSB 2. Elevated mercury levels were found in wells XSB 2 and 4. Well XSB 4 contained the highest mercury concentration (0.0123 mg/L). Elevated trichloroethylene concentrations were found in all wells monitoring the Old TNX Seepage Basin. Upgradient well XSB 2 contained the highest trichloroethylene concentration (0.593 mg/L) and an excursion of carbon tetrachloride (0.017 mg/L).

The *New TNX Seepage Basin* monitoring well YSB 4A had a single excursion of nitrate (11.7 mg/L) above the drinking water standard.

Other Sites

The only nonradioactive constituent with elevated concentrations found in the groundwater at the *Road A Chemical Basin* (Fig. 4-30, Vol. II) was lead (up to 0.155 mg/L) in well BRD 3. No elevated levels of nonradioactive constituents were found in the GBW 1 background well at the *Hawthorne Fire Tower*. Table 4-24, Vol. II, presents monitoring data for these wells.

1987 HIGHLIGHTS

- Three new well series were constructed around the Miscellaneous Chemical Basin, around the kaolinite diked area of R-Area Reactor Seepage Basins 1 and 3, and in the Z Area.
- Fifty-nine new wells were added to existing well series during 1987.
- Thirty RCRA point-of-compliance wells were installed at the F-Area Seepage Basins and analyzed for EPA Appendix IX constituents.
- Of all wells monitored on the SRP site, the highest activity levels of tritium were measured in the MGA through MGI well series monitoring the groundwater beneath the original Burial Ground.
- A well in the F-Area Tank Farm had the maximum nonvolatile beta value (34,623 pCi/L) for the SRP site, while a well at the F-Area Seepage Basins had the highest gross alpha activity, 1,850 pCi/L.
- No nonradioactive constituents were detected above drinking water standards in the Z Area, in the Central Shops Area, in the A-, C-, and K-Area Coal Runoff Basins, in the K-Area Ash Basin, in the Reactor seepage basins for K and L Areas, in the acid/caustic basins in P, F, K, and R Areas, in the D-Area Oil Disposal Basin, or in the burning/rubble pits of R Area.

5
Food and Drinking Water

SUMMARY — The results of the monitoring programs for milk, food, and drinking water, along with a description of each of the monitoring programs, are contained in this chapter. Drinking water supplies from 22 onsite facilities and 14 surrounding towns were sampled and analyzed for radioactive and nonradioactive constituents. The radiological analyses included gross alpha, nonvolatile beta, and tritium. The nonradiological analyses included residual chlorine, chlorocarbons, total coliform, and various water quality parameters. The guidelines recommended by the South Carolina Department of Health and Environmental Control (SCDHEC) and by the U.S. EPA are used as standards for nonradiological monitoring at SRP. The radiological monitoring of milk for ^{137}Cs, ^{131}I, tritium, and ^{90}Sr, and of farm products for tritium, ^{90}Sr, U/Pu (nonspecific), and $^{238,239}Pu$, indicated concentrations of radioactivity corresponding to an insignificant radiation dose.

RADIOACTIVE MONITORING

Milk

Description of Monitoring Program. Routine samples of milk are taken from production at five dairies within a 25-mile radius of SRP and from locally-produced inventories of a major local distributor. Milk samples are analyzed for ^{137}Cs, ^{131}I, tritium, and ^{90}Sr. Sampling locations are shown in Fig. 5-1, Vol. II.

Monitoring Results. Monitoring data for 1987 are presented in Table 5-1, Vol. II. Tritium in milk is attributed to releases from SRP. During 1987, tritium concentrations in routine individual milk samples ranged from less than 0.03 to 4.0 pCi/mL with an average of 0.6 pCi/mL. These very small tritium concentrations in milk do not correspond to significant radiation doses. For example, the 50-year dose commitment from drinking one half-liter of milk per day for a year with a 1 pCi/mL tritium concentration is approximately 0.01 mrem (0.0001 mSv). This dose is 0.003% of the average Central Savannah River Area (CSRA) individual's annual dose from naturally occurring radioactivity.

Concentrations of ^{90}Sr in milk ranged from 2 to 14 pCi/L with an average concentration of 7 pCi/L, and were within ranges observed in previous years. One milk sample collected in 1987 showed an ^{131}I concentration of 3.7 pCi/L, which was within ranges observed in previous years except 1986. The maximum ^{131}I concentration of 11 pCi/L dectected in milk in May 1986 reflected contribution from the Chernobyl accident. All other milk samples collected during 1987 had less than minimum detectable ^{131}I concentrations. Because of its short physical half-life (8 days), ^{131}I is not generally detected, except shortly after tests of nuclear weapons or in the wake of events such as the Chernobyl reactor accident. There were no announced atmospheric nuclear weapons tests or other major nuclear events in 1987.

Cesium-137 concentrations in milk ranged from less than 2 to 8 pCi/L with an average concentration of 2 pCi/L. These data from 1987 are in agreement with data from previous years. Concentrations of ^{137}Cs in milk from the SRP area are within the ranges reported by the EPA for the southeastern United States and are attributed to worldwide fallout from weapons tests.

Food

Description of Monitoring Program. Farm products representing the food categories of leafy vegetables, fruit, grain, poultry, eggs, and meat are collected at 14 localities in the six counties surrounding SRP. Six locations are near the plant perimeter and eight are at a distance of approximately 25 miles. Food samples are analyzed for gamma-emitting radionuclides, tritium, ^{90}Sr, U/Pu (non-specific), and $^{238,239}Pu$. Food sample locations are shown in Fig. 5-2, Vol. II.

Monitoring Results. Food radioactivity monitoring data are presented in Table 5-2, Vol. II. Concentrations of gamma-emitting radionuclides in foods were generally near or less than the minimum detectable concentrations. Concentrations of ^{40}K varied from less than detectable concentrations to

6.9 pCi/g and were within ranges normally observed in food and vegetation. Cesium-137 concentrations were near or below minimum detectable concentrations. The maximum ^{137}Cs concentration was 0.08 pCi/g in eggs.

Strontium-90 concentrations were within the ranges observed in past years. The maximum in 1987 was 0.63 pCi/g in pork, compared to a maximum in 1986 of 0.36 pCi/g in collards. U/Pu concentrations were at or below minimum detectable concentrations. Concentrations of ^{238}Pu in food ranged from 0.04 to 0.54 fCi/g. Plutonium-239 concentrations in food ranged from 0.01 to 0.76 fCi/g. All plutonium results were within values seen in previous years. Plutonium and ^{90}Sr in food result primarily from worldwide fallout that has accumulated in the soil.

Tritium concentrations in free water obtained from freeze-drying the food ranged from 0.28 to 4.3 pCi/mL and were within ranges routinely detected in food and vegetation. The maximum concentration was observed in fruits and collards.

The radiation dose from eating foods with these levels of radioactivity is a small fraction of the dose from natural sources of radioactivity. For example, if a person consumed collards at a maximum consumption rate of 64 kg/year (140 lb/yr), the 50-year whole body dose commitment would be 0.8 mrem (0.008 mSv) for ^{90}Sr (average 0.1 pCi/g) and 0.008 mrem (0.00008 mSv) for tritium (average 2 pCi/g). The sum is equal to 0.3% of the average CSRA individual's annual dose from naturally occurring radioactivity.

Drinking Water

Description of Monitoring Program. Drinking water supplies from 22 onsite facilities and 14 surrounding towns are sampled and analyzed for gross alpha, nonvolatile beta, and tritium. Public drinking water locations are shown in Fig. 2-1, Vol. II.

Two water treatment plants downriver from SRP supply treated Savannah River water to customers in Beaufort and Jasper Counties, SC, and Port Wentworth, GA (Fig. 5-3, Vol. II). The Cherokee Hill water treatment plant at Port Wentworth has been treating Savannah River water during the entire period of operation of SRP. Treated water from this plant is used primarily for industrial and manufacturing purposes in an industrial complex near Savannah, GA. It has a consumer population of about 20,000 people who are primarily adults working in industrial facilities. The Beaufort-Jasper water treatment plant near Hardeeville, SC, has been in operation since 1965. It serves a consumer population of approximately 50,000 people who live in Beaufort and Jasper Counties.

Raw and finished water treatment plant samples from these two plants and from a water treatment plant in North Augusta, SC, are collected daily by treatment plant personnel and composited for monthly analyses by SRP. The North Augusta water treatment plant is upriver of SRP and provides a control for the analyses. These samples are analyzed for gross alpha, nonvolatile beta, and tritium concentrations.

Monitoring Results. Drinking water radioactivity monitoring data for 1987 are presented in Table 5-3, Vol. II. Alpha and nonvolatile beta concentrations in drinking water collected onsite and from surrounding towns were within ranges attributed to naturally occurring radium and thorium. Studies conducted in South Carolina to determine levels of naturally occurring radionuclides in drinking water have indicated radium concentrations of over 20 pCi/L [Mi80]. EPA maximum contaminant levels (MCL) are 5 pCi/L combined ^{226}Ra and ^{228}Ra, and 15 pCi/L gross alpha activity (excluding radon and uranium).

Small but measurable concentrations of tritium were detected occasionally in drinking water samples collected in operating areas. The maximum onsite tritium concentration of 6 pCi/mL was 30% of the EPA drinking water standard. A special study conducted in 1987 indicated that trace levels of tritium detected in onsite drinking water samples are introduced after sample collection and do not reflect contamination in the aquifer. Chapter 8 discusses the study in more detail.

The maximum tritium concentration in drinking water supplies from surrounding towns was 0.9 pCi/mL, which is 5% of the EPA drinking water standard. Tritium, when present in water supplies that use surface water, is attributed to SRP releases and global fallout. The measurable tritium concentrations in surface water result from exchange of tritium from SRP atmospheric releases with hydrogen in rainwater and surface water.

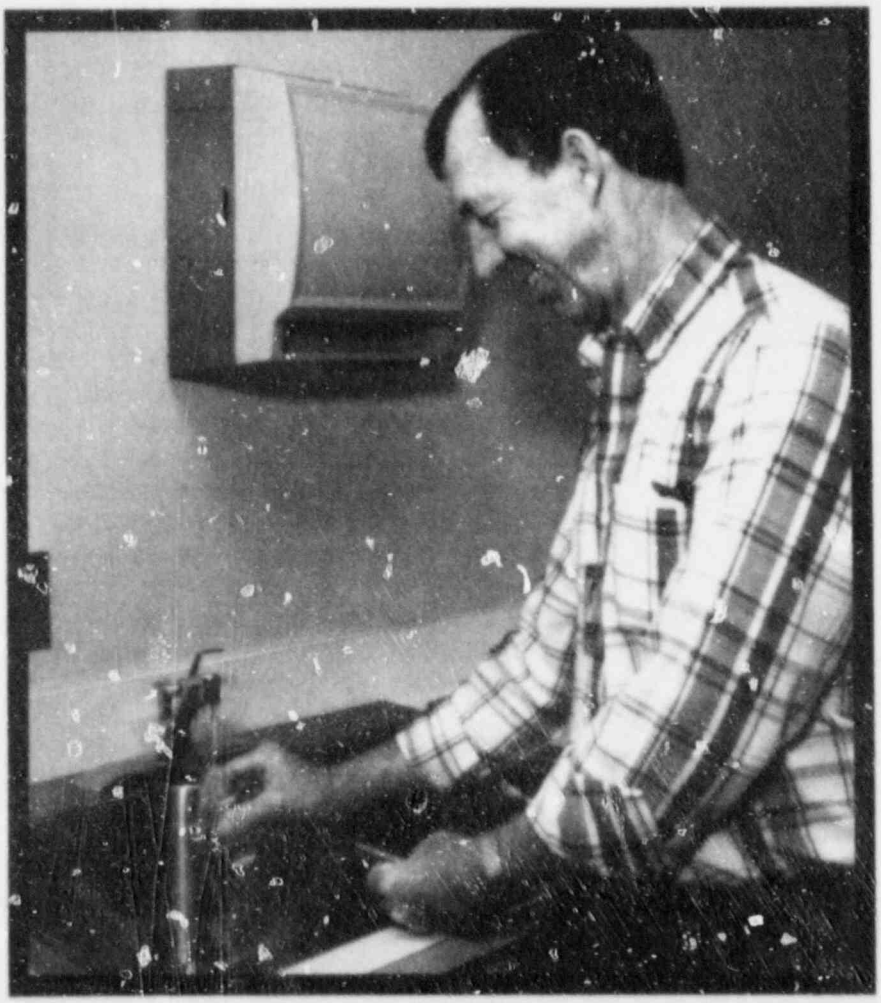
Analytical data from water treatment plants are shown in Table 5-3, Vol. II. Alpha concentrations at all three water treatment plants were less than the minimum detectable concentration of approximately 0.5 pCi/L. The maximum nonvolatile beta concentrations in finished water from the three plants ranged from 1.9 to 2.4 pCi/L. These concentrations were within the ranges observed in water from the Edisto River, which is approximately 20 miles from SRP and is negligibly influenced by SRP operations. The maximum nonvolatile beta concentration in water collected from the Edisto River during 1987 was 2.3 pCi/L (Chapter 3). These results for alpha and nonvolatile beta activity confirm that SRP operations have no significant impact on downriver concentrations. The only measurable SRP impact is from tritium. The maximum tritium concentration in finished water from both the Beaufort-Jasper and Port Wentworth treatment plants in 1987 was 3.3 pCi/mL with an average concentration of 2.3 pCi/mL. The average concentration is 12% of the EPA drinking water standard for tritium (20 pCi/mL).

NONRADIOACTIVE MONITORING

Drinking Water

Description of Monitoring Program. Drinking water at SRP is supplied primarily by deep wells that draw water from the Black Creek-Middendorf Formations (formerly called the Tuscaloosa Aquifer). The Savannah River is used for drinking water in 400-D Area. The drinking water is generally treated with chlorine to ensure that no harmful coliform bacteria are present.

Samples from drinking water supplies are routinely analyzed for residual chlorine and total coliform. The sampling frequency depends upon the potential for contamination and the amount of use. In addition, the primary supplies are analyzed annually for a comprehensive list of chemicals and other water quality parameters.



Sampling drinking water

Drinking water is also monitored for chlorocarbons. Groundwater in the vicinity of M-Fuel Fabrication Area was found to be contaminated with metal degreasing solvents in 1981. Followup sampling indicated that trichloroethylene and tetrachloroethylene (chlorocarbons) were present in Wells 20A and 53A in the A-Administration Area. These wells, which supplied both drinking water and process water for the A-Administration and M-Fuel Fabrication Areas, were shut down, and drinking water was supplied from Well 82A, which was free of chlorocarbons. Use of drinking water from Well 31A, which served as a backup source of drinking water, was also discontinued in 1983 because of the occasional presence of low concentrations of chlorocarbons. The drinking water and process water systems were then separated, and water from Wells 20A and 53A was restricted to process water applications. A

dense-bed activated charcoal filter system was installed on A-Administration/M-Fuel Fabrication Areas drinking water supplies in 1985. This action permitted the reactivation of Well 31A as a backup source of drinking water. In December 1986, the charcoal filter system was removed from service, and Well 31A is being converted to a process water well. New drinking water supply wells (112- and 113-G), approximately one and one-half miles east of the A-Administration Area, respectively, were placed in service in late 1986. No chlorocarbons have been detected in water from these wells. No chlorocarbons have ever been detected in drinking water systems.

Applicable Standards. SCDHEC maximum contaminant levels and recommended guidelines are used to ensure safe drinking water at SRP. The recommended guidelines call for a minimum of 0.2 part per million (ppm) chlorine at all parts of the water system. The maximum contaminant concentration limit for total coliform is a monthly average not greater than 1 colony/100 mL or an individual result not greater than 4 colonies/100 mL in two consecutive samples.

For total trihalomethanes, the standard is less than 100 µg/L for community drinking water supplies. Although SRP drinking water supplies are not classified as community drinking water supplies and are not required to meet this standard, SRP policy is to meet the requirement.

For other constituents, the "National Interim Primary Drinking Water Regulations" apply [EPA76].

For chlorocarbons, the EPA drinking water standard for tetrachloroethylene is 10 µg/L (parts per billion, ppb). The proposed EPA standards for trichloroethylene of 5 µg/L (ppb) and 1,1,1-trichloroethane of 200 µg/L (ppb) have not yet been adopted. Table 5-1 at the bottom of the page summarizes the drinking water standards.

Monitoring Results. Monitoring data show that residual chlorine concentrations were within expected ranges in 1987. Elevated total coliform counts were detected in domestic water samples in D Area (March 1987), TNX Area (April 1987), and K Area (September 1987). The elevated counts in D and TNX Areas were due to the use of unsterile sample containers. Residual chlorine levels were sufficient to keep the coliform counts less than 1 colony/100 mL in these samples. The elevated coliform count in K Area was detected in a sample taken after a water line repair was completed. This sink was not returned to service until two consecutive resamplings showed less than 1 colony/100 mL total coliform. Analytical results are presented in Table 5-4, Vol. II.

Concentrations of chemicals, metals, and organics were within applicable standards except for total iron, total manganese, turbidity, color, and pH at a few locations. Nine of the 15 samples had elevated total iron concentrations. These elevated iron con-

Table 5-1. Drinking Water Standards for Nonradiological Contaminants[a,b]

total coliform	either monthly average ≤ 1 colony/100 mL or ≤ 4 colonies/100 mL in 2 consecutive samples
total trihalomethanes	< 100 µg/L
tetrachloroethylene	< 10 µg/L[c]
trichloroethylene	< 5 µg/L[d]
1,1,1-trichloroethane	< 200 µg/L[d]

[a] SCDHEC-recommended guidelines call for a minimum of 0.2 ppm chlorine at all parts of the water system.
[b] For constituents not shown, the *National Interim Primary Drinking Water Regulations* apply [EPA76].
[c] EPA standard.
[d] Proposed EPA standard — not yet adopted.

centrations are attributed to natural sources. Three of the 15 samples had a low pH, with the minimum being 4.63 in an H-Area sample. No health hazard exists from drinking water with these levels. Analysis results are summarized in Table 5-5, Vol. II.

No confirmed positive concentrations of tetrachloroethylene, trichloroethylene or 1,1,1-trichloroethane were detected in monthly analyses of drinking water for the A-Administration/M-Fuel Preparation areas in 1987. The new 112- and 113-G Wells have also shown no confirmed chlorocarbon concentrations. Semi-annual analyses of other drinking water supplies at SRP showed no confirmed chlorocarbons.

Occasional low concentrations of trichloroethylene and tetrachloroethylene continued to be detected at the wellhead of Well 31A. The maximums for 1987 were 13 µg/L and 4 µg/L, respectively. Process water wells 20A and 53A continued to show elevated chlorocarbon concentrations. The maximum concentration was 123 µg/L of trichloroethylene. Monitoring results are presented in Tables 5-6 and 5-7, Vol. II. Well locations are shown in Fig. 5-4, Vol. II.

1987 HIGHLIGHTS

- Tritium concentrations in milk were similar to 1986 values, ranging from less than 0.03 to 4.0 pCi/mL, with an average of 0.6 pCi/mL.
- Strontium-90 concentrations in milk ranged from 2 to 14 pCi/L, with an average concentration of 7 pCi/L, which is somewhat higher than 1986, but within ranges observed in past years.
- Plutonium-238 and ^{239}Pu concentrations in foods were detected with maximum values of 0.54 and 0.76 fCi/g, respectively. Plutonium and strontium in food result mainly from worldwide fallout that has accumulated in soil.
- Alpha and nonvolatile beta concentrations in drinking water from onsite and surrounding towns were within ranges attributed to naturally occurring radium and thorium.
- In drinking water supplies, the maximum onsite tritium concentration of 6 pCi/mL was 30% of the U.S. EPA drinking water standard, while the maximum tritium concentration from surrounding towns was 0.9 pCi/mL.
- Concentration of chemicals, metals, and organics in drinking water were within applicable standards, except for total iron, total manganese, turbidity, color, and pH at a few locations.
- No confirmed positive concentrations of chlorocarbons were detected in drinking water from the A/M Areas in 1987. Process water wells 20A and 53A continued to show elevated chlorocarbon levels, the maximum concentration being 123 µg/L of trichloroethylene.

6
Wildlife Monitoring

SUMMARY — The results of the radiological monitoring of fish and seafood, deer and hogs, furbearers, ducks, and turtles, and the nonradiological monitoring of deer and hogs for metals are presented, along with a short description of each of the monitoring programs. A total of 155 Savannah River fish and 220 fish caught in SRP streams, ponds, and swamp areas were analyzed for gamma, alpha, and nonvolatile beta concentrations. Of the Savannah River fish, only 11 had concentrations greater than 1 pCi/g of ^{137}Cs. Crabs and oysters caught at the mouth of the Savannah River were analyzed for alpha-, beta-, and gamma-emitting radionuclides. The annual hunts on the SRP reservation yielded 606 deer and 123 hogs in 1987. Maximum concentrations of ^{137}Cs, ^{131}I, tritium, and ^{90}Sr found in deer and hogs were similar to results from previous years, with the consumption of the meat resulting in an insignificant radiation dose. Concentrations of gross alpha and beta, tritium, and ^{90}Sr in 22 furbearers trapped in 1987 were within expected ranges. Only two of 689 turtles trapped in 1987 had elevated readings with a G-M detector (Thyac).

RADIOACTIVE MONITORING

Fish and Seafood

Description of Monitoring Program. Savannah River fish are routinely trapped upriver of SRP, adjacent to SRP, and downriver of SRP. Additional fish are caught in the mouth of the Savannah River (river miles 0-8). Fish are also collected from plant streams and ponds and from Thurmond Lake (formerly Clarks Hill). Thurmond Lake fish are used as controls because the lake is upriver of SRP.

Seafoods (crabs and oysters) are collected from the mouth of the Savannah River near Savannah, GA, and analyzed for gamma-, alpha-, and beta-emitting radionuclides.

Monitoring Results. In 1987, a total of 155 individual fish from the Savannah River and Thurmond Lake were analyzed for gamma-emitting radionuclides. Cesium-137 was the only man-made gamma-emitting radionuclide detected. A total of 32 individual fish from the Savannah River were analyzed for gross alpha- and beta-emitting radionuclides. Table 6-1 at the top of p. 66 summarizes the maximum concentrations of alpha and beta activity and ^{137}Cs found in fish caught near and on the SRP site and in seafood caught near the Savannah River mouth. Savannah River sampling locations are shown in Fig. 5-3, Vol. II. More comprehensive fish monitoring data for 1987 are presented in Table 6-1, Vol. II. A summary with comparisons of ^{137}Cs data to those from earlier years is presented in Table 6-2, Vol. II.

Of the 155 river fish analyzed for gamma-emitting radionuclides, 96 contained measurable concentrations of ^{137}Cs. Except for 11 fish, ^{137}Cs concentrations were less than 1 pCi/g. The maximum ^{137}Cs concentration in these 11 fish was 2.2 pCi/g in a bream caught in Thurmond Lake. The radiation dose from eating fish with these ^{137}Cs concentrations is small. For example, the 50-year dose commitment from eating fish for a year (11.3 kg/year average consumption) with the maximum ^{137}Cs concentration of 2.2 pCi/g would be 1.2 mrem (0.012 mSv), which is 0.8% of the average Central Savannah River Area (CSRA) individual's annual dose from naturally occurring radioactivity.

Of the 32 river fish analyzed for gross alpha- and nonvolatile beta-emitting radionuclides, eight contained measurable quantities of alpha and all 32 fish contained measurable quantities of nonvolatile beta. The maximum concentrations for alpha and nonvolatile beta were 0.3 and 33 pCi/g, respectively, and were detected in a perch caught downriver of SRP at sampling station R-10. The average alpha and nonvolatile beta concentrations were within ranges observed during 1986. The maximum beta

Table 6-1. Radioactivity in Fish and Seafood Caught on and near SRP Site[a]

	Maximum concentration (pCi/g)		
	Gross alpha	Nonvolatile beta	^{137}Cs
Savannah River fish	0.3 (32)	33 (32)	2.2[b] (155)
Crabs[c]	0.75 (20)	5.9 (20)	0.17 (20)
Fish from SRP streams, ponds, and swamps	1.4 (106)	190 (106)	213[d] (220)

[a] Numbers in parentheses indicate numbers of specimens analyzed.
[b] Caught in Thurmond Lake, the control location. An individual eating 11.3 kg of fish (an average year's consumption) with this level of ^{137}Cs would receive 1.2 mrem (0.012 mSv) or 0.4% of the annual dose to an average CSRA resident from naturally occurring radioactivity.
[c] Caught at the mouth of the Savannah River.
[d] The maximum occurred in a bass taken from Pond B. Fish in Pond B and Par Pond are isolated from public access, and no migratory pathway exists to allow movement of these fish to the Savannah River.

value, while greater than the 1986 maximum, was within ranges normally observed in fish from Four Mile Creek.

Crabs and oysters caught at the mouth of the Savannah River were analyzed for gamma-emitting radionuclides. Cesium-137 was detected in five of the 20 crabs collected with a maximum concentration of 0.17 pCi/g. Cesium-137 was not detected in the oysters. These data are consistent with analytical results from previous years.

Of the 16 crabs analyzed for alpha- and nonvolatile beta-emitting radionuclides, three had measurable quantities of alpha and 13 had measurable quantities of nonvolatile beta. The maximum concentrations of alpha and nonvolatile beta in the crabs were 0.75 and 5.92 pCi/g, while the average concentrations were 0.18 and 2.4 pCi/g, respectively. Alpha and nonvolatile beta concentrations above the lower limit of detection were not detected in the oysters. In previous years, crabs and oysters were not analyzed for alpha- and beta-emitting radionuclides.

A total of 220 fish were caught in SRP streams, ponds, and swamp areas. Cesium-137 was the only man-made gamma-emitting radionuclide detected in the fish. The maximum concentration of ^{137}Cs in a stream fish was 9 pCi/g in a catfish collected from Four Mile Creek.

The highest ^{137}Cs concentration in fish caught in SRP ponds was 213 pCi/g detected in a bass from Pond B. Cesium-137 concentrations in all fish from Pond B were higher than other onsite locations with an average of 91 pCi/g. Pond B is located along the effluent canal from R Area to Par Pond. The R-Reactor effluents were discharged through this canal from the late 1950s to 1964 when R-Reactor operation was permanently discontinued. During this time, releases from R Area were approximately 170 Ci of ^{137}Cs.

Cesium-137 concentrations in Par Pond fish were also elevated with a maximum of 7 pCi/g detected in a bream. Par Pond receives reactor heat exchanger cooling water from P Area. Releases of radioactivity from this source consist of only small amounts of tritium. No measurable ^{137}Cs is released via this route into Par Pond. Almost all of the ^{137}Cs in Par Pond was released from R Area before R-Reactor was shut down in 1964.

Access to SRP streams and ponds is restricted, and no use of fish for food is allowed. Fish in Pond B and Par Pond are isolated from public access, and no migratory pathway exists to allow movement of the pond fish to the Savannah River.

Concentrations of ^{137}Cs generally decreased in plant stream and pond fish between 1971 and 1979. Since

1979, concentrations of ^{137}Cs in fish have remained fairly constant.

A total of 106 fish trapped in SRP streams and ponds were analyzed for gross alpha and beta. Gross alpha concentrations ranged from a maximum of 1.4 pCi/g to less than detectable concentrations. The maximum gross beta concentration was 190 pCi/g and the minimum was 0.81 pCi/g. The maximum alpha concentration was detected in a crappie caught in Upper Three Runs Creek, and the maximum beta concentration was detected in a bass from Pond B. Gross alpha and beta radioactivity data in fish are presented in Table 6-1, Vol. II.

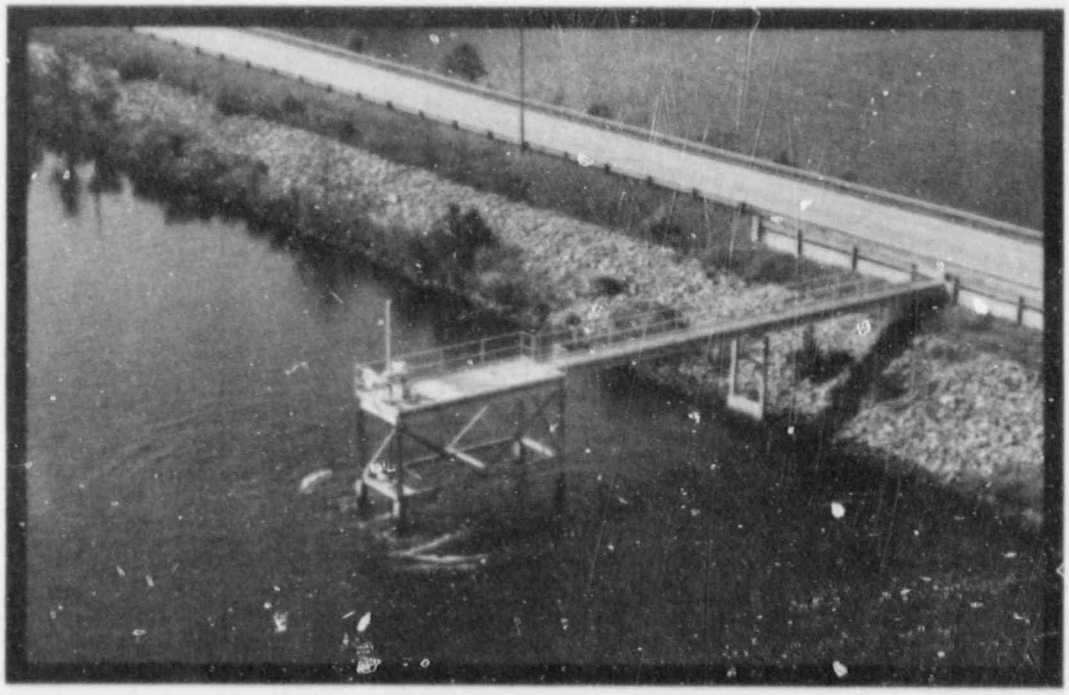
Deer and Hogs

Description of Monitoring Program. Annual hunts are conducted at SRP to control the plant deer and hog populations and to reduce animal-vehicle accidents. All animals are monitored for radioactivity with portable sodium iodide (NaI) detectors before they are released to the hunters. The 1987 hunts yielded 606 deer and 123 hogs, as compared with 944 deer and 127 hogs in 1986.

Monitoring Results. In deer, the maximum ^{137}Cs field measurement was 45 pCi/g of muscle tissue and the average was 5 pCi/g. Measurements in hogs were somewhat lower with a maximum ^{137}Cs concentration of 11 pCi/g and an average of 3 pCi/g. The 1986 maximum ^{137}Cs concentrations in deer and hogs were 29 pCi/g and 21 pCi/g, respectively. Table 6-2 (at the top of p. 68) presents maximum concentrations of ^{137}Cs, ^{131}I, tritium, and ^{90}Sr found in deer and hogs taken in hunts on the SRP reservation in 1987. A summary of monitoring data is presented in Table 6-3, Vol. II.

All deer and hog results were within ranges observed over the last several years, and consumption of the meat from these animals presents no radiation hazard. For example, edible meat from the deer with the highest ^{137}Cs concentration (45 pCi/g) weighed about 12 kg and contained approximately 0.55 uCi of ^{137}Cs. An adult consuming all of this meat would receive a 50-year radiation dose commitment of 27 mrem (0.27 mSv) or 9% of the average CSRA resident's annual dose from naturally occurring radioactivity.

Five deer collected from a controlled hunting camp located on the South Carolina Coastal Plain (SCCP) about 65 miles from SRP had an average ^{137}Cs concentration of 9 pCi/g, while 606 deer collected on SRP had an average concentration of 5 pCi/g. The SRP maximum concentration of 45 pCi/g was higher than the 15 pCi/g maximum detected in the deer from the controlled camp on the SCCP. The higher SRP maximum may reflect some uptake of ^{137}Cs



Fish in Par Pond are monitored for radioactivity

Table 6-2. Radioactivity in Deer and Hogs Killed in Hunts on SRP Site[a]

	Maximum concentration			
	^{137}Cs (pCi/g)	^{129}I (pCi/g)	Tritium (pCi/mL)	^{90}Sr (pCi/g)
Deer	45[b] (606)	16[c] (24)	645[d] (3)	120[e] (5)
Hogs	11 (123)	—	—	15[e] (4)

[a] Numbers in parentheses indicate numbers of specimens analyzed.
[b] Consumption of the meat of this deer would lead to a 50-year dose commitment of 27 mrem (0.27 mSv) from ^{137}Cs.
[c] Thyroid.
[d] Consumption of the meat of this deer would lead to a 50-year dose commitment of 0.02 mrem (0.0002 mSv) from tritium.
[e] Bone.

from SRP operations or it may reflect differences in the diets of the deer. The higher number may be due to the larger sample size of the SRP deer. A comparison of SRP and SCCP deer ^{137}Cs concentrations since 1968 has shown significant year-to-year variations in both maximum and average concentrations, as shown in Table 6-4, Vol. II.

Tissue samples were collected from 36 deer and 14 hogs to verify the field measurements and to determine whether other radionuclides were present. Statistical analysis of field measurements of ^{137}Cs, compared to laboratory measurements, indicated good agreement and supported the field monitoring results. Gamma analysis of the laboratory samples detected only ^{137}Cs and normal levels of naturally occurring ^{40}K. A comparison of field and laboratory ^{137}Cs measurements in the deer and hogs is presented in Table 6-5, Vol. II.

In addition to the ^{137}Cs laboratory analyses in deer and hog flesh, flesh samples from 20 deer were analyzed for ^{131}I, and bone samples from 24 deer were analyzed for ^{137}Cs. All the flesh samples had less than detectable concentrations of ^{131}I, except for one sample with an ^{131}I concentration of 3 pCi/g. Cesium-137 concentrations in the bone samples ranged from less than 0.2 to 3.5 pCi/g. These data are presented in Table 6-6, Vol. II.

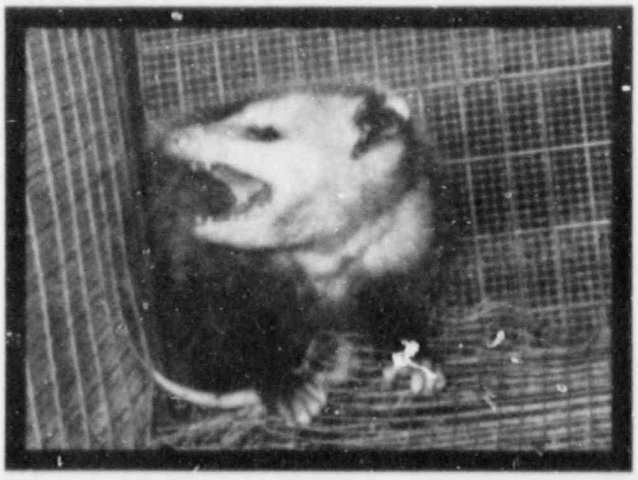
Analyses of tissue from three deer and one hog for tritium showed greatly varying concentrations ranging from 9 to 645 pCi/mL in the free water obtained by freeze-drying the tissue. The 1986 maximum tritium concentration in deer was 38 pCi/mL. Consumption of the deer with the higher tritium concentrations presents no radiation hazard. For example, meat consumed from the deer with the highest tritium concentration (645 pCi/mL) would result in a 50-year dose commitment of 0.02 mrem (0.0002 mSv), based on a total deer weight of 52 kg containing 0.33 μCi of tritium. This dose is 0.007% of the average CSRA individual's annual dose from naturally occurring radioactivity. Tritium concentrations in deer are presented in Table 6-7, Vol. II.

Tissue and bone samples from five deer and four hogs were analyzed for ^{90}Sr. As expected, concentrations for ^{90}Sr (which is a bone seeker) were higher in the bone samples than in the tissue samples. The concentrations in tissue were near or less than the minimum detectable value of 0.8 pCi/g. The concentrations in bone ranged from 6 to 120 pCi/g. The maximum 1987 concentration of 120 pCi/g was in the bone of a deer; in 1986, the maximum ^{90}Sr concentration in deer bone was 130 pCi/g. The 1987 maximum ^{90}Sr concentration in the bone of a hog was 15 pCi/g. Strontium-90 analysis was not performed in previous years on hog samples. These data are presented in Table 6-8, Vol. II.

Tissue and thyroid samples were collected from 24 deer and sent to the Department of Physiology and Biophysics, University of Tennessee, Memphis, for analysis. The tissue samples were analyzed for ^{137}Cs, and the thyroids were analyzed for ^{129}I and ^{137}Cs.

Concentrations of ^{137}Cs in the tissue samples ranged from less than 1 to 12 pCi/g and showed reasonably good agreement with the SRP field measurements. Iodine-129 concentrations in the thyroids ranged from 0.1 to 16 pCi/g, with an average of 3 pCi/g. These values for 1987 are similar to the average of 2 pCi/g and the range of 0.02 to 15 pCi/g detected in 1986. Concentrations of ^{137}Cs in the thyroids ranged from 0.2 to 6 pCi/g, with an average of 2 pCi/g. These data are presented in Table 6-9, Vol. II.

Furbearers



Opossum trapped for analysis

Description of Monitoring Program. The SRP site is closed to outside hunters except for the controlled hunts for deer and hogs. Therefore, furbearers (referred to in previous reports as terrestrial animals) are not a likely source of food to the surrounding population. Furbearing animals such as foxes, raccoons, and opossums are trapped and analyzed for gamma-emitting radionuclides.

The U.S. Forest Service administers a Du Pont contract for the trapping of beavers in selected areas within the SRP perimeter. The purpose of the trapping is to reduce the beaver population in particular areas of SRP and thereby to minimize dam building activities that result in flood damage to timber stands, primary and secondary roads, and railroad beds. Beavers are monitored with a G-M detector (Thyac) and disposed of in the SRP sanitary landfill. A few of the beavers are submitted for laboratory analysis of radionuclides.

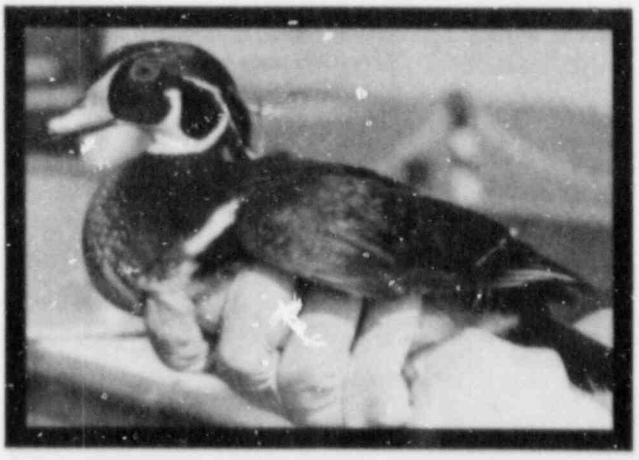
Monitoring Results. During 1987, 22 furbearers (not including beavers) were trapped along 10 transects across the SRP site and in the Savannah River swamp near Creek Plantation. Counting of the animals for gamma emitters indicated low concentrations of ^{137}Cs. The maximum concentration of ^{137}Cs was 3 pCi/g in an opossum from a location between Par Pond and Pond B. If this opossum left the SRP site and were used for food, the 50-year radiation dose commitment to an individual who consumed all edible portions (total weight 3.1 kg) would be 0.47 mrem (0.005 mSv) or 0.2% of the average CSRA individual's annual dose from naturally occurring radioactivity. The average ^{137}Cs concentration for all furbearers was 1.2 pCi/g. Animal monitoring results are presented in Table 6-10, Vol. II.

A total of 84 beavers were trapped during 1987. Field monitoring was performed on 53 of these animals. In addition to field monitoring, bone and flesh samples from four beavers were analyzed for concentrations of gross alpha and beta activity and tritium, ^{90}Sr, and gamma-emitting radionuclides. Cesium-137 and naturally occurring ^{40}K and were the only gamma emitters detected. Data from these analyses are summarized in Table 6-11, Vol. II.

Ducks

Description of Monitoring Program. Ducks are routinely trapped at Par Pond and counted whole for gamma-emitting radionuclides.

Monitoring Results. In 1987, a total of 13 ducks were trapped at Par Pond. Cesium-137 was the only gamma-emitting radionuclide detected. The maximum concentration of ^{137}Cs detected was 2.7 pCi/g in a horned grebe. The horned grebe is not a preferred table fare of waterfowl hunters. However, if this horned grebe left the SRP site and were used for food, the 50-year radiation dose commitment to an



Ducks are routinely monitored

individual who consumed the duck (total weight 504 g) would be 0.07 mrem (0.001 mSv) or 0.02% of the average CSRA individual's annual dose from naturally occurring radioactivity. All of the ducks monitored contained ^{137}Cs concentrations within ranges observed in previous years. Duck monitoring data are presented in Table 6-12, Vol. II.

Turtles

Description of Monitoring Program. As part of an ongoing study conducted by SREL to learn more about turtles' migratory behavior, specimens are trapped onsite and offsite, surveyed for radioactivity with a G-M detector (Thyac), aged, and sexed. Turtles collected from sites where no turtles had been previously collected and those with field radiation measurements above levels previously detected in turtles from those specific locations are submitted for laboratory analysis to determine the origin of radioactivity.

Monitoring Results. A total of 689 turtles, mainly pondsliders and eastern mud turtles, were trapped in 1987. Only two of the 689 turtles trapped had elevated Thyac readings. Both were pondsliders captured onsite; one was captured at Twin Lakes near C Reactor, and the other, found crossing the road in the 700 Area, very likely inhabited the 700-Area basins at one time.

None of the turtles trapped offsite showed detectable levels of radioactivity. These offsite turtles were taken from nearby private ponds in the Green Pond Church area, near the SRP boundary. No turtles were submitted for laboratory analysis in 1987, because analytical data compiled from previous years were judged to be sufficient.

NONRADIOACTIVE MONITORING

Fish

Description of Monitoring Program. Mercury has been detected in river and stream fish since analyses were begun in 1971. Initially, individual fish flesh samples were analyzed. In 1972, fish samples were analyzed quarterly by composites of bass, bream, and catfish. Analyses by species composites continued from 1973 to 1975 but on a semiannual basis. Since 1975, analyses have been performed on individual fish.

The concentrations of mercury are determined in the flesh of fish taken from onsite and offsite locations. The fish analyzed represent a random selection of the fish that were caught in traps. These analyses are performed to assess the uptake of mercury that is assumed to come principally from previous releases from industries upriver of SRP. The mercury concentrations detected in onsite fish reflect mercury in the Savannah River water that has been used as cooling water in site facilities and subsequently pumped into SRP streams and lakes.

Applicable Standards. The Food and Drug Administration (FDA) has established an action level of 1.0 μg Hg/g for a daily intake of mercury in edible fish. For this reason, it is more appropriate to compare average concentrations to the action level rather than maximum concentrations.

Monitoring Results. Because of the startup of a new laboratory facility, it was not possible to perform mercury analyses in fish during 1987. This program will be resumed in 1988. Maximum results in past years have indicated no significant accumulation of mercury in fish.

Deer

Description of Monitoring Program. As part of a special study, tissue samples were taken from the muscle, spleen, liver, and kidney of a number of deer and hogs killed during SRP deer hunts in 1986. These samples were analyzed for cadmium, chromium, lead, and mercury in 1987.

Monitoring Results. Tissue samples from a total of 70 deer and three hogs were analyzed offsite for cadmium, chromium, lead, and mercury. The highest metal concentrations, those of cadmium in the kidneys, ranged from less than 0.13 to 42 mg/kg. All the other metal concentrations found in muscle, spleen, liver, and kidney ranged from less than detectable concentrations to 7 mg/kg. Additional samples will be obtained in 1988 for followup analysis and data comparison. A summary of the metal concentrations in deer and hog tissues is presented in Table 6-13, Vol. II.

1987 HIGHLIGHTS

- The 50-year dose commitment from eating fish for a year (11.3 kg/yr) with the maximum ^{137}Cs concentration of 2.2 pCi/g (detected in a fish from Thurmond Lake) would be 1.2 mrem, or 0.8% of the average annual dose from naturally occurring radioactivity.
- Fish trapped in SRP streams and ponds had gross alpha concentrations ranging from less than detectable levels to a maximum of 1.4 pCi/g, and beta concentrations ranging from 0.81 to 190 pCi/g.
- An adult consuming all the edible meat from the deer with the highest ^{137}Cs concentration (45 pCi/g) would receive a 50-year dose commitment of 27 mrem, or 9% of the average annual dose from naturally occurring radioactivity. Average ^{137}Cs concentrations in SRP deer and offsite deer were 5 and 9 pCi/g, respectively.
- In 1987, the maximum ^{90}Sr concentration in the bone of a deer was 120 pCi/g, compared to the 1986 maximum of 130 pCi/g.
- In the 13 ducks analyzed, ^{137}Cs concentrations were within ranges observed in previous years, with a maximum of 2.7 pCi/g in a horned grebe.

7
Rainwater, Soil, Sediment, and Vegetation

SUMMARY —This chapter presents the results of the radiological monitoring of rainwater, soil, sediments, and vegetation from locations on and around the SRP site. Sampling protocol varied from quarterly analyses of rainwater obtained at the plant perimeter and at four 100-mile-radius stations, to soil sampling around the two separations areas and at the plant boundary, to the annual collection of sediment samples at six locations on the Savannah River and at nine SRP stream locations. Measurable quantities of alpha, nonvolatile beta, $^{89,90}Sr$, ^{137}Cs, and naturally occurring ^{7}Be were detected in rainwater samples during the year. The concentrations of radionuclides in soil varied significantly among locations because of differences in rainfall patterns and the mechanics of transport in different types of soil. Concentrations of radioactivity in river and stream sediments were similar to results from previous years with the exception of one stream ^{238}Pu concentration, which was slightly higher. Vegetation samples, collected at the plant perimeter, 25-mile radius, and 100-mile radius, had alpha, nonvolatile beta, and tritium concentrations that were approximately the same as those seen in 1986.

RADIOACTIVE MONITORING

Rainwater

Description of Monitoring Program. Small quantities of worldwide fallout that remain in the atmosphere are deposited on the earth in rainwater. The quantity deposited each year has decreased significantly since the 1960s and is now near or less than the minimum detectable quantity.

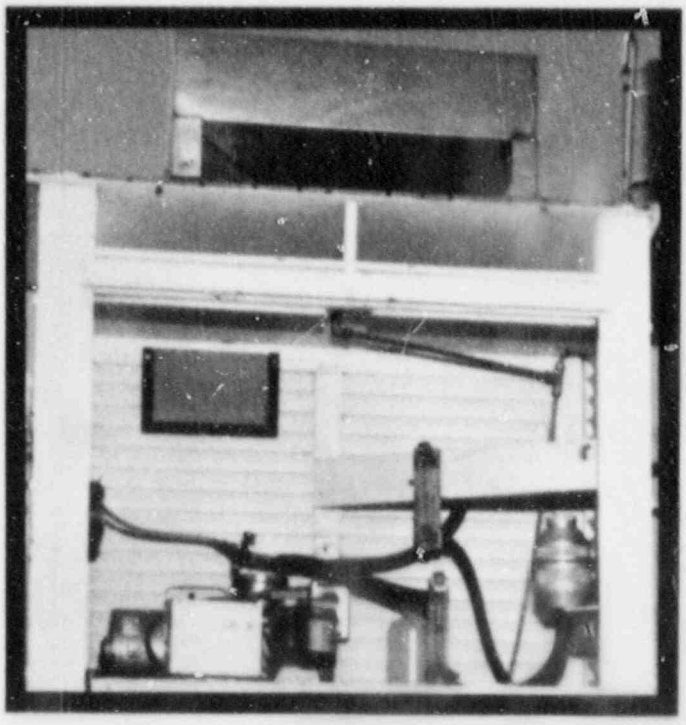
On occasions such as the Chernobyl accident or other unusual occurrences associated with radioactivity, the fallout in rainwater becomes more significant, because radionuclides in rainwater may provide a principal source of dose to persons through the grass to cow to milk to person pathway. Continuous measurements at a few stations are sufficient to identify these events when they occur.

As a part of its monitoring program for worldwide fallout and emissions from the plant, SRP maintains a network of sampling stations for rainwater. Locations of the stations, sampling frequencies, and methods of analysis are described in Chapter 10.

Changes in 1987 Monitoring Program. No changes in the monitoring program occurred between 1986 and 1987. In 1986, routine monthly analyses of rainwater were discontinued at all stations except Darkhorse and Barnwell Gate at the plant perimeter, Olar at the 25-mile radius (see Fig. 2-1, Vol. II) and quarterly analyses of samples obtained at the four 100-mile-radius stations. Rainwater samples at all locations are collected and held until the Darkhorse and Barnwell Gate analyses are complete. Samples from the other air monitoring stations are available for analysis should the need occur. The rainwater monitoring program was reduced because levels of worldwide fallout from previous nuclear weapons tests have decreased to such an extent that monitoring at a large number of stations is no longer considered necessary for adequate coverage.

Monitoring Results. Measurable quantities of alpha, nonvolatile beta, $^{89,90}Sr$, ^{137}Cs, and naturally occurring ^{7}Be were detected in rainwater samples during the year. Quantities of radioactivity deposited in rainwater are presented in Table 7-1, Vol. II.

Alpha concentrations in rainwater were approximately the same as in 1986 with a maximum alpha deposition of 42 pCi/m² at H Area. Nonvolatile beta activity deposited in rainwater ranged from 516 to 2,755 pCi/m². The maximum onplant nonvolatile beta deposition was 1,624 pCi/m² at the H-Separa-



Rain pan collects rainwater samples

tions Area. The average nonvolatile beta deposited at the plant perimeter stations was 869 pCi/m². The maximum deposition of 2,755 pCi/m² was observed at the 100-mile-radius station in Macon, GA.

The deposition of ^{137}Cs in rainwater ranged from less than the lower limit of detection to 590 pCi/m². The maximum ^{137}Cs deposition was at the Olar station at the 25-mile radius.

The deposition of ^{238}Pu in rainwater ranged from less than the lower limit of detection to 1.1 pCi/m²; deposition of $^{239,240}Pu$ ranged from the lower limit of detection to 1 pCi/m². These values are slightly higher than those observed in 1986.

Beryllium-7 concentrations ranged from 2,100 to 13,000 pCi/m². Deposition of $^{89,90}Sr$ due to worldwide fallout ranged from less than the lower limit of detection to 41 pCi/m². All ^{131}I results were less than the minimum detectable concentration. Tritium concentrations in rainwater averaged 4.6 pCi/mL at the plant perimeter and 0.13 pCi/mL at the 100-mile radius. The maximum tritium concentration in plant perimeter rainwater was 85 pCi/mL.

Soil

Description of Monitoring Program. Soil samples from uncultivated areas provide a measure of the quantity of radioactivity deposited from the atmosphere. Samples are collected from each of the four quadrants around the two separations areas and at the SRP boundary. Two control locations approximately 100 miles from SRP are also sampled.

Monitoring Results. The concentrations of radionuclides in soil vary significantly among locations because of differences in rainfall patterns and the mechanics of transport in different types of soil. Rates of migration in soil also vary significantly from one radionuclide to another. For example, strontium tends to migrate through soil more freely than cesium or plutonium. The chemical separation of radionuclides in soil samples in the laboratory is complicated by the nonhomogeneity of the soil and difficulty in stripping ions from the soil. Individual measurements of radionuclides in soil samples may not be representative of large areas. Averaged concentrations of multiple samples provide a better measure of soil radionuclide concentrations. Radioactivity concentrations in soil for 1987 are presented in Table 7-2, Vol. II. Deposition of radioactivity on soil, calculated in mCi/km² from the sample concentrations in Table 7-2, is presented in Table 7-3, Vol. II. A yearly summary of deposition values is shown in Table 7-4, Vol. II.

Strontium-90 concentrations in soil ranged from less than minimum detectable concentrations to 0.61 pCi/g around F and H Areas, to 0.03 pCi/g at the site boundary, and to 0.02 pCi/g at the 100-mile radius. These ^{90}Sr concentrations are similar to concentrations observed over the last several years and result primarily from worldwide fallout from nuclear weapons tests.

Cesium-137 concentrations ranged from 0.12 to 1.0 pCi/g around F Area and 0.48 to 2.0 pCi/g around H Area. The 2.0 pCi/g result likely reflects releases from H Area. Concentrations of ^{137}Cs at the plant perimeter and 100-mile radius ranged from 0.33 to 0.93 pCi/g. Offsite data are consistent with previous years and are within the concentrations observed from worldwide fallout.

Plutonium concentrations in soil samples around the separations areas are somewhat greater than those detected at the plant perimeter, reflecting F- and H-Separations Area releases. Cumulative atmospheric plutonium releases from the separations areas have totaled 0.7 Ci ^{238}Pu and 3.0 Ci ^{239}Pu

through 1987. The largest part of these releases occurred in earlier years of SRP operation. Releases for 1987 were 2.0 mCi of ^{238}Pu and 0.27 mCi of ^{239}Pu. Ranges of ^{238}Pu concentrations in soil were 0.016–0.073 pCi/g in F Area, 0.012–0.051 pCi/g in H Area, 0.003–0.021 pCi/g at the plant perimeter, and below minimum detection limits at the 100-mile-radius stations. For ^{239}Pu, the ranges were 0.006–0.094 pCi/g in F Area, 0.040–0.072 pCi/g in H Area, and 0.013–0.021 pCi/g at the plant perimeter; a maximum concentration of 0.02 pCi/g was reported at the 100-mile-radius stations. Most concentrations of ^{238}Pu and ^{239}Pu detected at the SRP boundary and 100-mile-radius sampling locations were near or less than minimum detectable concentrations, and all concentrations at those locations were within the ranges observed during previous years.

The quantity of ^{90}Sr, ^{137}Cs, and ^{238,239}Pu deposited in soil was calculated using soil density, sample volume, and the measured radionuclide concentration in soil. Results for 1987 were greater than ranges observed over the last several years. This effect is due to a calculational correction: a 5-cm depth factor was used in previous years instead of the correct 8-cm depth.

Sediment

Description of Monitoring Program. Sediment samples have been collected annually at six locations on the Savannah River above, adjacent to, and below SRP since 1975 and at nine plant stream locations since 1977. The samples are collected at locations where maximum accumulation of radioactivity in the river and stream beds is expected. Collection techniques are designed to obtain samples from the top 8 cm of sediment in areas where fine sediment has accumulated. Therefore, the samples are not representative of the entire stream bed. Sediment is analyzed for gamma-emitting radionuclides, ^{90}Sr, and ^{238,239}Pu.

Monitoring Results. Analytical results for 1987 and a summary since 1975 for both river and stream sediment samples are presented in Table 7-5, Vol. II. Concentrations of radioactivity in river sediments were within the ranges detected from worldwide fallout. Potassium-40, a naturally occurring radionuclide, and ^{137}Cs were the only gamma-emitting radionuclides detected in river sediment. The maximum 1987 ^{137}Cs concentration detected in the river sediment was 0.62 pCi/g; the 1986 maximum was 0.99 pCi/g. Concentrations of naturally occurring ^{40}K were within ranges observed in previous years with a maximum of 17 pCi/g.

The maximum ^{90}Sr concentration in river sediment for 1987 was 0.06 pCi/g, as compared to a maximum of 0.05 pCi/g in 1986. The maximum concentration of ^{239}Pu was 0.027 pCi/g. Plutonium-238 concentrations were less than the minimum detectable activity for the analysis.

In stream sediments, the maximum concentrations detected were 16 pCi/g of ^{40}K, 32 pCi/g of ^{137}Cs, 1.8 pCi/g of ^{60}Co, 0.98 pCi/g of ^{90}Sr, 0.66 pCi/g of ^{238}Pu, and 0.23 pCi/g of ^{239}Pu. Stream sediment results reflect contributions of radioactivity from SRP releases and are similar to results from previous years with the exception of ^{238}Pu concentrations. In past years, maximum ^{238}Pu concentrations of around 0.2 pCi/g have been detected at Four Mile Creek sampling location A-7A, as compared to the higher 1987 maximum of 0.66 pCi/g. The exact point at which a sample is collected in the stream may vary at a sampling location from year to year, and the higher ^{238}Pu concentration may be due to collecting the sample at a slightly different place than in previous years.

Vegetation

Description of Monitoring Program. Radioactive contamination of growing plants may result from sorption of radioactive materials from the soil or from radioactivity deposited from the atmosphere. Grass is analyzed routinely for radioactivity; Bermuda is used if it is available, because of its importance as a pasture grass for dairy herds and year-round availability. Grass also provides an early indication of fallout because of the relatively large surface area of the grass blades exposed to the air.

Vegetation samples are collected on the general plant site and at the plant perimeter, 25-mile radius, and 100-mile radius. Onsite samples are also collected around seepage and retention basins and in and around the Solid Waste Storage Facility (Burial Ground).

Monitoring Results. Radioactivity in vegetation data are presented in Table 7-6, Vol. II. Alpha concentrations for vegetation collected at the plant perimeter, 25-, and 100-mile-radius locations were near or less than the minimum detectable concen-

Counting for alpha-emitting radionuclides

tration of approximately 0.2 pCi/g. The maximum alpha concentration detected in vegetation was 0.5 pCi/g in a sample from the plant perimeter. Beta concentrations showed a relatively wide variation: from 9 to 35 pCi/g at the plant perimeter, from 4 to 25 pCi/g at the 25-mile radius, and from 11 to 28 pCi/g at the 100-mile radius. These differences are attributed to variations in worldwide fallout patterns.

Naturally occurring ^{7}Be and ^{40}K were the major contributors to the beta-gamma activity in vegetation. Maximum concentrations of ^{137}Cs detected at the plant perimeter and 100-mile radius were 0.56 and 0.25 pCi/g respectively. A maximum $^{89,90}Sr$ concentration of 1.7 pCi/g was detected at both the plant perimeter and 25-mile radius. These values are within ranges observed in previous years.

The average tritium concentration in the free water obtained from freeze-drying vegetation collected at the plant perimeter was 8.6 pCi/mL compared to 1.4 pCi/mL at 25-mile-radius stations and 0.9 pCi/mL at 100-mile-radius stations. Average concentrations for 1987 are approximately the same as those seen in 1986.

Analyses of vegetation from two locations around F and H Areas showed alpha concentrations approximately twice as high as those detected offsite and nonvolatile beta concentrations within the range observed at the SRP perimeter and offsite. The maximum concentrations were 0.37 pCi/g alpha and 23 pCi/g nonvolatile beta at H-Separations Area. Tritium concentrations in free water obtained from freeze-drying F- and H-Area vegetation were generally higher than those observed at the SRP perimeter and offsite and reflect SRP releases. The maximum tritium concentration in routine samples from F and H Areas was 380 pCi/mL. The maximum tritium concentration in onsite vegetation from a tritium release occurring on July 31, 1987, was 5,760 pCi/mL (the July tritium release is described in Chapter 8). Concentrations of gamma-emitting radionuclides and ^{90}Sr in onsite vegetation were within ranges observed in plant perimeter and offsite vegetation.

Vegetation samples were collected around seepage and retention basins located near reactor and separations areas. Samples from four to eight locations outside the fence of each basin were composited for alpha, nonvolatile beta, and $^{89,90}Sr$ analyses. Alpha and nonvolatile beta concentrations were near levels observed offsite with maximums of 0.13 and 49 pCi/g respectively. The maximum concentration of $^{89,90}Sr$ was 13 pCi/g at H-Separations Area seepage basin. These data indicate good control of radioactivity within the basins. Seepage and retention basin vegetation monitoring results are presented in Table 7-7, Vol. II.

Vegetation samples were collected inside the Solid Waste Storage Facility (643-G and -7G) to determine whether significant uptake of radioactivity by vegetation from buried waste has occurred. Vegetation was collected from a relatively large area at 51 locations inside the Solid Waste Storage Facility (Burial Ground) and composited by location for an annual analysis. This collection method provides coverage of a large part of the facility, yet keeps the number of samples to a minimum. The samples were analyzed for alpha-, nonvolatile beta-, and gamma-emitting radionuclides. Sample locations are shown in Fig. 7-1, Vol. II and data are presented in Table 7-8, Vol. II. The only radioactivity above ambient levels was detected in vegetation from locations 9A, 11 and 12. The maximum concentrations were 7.6 pCi/g alpha, 6,006 pCi/g nonvolatile beta, and 37 pCi/g of ^{137}Cs. Locations 9 and 10 have a history of contaminated vegetation. In 1965, contaminated vegetation with concentrations of up to 7.4×10^{6} pCi/g of $^{89,90}Sr$ was found near locations 9 and 10. Soil core samples at that time indicated up to 7.7×10^{7} pCi/g of nonvolatile beta (primarily $^{89,90}Sr$) within 2

ft. of the surface of the ground. The area has been cleared of vegetation and treated with a herbicide several times.

Vegetation samples were also collected quarterly around the outside of the Solid Waste Storage Facility (Burial Ground) fences. The maximum alpha and nonvolatile beta concentrations were 0.46 and 21 pCi/g respectively. A maximum ^{137}Cs concentration of 5.2 pCi/g was detected at BG 10. Both ^{7}Be and ^{40}K (naturally occurring radionuclides) were also detected. These surveys indicate control practices at the Solid Waste Storage Facility have been generally effective in preventing the spread of contamination from the facility, and vegetation sampling is an effective method of detecting the release of very small quantities of radioactivity. Vegetation sampling locations outside the Solid Waste Storage Facility are shown in Fig. 7-2, Vol. II, and monitoring data are presented in Table 7-9, Vol. II.

1987 HIGHLIGHTS

- Tritium concentrations in rainwater averaged 4.6 pCi/mL at the plant perimeter. The maximum tritium concentration in plant perimeter rainwater (85 pCi/mL) represents 4% of the Derived Concentration Guide (DCG) for water.
- Concentrations of ^{137}Cs in soil at the plant perimeter and 100-mile radius ranged from 0.93 to 0.33 pCi/g, consistent with data from previous years.
- In river sediment, the maximum 1987 ^{137}Cs concentration (0.62 pCi/g) was lower than the 1986 maximum of 0.99 pCi/g. The maximum ^{90}Sr concentration in river sediment in 1987 was 0.06 pCi/g, as compared to a maximum of 0.05 pCi/g in 1986. The ^{239}Pu concentration in sediment at one location was three times higher than the 1986 maximum concentration.
- Alpha concentrations in vegetation collected at the plant perimeter, 25-mile-, and 100-mile-radius locations were near or less than the minimum detectable concentrations of approximately 0.2 pCi/g.
- Radioactivity concentrations in vegetation collected around basins of the reactor and separations areas and around the outside of the Burial Ground were near offsite levels, indicating good control of radioactivity within the basins.

8
Special Surveys/Unusual Occurrences

SUMMARY — This chapter focuses on special radiological surveys of tritium and radionuclide releases by atmospheric and liquid pathways that have occurred during 1987, along with surveys of various areas around the SRP site, including the Savannah River swamp. In addition, a comprehensive survey of the intake and discharge systems of the Beaufort-Jasper and Port Wentworth water treatment plants was conducted, and the results of analyzing sediment, vegetation, and water samples for gross alpha and nonvolatile beta activity and for tritium, strontium, plutonium, and gamma-emitting radionuclides are presented. An atmospheric radon study made at SRP and at residences in the region of the plant indicated that doses from radon were equivalent to those in other areas of the U.S. Other topics discussed include a low-level gamma analysis technique for detecting ^{137}Cs in Savannah River water; an environmental data exchange among SRP, SRL, DOE, Georgia Power Company, Georgia Department of Natural Resources, and SCDHEC; the results of a Four Mile Creek survey undertaken before initiation of a sampling program by SREL; and surveys of dry monitoring wells in both the F- and H-Separations Areas waste management facilities, and in offsite Creek Plantation wells. The chapter also contains a section on the nonradiological monitoring of water and sediments for pesticides, herbicides, and polychlorinated biphenyls, and a report on oil and chemical spills in 1987.

RADIOLOGICAL SURVEYS

Tritium in the Environment

Tritium may be present in a variety of chemical forms including oxide (HTO, T_2O), elemental (HT, T_2), or as tritium-labeled organics. Because of its chemical similarity to a water molecule, tritium oxide is more readily assimilated into environmental media and human tissues than either the elemental or organic form. The organic forms represent less than 1% of the tritium releases from SRP.

Tritium has a physical half-life of 12 years. The low energy beta particle emitted by tritium during decay will penetrate only 0.013 cm of human tissue. As an elemental gas, tritium is nearly biologically inert and constitutes relatively little hazard. The weak beta particle is completely attenuated by the inert external skin layer (epidermis) and because only 0.004% of elemental tritium inhaled is converted to the oxide and retained in the body [NCRP79].

Almost all of the oxide form (water vapor) inhaled is absorbed in the lungs and enters the body water pool, thereby exposing all body tissues. In addition, approximately one-half as much tritium oxide is absorbed through the skin as is absorbed in the lungs by inhalation [USNRC79]. The half-life for biological removal of tritium oxide from the body is approximately 10 days.

Both tritium oxide and elemental tritium are released to the atmosphere during routine operation of the tritium facilities. The reactor facilities also release tritium, but this tritium is primarily in the oxide form. Because hydrogen in tritium oxide readily exchanges with hydrogen in other materials (such as water), low-level concentrations are routinely detected in the SRP environment. The average atmospheric tritium release from all facilities in 1987 was approximately 1,570 Ci per day and represented a 31% increase compared to 1986. However, the total amount of tritium oxide released was similar to the 1986 value. Tritium oxide comprised approximately 44% of the total amount of tritium released to the atmosphere in 1987.

All of the tritium released to the river or streams is in oxide form. The average liquid release of tritium from all plant sources in 1987 was approximately 62 Ci per day compared to approximately 80 Ci per day in 1986.

Special environmental surveys were conducted when short-term tritium releases occurred on three occasions in 1987. The purpose of the surveys was to determine whether the releases carried a significant risk of detriment to the public health or to the offsite environment.

Tritium Releases

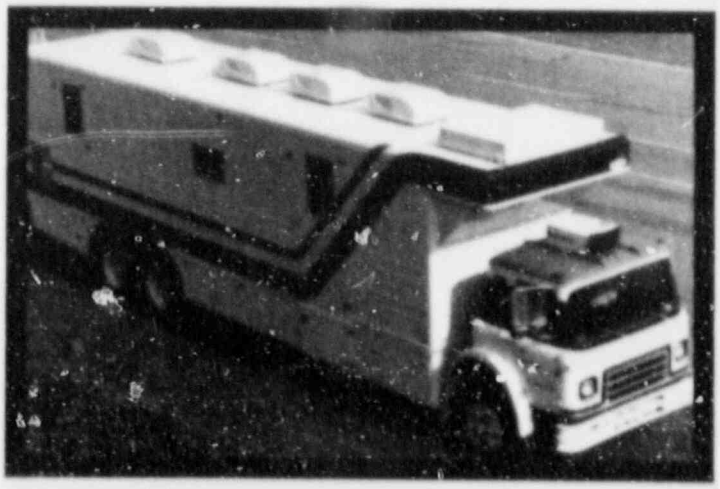
Atmospheric Tritium Release on July 31, 1987. Approximately 172,000 Ci of tritium was released to the atmosphere on July 31, 1987, from the H-Area tritium facilities as a result of a line break during a maintenance operation [Ku87]. Approximately 3% of the tritium released was in the oxide form (HTO) and 97% was elemental tritium (HT). The maximum calculated dose to an individual at the site boundary from this release was 0.02 mrem (0.0002 mSv).

At the time of the incident wind direction was initially toward the east, then shifted toward the north-northeast. The TRAC (Tracking Radioactive Atmospheric Contaminants) van, SRL's mobile laboratory, responded to the release and obtained measurements along the path of the plume. Sampling teams obtained air concentration measurements on the day of the release. Vegetation and surface water samples were collected at locations onsite, along the plant perimeter, and along a 15- and 25-mile radius in the path of the plume. Milk samples were collected from offsite dairies. South Carolina Department of Health and Environmental Control (SCDHEC) collected vegetation samples offsite. Fig. 8-1 on p. 81 (also in Vol. II) shows the movement of the tritium cloud as predicted by the WIND system. The circles on the figure indicate puff positions and the width of the release every 60 minutes. The lined area indicates the region where the cloud "broke up" due to nearby thunderstorms. Sampling locations and tritium concentrations for those samples within the plume path are presented in Tables 8-1 and 8-2, Vol. II.

The tritium concentrations in surface water and vegetation were similar to previous releases of this magnitude. The maximum tritium concentrations detected in vegetation were 5,760 pCi/mL at NPDES site H-004 near H Area, 4,690 pCi/mL at the plant perimeter, and 8 pCi/mL at a location 25 miles from the plant perimeter. The maximum vegetation concentration in the samples collected by SCDHEC was 2,069 pCi/mL. This value compares well with SRP measurements from sampling locations 104 through 108, which ranged in concentration between 22 and 2,190 pCi/mL. Sampling locations 104 through 108 were within two miles of the SCDHEC locations. Tritium concentrations in surface water ranged from a maximum concentration of 48 pCi/mL at the plant perimeter to 4.0 pCi/mL at the 25-mile radius.

The maximum offsite tritium oxide concentrations detected in air were 286,000 pCi/m^3 HTO at the plant boundary and 45,100 pCi/m^3 HTO at approximately 20 miles downwind.

Liquid Tritium Releases. On February 15, 1987, a thermal diffusion column failure in an H-Area tritium facility caused water contaminated with tritium to enter the process cooling water system and subsequently to be released to Four Mile Creek. The maximum tritium concentration detected in Four Mile Creek after the failure was 5,200 pCi/mL, at sampling location FM-1C. The average concentration detected in Four Mile Creek during 1986 was 70 pCi/mL. The process cooling water was diverted to the seepage basin on February 15, 1987; however, the tritium level in the effluent did not return to normal until mid-March. The total release to Four Mile Creek due to this release was 156 Ci.



SRL's TRAC van

Elevated concentrations of tritium were detected in water samples collected from the 400-D Area process sewer on May 11, 1987. Subsequent laboratory analyses indicated 433 Ci of tritium was released to Beaver Dam Creek from May 5 to May 12, 1987. Investigation revealed that the release occurred on May 10, 1987, during startup of a 400-D heavy water rework facility.

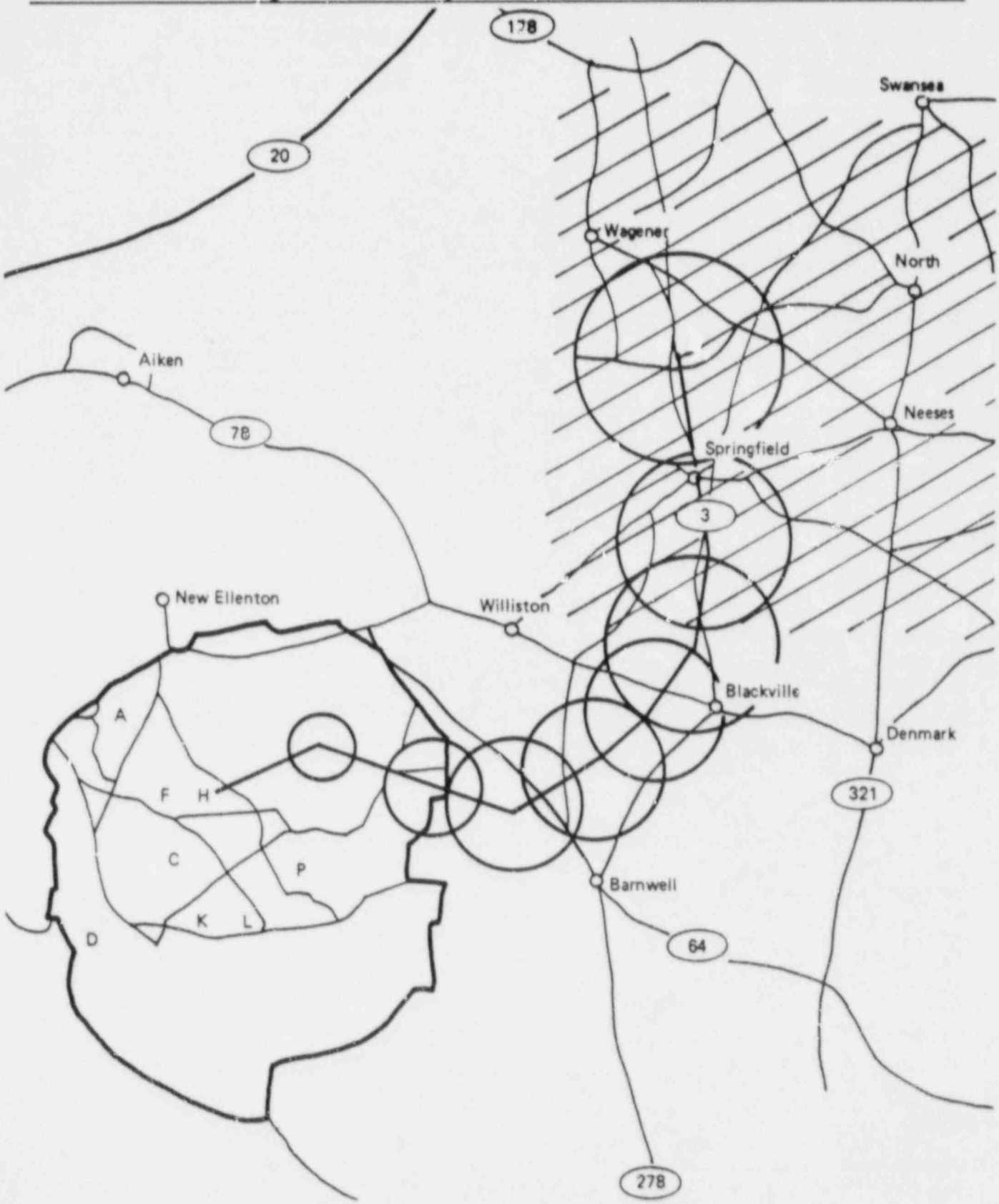


Fig. 8-1. Movement of tritium cloud as predicted by WIND system

Other Radionuclide Releases

H-Area Solvent Release. On January 1, 1987, overflow of a solvent sump area resulted in elevated concentrations of gross alpha-beta radioactivity in Upper Three Runs Creek. Special samples were collected along the release path of H-004 outfall, S-Area Settling Basin, Crouch Branch, Upper Three Runs Creek, and the Savannah River, successively. An estimated 1.5 Ci of mixed radionuclides were released through the storm sewer to the H-004 outfall. The release for the period from December 29, 1986 to January 2, 1987, was 3 mCi alpha and 8 mCi nonvolatile beta activity to Upper Three Runs Creek. During the period from January 2 to January 13, 1987, the release of radioactivity decreased to 2 mCi alpha and 7 mCi nonvolatile beta. Gamma analysis yielded background results for Upper Three Runs Creek.

The majority of the activity released was retained in the S-Area Settling Basin sediment. The primary gamma-emitting radionuclides detected were ^{103}Ru, ^{106}Ru, ^{95}Zr, and ^{95}Nb with a maximum concentration of 181 pCi/g of ^{106}Ru.

H-Area Atmospheric ^{137}Cs Release. On November 24, 1987, 1 Ci of ^{137}Cs and 33 mCi of ^{134}Cs were released to the atmosphere from an H-Area evaporator in the waste management facilities. The release resulted from a valve flange steam leak. Elevated nonvolatile beta and cesium concentrations were detected at onplant and plant perimeter ambient air monitoring stations. The maximum ^{137}Cs concentrations detected onplant and at the plant perimeter were 0.70 pCi/m^3 (at the onplant H-Area monitoring station) and 0.79 pCi/m^3 (at the plant perimeter D-Area monitoring station). The maximum concentration of 0.79 pCi/m^3 was 0.2% of the DCG for ^{137}Cs. Vegetation sample analysis showed elevated ^{137}Cs concentrations around H Area with a maximum of 17.6 pCi/g southeast of H Area. The H-Area rainwater sample did not show ^{137}Cs concentrations above the lower limit of detection of 0.009 pCi/mL.

Special Study of Tritium Concentrations in Drinking Water

A special study was performed in 1987 to determine tritium concentrations in drinking water and well water in several SRP operating areas. Analyses show that no tritium contamination in the Black Creek-Middendorf Formations (formerly called the Tuscaloosa Aquifer) is present at levels detectable by sensitive environmental radiometric methods. The study confirms low levels of tritium detected by routine analysis of drinking water samples are introduced after the water is drawn from the aquifer. The tritium may be introduced into the water samples during chemical treatment or through exposure to atmospheric tritium during aeration.

Duplicate drinking water samples were collected in specially prepared bottles from P, K, L, and H Areas. In the first two weeks of sampling, water was taken from drinking water fountains. In the next two weeks, water was collected directly from the well head. The SRL Environmental Radiometrics laboratory analyzed the samples in low-level tritium facilities and determined tritium concentrations by proportional counting of the hydrogen gas generated from the water. The SRP Environmental Monitoring laboratory analyzed duplicate samples in its routine facilities using distillation and liquid scintillation counting.

Concentrations or minimum detectable amounts are shown in Table 8-3, Vol. II. Results from the SRP Environmental Monitoring laboratory indicated low-level contamination of the water samples during chemical treatment and aeration, as described previously. SRL Environmental Radiometrics results showed low but positive concentrations in four of the water fountain samples. One of the samples collected directly from the well head and the control sample taken from a well in Jackson, SC, showed concentrations at the minimum detection level and do not reflect contamination of the aquifer.

Measurements of ^{129}I in Groundwater and Surface Water

The Savannah River Laboratory has conducted a study at irregular intervals since 1970 to determine the ^{129}I content of groundwater and surface water at onplant and offplant locations [Ka87]. Measurements were made by neutron activation analysis. Iodine-129 was detected in groundwater near the Burial Ground and near the seepage basins of the Separations Areas. For reference, ^{129}I concentrations in the groundwater can be compared to the EPA drinking water standard. At a few locations, the concentrations exceeded both the existing and pending EPA drinking water standards of 1 and 100 pCi/L, respectively. In surface water, Four Mile Creek was the only SRP stream found to transport significant ^{129}I to the Savannah River. Dilution by C-Reactor discharge and the Savannah River reduced

the offplant ^{129}I concentrations in river water to less than 1% of the existing EPA drinking water standard and less than 0.01% of the pending standard.

A quarterly sampling program for ^{129}I in Savannah River water upstream and downstream of SRP was reactivated in 1986 after five years of dormancy. Sampling of water at the two water treatment plants downriver of SRP is planned for 1988.

Savannah River Swamp Survey

Description of Monitoring Program. The Savannah River swamp between Steel Creek and Little Hell Landing was contaminated with approximately 25 Ci of ^{137}Cs and less than 1 Ci of ^{60}Co in the 1960s. The contaminated swamp area extends beyond the SRP site boundary to private property known as Creek Plantation. The offsite swamp area is uninhabited and inaccessible except for possible occasional hunting or fishing.

The source of the radioactivity was failed fuel elements that leaked radioactivity into storage basin water used to shield and cool irradiated fuel elements. Over time, portions of the fuel storage basin water containing the ^{137}Cs and ^{60}Co were discharged to Steel Creek. The radioactivity settled in the swamp during periods when Steel Creek flowed across the swamp before entering the river at Little Hell Landing. The failed fuel elements were removed from P-Area fuel storage basins in 1970.

Ten sampling trails were established in the swamp in 1974 in order that specific locations could be repetitively monitored to determine whether radioactivity in the swamp was migrating (Fig. 8-2, Vol. II).

Typical Savannah River swamp

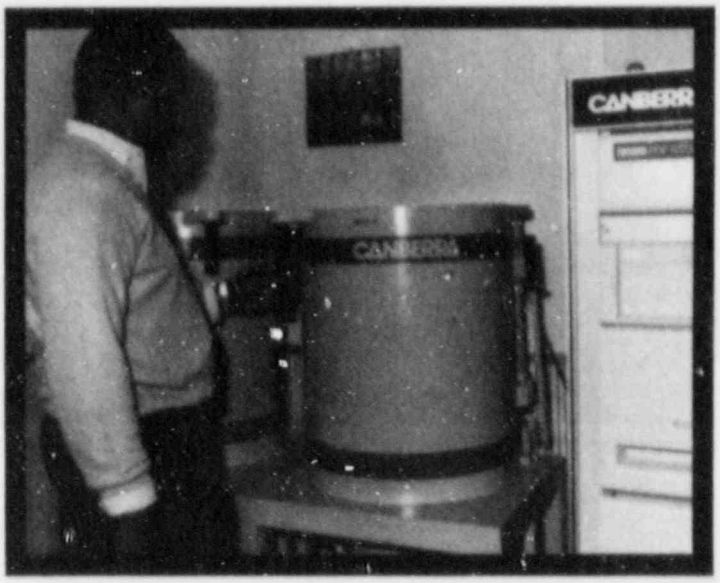
Comprehensive surveys were made annually along the trails between 1974 and 1977. These comprehensive surveys included TLD gamma radiation measurements and analysis of vegetation, soil, and fish samples. The frequency of comprehensive surveys was reduced to five-year intervals after 1977, because the surveys indicated no significant changes in radiological conditions. Interim monitoring was provided by annual TLD measurements along the 10 transects. A routine comprehensive survey was conducted in 1982. Another comprehensive survey was performed in 1985 during construction of L Lake. Cursory surveys were performed in 1986 and 1987.

Monitoring Results. During 1987, soil and vegetation samples were collected at three locations along trails 1, 5 and 10 in addition to the annual TLD measurements. Samples were collected to continue monitoring for any changes that may have resulted from the restart of L-Reactor. Samples for 1987 were collected as near as possible to the locations sampled in earlier years. Monitoring data are presented in Tables 8-4 through 8-9, Vol. II.

TLD gamma radiation measurements were made by placing dosimeters one meter above the ground at previously identified locations along the trail. The dosimeters were collected for processing after an exposure period of approximately 30 days. The 1987 results ranged from 0.17 to 0.94 mR/day and were in general agreement with data from previous years. TLD radiation measurement data are presented in Table 8-4, Vol. II.

TLD data collected during the 1986 survey were found to be unusual when compared with previous years. A resurvey conducted during April 1987 confirmed that the original 1986 survey results were biased by improper analytical technique. These resurvey data are also presented in Table 8-4, Vol. II.

Soil core samples, collected at selected locations along trails 1, 5, and 10, were analyzed for gamma-emitters, ^{90}Sr, and $^{238,239}Pu$. Analytical data are presented in Tables 8-5 and 8-6, Vol. II. Cesium-137 was the only gamma-emitting radionuclide detected. The concentrations of ^{137}Cs in soil were within ranges observed during the last several years and showed a maximum of 178 pCi/g. Strontium-90 concentrations in soil showed a maximum of 0.34 pCi/g and were within ranges observed in previous years. The maximum $^{238,239}Pu$ concentrations in soil were 0.05 and 0.10 pCi/g, respectively, and all



Monitoring for gamma-emitting radionuclides

^{238,239}Pu concentrations were within ranges observed during the last several years. Concentrations of radionuclides in soil vary from sample to sample and from year to year because of slight differences in sampling location and the non-homogeneity of soil.

Vegetation samples were also collected along Trails 1, 5 and 10 and analyzed for alpha- and gamma-emitting radionuclides. Alpha concentrations were within the ranges observed in previous years and showed a maximum of 0.63 pCi/g. Alpha data are presented in Table 8-7, Vol. II. The only gamma-emitting radionuclides detected in vegetation were ^{137}Cs and naturally occurring ^{40}K. Cesium-137 concentrations were within the ranges detected in previous surveys. The maximum ^{137}Cs concentration was 2.4 pCi/g. Data are shown in table 8-8, Vol. II.

Fish were collected from two of the three lakes in close proximity to the swamp trails. Boggy Gut Lake is normally sampled but was dry in 1987. Concentrations of ^{137}Cs in the 10 fish analyzed were within ranges observed during previous years and are presented in Table 8-9, Vol. II. The maximum ^{137}Cs concentration was 1.2 pCi/g in a bream from Cannuck Lake. The maximum concentration in the 27 fish from the River-2 control location upriver of SRP was 1.1 pCi/g in a bream. The 50-year ^{137}Cs dose commitment from eating fish for one year (163 kg average consumption) collected from Cannuck Lake and Jacks Lake (maximum 1.2 pCi/g) would be 0.7 mrem (0.007 mSv) or 0.002% of the annual dose to an average resident of the Central Savannah River Area (CSRA) from naturally occurring radioactivity.

Special Creek Plantation Well Survey

Wells on the Creek Plantation were sampled and analyzed for radioactivity during August 1987. This study was conducted to confirm these wells have not been impacted by SRP operations. The results are presented in Table 8-10, Vol. II. All results were below EPA Drinking Water standards and were within ranges observed for other drinking water wells routinely sampled.

Low-Level Gamma Analysis of River Water

Cesium-137 was detected by SRL both upriver and downriver of SRP using a special low-level analysis technique. The technique consists of sampling large volumes of water and measuring the radioactivity in a low background counting facility. The continuous sampler typically processes 300 to 500 liters of water per week. Cesium-137 and ^{60}Co in the water are selectively concentrated on ion exchange material and counted for approximately 16 hours on an HPGe detector in a low background counting facility. The special low-level ^{137}Cs data are presented in Table 8-11, Vol. II. A graph of all data collected since 1983 is shown on p. 85 in Fig. 8-2 (shown as Fig. 8-3, Vol. II).

In 1987, ^{137}Cs concentrations upriver of SRP (Shell Bluff) averaged 0.010 pCi/L. The downriver (Highway 301) concentrations averaged 0.057 pCi/L. The difference between the upriver and downriver concentrations is attributed to releases from SRP operations. The maximum ^{137}Cs concentration of 0.103 pCi/L was 2,000 times less than the EPA drinking water standard of 200 pCi/L. Concentrations of ^{60}Co were less than the minimum detectable concentration of 0.01 pCi/L both upriver and downriver of SRP.

Comprehensive Surveys at the Beaufort-Jasper and Port Wentworth Water Treatment Plants

Comprehensive surveys of the intake and discharge systems of the Beaufort-Jasper and Port Wentworth water treatment plants (about 100 miles down-

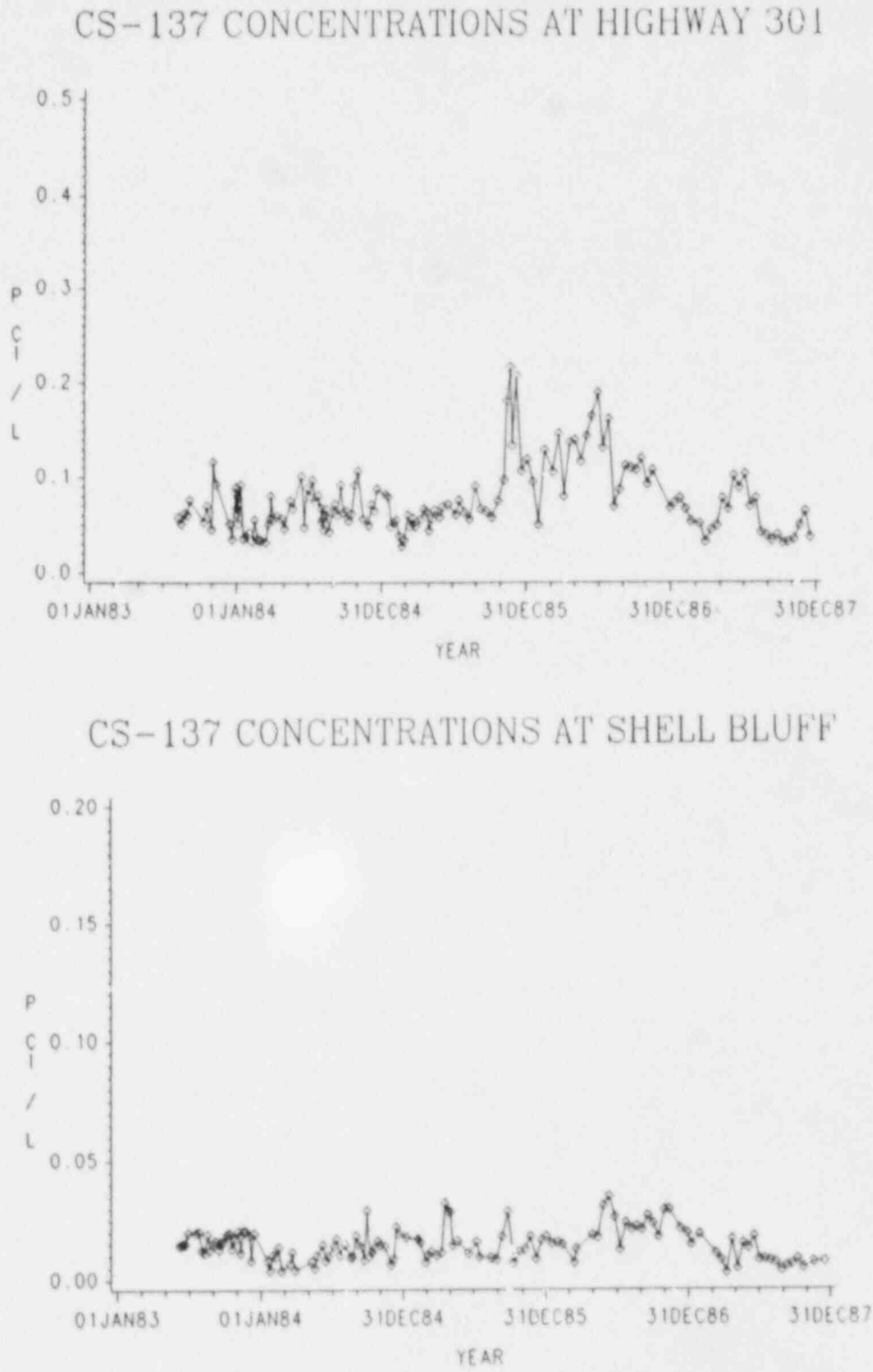


Fig. 8-2. Low-level ^{137}Cs concentrations in the Savannah River

stream from SRP) were conducted following the 1985 startup of L-Reactor. Fig. 5-3 in Vol. II shows the locations of the water treatment plants. The surveys were conducted quarterly beginning in June 1986, and ending in April 1987. Data from the first three quarters of sampling were included in the 1986 SRP Environmental Report [Ze87]. Complete survey results are presented in this report.

Surveys were conducted to meet Environmental Impact Statement requirements and to determine whether the L-Reactor startup affected the water from treatment plants below SRP. Similar surveys were conducted in 1983 to provide baseline data on environmental conditions prior to L-Reactor startup in October 1985. In addition to radioactivity measurements, water quality measurements were also performed. Monitoring results showed no significant change to the water from the treatment plants as a result of L-Reactor startup.

Beaufort-Jasper Survey. Samples consisted of sediment cores, vegetation, water, fish, and turtles in the intake canal between the Savannah River and the Beaufort-Jasper water treatment plant. Some samples were also collected from the raw water holding pond (RWHP) and the backwash holding ponds (BWHP).

The RWHP is a reservoir of approximately five acres that supplies feed water from the Savannah River to the water treatment plant. Water reaches the holding pond via an 18-mile-long canal and pipeline from the river. At the water treatment plant, raw water is treated with alum to coagulate suspended solids. After coagulation and settling, the water is passed through sand filters to remove remaining filterable solids. Residues from the coagulation process and from sandfilter backflushes are released to two holding ponds (BWHPs). Figure 8-4, Vol. II, shows a diagram of the holding ponds at the Beaufort-Jasper treatment plant.

Fourteen transects across the canal were selected for sampling. Water samples were collected at the approximate midpoint of each transect, one from the RWHP and one from each of the BWHPs. These samples were analyzed for gross alpha and nonvolatile beta activity and tritium, strontium, plutonium, and gamma-emitting radionuclides. Radioactivity in water is presented in Table 8-12, Vol. II.

Alpha concentrations in water ranged from less than detectable concentrations to 4.5 pCi/L. Nonvolatile beta concentrations ranged from 0.8 to 16 pCi/L. The maximum alpha and beta concentrations were higher than 1983 maximums of 0.88 and 4.3 pCi/L, respectively. However, routine analysis of water from the Beaufort-Jasper plant indicated normal ranges with a maximum of 0.73 and 4.7 pCi/L, respectively, during the same period as the 1986-1987 survey. The maximum tritium concentration detected was 5,000 pCi/L. This value is above the baseline maximum of 2,300 pCi/L. Tritium concentrations in the fourth quarter ranged from 740 to 1,680 pCi/L, lower than concentrations seen in the first three quarters of the survey. However, these results were consistent with lower levels also detected at the SRP River-10 location (1,850 pCi/L). Cesium concentrations were less than lower limit of detection values. The 16 pCi/L beta and the 5,000 pCi/L tritium values appear to be spurious results.

Twenty-seven vegetation samples were collected from the banks of the canal along each transect and along the banks of the RWHP and BWHPs. Vegetation monitoring data are presented in Table 8-13, Vol. II. All sample results for vegetation are reported in activity per gram of dry weight. Gross alpha concentrations in vegetation ranged from 0.04 to 1.0 pCi/g which were near or less than the values detected in 1983 when the maximum was 1.6 pCi/g. The only gamma-emitting radionuclides detected were ^{137}Cs and naturally occurring ^{40}K. Maximum concentrations of ^{40}K and ^{137}Cs were 46 and 1.0 pCi/g, respectively, as compared to 1983 maximums of 65 and 1.5 pCi/g, respectively. Most samples had ^{137}Cs concentrations below the minimum detectable concentration range of 0.1 to 2.0 pCi/g. In samples analyzed for $^{89,90}Sr$, the maximum concentration detected was 1.4 pCi/g. The maximum ^{238}Pu concentration detected was 1.0 fCi/g, and the maximum ^{239}Pu concentration detected was 1.0 fCi/g.

Sixty-three sediment samples were collected at intervals along each transect and holding pond. The sediment cores ranged from three to 12 in. in depth in the canal ponds. Radioactivity data for sediment are presented in Table 8-14, Vol. II. All sediment sample results are in activity per gram of dry weight. Gross alpha concentrations ranged from 0.2 to 5.7 pCi/g. Beta concentrations ranged from 3.1 to 9.3 pCi/g. Alpha and beta analyses were not performed in 1983. Cesium-137 was the only manmade gamma-emitting radionuclide detected. Its concentrations ranged from less than 0.03 to 3.5 pCi/g. The maximum concentration detected in 1983 was 2.0 pCi/g. Those concentrations above 1 pCi/g may reflect some contribution from SRP releases. Concentrations up to about 1 pCi/g are detected at locations not influenced by SRP operations and are attributed to worldwide fallout from nuclear weapons tests. Strontium-89,90 concentrations ranged from 0.1 to 3.1 pCi/g. Samples were not analyzed for $^{89,90}Sr$ in 1983. Concentrations of ^{238}Pu detected in

sediment ranged from less than detectable concentrations to 34 fCi/g. The maximum ^{238}Pu concentration detected in 1983 was 2.0 fCi/g. Plutonium-239 concentrations ranged from 0.1 to 13 fCi/g. The maximum ^{239}Pu concentration in 1983 was 8.0 fCi/g. The higher 1986-1987 plutonium values may represent some contribution from SRP releases and better quality of analytical techniques.

Gamma pulse height analysis (PHA) of 39 fish from the canal and holding ponds showed detectable ^{137}Cs in one fish sample from BWHP of 0.04 pCi/g. All 1983 ^{137}Cs values for fish were less than the minimum detectable concentration. Fish data are presented in Table 8-15, Vol. II.

Twenty-one water samples were collected for water quality analyses. These samples were analyzed for temperature, pH, dissolved oxygen, turbidity, conductivity and suspended solids. No noticeable trends in the water quality were evident except that turbidity and suspended solids were slightly lower than in 1983 and conductivity was slightly higher than in 1983. These data are presented in Table 8-16, Vol. II.

Port Wentworth Survey. Water, sediment, vegetation, and aquatic specimens were collected near the inlet line to the Port Wentworth water treatment plant at Abercorn Creek and its pumping station, at the plant settling basin, and near the waste water discharge at St. Augustine Creek. Water is supplied to the Port Wentworth water treatment plant through a seven-mile-long pipeline from Abercorn Creek. Waste materials from the treatment plant are discharged through a series of lines and ditches to a swampy area that drains to St. Augustine Creek.

Sixteen water samples were collected from the intakes and discharges for the treatment plant and analyzed for gross alpha, nonvolatile beta, tritium, and gamma-emitting radionuclides. Water sample data are presented in Table 8-17, Vol. II. Gross alpha values ranged from less than minimum detectable values to 3.9 pCi/L. In 1983, alpha values were less than minimum detectable concentrations. Nonvolatile beta concentrations ranged from 0.4 to 20 pCi/L, which is higher than the 1983 maximum beta concentration of 3.0 pCi/L. Tritium concentrations were similar to routine measurements at the treatment plant and ranged from 1,320 to 4,500 pCi/L. The 1983 survey maximum was higher at 5,600 pCi/L. Concentrations of all gamma-emitting radionucludes were less than the lower limit of detection.

Collecting water samples

Sixteen vegetation samples were collected along the banks of Abercorn and St. Augustine creeks and the Port Wentworth settling basin. Vegetation monitoring results are presented in Table 8-18, Vol. II. All analyses are in activity per gram of dry weight. Gross alpha concentrations ranged from less than detectable concentrations to 0.5 pCi/g. The alpha values are less than the 1983 maximums. Concentrations of $^{89,90}Sr$ ranged from less than detectable concentrations to 0.7 pCi/g, compared to a 1983 maximum of 0.36 pCi/g. Gamma analysis showed only naturally occurring ^{40}K (34 pCi/g maximum) and ^{137}Cs (2.0 pCi/g maximum). These results compare favorably with 1983 values. Concentrations of ^{238}Pu ranged from 0.1 to 10 fCi/g, while concentrations of ^{239}Pu ranged from 0.04 to 2.0 fCi/g. Plutonium analyses were not performed in 1983. Concentrations of $^{89,90}Sr$ ranged from from less than detectable concentrations to 0.7 pCi/g. This analysis was not performed in 1983.

Thirty-two sediment cores were collected from Abercorn Creek (at the mouth and pumping station), St. Augustine Creek, and the plant settling basin. The cores were analyzed for concentrations of alpha, nonvolatile beta, $^{238,239}Pu$, $^{89,90}Sr$, and gamma emitters. The cores ranged in depth from three to 10 inches. Sediment monitoring data are presented in Table 8-19, Vol. II. Gross alpha concentrations ranged from less than detectable concentrations to 1.3 pCi/g. Nonvolatile beta concentrations ranged from 2.3 to 15 pCi/g. These analyses were not performed in 1983. As in 1983, ^{137}Cs and naturally occurring ^{40}K were the only gamma emitters detected in sediment. Cesium-137 concentrations ranged from less than 0.05 to 9.0 pCi/g. In 1983, the maximum ^{137}Cs was 3.0 pCi/g. Concentrations of ^{40}K ranged from 2.8 to 37 pCi/g. In 1983, the maximum ^{40}K value was 14 pCi/g. Concentrations of ^{238}Pu ranged from 0.20 to 57 fCi/g, and ^{239}Pu concentrations ranged from 0.04 to 26 fCi/g. Plutonium analyses were not performed in 1983.

Nine fish from Abercorn Creek were analyzed for gamma-emitting radionuclides. As in 1983, ^{137}Cs concentrations were less than 1.0 pCi/g. These data are presented in Table 8-20, Vol. II.

Water samples were analyzed for temperature, pH, dissolved oxygen, turbidity, suspended solids, and conductivity. All water quality measurements were within ranges normally observed in the river except for conductivity, which was higher at the plant settling basin and St. Augustine Creek locations. Conductivity has been erratic at these locations in the past. Water quality data are presented in Table 8-21, Vol. II.

Special Atmospheric Radon Study

A study was conducted to (1) summarize the source, dosimetry, and risk related to radon and radon progeny; (2) to review the results of radon measurement data collected by the Savannah River Plant; and (3) to recommend how radon monitoring data could be included in routine environmental reports to provide a comparison between risks from plant-generated radionuclides and those from naturally occurring radon.

From the period of September 1984 through March 1985, several sets of atmospheric radon measurements were made at various locations at the Savannah River Plant and in various homes throughout the local area. The purpose of these measurements was:

- to improve the definition of the natural background of radon and radon daughter products in indoor locations at the Savannah River Plant and in the local area,
- to estimate the radiation dose associated with the levels of radon and radon daughters using reference dosimetric methods, and
- to describe an average radon and radon daughter contribution to background radiation dose.

Measurements of radon were made at the SRP and at residences in the region of the plant using charcoal canisters supplied by the Department of Energy's Environmental Measurements Laboratory. Data were collected over different periods to study seasonal variations in radon levels in buildings. Specific instructions to ensure uniformity of sampling were issued with the canisters.

From this study, the geometric mean of effective dose equivalent for continuous exposure in homes during warm and cool weather is estimated to be 252 and 415 mrem/year, respectively. The annual average effective dose equivalent to residents in the Savannah River region from radon is estimated to lie between 100 and 300 mrem/year. This estimate is based on assumptions that individuals are not con-

tinuously exposed to radon and that indoor radon concentrations vary seasonally. A comprehensive assessment of radiation exposure of the U.S. population reported by the National Council on Radiation Protection and Measurements (NCRP) in 1987 estimated the average radon dose to be 200 mrem/year [NCRP87a].

This study of radon in homes near the Savannah River Plant and buildings on the plant lends significant insight into typical radon concentrations in the region. Although this study does not represent a comprehensive analysis of radon in the Savannah River Plant area, these data along with the data reported by the South Carolina Department of Health and Environmental Control indicate that levels of radon in the region are approximately equivalent to the national average suggested by the Environmental Protection Agency of 1 pCi/L. The dosimetry of radon is reviewed in ICRP Publication 32 [ICRP81].

Environmental Data Exchange

During 1987, representatives from South Carolina Department of Health and Environmental Control (SCDHEC), Georgia Department of Natural Resources (GDNR), Georgia Power Company, Department of Energy (DOE), Savannah River Laboratory (SRL), and Savannah River Plant (SRP) met to discuss mechanisms for routine exchange of data from environmental radioactivity sampling. The exchange of sample results among the groups is intended to provide an additional interlaboratory quality assurance (QA) check, to increase confidence in each group's monitoring program, to enhance public confidence in monitoring around SRP, and to provide a mechanism for timely communication of technical data.

Common sampling locations and types were identified, and analytical schemes were selected. The table below lists the samples chosen for the first phase of data exchange scheduled for 1988.

Other types of samples such as vegetation, soil, and fish were identified as possible candidates for split sampling and parallel analysis among the participants in future data exchanges. The group agreed on a quarterly reporting frequency, using a common format for the data, which would be collated and redistributed by participants on a rotational basis.

Special Four Mile Creek Survey

Savannah River Ecology Laboratory (SREL) began sampling in the main Four Mile Creek (FMC) channel below C Area in 1987. SREL requested a special survey of the FMC work area to be completed before initiation of their sampling activities. Data from this survey were used to assess potential exposures of

Sample Type and Location	Analysis
SAVANNAH RIVER: Port Wentworth Water Treatment Plant Beaufort-Jasper Water Treatment Plant Highway 301 Bridge	gross alpha and beta, tritium, gamma-emitting radionuclides
AMBIENT AIR MONITORING: Waynesboro, GA Highway 21/167	gross alpha and beta, gamma-emitting radionuclides, radioiodine
TLDs: 5 SRP locations Waynesboro, GA Columbia, SC	gamma radiation

personnel in or near the stream to ionizing radiation and heavy metals.

Radiation doses were calculated on the basis of assumptions and empirical measurements in the vicinity of FMC. The maximum potential dose from tritium exposure via inhalation and submersion for 25 weeks, 40 hours per week, was 2.07 mrem (0.021 mSv). A more realistic average dose from exposure via these two modes is 1.62 mrem (0.016 mSv). TLDs were used to measure gamma radiation from FMC sediments and along the stream bank. TLD measurement data are shown in Table 8-22, Vol. II. The average net dose from sediment (above background) would be 3.75 mrem (0.038 mSv) to an individual working in the creek 25 weeks (1,000 hours). A more realistic dose of 3.3 mrem (0.033 mSv) is projected by assuming that an individual divides his work hours between being in the creek and sampling along the creek bank.

Results were less than lower limits of detection for atmospheric ^{131}I and gamma-emitting radionuclides in airborne particulates. In addition, water and sediment samples were collected by SREL from FMC at Road C down to Four Mile Delta. Samples were analyzed for tritium, ^{90}Sr, ^{99}Tc, and ^{137}Cs. Radioactivity monitoring data are presented in Table 8-23, Vol. II. Samples were also analyzed for volatile organics, base/neutral and acid extractable compounds, pesticides and PCBs, metals, and cyanide as shown in Table 8-24, Vol. II. The samples were analyzed by International Technology Corporation (IT), Oak Ridge, TN. A comparison of IT and SRP analytical results from common locations is shown in Table 8-25, Vol. II.

Surveys of Dry Monitoring Wells in Separations Areas Waste Management Facilities

Profile radiation measurements were taken in dry monitoring (DM) wells in both the F- and H-Separations Areas waste management facilities. Figs. 8-5 and 8-6 in Vol. II show the location of the dry monitoring wells. DM wells are two-inch diameter closed bottom steel cased wells that terminate above the water table. Each well is cement grouted and capped to keep surface water from leaking into the well. The wells are located at points considered most vulnerable to leaks from piping which serves the storage tanks.

Four of 11 DM wells in the F-Area facilities were surveyed in 1987. Background radiation levels were measured in these four wells, all of which monitor diversion box #1. Seven DM wells were not surveyed because of water in the wells.

Radiation measurements were made in an additional 37 of 38 DM wells installed in a contaminated area near Tank 8 in the F-Area waste management facilities. Radiation levels measured in the Tank 8 wells define the zone of major contamination, as shown in Fig. 8-5, Vol. II. This contamination is attributed to overfilling the tank in 1961. Radiation levels around Tank 8 remained high during the 1987 survey. The maximum radiation level in the wells was 86 R/hr in RP-6 at a depth of 19 ft.

Fifteen of 16 DM wells in service in the H-Separations Area waste management facilities were surveyed. HDM wells showed no significant 1987 changes from previous years, with the exception of HDM wells 7 and 23. These wells showed background radiation levels during 1987, while 1986 radiation levels were greater than background. Radiation levels for dry wells in the F- and H-Separations Area waste management facilities are represented in Figs. 8-7 and 8-8, Vol. II.

NONRADIOLOGICAL SURVEYS

Monitoring for Pesticides, Herbicides, and Polychlorinated Biphenyls

Description of Monitoring Program. Water and sediment samples from seven site stream locations were analyzed for 32 pesticides, herbicides, and polychlorinated biphenyls (PCBs) during 1987. A listing of the 32 constituents and typical minimum detectable concentrations are shown in Table 8-26, Vol. II. This program has been conducted since 1976 to assess concentrations of these materials in streams and the Savannah River.

Monitoring Results. Concentrations of all the parameters analyzed in river and stream water and sediment were less than the minimum detectable concentrations, except for the herbicide dicamba in Four Mile Creek at Road A. The dicamba concentrations in water and sediment samples were 2.0 µg/L and 36 µg/kg, respectively. There are no known drinking water standards for dicamba.

Dicamba is not used at SRP, and its presence in SRP streams is attributed to offsite farming operations or upriver Savannah River water pumped to SRP facilities and then released to streams. A history of detectable pesticides, herbicides, and PCBs in SRP

stream water is presented in Table 8-27, Vol. II, and stream sediment in Table 8-28, Vol. II. Note that some detection limits have changed from year to year, partly because of sample matrix interferences.

Spills

Description of Monitoring Program. A site-wide procedure requires prompt reporting of oil and chemical spills to a spill coordinator. The coordinator ensures that spills are reported to the DOE, EPA, and SCDHEC as appropriate to satisfy regulatory requirements.

A spill is defined as any unintentional discharge to the environment. Environment is broadly defined as any water, land, or ambient air. If a substance is spilled on a concrete floor inside a building, it is not reportable because it does not reach the environment. If the same spill were to go down a drain to a sewer line, it would be reportable. All chemical releases to the atmosphere (e.g., chlorine gas) are considered spills for reporting purposes.

The spill coordinator advises custodians on remedial action and helps determine whether a spill is reportable to the EPA and SCDHEC under guidelines of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). CERCLA is commonly called Superfund. A well-trained spill response team is on call to assist with confinement of spilled material.

Spills During 1987. In 1987, there were 145 spills reported to the spill coordinator. Most of these were minor spills of petroleum products. None of the spills were reportable under CERCLA.

1987 HIGHLIGHTS

- The average atmospheric tritium release from all facilities in 1987 was approximately 1,570 Ci per day and represented a 31% increase compared to 1986. However, the total amount of tritium oxide released was similar to the 1986 value. Tritium oxide comprised approximately 44% of the atmospheric tritium released in 1987.
- The maximum calculated dose to an individual at the site boundary from an accidental release of 172,000 Ci of tritium in July was 0.02 mrem (0.0002 mSv).
- After an accidental release of 1 Ci of ^{137}Cs and 33 mCi of ^{134}Cs to the atmosphere from H Area in November, the maximum concentration of 0.79 pCi/m^3 at the plant boundary was 0.2% of the DCG for ^{137}Cs.
- Results of TLD gamma measurements and analysis of soil, vegetation, and fish samples from the Savannah River swamp were within ranges observed in previous years.
- Water from offsite Creek Plantation wells had radioactivity levels below EPA drinking water standards and were well within ranges observed for other drinking water wells.
- Alpha concentrations in water intake from the intake canals to the Beaufort-Jasper and Port Wentworth water treatment plants ranged from less than detectable to 4.5 pCi/L, lower than the drinking water standard of 15 pCi/L.
- Concentrations of pesticides, herbicides, and polychlorinated biphenyls analyzed in river and stream water and sediments were less than the minimum detectable concentrations, except for the herbicide dicamba in Four Mile Creek at Road A. The elevated concentrations appear to be contributed to the river by upriver industrial operations since dicamba is not used at SRP.
- In 1987, there were 145 minor spills reported to the spill coordinator, but none were reportable under CERCLA.

9
Methods for Calculating Offsite Radiation Doses

SUMMARY — The methodology for calculating radiation doses to the population surrounding the SRP site is described. Radiation dose terms, including *dose commitment, population dose commitment, organ-specific dose factors,* and *effective dose equivalent* are defined, and applicable dose standards are given. The relative effects of the two chemical forms of tritium released to the atmosphere from SRP operations are calculated separately in this report. Finally, the mathematical models used for calculating the SRP offsite doses are described. These radiation transport and exposure pathway models are necessary because conventional monitoring methods do not detect the very low concentrations of radioactive materials dispersed in the atmosphere once they are released from SRP. These models are implemented at SRP in three different computer programs: MAXIGASP, which calculates dose to offsite individuals from atmospheric releases; POPGASP, which calculates population doses from atmospheric releases; and LADTAP, which calculates doses to offsite individuals and to the population from liquid releases.

This chapter discusses radiation dose terminology and describes how the offsite doses presented in Chapters 2 and 3 (and summarized in the Executive Summary) were calculated.

DEFINITION OF RADIATION DOSE COMMITMENT

As used in this report, the term *dose* normally means "effective dose equivalent," as defined by the International Commission on Radiological Protection [ICRP77, ICRP79] and discussed in more detail further in this chapter. The term *dose commitment,* as it is applied to an individual, means "committed effective dose equivalent," which is a measure of the amount of radiation dose received by the individual over a lifetime as a result of exposure to all radiation pathways during the year being considered. In this report, the individual's lifetime is assumed to extend 50 years beyond the time of exposure.

The dose commitment to an individual is usually expressed in units of millirem (abbreviated "mrem") or millisievert (abbreviated "mSv") (1 mrem = 1/1000 rem; 1 mSv = 1/1000 Sv; 1 Sv = 100 rem). To put these units in perspective, note that an individual in the Central Savannah River Area (CSRA) receives an average annual natural radiation dose of about 295 mrem (2.95 mSv) from natural radiation [NCRP87a]. Of this total dose, approximately 95 mrem (0.95 mSv) is from natural radiation from cosmic and terrestrial sources, and from naturally occurring radionuclides that have been taken into the human body; approximately 200 mrem (2.00 mSv) is from the inhalation of natural radon gas in homes [NCRP87a]. Many individuals also receive additional exposures from medical examinations or treatments.

Population dose commitment is the sum of individual dose commitments in a population group and is expressed in units of person-rem (person-sievert). For example, if each person in a population of 1,000 receives a dose commitment of 1 rem (0.01 Sv), the population dose commitment would be 1,000 person-rem (10 person-Sv).

In this report, offsite doses that are given for SRP releases of radioactive materials to the environment are for the individuals and population groups who receive the maximum calculated dose commitments. Table 9-1 in Vol. II shows the demographic data used to calculate the doses for populations within an 80-km radius of the SRP and for populations served by the Cherokee Hill water treatment plant at Port Wentworth, GA (near Savannah), and by the Beaufort-Jasper water treatment plant (near Beaufort, SC).

Table 9-1. DOE Revised Interim Radiation Dose Limits

All Pathways. The effective dose equivalent for any member of the public from all routine DOE operations[a] (natural background and medical exposures excluded) shall not exceed the values given below:

	Effective dose equivalent[b] mrem/year	(mSv/year)
Occasional annual exposures	500	(5)
Prolonged period of exposure[c]	100	(1)

No individual organ shall receive a committed dose equivalent of 5 rem/year (50 mSv/year) or greater.

Air Pathway Only (Limits of 40 CFR 61, Subpart H)

	Dose equivalent mrem/year	(mSv/year)
Whole body dose	25	(0.25)
Any organ	75	(0.75)

[a] "Routine DOE operations" means normal planned operations and does not include additional planned or unplanned releases.
[b] Effective dose equivalent is expressed in rem (or mrem) with the corresponding value in Sv (or mSv) in parentheses.
[c] For the purpose of these standards, a prolonged exposure is one that lasts, or is predicted to last, longer than 5 years.

The individual and population dose commitments for 1987 SRP releases, calculated by the methods described in this chapter, are compared with the average annual dose commitments from natural and medical sources in Table ES-2 in the Executive Summary.

APPLICABLE DOSE STANDARDS

The DOE radiation standards for the protection of the public in the vicinity of the SRP are given in Order DOE 5480.1A. These standards are based on recommendations of the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP).

In 1985, a draft DOE order was issued that contained revised interim standards incorporating the recommendations and dose models contained in ICRP Publications 26 and 30 [ICRP77, ICRP79]. (The previous standards had been based on ICRP Publications 2 and 10 [ICRP59, ICRP68].) These revised interim standards, which also include EPA limits for the atmospheric pathways contained in 40 CFR 61, Subpart H [EPA85], are given in Table 9-1 above.

EPA drinking water standards which apply at downriver water treatment plants are based on an annual whole body dose of 4 mrem (0.04 mSv) from the annual consumption of two liters of water per day [EPA75]. SRP dose estimates are based on similar criteria and can be compared with the EPA dose standard.

INTERNAL DOSE FACTORS

Organ-Specific Dose Factors

The internal radiation dose estimates presented in this report are ultimately derived from a set of internal organ-dose factors, which are based on the methodology developed by the ICRP [ICRP79] and have been calculated for intake by inhalation and ingestion, for those radionuclides of interest in environmental dosimetry, and for approximately 20 organs of the body. Each factor relates the intake of a unit quantity of a radionuclide to the dose received

by an organ during the 50 years following the intake. Their units typically are mrem/pCi (mSv/Bq). Multiplication of the dose factor by the number of pCi (Bq) of the radionuclide taken into the body gives the dose to the organ in mrem (mSv).

Effective Dose Equivalent

Almost every intake of radioactive material into the human body involves the irradiation of more than one organ or tissue, usually at different rates, and the sensitivities of these organs or tissues to radiation differ from one another. It was to account for the differing dose rates and radiosensitivities that the ICRP adopted the concept of effective dose equivalent. In calculating the effective dose equivalent, the dose to each organ or tissue is multiplied by a weighting factor, and the resulting products are summed. Each weighting factor represents the ratio of the somatic and genetic risk resulting from the irradiation of a specific organ or tissue to the total risk that would result from the uniform irradiation of the whole body. Thus, effective dose equivalent accounts for nonuniform irradiation of the body and also provides a common basis for comparing and combining (adding) the doses from different internally deposited radionuclides (which may cause different distributions of doses to different organs) and the doses from external sources of radiation.

The organ-specific internal dose factors are combined, by the process outlined above, into factors for effective dose equivalent. Such a factor represents effective dose equivalent for 50 years following the intake of a unit quantity of a radionuclide. It is specific to the mode of intake (inhalation or ingestion) and the radionuclide taken into the body; it is *not* specific to a particular organ or tissue, because it represents a risk-weighted average of the doses to all organs or tissues irradiated by the intake. Hereafter, unless a statement to the contrary is made, the term *internal dose factor* will refer to a 50-year committed effective dose equivalent factor.

Because the current ICRP methodology is relatively new, only internal dose factors for adults are available at present. Age-specific dose factors for infants and adolescents probably will not become available for several years. As an interim procedure, the doses for all age groups are calculated with the adult dose factors. But age-specific intake rates of food and water have been used in the dose calculations. These intake rates are shown in Tables 9-2 and 9-3 of Vol. II.

RELATIVE EFFECTS OF DIFFERENT CHEMICAL FORMS OF TRITIUM IN THE ATMOSPHERE

Tritium released to the atmosphere from SRP operations is primarily in two chemical forms: tritium oxide (tritiated water vapor: THO, T_2O) and elemental tritium (HT or T_2). The effective dose equivalent factors for exposure to tritium in air differ by four orders of magnitude for the two chemical forms; also, the two forms behave differently in the environment. Therefore, releases of tritium to the atmosphere must be identified by chemical form and the doses from the two chemical forms calculated separately.

The dose calculations must also consider the different ways in which tritium is biologically assimilated by the body. Tritium oxide is readily absorbed by the body when tritiated water vapor is inhaled or when tritium oxide is ingested in drinking water or in food. An individual exposed to airborne tritiated water vapor normally absorbs about one-half as much tritium through the skin as by inhalation [ICRP78]; thus the effective dose equivalent factor corresponding to intake by inhalation is increased by 50% to account for the incremental uptake of tritium oxide through the skin. Tritium oxide assimilated by the body is assumed to be eliminated at the same rate as body water.

Elemental tritium, on the other hand, is not efficiently assimilated by the human body. Of the elemental tritium gas inhaled, only about 0.004% is converted to the oxide and retained as free water [NCRP79]. The need for limiting exposure to elemental tritium in air is governed by the dose to the lung as the airborne HT gas passes through .

In this report, the releases of tritium to the atmosphere are identified by chemical form.

CALCULATIONAL MODELS

With few exceptions, most of the radioactive materials released from the SRP are of such low concentrations that when dispersed in the environment they are not detectable by conventional monitoring procedures. Therefore, radiation doses to offsite populations are calculated with mathematical models that use known transport mechanisms for atmospheric and liquid releases and known major pathways of exposure to man. Environmental measurements of

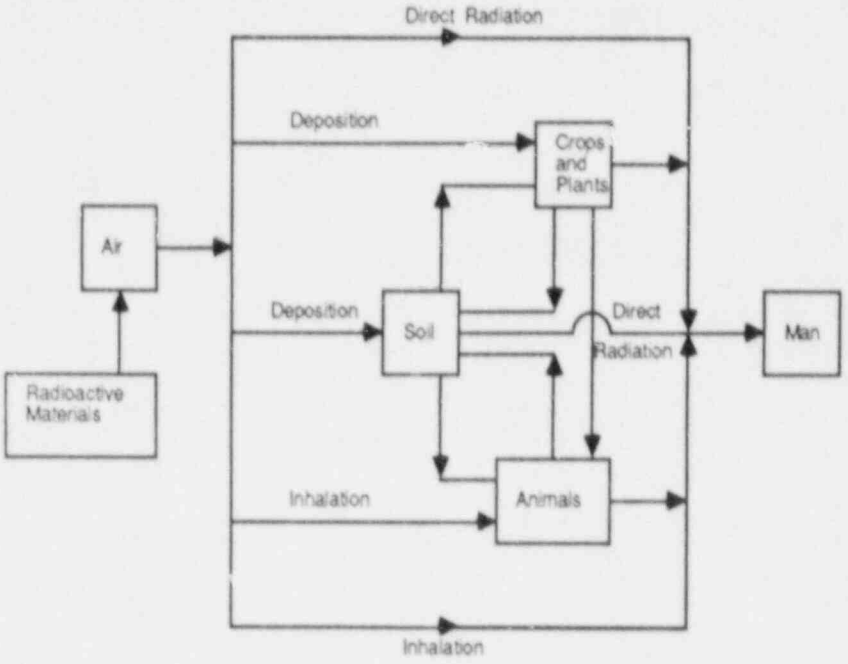


Fig. 9-1. Simplified pathways between radioactive materials released to the atmosphere and man

tritium oxide that is released from production areas in small quantities are used to verify atmospheric dispersion in the transport models [Ma84].

The models used for calculating the SRP offsite doses are radiation transport and dose models developed for the nuclear industry [USNRC71] to assess the effects of operations of licensed commercial nuclear facilities. The models are implemented at SRP in the following computer programs:

- MAXIGASP: calculates maximum and average doses to offsite individuals from atmospheric releases.
- POPGASP: calculates population doses from atmospheric releases.
- LADTAP: calculates maximum and average doses to offsite individuals and to the population from liquid releases.

MAXIGASP and POPGASP are SRL-modified versions of the Nuclear Regulatory Commission (NRC) program called GASPAR. The modifications are those needed to meet the requirements for input of specific SRP physical and biological data. The basic calculations in the GASPAR program are not modified. LADTAP is an unmodified version of the NRC program of the same name. (For details on these environmental models and computer programs, see references [USNRC71], [Ec80], and [Si80].)

The Environmental Protection Agency (EPA) requires the use of the CAAC computer code (Clean Air Act Code, formerly AIRDOS-EPA) to calculate offsite doses from existing and proposed facilities in order to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP). At SRP, the CAAC dose estimates are computed to show NESHAP compliance, but they are not included among the offsite dose estimates prepared for this report. The primary reason for not adopting the CAAC methodology is its conservative approach to calculating doses from tritium oxide in food. The CAAC model assumes that airborne tritium oxide at a given location is diluted with the atmospheric moisture, for which a generic specific humidity of 8 g H_2O/m^3 is used by the code. It makes no provision for user input of a specific humidity value appropriate for the particular site and season. Because of this parameter value, CAAC doses are believed to be substantial overestimates for the humid SRP area. The MAXIGASP and POPGASP codes incorporate a specific humidity parameter of 11 g H_2O/m^3, which was determined by a review of weather bureau records for Augusta, GA. Another conservative assumption of the CAAC methodology is that the water content of foods reaches an equilibrium content of tritium equal to the tritium content of atmospheric moisture.

Modeling the Dispersion of Radioactive Releases to the Atmosphere

Radioactive materials released to the atmosphere generally become involved in a complex series of physical, chemical, and biological processes. Some of these processes involve dilution, while others involve physical or biological reconcentration, followed by transfer through various pathways to man. Figure 9-1 at the top of this page gives a simplified representation of some of the pathways followed by radioactive materials that are released to the atmosphere and eventually reach man.

Meteorological Data Base. The transport of radioactive materials from SRP by the atmosphere is calculated on the basis of meteorological conditions

measured continuously at seven onsite meteorological towers and at a 1,200-ft television transmitting tower that is 30 km (18.8 miles) northwest of the geometric center of the SRP. For this report, meteorological dispersion and deposition were calculated from meteorological measurements made over a five-year period (1982–1986) collected at a meteorological tower located near the center of the SRP site (H-Separations Area). (These meteorological data are presented in Table 9-4 of Vol. II.)

The meteorological measurements, which are expressed in terms of frequencies of wind speed, direction, and atmospheric stability, are used to calculate the dispersive characteristics of the atmosphere. These dispersive characteristics are calculated by methods used in the nuclear industry [USNRC73] as implemented in the computer program called XOQDOQ [Sa77]. As noted above, the calculated dispersion is verified by environmental measurements of tritium oxide [Ma84]. Also, measured annual average concentrations of tritium oxide in the atmosphere are compared with concentrations calculated with XOQDOQ and are published annually in this report (see Chapter 2).

Dose Calculations for Atmospheric Releases. The annual average concentration and deposition factors calculated with the XOQDOQ program, together with the measured annual releases of radioactivity to the atmosphere, are used in the MAXIGASP and POPGASP programs, along with data on population distribution and production data for vegetable crops, milk, and meat, to calculate the intakes of radioactivity and exposure to external radiation sources by offsite populations. The intakes are based on inhalation rates and consumption rates for food and water, as shown in Tables 9-1, 9-2, 9-5, and 9-6 of Vol. II.

The intakes of radioactivity by offsite populations are converted to dose commitment by use of the ICRP internal effective dose equivalent factors, which as described previously, provide estimates of a 50-year dose commitment for intake of a unit quantity of radioactivity. The term *environmental dose commitment* refers to population dose that is calculated to account for the persistence in the environment of some radioactive materials and thus for continued human exposure to external and internal sources of radiation that are due to the release or operation under study. The calculated population doses in this report include an estimate of environmental dose commitment for a 100-year period following the release of radioactivity.

The Weather Information and Display (WIND) system is used to calculate offsite doses resulting from unexpected releases from SRP. The assimilated (or

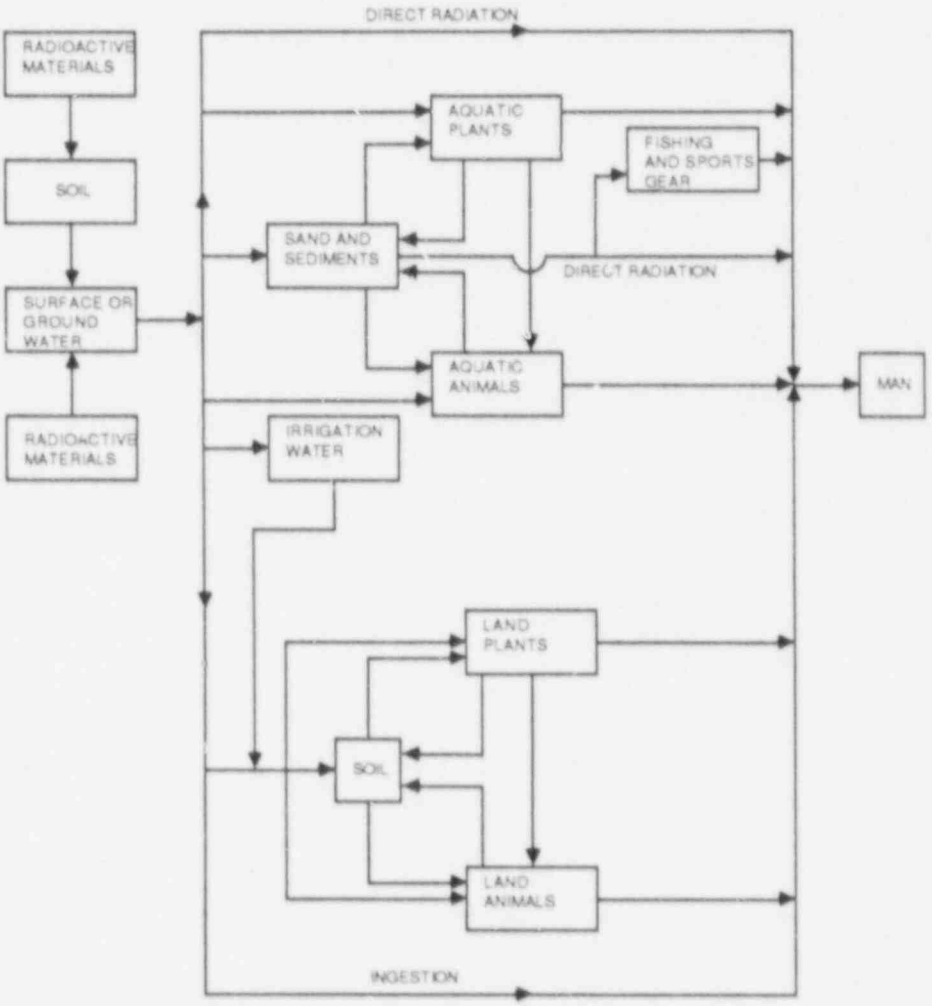


Fig. 9-2. Simplified pathways between radioactive materials released to the ground or to surface waters and man

internal) dose estimates use the ICRP-30 50-year dose commitment factors based on an active adult's breathing rate. The models in the WIND system which provide these individual dose estimates are PUFF/PLUME and 2DPUF. External doses from a plume- or puff-emitting gamma radiation are also calculated by PUFF/PLUME.

Modeling the Dilution and Transport of Radioactivity Released to Surrounding Streams

Radioactive materials released to SRP streams flow to the Savannah River, and although many of the radionuclides are measurable at the point of release, they are below the minimum detectable concentrations after dilution with river water. Only tritium oxide and trace amounts of ^{90}Sr and ^{137}Cs are routinely detected in the river. Thus, to account for the offsite doses from all releases to the streams, it is necessary to employ an analytical model.

The radioactive materials released into the streams, like those released to the atmosphere, become involved in a complex series of physical, chemical, and biological processes. Some of these processes involve dilution, while others involve physical or biological reconcentration, followed by transfer through various pathways to man. Fig. 9-2 on p. 97 [ICRP65] is a simplified representation of some of the more important exposure pathways followed by radioactive materials released to liquid effluents and eventually reaching man. In previous years, dose calculations for the irrigation water pathway were not included, because no use of river water for irrigation downriver from SRP is known. However, because irrigation along the river by a small farming operation is a possibility, potential doses via this pathway were calculated for 1987.

Flow-Rate Data. Dilution of radioactive materials in the river is based on continuous flow-rate measurements made at the SRP site. The average river flow rate in 1987 was about 10,328 ft^3/sec and represents 146% of the 1986 flow rate of 7,070 ft^3/sec. The flow rate varies annually, depending on the amount of rainfall in the river watershed area and the quantity of water released by Thurmond Lake Dam (formerly Clarks Hill Dam).

Dose Calculations for Stream Releases. Average river flow rates and measured annual releases of radioactivity to the river are used in the LADTAP program, along with data for population, sports and commercial fish harvest [Tu83], community water consumption, and recreational use of the river [Tu83b], to calculate offsite dose commitments. Many of the data used in these calculations, as well as human consumption rates for water and fish, are shown in Tables 9-1, 9-3, 9-5, 9-6, and 9-7 of Vol. II.

1987 HIGHLIGHTS

- Internal dose factors for adults, which are the only internal dose factors available at present that incorporate the new ICRP methodology, are used for calculating doses for all age groups. However, age-specific intake rates of food and water have been used in the dose calculations.
- NRC computer programs developed for the nuclear industry are used for calculating offsite doses to the public.
- Meteorological conditions are measured continuously at seven onsite meteorological towers and at a 1,200-ft television transmitting tower located 30 km (18.8 miles) northwest of the geometric center of SRP.
- The average river flow rate in 1987 of 10,328 ft^3/sec was a more typical flow and represents a 46% increase in the flow rate since 1986. The 1986 flow was smaller due to reduced rainfall.

10
Sample Collection and Analytical Procedures

SUMMARY — Procedures for the collection, preparation, and analysis of environmental samples for both radioactive and nonradioactive constituents are described in detail. The instruments and detector types for determining radionuclide concentrations in environmental samples, as well as the routine counting geometries for gamma spectrometry, are outlined. For radiological analysis, air, streams, the Savannah River, the seepage basins, groundwater, milk, drinking water, food, rainwater, wildlife, soils, sediments, and vegetation are sampled in clearly outlined procedures. Thermoluminescent dosimeters are used to measure external radiation. For nonradiological analysis, four ambient air monitoring stations on the site measure sulfur dioxide, oxides of nitrogen, ozone, and total suspended particulates. In addition, water from streams and rivers, groundwater and drinking water, and soils and sediment are analyzed for physical properties such as alkalinity, conductivity, and temperature, and for nonradioactive constituents such as metals, pesticides, and volatile organics.

INTRODUCTION

This section describes sample collection and preparation procedures and the analytical techniques used to determine concentrations of radionuclides in environmental samples. Listed below are instruments and detector types used for these measurements:

- Gas-flow proportional counters for alpha and beta emitters
- Liquid scintillation counters (LSC) for low-energy beta emitters
- Semiconductor alpha spectrometers for isotope-specific quantification of alpha emitters
- High-purity germanium (HPGe) detectors for high-resolution gamma quantification
- Sodium iodide [NaI(Tl)] detector for high-efficiency detection of gamma emitters

Specific counting geometries for gamma spectrometry of different types of samples are required for accurate analysis. Standardized sources of radioactivity with known gamma field characteristics are used to calibrate the detection instruments; the counting geometries correspond to the sizes and shapes of the standardized sources.

A brief description of the routine "standard" counting geometries for gamma spectrometry follows:

Geometry #1
Used for analyses of samples physically similar to flat 3-in.-dia air filters. All air filters are analyzed, either individually or by collective composite, using this geometry. All analyses of this type are performed on systems using SPECTRAN-F software.

Geometry #2
Used for analyses of samples physically similar to 200 mL of water in a "standard" 500-mL 3.25-in.-dia polyethylene bottle. Air sample charcoal cartridges are also routinely analyzed in this geometry.

Geometry #3
Used for analyses of samples physically similar to 1 L of water in a "standard" 1-L polyethylene Marinelli beaker. Relatively new for SRP, this configuration is becoming the standard analysis geometry for liquid environmental samples having low activities.

Geometry #5
Used for analyses of samples physically similar to 500 mL of water in a "standard" 500-mL 3.25-in.-dia polyethylene bottle. This geometry was used for all direct-mount liquid sample analyses prior to 1986.

As new HPGe detector systems are placed in service, many samples such as stream and river water, foodstuffs, and groundwater that were analyzed in past years using only Geometry #5 (500 mL) will now use

Geometry #3 (1000 mL). One such system, referred to as HPGe Detector #3, was used extensively in 1987. At least one additional new system, HPGe Detector #4, will be used in a similar configuration in 1988.

The following tables in Volume II present sample media and counting data:

Table 10-1 Sample Media Data
Table 10-2 Gas-Flow Proportional Counting Data
Table 10-3 Liquid Scintillation Counting Data
Table 10-4 Alpha Spectrometer Counting Data

Additional tables in Volume II provide lower limits of detection (LLD) for HPGe detectors and for selected sample types. Those tables are referenced in Chapter 11.

RADIOLOGICAL PROCEDURES

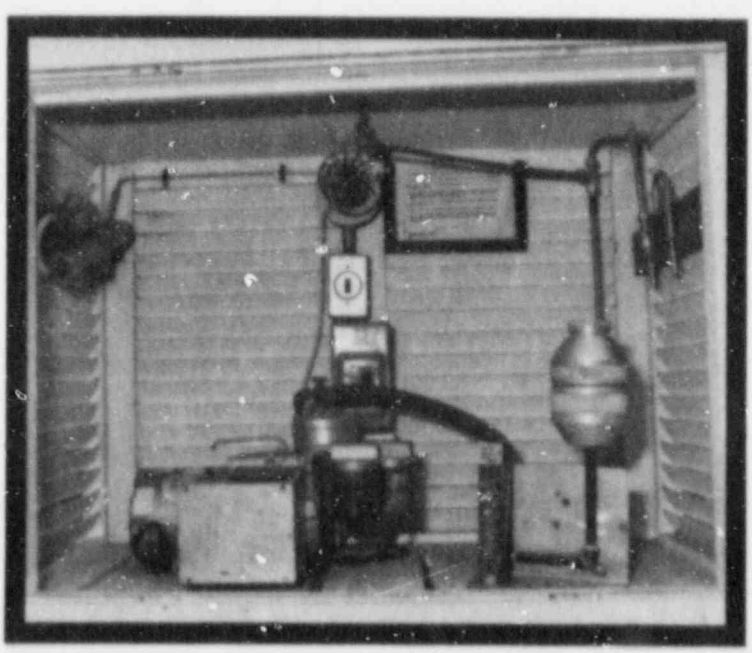
Air

Particulate airborne radioactivity is sampled continuously at each monitoring station by drawing air through a 2-in.-dia. high-efficiency paper filter at about 70 L/min (2.5 ft^3/min). An auxiliary running time meter and air flow meter record the volume of air that passes through the filter and the total sampling time. Sample filters are collected weekly from 35 monitoring stations for analyses.

Alpha- and beta-emitting radionuclides are determined simultaneously by a direct gross count of individual particulate filters using a gas-flow proportional counter. The weekly filters are then composited monthly by location group (700-A, Burial Ground North, Burial Ground South, 200-F, 200-H, plant perimeter, 25-mile radius, and 100-mile radius) and counted for gamma emitters on a high-purity germanium (HPGe) detector. After gamma counting, each filter in the composite groups is cut in half; one half is used for strontium analysis and the other for plutonium analysis.

Strontium-89,90 are leached from the filters with 8*N* (normal) nitric acid, precipitated with fuming nitric acid, scavenged with ferric hydroxide, precipitated as the carbonate and transferred to a stainless steel planchet (holder) for counting on a gas-flow proportional counter.

For $^{238,239}Pu$ analysis, each filter composite is dry ashed and leached with acid. The solution is evaporated to dryness, dissolved in 7.2*N* nitric acid, and passed through an anion exchange resin. The extracted plutonium is eluted from the resin column with an ammonium iodide–hydrochloric acid solution, which is then evaporated to dryness. The residue is redissolved in a sulfate medium. Any plutonium present in the sample is electrodeposited on a stainless steel disk and counted on a silicon surface barrier detector.



Air monitoring station

Samples for gaseous radioiodine are collected on cartridges containing 5% triethylene diamine– (TEDA)-impregnated charcoal. The charcoal cartridges, located downline from the particulate filters, are collected weekly. Iodine-131 is measured by a direct count of the charcoal cartridge on an HPGe detector.

Moisture is collected from the atmosphere for determination of tritium oxide by drawing air through a silica gel column at a continuous rate of 150 mL/min (0.005 ft/min). The column contains non-indicating silica gel and is backed up by an in-line column of indicating silica gel. The indicating silica gel changes color if moisture saturates the primary silica gel column during the sampling period. These samples are collected twice a month for analyses.

The non-indicating silica gel is distilled using low heat to remove free water. The distillate, representing the moisture content in the air sampled is suspended in a liquid scintillation cocktail. The concentration of tritium oxide in the moisture is determined by liquid scintillation counting. The concentration of tritium oxide in the air is calculated from the tritium oxide in the atmospheric moisture and the absolute humidity (moisture in the air) for the volume of air sampled.

External Radiation

Thermoluminescent dosimeters (TLDs) are used to measure external radiation. The SRP-designed TLD, which was used for many years, contains a calcium fluoride dysprosium (CaF_2) crystal positioned behind a silver filter to measure dose from photons with energies above 100 keV. Energies below 100 keV are measured with lithium fluoride (LiF) TLDs positioned behind a paper filter. During 1986, a special study was conducted to compare the SRP-designed TLD with a new Panasonic 801 TLD. The Panasonic dosimeter, which contains two calcium sulfate ($CaSO_4$) crystals and two lithium borate ($Li_2B_4O_7$) crystals, was chosen for several reasons. The more efficient Panasonic system requires less labor, provides improved quality assurance, and is automated. Dosimeters of both types were exposed at selected field locations to verify that variable environmental conditions (rain, temperature, humidity, and sunshine) would not adversely affect the results of the Panasonic dosimeters. The Panasonic test results were favorable. Fig. 10-1, Vol. II, shows the relationship between the SRP and Panasonic TLD measurements.

SRP and Panasonic TLDs were used at sample locations during 1987 with a complete conversion to the Panasonic TLDs occurring by the fourth quarter. The TLDs are annealed, placed in holders that are then sealed in plastic bags, and mounted on stands one meter above the ground. They are collected quarterly and read to determine gamma radiation absorbed by the crystals. Calibration TLDs accompany each set of field TLDs to assure accurate measurements.

Streams

Plant streams are sampled continuously by paddle-wheel samplers. Each sampler consists of a Plexiglas wheel suspended on two pontoons and anchored in the stream. The wheel is turned by the stream flow. The sample is collected in a small cup or cups attached to the paddle. The cup containing the sample is emptied into a trough attached to the sampler. The sample flows by gravity from the trough through a connecting tube into a polyethylene jug attached to the sampler. Samples are collected weekly.

Typical TLD station

Alpha- and beta-emitting radionuclides are measured by a direct count of the residue remaining from evaporation of a one-liter water sample. The sample residue is transferred to a 2-in. stainless steel planchet. The planchet is flamed to remove volatile material before being counted on a gas-flow proportional counter. Gamma-emitting radionuclides are determined by direct count of either a 500-mL or a 1,000-mL aliquot of the sample on an HPGe detector.

Alpha-emitting radionuclides are extracted from a one-liter sample with triisooctylamine (TIOA) in xylene. Uranium and plutonium are selectively stripped from the TIOA organic layer with 0.1*N* hydrochloric acid, and the solution is evaporated to dryness. The residue is dissolved in 8*N* nitric acid and transferred to a stainless steel planchet for counting on a gas-flow proportional counter.

Paddlewheel sampler

Tritium is measured in a 3.0-mL undistilled aliquot of the sample by liquid scintillation counting.

For $^{89,90}Sr$ analysis, an aliquot of sample is evaporated to dryness. The sample is precipitated with fuming nitric acid, scavenged with ferric hydroxide, precipitated as the carbonate and transferred to a stainless steel planchet for counting on a gas-flow proportional counter.

For ^{90}Sr analysis, an aliquot of the sample is evaporated to dryness and the residue dissolved in 0.08*N* hydrochloric acid. Yttrium-90 is stripped from the strontium using di-2-ethylhexyl phosphoric acid (HDEHP) in toluene. Equilibrium of ^{90}Y is approached over a 15-day period, and then the short-lived ^{90}Y daughter is stripped once again. The yttrium is transferred to a stainless steel planchet and counted in a gas-flow proportional counter. The amount of ^{90}Sr is calculated by relating the ^{90}Y buildup to the original ^{90}Sr concentration.

Cesium is selectively precipitated from the sample by phosphotungstic acid. The precipitate is slurried in ammonium hydroxide and transferred to a planchet for counting in a gas-flow proportional counter.

Savannah River

The Savannah River is sampled continuously by paddlewheel samplers equipped with 26-liter polyethylene collection containers. Samples are collected weekly.

Alpha- and beta-emitting radionuclides are measured by direct count of the residue remaining from evaporation of a one-liter sample aliquot on a planchet. The planchet is flamed to remove volatile material before being counted on a gas-flow proportional counter.

Gamma-emitting radionuclides are measured by passing approximately 20 liters of the sample through a cation-anion ion exchange column to concentrate radionuclides present and thereby achieve increased analytical sensitivity. The column is counted on an HPGe detector. Radionuclides are then eluted from the resin column with 3*N* nitric acid, followed by 14*N* nitric acid for subsequent analyses.

Plutonium-238,239 are determined from an aliquot of the eluate from the ion exchange column. The analytical procedure is the same as that used for air filters.

Strontium-90 is recovered from an aliquot of the column eluate, and the same procedure is used as that described for stream samples. Strontium-89,90 concentrations in the eluate are determined by the same procedure used for stream samples.

Tritium concentration is determined by liquid scintillation counting of a 3.75-mL aliquot of the distilled sample.

Seepage Basins

One-liter grab samples are generally collected quarterly from the seepage basins. Analytical procedures are the same as for other surface water samples.

Groundwater

Most groundwater wells are sampled quarterly. Samples are removed from each well either by pumping a minimum of four well volumes before collecting the sample, or by lowering a weighted one-liter bailer into the well to collect the sample. Each dip-sampled well is equipped with a stainless steel bailer that remains at the well to prevent cross-contamination. The normal sample volume collected for analysis is approximately two liters (or what can be sampled if the water in the well is less than two liters).

Each monitoring well has a gravel packing in the screen zone which is beneath a bentonite seal and cement grout to the surface. The grout discourages leakage of shallow groundwater into the well. The top of the well is either capped or sealed to prevent introducing atmospheric water into the sample.

The analytical techniques are the same as described for stream and river samples.

Milk

Fresh raw milk is collected from local dairies every two weeks and analyzed for iodine, cesium, and tritium. Once per quarter the samples are also analyzed for ^{90}Sr. Iodine-131 and ^{134,137}Cs concentrations are determined by direct count of a one-liter aliquot using an HPGe detector. Strontium and yttrium are scavenged from the milk by a cation exchange resin and put into solution in the chloride form. Using the same extraction described earlier for stream and river samples, ^{90}Sr is determined with a gas-flow proportional counter. To determine tritium oxide concentration, the milk is distilled to reduce quenching interferences and a 3.75-mL aliquot used for liquid scintillation counting.

Food

Local foods are obtained from farms located within a 25-mile radius of SRP. With the exception of grains, all foods are prepared as though for human consumption; i.e., peelings, seeds, and other inedible parts are removed. Wheat, containing the whole grains only, and oats, containing both grains and husks, are processed unwashed. After removal of a portion of the original sample for tritium analysis, the sample is dried and ashed. The residue is dissolved in a hydrochloric acid solution.

Gamma-emitting radionuclides are determined by direct count on an HPGe detector. Plutonium-238,239 are determined by the same procedure as described for other media. Strontium-90 analysis of the prepared solution is performed with the same procedure used for water. Tritium is measured in the free water obtained by freeze-drying a portion of the original sample. The water is counted in a liquid scintillation counter.

Drinking Water

Drinking water is collected at onplant sampling locations and in communities surrounding SRP to monitor alpha- and beta-emitting radionuclides and tritium. Some onplant samples are collected monthly, while others are collected quarterly. Offplant samples are collected semi-annually. Samples are collected from faucets or drinking fountains. All drinking water samples are analyzed annually for ^{90}Sr. Analytical procedures for drinking water are the same as those used for other water samples.

Wildlife

Fish are caught in traps or by hook and line. Whole fish are analyzed for gamma-emitting radionuclides on a 9 × 9-in. NaI well detector or on an HPGe detector.

Deer and hogs are monitored at the hunt site for ^{137}Cs using 2 × 2-in. NaI detectors. The detectors are calibrated so that ^{137}Cs concentrations in flesh may be derived from the field measurements. Accuracy of the calibrations is verified by laboratory analyses of approximately 5–10% of the deer. Laboratory samples are counted on an HPGe detector. Flesh samples are collected randomly from deer during each hunt and analyzed for ^{90}Sr and tritium by the same procedures described earlier for other media. Muscle tissue and thyroids are randomly collected from deer during each hunt and analyzed for ^{137}Cs and ^{131}I on either an HPGe or NaI detector.

Fish caught for analysis

Furbearing animals, including racoons, oppossums, foxes, and beavers, are trapped. All animals except beavers are counted whole for gamma-emitting radionuclides in a 9 × 9-in. NaI well detector or on an HPGe detector. Beavers are monitored in the field with a portable NaI detector.

Ducks are trapped and counted whole for gamma-emitting radionuclides on a 9 × 9-in. NaI well detector or on an HPGe detector.

Rainwater

Radioactivity deposited in rainwater is determined from continuous samples that are collected for analysis every month. Rainwater is collected in metal pans that are 2 ft square. At stations equipped with ion exchange columns, the water passes through the column and into a polyethylene jug. At stations not equipped with ion exchange columns, the water is simply collected in the pan and drained directly into the jug.

The ion exchange columns are counted directly for gamma-emitting radionuclides on an HPGe detector. The columns are then eluted for alpha, beta, plutonium, and strontium determinations and analyzed by the same procedures described earlier for other media. Tritium concentrations are determined by analysis of the rainwater collected in the jugs.

The amount of each radionuclide deposited at a station during the year is obtained by adding all values that are greater than the minimum detectable concentration.

Analytical results are not corrected for dry deposition that may have escaped from or been deposited in collection pans during periods of dry, windy weather. A study, utilizing "wet" and "dry" collection pans, was conducted to determine the effect of dry deposition on rainwater analysis results. The "wet" and "dry" collection pan system consisted of two pans that had a cycling cover. The cover moved over the "wet" pan during periods of dry weather and over the "dry" pan during periods of precipitation. The data confirmed that contribution or removal of material from the "wet" pan is extremely variable and unpredictable. Difficulties were encountered in comparing results because of differences in sampling periods, collection techniques, and analytical methods. No correlation was seen between the results obtained from the "wet" or "dry" pans and the routine rainfall collection pans. Given the qualitative nature of deposition and rainfall analyses, it was concluded that no correction factor should be applied to routine rainfall analysis data as a result of this study.

Soil and Sediment

At each sampling location, 10 soil cores, 8 cm deep, are taken in a straight line 30 cm apart. Soil cores are composited by location and analyzed for ^{90}Sr, $^{238,239}Pu$, and gamma-emitting radionuclides. Sediment collection techniques for streams and rivers are designed to obtain samples from the top 8 cm of sediment in areas where fine sediment has accumulated. Therefore, the samples are not representative of the entire stream bed.

Soil and sediment samples are dried, sieved, pulverized, and blended before analysis. For determination of gamma-emitting radionuclides, an aliquot of the pulverized soil is placed in a 500-mL plastic bottle and counted on an HPGe detector. Analysis of the soil and sediment for $^{238,239}Pu$ follows the same procedure as described earlier for other media.

For ^{90}Sr, a portion of the pulverized soil is leached with 1*N* ammonium acetate and the solution evaporated to dryness. The residue is dissolved in 0.08*N* hydrochloric acid and the sample analyzed by the same method used for water.

Vegetation

Vegetation samples are collected on-plant and within a 100-mile radius of SRP. They are taken quarterly at some locations, annually at others.

Core sampling

For gross determination of alpha- and beta-emitting radionuclides, a portion of dried and ashed vegetation is dissolved in nitric acid and transferred to a planchet for counting in a gas-flow proportional counter.

Gamma-emitting radionuclides are determined by counting dried vegetation in a standard geometry on an HPGe detector. Strontium-89,90 are determined using the same procedure as described for other media. Tritium is measured by liquid scintillation counting of water obtained by freeze-drying the sample.

NONRADIOLOGICAL PROCEDURES

Air

Four ambient air monitoring stations on the site house instruments to monitor for sulfur dioxide (SO_2), oxides of nitrogen (NO_x), ozone (O_3), and total suspended particulates (TSP). Instrumentation used is as follows: Four NO_x analyzers, two SO_2 analyzers, one O_3 analyzer, and five TSP samplers (one TSP sampler at each station and an additional co-located sampler). Sampling and analysis are performed in accordance with EPA requirements and SCDHEC guidelines.

NPDES Outfall Samples

Samples from SRP outfalls regulated by SCDHEC under the National Pollutant Discharge Elimination System (NPDES) are collected according to procedures consistent with EPA and SCDHEC methods.

All samples except those for fecal coliform analyses are analyzed by offsite laboratories. The fecal coliform analyses are performed by the onsite laboratory in D Area because these analyses must be started within six hours of sample collection. All laboratories analyzing NPDES samples are certified by the EPA or the appropriate state regulatory agency.

Streams and River

Laboratory analyses, except for fecal coliform, are performed in the SRP Environmental Monitoring laboratory. The fecal coliform analyses are performed in the D-Area laboratory. All sample collection, preservation and analyses procedures are in accordance with EPA approved methods. A sampling of the analytical methods used is shown in Table 10-1 shown on p. 108.

Plant streams and the Savannah River are sampled continuously by paddlewheel samplers for metals analysis. Weekly samples are collected, preserved according to EPA procedure, and composited monthly. Aliquots from the three months in each quarter are combined to create a quarterly composite, which is analyzed by atomic absorption spectroscopy.

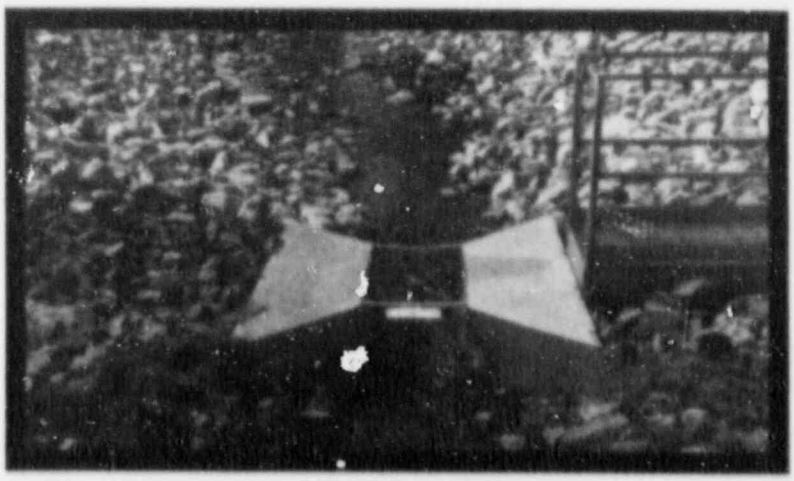
Because of short EPA recommended holding times and restrictive preservation requirements for parameters such as total dissolved solids and chloride, composited samples are not used for non-metals analyses. Grab samples are collected for non-metal parameters and analyzed according to EPA procedures.

Measurements for pH, dissolved oxygen, conductivity, turbidity, and temperature are made at the sampling locations.

Groundwater

Samples of groundwater are collected according to procedures that are consistent with EPA and SCDHEC methods. A pump installed in each well allows adequate purging before a sample is collected.

Generally, four times the volume of water standing in the well is purged to ensure that the sample is rep-



NPDES outfall

Table 10-1. Chemical Analyses and Methods for Stream and River Samples

Analysis	Method[a]
Non-Metals	
Alkalinity	EPA 310.1
Total Solids, Volatile Solids, Fixed Residue, Suspended Solids, Total Dissolved Solids	EPA 160
Chemical Oxygen Demand	EPA 410.2
Chloride	EPA 325.3
Nitrate-Nitrite-Nitrogen	EPA 253.2
Sulfate	EPA 375.4
Phosphate - Phosphorus	EPA 365.1
Ammonia - Nitrogen	EPA 350.1
Metals	
Aluminum	EPA 202.2
Cadmium	EPA 213.2
Calcium	EPA 215.1
Chromium	EPA 218.2
Copper	EPA 220.2
Iron	EPA 236.2
Lead	EPA 239.2
Magnesium	EPA 242.1
Manganese	EPA 243.2
Mercury	EPA 245.1
Nickel	EPA 249.2
Sodium	EPA 273.1
Zinc	EPA 289.2
Hardness	SM 314A

[a]Methods from *Methods for Chemical Analyses of Water and Wastes*, USEPA, EPA-600/4-79-020 (March 1979); and *Standard Methods for the Examination of Water and Wastewater*, 15th Edition, APHA/AWWA/WPCF.

resentative of the groundwater. EPA-recommended preservatives and sample handling procedures are used during sample collection.

Field measurements are made quarterly at each well for pH, temperature, conductivity, and water depth. A comprehensive chemical analysis is performed on every well every two years. At least once a year, samples are analyzed for suspected constituents (e.g., sulfate in wells near coal piles). The frequency of additional sampling for a constituent depends on concentration levels in the sample and on special requests to satisfy regulations. A computer program flags results that are above specific limits. Samples with flagged results are analyzed once or twice during the year for the constituents of concern. Occasionally, additional analysis requests are made. In response to a special request, analysis for priority pollutants at selected sanitary landfill wells was performed during 1987. Also during 1987, in anticipation of issuance of RCRA Part B permits for F- and H-Area Seepage Basins, Appendix IX analyses were performed on samples from F-Area Basin wells. Similar analyses on H-Area Basin wells are planned for 1988.

In 1987, Envirodyne Engineers, Inc., of St. Louis, MO, a certified offsite laboratory, performed all routine analyses using EPA-approved procedures. A representative list of analyses performed and methods used is shown in Table 10-2 on the facing page.

Drinking Water

Drinking water at SRP is supplied primarily by deep wells that draw water from the Black Creek-Middendorf Formations (formerly called the Tuscaloosa Aquifer). There are 27 drinking water systems at SRP.

The 16 large drinking water systems are routinely sampled by the SRP Power Technology Department and analyzed for pH, residual chlorine, and bacteria. The smaller systems (located at plant barricades) are not routinely analyzed for these parameters. All analyses are based on SCDHEC regulations, and the sample frequency is based on the number of people using the system. Barricade wells are exempt from routine analysis because they serve only a few people.

Three systems, in which polyphosphates are used to treat the water, are sampled and analyzed daily for PO_4 residuals. Turbidity is measured daily in drinking water from a surface water treatment plant located in D Area.

Annually, drinking water is analyzed for a comprehensive list of chemicals. Samples are taken from sample locations designated by SCDHEC.

Soil and Sediment

Sediment samples are collected annually at seven stream locations and two Savannah River locations. These samples were analyzed for 32 pesticides,

Table 10-2. Chemical Analyses and Methods for Groundwater Samples

Analysis	Method*
Conductivity	EPA 120.1
Arsenic and Selenium	EPA 270.3
Silver and Lead	EPA 200.0 (Auto Analyzer flameless)
Barium, Cadmium, Chromium, Copper, Iron, Lithium, Manganese, Sodium, Nickel, Lead, Uranium, and Zinc	EPA 200.7 (plasma torch)
Chloride	EPA 325.3
Cyanide	EPA 335.2
Fluoride	EPA 340.1
Mercury	EPA 245.1
Volatile Organics	EPA 624.0 (gas chromatograph Mass spectrophotometer) or EPA 601.0 (gas chromatograph)
Endrin, Lindane, Methoxychlor, and Toxaphene	EPA 608
Silvex and 2,4-D	EPA 615

* Methods from *Methods for Chemical Analysis of Water and Wastes*, USEPA, EPA-600/4-79-020 (March 1979) and *Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater*, USEPA, EPA-600/4-82-057 (July 1982).

herbicides, and polychlorinated biphenyls (PCBs) during 1987. This program, in conjunction with stream and river water sampling, has been conducted since 1976 to assess concentrations of these materials in SRP streams and in the Savannah River.

A one-liter grab sample was collected at each location. The samples were shipped to Envirodyne Engineers, Inc. (EEI), in St. Louis, MO. EEI analyzed the samples using EPA methods 608 and 615.

1987 HIGHLIGHTS

- The standard analysis geometry for liquid environmental samples having low activities has changed to a new geometry utilizing a "standard" one-liter polyethylene Marinelli beaker.
- Both SRP calcium fluoride dysprosium TLDs and Panasonic 801 TLDs, which contain calcium sulfate and lithium borate crystals, were used at sample locations during 1987 with a complete conversion to the Panasonic TLDs by the fourth quarter.
- In 1987, Envirodyne Engineers, Inc., a certified offsite laboratory, performed all routine groundwater and sediment analyses using U.S. EPA-approved procedures.
- Sediment samples, collected at seven stream locations and two Savannah River locations, were analyzed for 32 pesticides, herbicides, and polychlorinated biphenyls (PCBs) during 1987.

11
Data Analysis and Quality Assurance

SUMMARY — This chapter describes the lower limits of detection (LLDs) of radioactivity in samples gathered at SRP and reviews the 1987 quality assurance/quality control (QA/QC) programs for both the radiological and the nonradiological environmental monitoring programs. The QC program for radiological monitoring was performed internally and continued to focus on the calibration of the counting instruments, source and background counts, yield determinations of radiochemical procedures, and replicate analyses to check precision. In 1987 a "blind sample program" was added to verify the maintenance of procedural controls, and SRP successfully participated in two interlaboratory quality assurance programs conducted by the Environmental Protection Agency and the Department of Energy. In general, SRP's analyses agreed with EPA and DOE values within ±20%. The responsibility for the QC programs for nonradiological monitoring was shared by SRP and several outside contractors. The ambient air quality program was conducted by Zedek Corporation, which through quarterly audits and evaluations of the monitoring stations showed that SRP's gaseous analyzers and total suspended particulate samplers performed satisfactorily. The liquid effluents program was carried out by two contractors, Environmental Testing, Inc. (ETI) and Environmental and Chemical Services (ECS), each of which maintained internal quality control programs; in addition, ECS, the major contractor, successfully participated in an EPA-sponsored performance evaluation. The stream and river water quality control program included an internal review of the SRP Environmental Monitoring methods; it also included replicate sample analyses by ECS and Envirodyne Engineers, Inc. (EEI). The groundwater program consisted of intercomparisons of sample analyses performed by four contractors (EEI, ECS, Enwright Laboratories, and Weston Analytic) plus the establishment of a QA/QC program specifically for SRP samples by the primary contractor (EEI). Reviews of all these programs showed SRP to be in compliance with the various QA/QC requirements during 1987.

INTRODUCTION

The environmental monitoring program at SRP is one of the largest and most comprehensive in the United States. Extensive programs are conducted in both radioactive and nonradioactive monitoring. A total of 177,000 analyses (89,000 radiological and 88,000 nonradiological) were performed in 1987.

Each year, extensive radioactive monitoring is performed in a 2,000-square-mile area in the immediate vicinity of SRP and representative samples are collected from an additional 30,000-square-mile area. In this 30,000-square-mile area, many different types of samples are collected routinely and analyzed for radioactivity. The radioactive monitoring program generated approximately 23,800 samples and 89,000 analyses in 1987.

In addition to the extensive monitoring program for radioactivity, SRP conducted a large monitoring program for nonradioactive chemicals, metals, and physical properties in 1987. Samples analyzed for potential pollutants included those taken from SRP air, liquid effluents, surface water, and groundwater. The nonradioactive monitoring program generated approximately 88,000 analyses in 1987.

LOWER LIMITS OF DETECTION (LLDs) OF RADIOACTIVITY

In the analysis of samples gathered in the radioactive monitoring programs, the estimated *minimum detectable concentration* (MDC) for analyses refers to the amount of radioactivity that can be detected, at the 95% confidence level, by the radiochemical analytical technique in use. Within the context of

this report, the term *lower limit of detection* (LLD) is used interchangeably with the MDC. This statistic can be influenced by such factors as counter efficiency, procedure yield, length of count, instrument background, sample geometry, sample volume and density, radioactive decay during the interval between collection and analysis, and the number of radionuclides present in the sample.

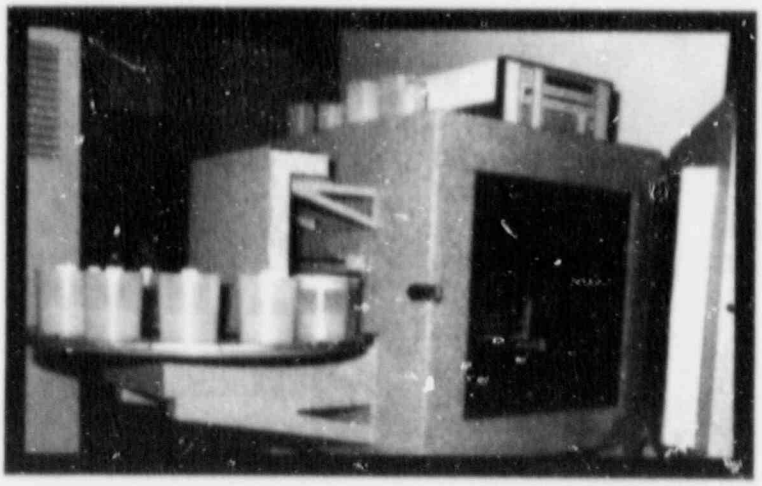
In 1986, SRP standardized the algorithm through which minimum sensitivities or LLDs for all of its nuclear counting systems are determined in order to conform with the industry-standard formula listed below [NCRP78, NUREG84, HPSR80]:

$$k^2 + 2\sqrt{2}ks = 2.71 + 4.65\ s,$$

where
k = 1.645 (95% confidence level),
s = standard deviation of the background.

The resulting values listed in the LLD tables (see Vol. II) contain corrections for sample aliquot, chemical yield, radioactive decay (where specified), and detector efficiency, although the uncertainty in these factors is not always propagated.

LLDs for gamma spectrum analyses of individual environmental samples, such as streams, foodstuffs, and groundwater, may vary significantly because of the geometry of the sample during counting. Specific geometries used are presented in Chapter 10, "Sample Collection and Analytical Procedures." LLDs for certain sample types are listed in Tables 11-1, 11-2, and 11-3, Vol. II. LLDs may also vary because of differences in performance characteristics among the three primary counting systems used: a 25% Reversed-Electrode ("n-type") closed-end coaxial HPGe (high-purity Ge) detector, a 30% standard ("p-type") closed-end coaxial detector, and a 35% standard ("p-type") closed-end coaxial detector. The LLD tables quoting values derived from Canberra Industries' APOGEE gamma spectrum analysis software are all based on counts obtained from the midrange "30% relative efficiency" detector. Both the individual efficiency and the resolution parameters for the specific detector influence the minimum sensitivity of the sample analysis. LLDs for HPGe systems using APOGEE software are shown in Table 11-4, Vol. II.



Gamma analysis using APOGEE software

Analyses of routine samples (other than milk and air charcoal cartridges, performed on the older detectors) using Canberra's SPECTRAN-F gamma spectrum analysis software are based on spectra acquired over a 3,000-second count interval as opposed to the otherwise standard 5,000-second count. This reduced counting interval elevates the LLD (i.e., degrades the sensitivity) associated with each analysis, and the SPECTRAN-F–derived LLDs are higher than the APOGEE-derived LLDs for equivalent geometries/analyses. LLDs for HPGe systems using SPECTRAN-F software are presented in Table 11-5, Vol. II.

It is important to distinguish the LLDs from the uncertainty or error statistics that accompany analysis results. The LLD is an *a priori* (before the fact) estimate of a system's minimum detection capability, based on knowledge of its physical performance characteristics and predetermined analysis parameters.

The uncertainty statistic (±) places an *a posteriori* (after the fact) confidence window around an actual measurement value, or a collection of values. Generally, the errors on the analytical results are lower than the LLD for a particular measurement.

Many of the concentrations of radioactive materials in ambient environmental samples approach zero and should statistically show a distribution around zero. When an instrument background is subtracted from an environmental measurement, it is possible to obtain net values less than the MDC or LLD. It is also possible to obtain zero and negative values (values less than zero). Note that gamma spectrometry analytical results are usually not reported as

activity concentration values, but as "less than" values representing the 95% confidence level LLD.

Analytical results less than the LLD or MDC should not necessarily be interpreted as non-detectable. Values greater than one-half the LLD can be interpreted as probably indicating a positive analyte presence. In many cases, values less than one-half the LLD, less than the accompanying error (±) statistic, or even less than zero (negative) are reported (except for gamma spectrometry results). This practice is useful in evaluating a series of data and provides a better estimate of the mean by averaging negative values with the zero and positive values. This approach allows all data to be reported and is useful in identifying trends and biases and in refining concentration boundary values. It may also result in improved analysis sensitivity.

In some tables the standard deviation is not calculated because of the small number of sample results (designated "insufficient data"). When "plus-or-minus" accompanies an individual result, such as the maximum (MAX) or minimum (MIN), it represents the statistical counting uncertainty or 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 concentrations found in a single sample collected during the year.

The average of all values obtained for a specific location or analysis also is usually accompanied by a plus-or-minus (±) value, designated as the standard deviation of the average at the 95% confidence level. It serves as an indicator of the deviation of concentrations encountered at that location. When the average is given for groups of locations, the plus-or-minus value is the measure of the range of concentrations found at all locations.

LLD values quoted for gross alpha and nonvolatile beta results generally do not include correction for self-absorption. Other analyses, such as those for chemical cesium and ^{90}Sr, do include self-absorption factors within their derived procedural recovery factors.

QUALITY CONTROL OF RADIOLOGICAL MONITORING PROGRAMS

An internal quality control (QC) program for the radiological monitoring programs is maintained by the routine checks listed at the top of the right hand column:

- calibration of counting instruments
- source and background counts for all counting systems
- yield determinations of radiochemical procedures
- replicate analyses to check precision

The accuracy of the radioactivity measurements is established by use of standards traceable to the National Bureau of Standards (NBS). Histories of the performance of the counting instruments are maintained in logbooks and computer files.

The SRP Environmental Monitoring Laboratory began a "blind sample" program in 1987. After an initial evaluation period, the blind sample program was incorporated as a formal part of the QC effort. Blind samples consist of water or air filters containing known radionuclide activity levels that correspond to typical levels found in routinely analyzed samples. Whenever possible, the blind samples are prepared from NBS-traceable material or standardized against NBS material. The data are used to verify that procedural controls are maintained by the laboratory.

In addition to the internal quality control program, SRP participated in two interlaboratory quality assurance programs during 1987. One program is conducted by the Quality Assurance Division (QAD) of the Environmental Protection Agency. The second is the Quality Assessment Program (QAP) conducted by the Department of Energy Environmental Measurements Laboratory (EML). Under both programs, a variety of samples are sent to the participating laboratories at intervals throughout the year. Sample results and SRP's performance in the QAD and QAP programs are presented in Tables 11-6 and 11-7, Vol II.

The ±20% indicator shown in the tables is a convenient measure of overall relative performance but cannot be used as a sole determinant for accuracy and/or precision. SRP's participation in the interlaboratory comparison programs is based on the assumptions that the QAD and QAP samples are similar in activity level to routinely analyzed samples and that they are analyzed for radionuclides included in the routine program. Where the true value of the comparison sample approaches the MDC (minimum detectable concentration) for the analysis, the associated statistical uncertainty of the measurement at the 95% confidence level will probably exceed the ±20% range. In such cases, the

routine analytical process is not designed to quantify the presence of those particular radionuclides at the specified activity levels. A more precise determination of laboratory performance is adherence to established control limits for the analysis.

The SRP results were generally within ±20% of the EPA or DOE values. Results that fell outside of the ±20% range were investigated, and corrective action was taken if needed.

QUALITY CONTROL OF NONRADIOLOGICAL MONITORING PROGRAMS

Ambient Air Quality

The ambient air quality monitoring program is conducted by Zedek Corporation, under contract to Du Pont. Quarterly QA audits are performed at the four SRP ambient air quality monitoring stations to verify instrument calibration, accuracy, and performance. The stations are equipped with a total of 11 gaseous analyzers to monitor for sulfur dioxide, oxides of nitrogen, and ozone and five samplers to monitor for total suspended particulates. In addition to the quarterly audits, daily zero and span checks are performed on each analyzer.

Results of the quarterly audits are evaluated by two methods: (1) by a comparison of audit values and instrument measurements at each audit point; and (2) by a linear regression analysis. The linear regression analysis uses paired points (audit concentration and analyzer response) to generate the best straight line that represents the sets of paired points. The difference determined by the slope of the linear regression line and the bias determined by the intercept of the line are used to determine the status of data quality and analyzer calibration.

The following difference criteria are used for data evaluation and corrective action for the gaseous analyzers:

Difference	Conclusion	Action
0–15%	satisfactory data	—
15–25%	satisfactory data	recalibrate analyzer
>25%	unsatisfactory data	recalibrate analyzer

Calibration of each of the analyzers is checked quarterly using the appropriate calibration gas. Of the 36 tests conducted in 1987, 34 showed differences less than 15% and two showed differences that were in the 15 to 25% range. All gaseous analyzers were therefore producing satisfactory data throughout the year.

The audit criterion for satisfactory calibration of the total suspended particulate samplers is a difference of 0–7%. All of the samplers, including one co-located control sampler, are audited on a quarterly basis. Of the 22 tests conducted in 1987, 19 showed a difference of less than 7%. The three samplers that showed a difference greater than 7% were adjusted and recalibrated.

Individual results of the Zedek Corporation quarterly audits are presented in Table 11-8, Vol. II.

Liquid Effluents

SRP liquid effluent samples are collected at the outfalls according to the National Pollutant Discharge Elimination System (NPDES) sampling schedule approved by the South Carolina Department of Health and Environmental Control (SCDHEC). The effluent samples are collected by SRP personnel for onsite analyses for fecal coliform and biochemical oxygen demand and offsite analyses for other constituents. The primary offsite contractors for this program in 1987 were Environmental Testing, Inc. (ETI), Charlotte, NC (Jan - Feb 1987), and Environmental and Chemical Services (ECS), New Ellenton, SC (Mar - Dec 1987).

ETI and ECS Programs. Both ETI and ECS maintain specific analytical quality assurance programs to ensure reliability of their analytical data. The established programs, based on their QA manuals, cover the following topics:

- laboratory administrative control
- personnel qualifications
- personnel training
- procedural compliance
- sample acquisition and custody documentation
- laboratory specification
- instrument specifications, calibrations and maintenance
- analytical quality assurance

ETI and ECS use their QA manuals in conjunction with *Methods for the Chemical Analysis of Water and Wastes,* EPA-600/4-79-020, and *Standard Methods for the Examination of Water and Wastewater,* 15th edition, American Public Health Association (APHA), 1980, to assure the quality of the analytical data.

ETI's quality assurance program includes the following specific items:

- standard curves prepared and verified daily;
- precision of each analysis determined daily using quality control charts;
- precision data reviewed and approved by the laboratory director;
- precision data outside of control limits reviewed and signed by QA coordinator;
- bias determined for at least 10% of the samples analyzed and plotted on control charts;
- bias data reviewed by the laboratory director;
- bias data outside of control limits reviewed and signed by QA coordinator.

ECS's quality assurance and control procedures, described in their QA manual, include regularly scheduled performance checks and calibrations to ensure the reliability of measurements and the following instrumentation checks:

- balances – daily performance checks using known weights;
- pH meters – daily intercalibrations by obtaining a second reading on pH 7 buffer after adjusting the slope with a different buffer;
- UV/visible spectrophotometers – daily preprogrammed performance checks; tolerance for all wavelength checks is ±1.0 nm;
- conductivity meters – monthly standard check; measured conductivity of the standards should be within ±5%.

In addition to instrument tests, analytical performance checks are made in which 10% of all samples in a batch are replicated and precision of the analysis is determined. Spikes (samples to which known concentrations of the standard solution are added) represent another 10% of each batch of samples. The accuracy of the analysis is determined from the spike results. Laboratory blanks (deionized water) are analyzed with each batch of samples.

Known standards from the EPA or another reliable source are analyzed quarterly for each routine parameter. Data verification procedures require that 20% of all calculated analytical values must be recalculated by another analyst or supervisor. If any calculations are in error, the entire set must then be recalculated.

Performance Audits. In 1987, ECS participated in an EPA-sponsored performance evaluation program in which EPA provided samples spiked with known concentrations of the constituents of interest to SRP as part of SRP's NPDES quality assurance program. The samples were forwarded to ECS for analysis of trace metals (aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel and zinc), nutrients (nitrate-nitrogen and total phosphorus), biochemical oxygen demand, and miscellaneous constituents such as pH, oil and grease, and total suspended solids.

All analytical results produced by ECS were within the EPA acceptable limits except for copper and manganese, which were 4% and 2% above the upper acceptance limit, respectively. Operator notes from the day the samples were analyzed indicate that the reproducibility of results from the atomic absorption spectrophotometer may not have been optimal. A summary of the EPA performance evaluation report is presented in Table 11-9, Vol. II.

Compliance Audits and Sampling. In 1987, SCDHEC performed eight NPDES compliance audits at SRP during seven monthly visits and one comprehensive annual survey (in October). SCDHEC collected two series of samples from the 68 active NPDES sampling stations and SRP collected duplicate samples from each series for comparison.

In addition to collecting samples for the NPDES-permit constituents, SCDHEC also collected samples at each location for dissolved oxygen and chlorine analyses during the annual audit. Of the 11 permit categories audited during October, SRP received a satisfactory rating in 10. One permit category—effluent receiving water— was rated as unsatisfactory because two results out of 400 parameters analyzed were outside of permit limits During 1987, SRP achieved an overall NPDES com-

pliance rating of 99.7% (6,432 analyses within permit limits out of 6,450 parameters analyzed).

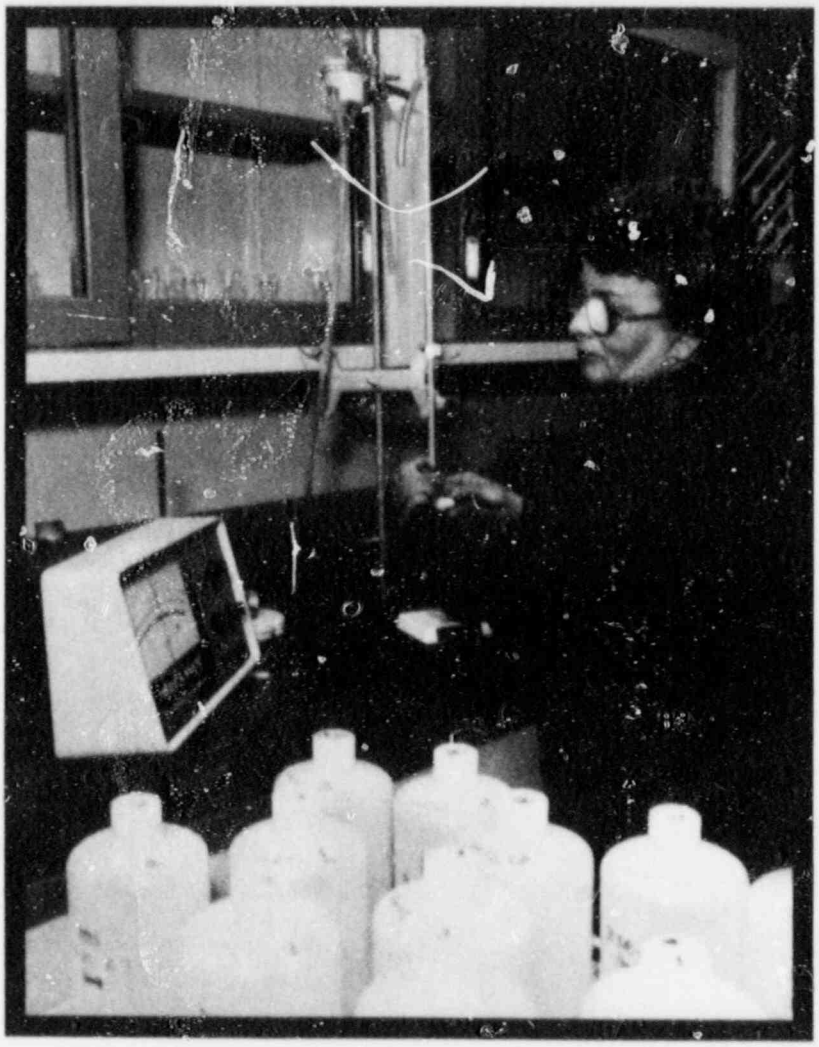
Stream and River Water Quality

Most stream and river water quality analyses are performed by the SRP Environmental Monitoring Laboratory based on accepted methodology detailed in the EPA's *Methods for the Chemical Analysis of Water and Wastes* (EPA-600-4-79-020) and *Handbook for Analytical Quality Control in Water and Wastewater Laboratories* (EPA-600-4-79-019), and in the APHA's *Standard Methods for the Examination of Water and Wastewater*. Measures taken as part of the quality control program are as follows:

- EPA-approved analytical methods are used;
- "spiked" samples with known analyte concentrations are analyzed with every run to determine accuracy;
- 10% replicate analyses are performed to determine precision;
- titrating solutions are routinely standardized;
- sample chain-of-custody is maintained;
- data are verified before an analytical report is issued.

The quality control measures vary depending on the type analysis. Specific QC procedures to ensure accurate results have been established for each analysis.

As part of the quality assurance program, an annual review verifying conformance of laboratory operating procedures to approved EPA or standard methods procedures is performed and formally documented. Also, NBS-traceable standard solutions are used whenever available to add to samples in known quantities to provide procedure yield determinations which are plotted on operational control limit charts. Control chart acceptance limits are well defined to provide an immediate evaluation of the accuracy and precision of each analytical method.



Stream and river water analysis

Operating procedures define the frequency of replicates and spikes and of reagent standardization determinations. The procedures also provide instruction for using work sheets to record method calibration and instrument settings.

The chain-of-custody form lists the preservatives to be used at the time of collection, methods of collection and transport, the person collecting the sample, the time and date of collection, and which analyses are required. When the samples are transferred to another person, verification signatures are required by both the persons submitting and receiving the sample. When the analysis is completed and the sample is discarded, the verification signature of the analyst is required.

Data verification is documented by authorized signatures on the operational work sheets. All calibra-

tion information is verified, and control charts are reviewed to determine that the methods are within control limits. Each calculation determining sample concentration is checked and approved. Data transfer to the final report is verified by signature approval.

During the first two quarters of 1987, metals analyses of water quality samples were performed on replicate samples by certified offsite laboratories, Environmental and Chemical Services (ECS) and Envirodyne Engineers, Inc. (EEI). These interlaboratory comparison data are presented in Table 11-10, Vol. II. Average concentrations from 1986 serve as appropriate reference values and are also shown in the table. The ECS and EEI results agree and compare favorably with the 1986 values.

Groundwater

Sampling and analyses of groundwater are performed by contractors. Sampling, the addition of preservatives, and chain-of-custody procedures are consistent with EPA-recommended procedures. Samples are analyzed within recommended holding time intervals.

During 1987, three quality control procedures continued to enhance the quality of the analyses. These quality control procedures are listed below:

- The primary laboratory, Envirodyne Engineers Inc. (EEI), analyzed 10% of the samples in duplicate.
- Replicates of 3% of the samples were submitted to a second laboratory, Environmental and Chemical Services (ECS), for comparative analyses during the first three quarters. In the fourth quarter, 5% of the samples were submitted to Enwright Laboratories, Greenville, SC, and Weston Analytic, Lionville, PA, for comparative analyses.
- Blind samples representing 2% of the total number of samples were sent to the two laboratories for comparative analyses.

EEI Program. To ensure the reliability of its analytical data, EEI has established a QA/QC program specifically for SRP samples [ENV]. This established program is based on *Handbook for Analytical Quality Control*, which covers the topics listed at the top of the right column.

- approach to analytical quality control in the Envirodyne laboratory;
- data handling and reporting;
- experimental design for preliminary estimate of precision and bias;
- calibration and quality control procedures for the following instruments: atomic absorption spectrophotometers, UV/visible spectrophotometers, Technicon auto analyzers, gas chromatographs, and gas chromatograph/mass spectrometers;
- preparation of reference standard solutions for gas chromatography;
- chain-of-custody procedures;
- approved EPA test procedures.

The normal QA/QC program consists of the following established methods:

- applying recommended preservation techniques and holding times;
- analyzing samples within the prescribed daily calibration of instrumentation and adhering to scheduled maintenance procedures for instruments and equipment;
- training personnel in use of equipment and methods;
- data validation.

Each lot of samples includes analysis of a blank, a duplicate sample, and a spiked method blank or check standard (an aliquot of deionized water fortified with known concentrations of the material of interest).

Typically, a lot consists of 10 or fewer samples. The results of the spiked method blank are recorded on a quality control chart and compared by EEI. Blanks and duplicates are also recorded for each lot. If the results of any one of these analyses are considered to be out of control limits, the cause of the problem is investigated and corrected and the entire sample lot is reanalyzed.

In addition to the daily quality control, EEI periodically participates in interlaboratory programs sponsored by the EPA. These involve analyzing unknown performance evaluation samples, known EPA performance standards, and laboratory check standards.

A summary of the quality control procedure used for each measurement is given in the table at the bottom of the page.

Performance Audits. EEI's QA/QC program was audited by SRP in 1987. This quality assurance audit was divided into seven areas of investigation listed below.

- personnel
- QA/QC manual
- facility inspection
- sample handling
- instrumentation
- chemical procedures
- data validation and reporting

The general audit results were favorable. Recommendations made by the audit report were implemented by EEI during 1987.

INTERNAL REVIEW OF SRP QA/QC PROGRAMS

During 1987, the SRP Environmental Monitoring Quality Assurance/Quality Control Program was internally reviewed. Both radiological and nonradiological programs were evaluated. The review was conducted as part of a continuing effort to enhance the QA/QC program. Areas reviewed included the following:

- sampling techniques
- instrument calibration
- radioanalytical procedures
- counting methods
- error limits
- data reporting
- documentation of QA/QC activities

Recommendations for improving the program included the following:

- employment of a full-time QA/QC coordinator (a full-time coordinator has been hired in 1988);
- development of a comprehensive quality assurance manual;
- establishment of a complete calibration plan for all equipment and standards;
- use of chain-of-custody for all samples (will be done in 1988).

Measurement	Typical Procedure
Cyanide	Blank, check standard to verify previously established calibration curve, duplicate sample.
Sulfate	Seven-point calibration curve, blanks between samples, check standard every 10 samples, one duplicate/10 samples.
Total Organic Carbon	Four point calibration curve, blank, duplicate, check standard.
Fluoride	Blank, check standard to verify previously established curve, duplicate sample.
Phenol	Five-point calibration curve, blanks between samples, check standard and duplicate for each 10 samples.
Surfactants	Six-point calibration curve, blank, duplicate/10 samples.
Sulfide	Standardize titrant, blank.
Metals	Five-point calibration curve, two check standards, two blanks, duplicate/10 samples.
Pesticides	Blank, calibration standard to verify curve, duplicate, check standard
Herbicides	Blank, calibration standard to verify curve, duplicate, check standard.
GCscan	Blank, calibration standard to verify curve, duplicate, check standard.

The radiochemist who reviewed the program provided technical assistance in implementing several improvements. Regular calibration of all instruments was identified as the most important area needing improvement, and a systematic, documented calibration program was established for several key instruments. Instrument history books were established for several instruments, including nuclear counting systems, analytical balances, conductivity and turbidity meters, ion chromatographs, drying ovens, and atomic absorption spectrophotometers. The history books contain the following:

- equipment and instrument calibration forms
- quality control check forms
- control charts
- equipment nonconformance notice forms.

1987 HIGHLIGHTS

- SRP uses a standardized algorithm to determine the lower limits of detection (LLDs) for all its nuclear counting systems and adjusts the values for various factors, including sample geometry, detector efficiencies, and radioactive decay.
- LLD values for various radionuclides are given (in Vol. II) for SRP's HPGe gamma-ray spectrometer systems as derived from two different spectrum analysis software systems.
- Results of the EPA and DOE interlaboratory programs verify SRP's analytical accuracy.
- The 1987 results of the ambient air quality program, conducted by Zedek Corporation, showed that SRP's gaseous analyzers and total suspended particulate samplers were performing satisfactorily.
- NPDES compliance audits by the South Carolina Department of Health and Environmental Control resulted in a 99.7% compliance rating for the SRP liquid effluent program.
- Metals analyses performed by outside contractors ECS and EEI on replicate samples from SRP streams and the Savannah River were in agreement and compared favorably with SRP's 1986 values.
- An SRP audit of the groundwater QA/QC program established by the primary contractor, EEI, yielded favorable results.
- A full-time QA/QC coordinator has been hired as a result of a 1987 internal review of all of SRP's QA/QC programs for environmental monitoring. Other recommendations for further improvements are being implemented.

12
Environmental Management and Research Programs

SUMMARY — This chapter describes various SRP and SRL environmental management and research programs, including Savannah River Ecology Laboratory programs and Savannah River Forest Station programs. (1) The comprehensive SRP Environmental Implementation Plan was completed and will be presented to Congress in 1988, and SRP initiated and/or participated in a number of activities to ensure compliance with regulations mandated by the Environmental Protection Agency, the South Carolina Department of Health and Environmental Control, and the Department of Energy, particularly as embodied in SARA Title III, and the RCRA Part B permit. Environmental impact statements were issued on groundwater protection and alternative cooling water systems. (2) SRL management and research programs included a number of studies to follow the dispersion and effect of SRP pollutants in the environment, to develop and implement procedures to comply with regulations and to conduct pollution abatement activities, and to meet permit or environmental impact statement requirements. (3) Savannah River Ecology Laboratory programs included biogeochemical ecology studies, stress and wildlife ecology studies, and wetlands ecology research. (4) U.S. Forest Service Savannah River Forest Station programs included a forest management program and several forest research programs, plus studies of endangered species.

This chapter describes the environmental management and research programs of the Savannah River Plant, the Savannah River Laboratory, the Savannah River Ecology Laboratory, and the Savannah River Forest Station of the U.S. Forest Service.

SAVANNAH RIVER PLANT ENVIRONMENTAL MANAGEMENT PROGRAMS

Environmental Implementation Plan

SRP has developed a comprehensive Environmental Implementation Plan (EIP) that has set specific environmental goals for the site for the next five to 10 years and will provide an integrated approach to SRP environmental programs. The plan, which the Department of Energy (DOE) will present to Congress in early 1988, outlines specific programs to maintain air quality, to prevent surface water and groundwater contamination, and to protect wildlife. It also establishes the associated manpower and budget requirements.

Environmental Audits and Appraisals

SRP environmental programs are reviewed annually by the Environmental Protection Agency (EPA) and the South Carolina Department of Health and Environmental Control (SCDHEC) by compliance audits. The Department of Energy and Du Pont also conduct internal environmental appraisals and audits.

From the third quarter of 1986 into 1987, EPA, assisted by SCDHEC, conducted the largest SRP environmental audit. The audit, known as a multimedia audit, required 17 EPA and eight SCDHEC representatives and encompassed seven areas: hazardous waste (as defined by the Resource Conservation and Recovery Act [RCRA]), solid waste management units (SWMUs), wastewater (as covered by the National Pollutant Discharge Elimination System [NPDES]), drinking water, groundwater, toxic substances, and air quality. The audit identified no major problems and 98 administrative findings, which were immediately corrected. During its

followup audit May 20-29, 1987, EPA noted the initiatives taken by SRP to correct the administrative items and complimented SRP for a much improved environmental performance.

In January 1987, the Department of Energy Headquarters (HQ) conducted a comprehensive environmental survey at SRP, fulfilling its commitment to Congress to perform a baseline environmental survey of all DOE facilities. The three-week DOE-HQ survey surpassed the scope of the EPA multimedia audit and required over six man-years of SRP effort.

Responses to Superfund Amendments and Reauthorization Act, Title III

In 1986, Congress passed the Superfund Amendments and Reauthorization Act (SARA), which included a Community Right-to-Know section (Title III). This title requires SRP to make public a substantial amount of information on the safety, use, and locations of chemicals used on the plant. In addition, SRP must participate with local emergency planning commissions (LEPCs) in preparing plans to handle emergencies involving hazardous chemicals.

In September 1987, SRP sponsored a Title III Workshop attended by over 100 people, including members of the Central Savannah River Area LEPCs, local industry, law enforcement agencies, news media, and state planning committees. In October 1987, SRP provided the Aiken, Allendale, and Barnwell county LEPCs a detailed list of approximately 8,000 Material Safety Data Sheets (MSDSs) for chemicals and chemical products used at SRP.

Operations Under Hazardous Waste RCRA Part B Permit

On September 30, 1987, SCDHEC issued to SRP a RCRA Part B Permit for operation of the Hazardous Waste Storage Facilities (Buildings 709-G, 709-2G, 709-4G, and 710-U) and post-closure maintenance of the M-Area Settling Basin and vicinity (overflow ditch, seep area, and Lost Lake). The permit expires on September 30, 1992. The EPA issued the federal portion of the permit covering the requirements of 3004 (u) and 3005 (h) of the 1984 RCRA Amendments. This portion of the permit identifies 65 solid waste management units at SRP that will require a RCRA Facility Investigation (RFI). The EPA portion of the permit became effective on November 1, 1987, and expires on November 1, 1992.

RCRA Facility Investigation. For coordination and oversight of the EPA portion of the SRP Part B Permit, the SRP Environment and Energy Department formed a task team to develop an overall RFI program plan, which is to be followed by waste-site-specific RFI plans, investigations, and reports. The RFI program plan is scheduled to be submitted to SCDHEC on or before April 1, 1988. Following SCDHEC review and approval, the waste-site-specific RFI plans will be developed and submitted according to a set schedule, on or before October 1, 1989. The waste-site–specific investigations and RFI reports will follow similar schedules. The closure actions and schedules will be determined by the RFI reports. The cost of this effort (excluding closures) is expected to be over $4 million.

Addition of Radioactive Waste Facilities. On May 1, 1987, DOE issued a final interpretive rule for the "by-product material" as defined in the Atomic Energy Act of 1954, as amended. Under this final rule, radioactive wastes that are also RCRA hazardous wastes are to be jointly regulated by DOE and EPA, with DOE continuing oversight for the radioactive component of the waste and EPA assuming regulatory authority over the hazardous component. As a result of this final rulemaking, SRP filed protective revisions to its RCRA permit application. Facilities added to the application include the High Level Radioactive Waste Tanks, the Defense Waste Processing Facility (DWPF), the Savannah River Laboratory (SRL) Waste Tanks, and the Transuranic (TRU) Storage Pads. EPA was requested to provide a ruling as to whether the waste tanks and DWPF could be permitted as wastewater treatment units.

Environmental Awareness/Training Programs

In 1987, an Environmental Awareness/Training Coordinator was designated by the SRP E & E Department with responsibilities for implementing a program to communicate site environmental goals and enhance employee commitment to protecting the environment. Employee training is a line management responsibility, and E & E assists line management with environmental training to satisfy regulatory requirements. Three specialized courses, "Environmental Auditing," "Clean Water Act Overview," and "Fundamentals of RCRA," were offered

onsite by E & E. These awareness and training programs will provide employees with the appropriate mixture of environmental awareness and job-specific environmental training.

Preparation of NEPA Documentation for SRP/SRL Activities

The National Environmental Policy Act (NEPA) of 1969, the Council on Environmental Quality implementing regulations (40 CFR 1500–1508), and DOE guidelines (52 FR 47662) require the early consideration of environmental factors during the planning and assessment process for all proposed federal actions. The NEPA Group of the E & E Department is responsible for preparation and/or coordination of all appropriate NEPA documentation for SRP/SRL activities. It manages the transmittal of NEPA document recommendations and information to the DOE-Savannah River (DOE-SR), with approval of the SRP/SRL management required for all formal transmissions. In order to ensure their technical accuracy, SRL staff reviews many of the NEPA documents prepared for DOE. Determination of the appropriate level of documentation is the responsibility of DOE.

In 1987, the NEPA group processed 289 SRP/SRL activities. The NEPA and Permits Groups reviewed the SRP/SRL NEPA, safety analysis, and permits checklists for these activities to determine the appropriate level of NEPA documentation and for permitting requirements. Du Pont issued one Memorandum-to-File (MTF) for a Test Authorization and DOE-SR issued 10 MTFs for projects based on draft MTFs prepared by Du Pont personnel.

During 1987, DOE-HQ continued to edit, with NEPA personnel assistance, the final Environmental Assessment (EA), *Management Activities for Retrieved and Newly Generated Transuranic Waste—SRP* (DOE/EA-0315), which will be issued early in 1988.

Preparation of Environmental Impact Statements

During 1987, the following two Environmental Impact Statements (EISs) were issued:

Waste Management Activities for the Protection of Groundwater at the Savannah River Plant, DOE/EIS-0120, December 1987. (The Record of Decision was issued in March 1988.)

Alternative Cooling Water Systems, SRP, DOE/EIS-0121, October 1987. (The Record of Decision was delayed until early 1988 pending a decision on an EPA and SCDHEC recommendation to install a recirculating cooling tower for K Area. The Record of Decision was issued on February 12, 1988, and recommended installation of the tower.)

SRL ENVIRONMENTAL MANAGEMENT AND RESEARCH PROGRAMS

Special Studies for Determining the Dispersion and Effect of SRP Pollutants

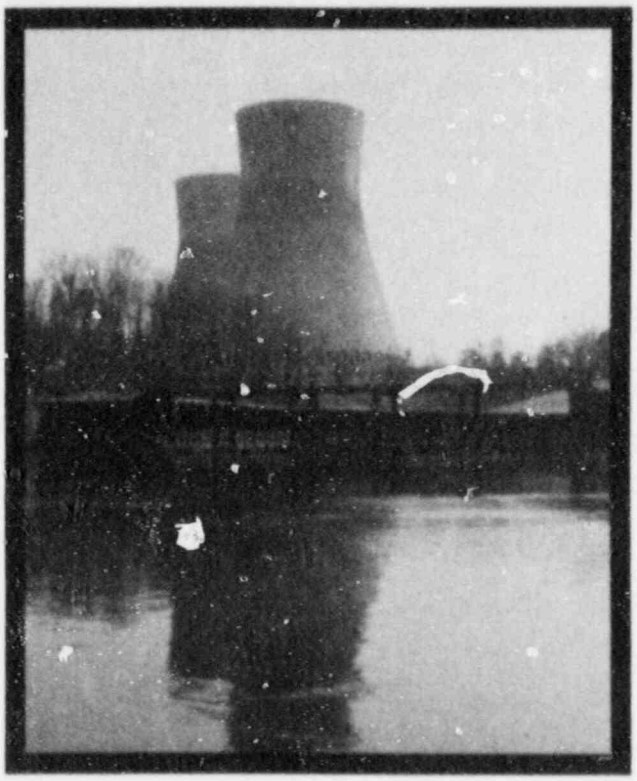
Development of Mass Spectrometry Methods. Development of high sensitivity isotope dilution mass spectrometric (IDMS) methods for measuring plutonium (Pu) in body fluids is in progress. IDMS bioassay methods are greater than 1000 times more sensitive than ultra-low–level counting techniques and will permit assessment of the average Pu body burden in the population caused by global fallout. These levels are too low to be measured easily by conventional counting techniques. Development of IDMS methods for measuring ^{99}Tc and ^{237}Np in the environment is also in progress.

In addition, a mass spectrometer is being designed to measure the nonradioactive fission-product isotopes of Kr and Xe at ultra low levels in the environment. Direct measurement of these isotopes will permit more accurate assessment of environmental releases of the short-lived radioactive Xe and Kr isotopes.

In a third study, the ^{3}He/^{4}He mass spectrometer is being used to confirm very low concentrations of environmental tritium. Samples are collected directly or by removing moisture from air streams and adsorbents followed by recovery of the water in the laboratory. Trapped ^{3}He is removed by degassing under vacuum, and the sample is then sealed and stored to allow ^{3}He to accumulate from the decay of tritium. After a suitable accumulation period, the ^{3}He is removed and measured in the mass spectrometer.

The ^{3}He/^{4}He mass spectrometer is also being used to measure the consistency of atmospheric ^{3}He/^{4}He ratios directly in small volumes of air. The resulting baseline will be useful in studying very low concentrations of atmospheric tritium.

Improvement of Aqueous Effluent Tritium Monitors. An evaluation of effluent tritium monitors showed that proposed improvements would allow prompt detection of tritium releases of 1 Ci/hr from 400-D Area. The proposed monitor uses a flow-through design and a solid scintillant. A prototype monitor is to be built and tested in 1988.



Vogtle 1 cooling towers

Environmental Surveys in the Vicinity of Vogtle 1 Nuclear Power Plant. Environmental radionuclide concentration data were collected by SRP personnel in the vicinity of Vogtle 1 Nuclear Power Plant (near Waynesboro, GA) over a four-month period prior to its startup operation in the spring of 1987. Soil, stream, and sediment samples were examined for ^{3}H, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{238}Pu, and ^{239}Pu. Background natural radioactivities were also examined as a consistency check. The samples were analyzed using low-level counting capabilities of the TRAC van (Tracking Radioactive Atmospheric Contaminants), the Ultra-Low-Level Counting Facility, and the Underground Counting Facility. All results were consistent with typical earlier measurements in comparable areas.

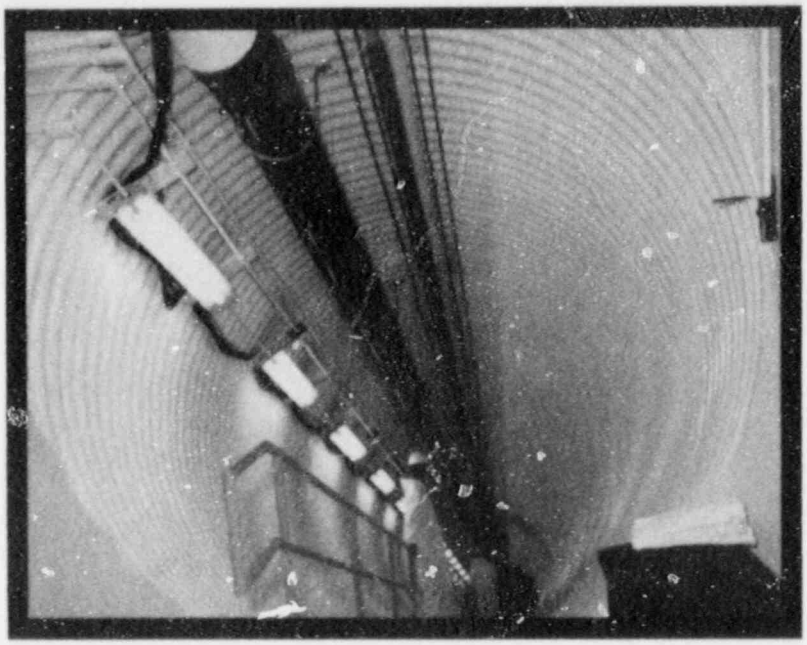
In the Vogtle vicinity, ^{137}Cs was the only manmade radionuclide readily detected. Average concentrations of 0.5 pCi/g were found in soils, 0.012 pCi/L in the Savannah River, and 0.015 pCi/g in the river sediment. Other radionuclides were lower by an order of magnitude or more, except for ^{3}H. Tritium concentrations were determined with less sensitivity and were less than 2 pCi/mL in the river. All levels were below 1/1000 of the DOE guides for drinking water.

In post-operational surveys, controlled releases by Vogtle 1 were detected in the Savannah River near the plant and farther downstream. During a May 1987 release, a maximum ^{58}Co concentration of 1.34 pCi/L was observed in samples taken about 0.1 mile below the outfall. The only other release occurred in October/November 1987, when a maximum ^{58}Co concentration of 13.2 pCi/L was observed at the same sample location. At downstream locations, these activities decrease by dispersion to approximately 10% of the maximum at Highway 301 bridge and approximately 1% at Beaufort-Jasper. In addition to ^{58}Co, minor amounts of ^{51}Cr, ^{54}Mn, ^{59}Fe, ^{60}Co, ^{95}Nb, and ^{95}Zr were observed. All observed levels were below 1/1000 of the DOE guides for drinking water.

The SRL measurements have been compared with those made by Vogtle staff. The SRL time-dependent activity profiles agree well with the Vogtle release data. SRL measurements 0.1 mile below the outfall are about 1/5 as large as Vogtle measurements at the discharge site. This fraction is reasonable in view of dispersion by the river. The mutual sharing of SRL/Vogtle data related to discharges will continue, as these studies have already illustrated a sensitive capability for detecting potential release problems well before they develop into hazards. The ^{58}Co was detected down to 1/1,000,000 of the DOE guide levels.

Studies of ^{14}C Stack Emissions. Stack emissions from P-Reactor were sampled for ^{14}C during the site-wide environmental survey conducted in the fall of 1987. During 1988, ^{14}C samplers will be installed in all reactor stacks and also in the H-Area Separations stack. Operation of the existing sampler in the F-Area Separations stack will continue.

Studies of ^{129}I Releases. Measurements of ^{129}I in surface waters and groundwater on the plant site since 1970 were compiled into a comprehensive report. Monitoring of the separation stack emissions was continued. Reactor stack emissions will also be monitored in 1988.



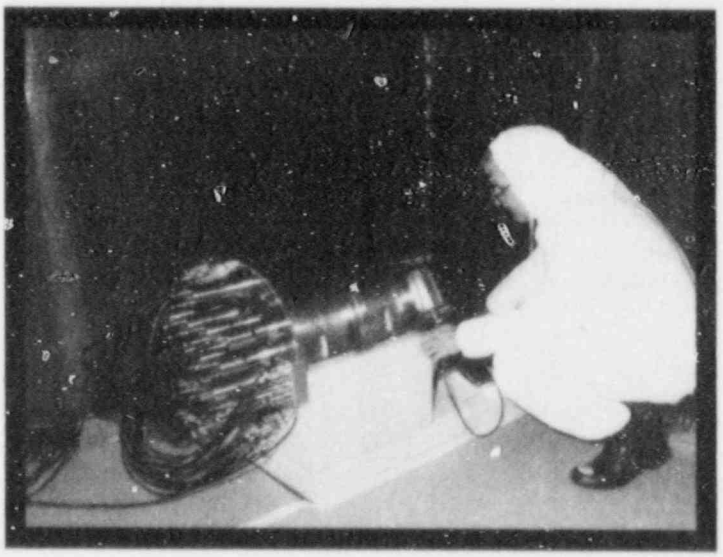
Entrance to Underground Counting Facility

Development of Remote Sensing Techniques. Development of remote sensing techniques continued in 1987 as a cost-effective means of environmental monitoring of large areas, such as L Lake, Par Pond, the SRP Savannah River swamp, and F- and H-Area seepage basins. Remote sensing methods currently used include airborne multispectral scanner (MSS) surveys, airborne (helicopter) gamma radiation surveys, and vertical and oblique aerial photography. Test overflights of a variety of landcover types on SRP were also made with three different types of multispectral video cameras mounted in small aircraft. Data were collected primarily through contracts to EG&G (MSS, photography, and gamma surveys), and ITD/NASA (MSS surveys). In addition, MSS and panchromatic data from the French SPOT satellite were acquired.

Data analysis yielded information on the environmental impact to wetlands, the potential habitats for endangered species, thermal patterns and dye studies of L Lake, and the distribution of radionuclides on site. Techniques to determine the water quality and algae distributions in Par Pond and L Lake were developed. The photographic and MSS data were valuable in mapping potential outcrop areas to the upper Four Mile Creek watershed from the F- and H-Area seepage basins. Information gathered by remote sensing supported the L Lake studies, the Comprehensive Cooling Water Study, and various NEPA activities, including the Alternative Cooling Water Systems EIS and technical support documentation.

Lower cost MSS systems are being evaluated in the newly developed SRL remote sensing analysis laboratory. These systems include a false color infrared video camera and SPOT MSS data. Use of SPOT MSS data may provide a low cost supplement for landcover characterization for environmental, wetlands, and habitat assessment. The relatively high resolution of the SPOT satellite sensor system may provide detailed seasonal and regional coverage not previously available in a format readily used at SRP.

Studies of Plants Exposed to Tritium in Controlled Environments. Research at SRP has indicated that the concentration of organically bound tritium in plants is higher than the equilibrium concentration in the plant tissue water. It has been suggested that this effect may be caused by the combination of a physiological process for incorporation of tritiated hydrogen in plants and the relatively high specific activity of tritiated hydrogen in the environment of SRP. A controlled environmental chamber system has been constructed as part of a research program designed to understand the role of tritiated hydrogen in determining the organic tritium content of



Ultra-low-level gamma analysis

exposed plants. The chamber system consists of a conditioning system which supplies air at controlled temperature and humidity to three glass exposure chambers. Tritium gas of carefully controlled specific activity is mixed with the air in the chambers.

Tomato, pepper, and pine plants have been exposed in the chambers for 2-hr periods under conditions controlled by a microcomputer, which also monitored the experiments and provided environmental data ready for computer analysis. Water was removed from the plants by freeze-drying, and the dry plant material was exposed to a saturated air stream for 72 hr to remove easily exchangeable tritium. The plant material was then combusted in a furnace and the water of combustion collected and analyzed for tritium. The amount of tritium in the organic fraction was very small—below detection in some cases.

During the exposure period, small but measurable amounts of tritium were oxidized to tritiated water in the plants. Measurable organic tritium was found only in the vegetation containing the highest levels of tritiated water. This suggests that most of the tritium is incorporated from tritiated water, probably by photosynthesis. Further exposures of longer duration are planned to provide greater accumulations of tritium in the organic fraction. This will provide a better measure of the rate of organic tritium uptake and the factors which influence uptake.

Studies of the Microbiology of the Deep Subsurface. Together with a consortium of national laboratories and universities, SRL and the Ecological Research Division of DOE are working to characterize the biomass, community structure, and environmental factors that control microbial communities of the deep subsurface. A long-term goal is the use of active microorganisms in in-situ bioreclamation (ISB) to degrade organic contamination at SRL and other DOE sites.

A two-phase program is under way. Phase I (FY 1986 and FY 1987), an exploratory research phase, focused on the presence, abundance, and diversity of indigenous microorganisms, on their community structure, and on the hydrogeologic, geochemical, and physical interactions that control the presence and activity of microorganisms at depth. Preliminary information on biodegradation capabilities and functioning of these organisms, as well as a Subsurface Microbiological Culture Collection (SMCC), has been developed. Phase II (FY 1988 to FY 1997) is concentrating on exploiting some of the scientific advances and research opportunities identified in Phase I. Phases I and II will provide information that will lead to an understanding of the interaction between the biosphere and geosphere. They will also lead to microbial processes for mitigation of subsurface contamination, to environmental understanding of stimulation techniques that will contribute to mitigation, and in time, to evaluation of the impact of bioengineered organisms on subsurface ecosystems.

The program began in 1986 with the drilling of three wells through the various water-bearing formations to the bedrock. Microbiological samples were collected in an aseptic, undisturbed manner to a depth of 851 ft. Pore water chemistry has been analyzed for 49 different physical-chemical parameters, including metals, anions and cations.

Microbiological data indicate that microorganisms occur in great diversity and densities regardless of the sample depth. The densities are comparable to surface densities, one to 10 million bacteria per gram of soil sample, and their diversity is very great. Rates of denitrification, nitrogen filtration, and carbon metabolism have been measured at depths of 850 ft and are higher in sands than in clays. All functional groups of microorganisms are present at depth.

Fungi and protozoa are also present at depth. Protozoa have been found to a depth of 700 ft and at concentrations high enough to significantly reduce the densities of bacteria on which they feed. At depths of 232 to 235 ft and 667 to 670 ft, bacteria were not isolated. This indicates the samples were collected in such a manner to ensure that microbiological contamination from other sources did not occur.

Sitewide Seismic Survey. A reflection-refraction seismic survey was conducted on the SRP site in 1987 to define subsurface geological structure and stratigraphy. About 218 km of seismic lines were recorded across the 816 km^2 site. Data quality was generally good. A refraction velocity of 5.49 km/sec measured in the crystalline basement provided a distinct contrast to the overlying sediments and the sedimentary rocks in the Dunbarton Triassic Basin. Results of the seismic survey will provide a three-dimensional representation of the geologic structure

beneath the SRP for use in permitting and environmental documents and in safety analyses.

Activities to Aid Compliance with Pollution Abatement Regulations

Improvements in Emergency Response System. Several changes were made to the remote environmental monitoring system for emergency response. Data signals from the tritium monitors on the stacks of the separations facilities and at 12 perimeter sites were linked to the Weather INformation and Display (WIND) system computer and incorporated into the VANTAGE data management system. Previously, incoming signals consisted only of meteorological data, river and stream monitoring data, and L-Lake thermal monitoring data. When fully implemented, this system will provide automatic monitoring of abnormal stack releases from all process facilities and automatic inclusion of these source terms in the emergency response codes.

New instrumentation and data acquisition/transmission systems were installed on meteorological monitoring towers in eight production areas. The new instruments are more accurate, sensitive, and reliable and require less frequent calibration than the instruments they replaced. The new data acquisition system eliminates susceptibility to total system failure by having each tower feed data independently into the WIND system computers over dedicated telephone lines. The data available from the WIND system are supplemented by data from a second data acquisition system that provides continuous display of 1-min–average wind data in each production area control room. The new system also provides for system maintenance and surveillance by constant monitoring of vital functions by telephone. An uninterruptible power supply at each site provides continuous service during short power failures.

Revision of WIND system software continued during the year. This revision included modularization of key functions, as well as improved methods to the control and documentation of software.

A Geographic Information System (GIS) was installed in the Weather Center Analysis Laboratory (WCAL). The GIS will couple data from the emergency response codes to environmental and geographic digital databases. Coupling of these data will provide and display information on population distribution and dose, road networks, routing and location of emergency response vehicles, land use, topography and maps of the impact regions.

Additional computer hardware was installed in the environmental transport area of the SRP Emergency Operating Center (EOC). A super microcomputer was linked to the WIND system computer to improve reliability of emergency response support. It provides a backup menu of WIND system emergency response codes to the EOC if WIND system computers are unavailable. An upgraded computer terminal and printer were also installed.

The Tracking Radioactive Atmospheric Contaminants (TRAC) mobile laboratory was used in experiments to study the dispersion of a harmless tracer gas SF_6 during the transition from nighttime to daytime. The SF_6 was released from a 60-m stack, and surface concentrations were measured with a continuous analyzer onboard the TRAC vehicle. Meteorological data were obtained with SRL's tower system and a Doppler sonar.

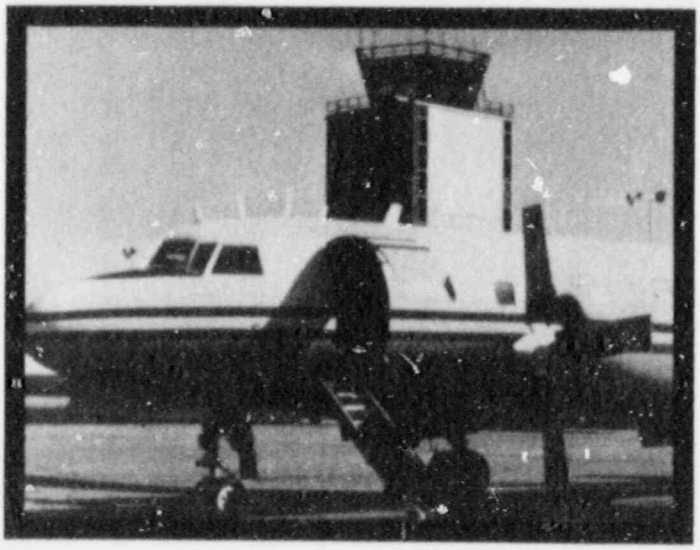
Two NaI detectors have been installed in the TRAC mobile laboratory to allow terrestrial scans. The detectors will be useful in localizing (at a distance) any land masses that might inadvertently become contaminated due to an unplanned release. In effect, the monitors will act as the plume monitor, except they will view the ground rather than the sky. Performance tests on the monitors are currently under way.

Monitoring ^{137}Cs Transport from L-Reactor. A comprehensive environmental sampling and analysis program to monitor ^{137}Cs transported from Steel Creek prior to and following the startup of L-Reactor continued. This program provides the transport and material balance data necessary to demonstrate that no significant offsite changes occur in ^{137}Cs concentrations associated with the restart of the L-Reactor in 1985.

Evaluation of the effect of L-Reactor restart on the concentrations of ^{137}Cs in the Savannah River and downriver water treatment plants has been completed. Cesium-137 concentrations increased slightly in the Savannah River below SRP (from 0.078 pCi/L in 1985 to 0.118 pCi/L in 1986) the year after L-Reactor restart, partially because of low flows in the Savannah River. Annual average ^{137}Cs

concentrations in the drinking water result in a dose of less than 0.003 mrem/yr. This is approximately 0.001% of the average person's exposure to natural radiation (295 mrem/yr) in the United States.

Measurements of ^{137}Cs transport across the Savannah River floodplain at the site boundary during flooding were not made until 1987. (The river was not in floodstage during 1986.) Normally, SRP streams discharge directly into the Savannah River, but during floodstage, the discharges are constrained to flow near the upland edge of the floodplain for a distance of about five miles before mixing with the full flow of the Savannah River. Cesium-137 concentrations measured in the floodplain while the river was in floodstage in 1987 showed that L-Reactor restart had only a minor effect on ^{137}Cs transport offsite. Less than 1 Ci of ^{137}Cs was transported across the floodplain during flooding in 1987.



Airplane used in overflight studies

Thermal Studies of SRP Cooling Ponds. The research program to enhance understanding of the cooling process in L Lake and Par Pond and to evaluate methods that may improve the cooling efficiency of L Lake was continued.

A new canal was constructed to divert the hot water from the reactor to the upper end of L Lake. Dye tracers were used to show that the new canal increased the flow time to the middle of the lake by several hours, which allowed a slight increase in production in L Reactor. The dye tracer distribution was mapped using aerial remote sensing and surface measurements from boats.

In order to further study the cooling efficiency of L Lake, SRL developed cooling pond models. These models have been effective in delineating steady-state conditions at L Lake but have been less successful in modeling conditions during specific periods, partly because of the lake surface's sensitivity to changing meteorological conditions.

The thermal conditions in L Lake can be portrayed accurately by combination of high-resolution qualitative thermal imagery (generated during overflights conducted by EG & G, Inc.) and monitoring data gathered by 31 floating platforms near the center of L Lake. However, EG & G overflights are expensive and are routinely available only as supplements to other annual SRP surveys. Satellite multispectral imagery gathered by a Land Resources Observatory Satellite (LANDSAT) is available frequently (four times a month) and could prove useful in providing data to supplement monitoring data and to refine the cooling pond models. However, to date LANDSAT data have been less useful than other data owing to the satellite's lower resolution and poor calibration of atmospheric effects.

SRL is collaborating with NASA to perform LANDSAT thermal imagery calibration studies at SRP's cooling ponds. To date, four experiments have been conducted at Par Pond and C Pond. SRL is gathering ground data from instrumental buoys, surface water observation by infrared thermometers, and tethered balloons and air sondes, which measure temperature and humidity profiles through the atmosphere.

STABLE Program: Study of Contaminant Dispersal Through Cooling of SBL Air Layer. The stable planetary boundary layer (SBL) is the warm layer in the night air. Lying just above the ground, it is cooled by contact with the cold ground. Because chemical and radioactive accidents can happen at night (e.g., Bhopal, Chernobyl), it is important to understand how airborne contaminants disperse in the SBL.

The STABLE (Stable Atmospheric Boundary Layer Experiment) is an effort to understand how turbulence and diffusion in the SBL affect dispersion of contaminants. Active groups in the project are

DOE-affiliated laboratories (SRL, Atmospheric Turbulence and Diffusion Division, and Lawrence Livermore National Laboratory) and North Carolina State University.

A goal of the program is to investigate how turbulence in the SBL transports and disperses airborne contaminants. STABLE's initial efforts produced a "climatology" of turbulence structure for the SBL at the SRP site using SRL's turbulence data base. SRL's turbulence data base was collected from 1973 through 1979 when bivane and cup anemometer measurements at seven levels on an 1100-ft TV tower were digitized every 5 sec and stored on magnetic tapes.

The SBL climatology study has shown that a variety of phenomena occur including waves, turbulent episodes, large shear zones, and mesoscale eddies. The turbulent episodes have been linked to changes in the Richardson number, a parameter comprised of wind speed and temperature gradient. Further extensive investigations are planned for 1988, including a two-week field program for intensive measurement and documentation of the intermittent episodes of the SBL.

Calculation of Offsite Doses with CAAC Code. To demonstrate compliance with EPA National Emission Standards for Hazardous Air Pollutants (NESHAPS): Standards for Radionuclides (Title 40 Part 61 Code of Federal Regulations), SRP developed a capability to calculate offsite doses from atmospheric releases of radioactivity with the EPA-approved CAAC Code [CAAC86] (Clean Air Act Code, formerly called AIRDOS-EPA). This computer code calculated offsite radiation doses for four projects planned for the Savannah River Plant, with the results showing that offsite effects would be negligible. This information was used in NESHAPS applications for new emission-source permits required by the Clean Air Act for construction of new facilities that will release radioactive materials to the atmosphere.

Meteorological Data for Dispersion Calculations. Wind data from the production area meteorological towers are stored on magnetic computer tape and are used for periodic updating of the databases used in calculating dispersion of atmospheric releases of radioactive (and also nonradioactive) materials to the atmosphere. In 1987, data from the seven towers for the period 1982-1986 were verified and processed to prepare joint frequency distribution tables for each tower. These tables are now being used in computer programs to calculate offsite effects of normal releases of radioactivity to the atmosphere and the effects of hypothetical unplanned release events.

Activities to Meet Permit or Environmental Impact Statement Requirements

Monitoring L Lake Status. Only three years old, L Lake is classified as a young lake. As a lake ages, structural and functional internal adjustments occur within the lake's communities and ecosystem. These internal changes respond to several external physical, chemical, and biological forces. The forces affecting the successional process of L Lake include water quality characteristics of the Savannah River input, thermal load from L Reactor, depth of withdrawal at the lake's outlet dam, weather conditions which impact rainfall, cloud cover, temperature, and the nature of the drainage basin itself.

The pelagic region (open water) of L Lake comprises the lake's plankton and contains most of the lake's biomass. This region is responsible for most of the lake's energy flux. Its structural and functional characteristics respond to several physical conditions, including temperature, dissolved oxygen, pH, and submarine irradiance. In L Lake, temperatures ranged from 13 to 34°C during 1986 through 1987. When the lake was thermally stratified, epilimnetic temperatures ranged from 14 to 34°C and hypolimnetic temperatures from 13 to 28°C. Dissolved oxygen (DO) ranged from 1 to 6 ppm, similar to other area reservoirs. Correspondingly, pH varied from 6.5 to 9.0 during these periods, which is also comparable to other basins in this part of the country.

The littoral (inshore) community, an important nursery for juvenile fish, is known for its high rates of macrophyte productivity and plays a significant role in stabilizing the lake's shoreline. From January through August 1987, Savannah River Ecology Laboratory (SREL) personnel planted five vegetative types of macrophytes in L Lake. In October, monitoring efforts with plot counts and remote sensing techniques indicated that the plantings were successful.

For the past two years, insects, mostly midges (*Chironomidae*), have dominated the benthic (lake bottom) and littoral communities. In addition to

midges, the amphipod *Hyalella asteca*, common throughout North America, was another summertime dominant in L Lake. Total densities were comparable to other southeastern reservoirs, including Par Pond.

Successional changes in the fish community of L Lake have been apparent throughout its history. Initially, stream, swamp, and pond species were successful in L Lake, including golden shiners, several species of minnows, brook silversides, and mosquitofish. In late 1987, the threadfin shad, a common pelagic species in southeastern United States reservoirs, made a significant increase. The present populations are considered healthy and the observed succession in L Lake has been typical of other reservoirs. Largemouth bass and adult bluegills continue to play an important role as the top keystone predators in the lake. Their feeding habits significantly structure planktivorous fish populations and their recruitment.

Comprehensive Cooling Water Study. The Comprehensive Cooling Water Study (CCWS) was initiated in 1983 to evaluate environmental effects associated with SRP cooling water withdrawals and discharges, and to determine the significance of the effects on the onsite and downriver environments. The CCWS report, published in October 1987, summarizes historical information and presents the results of the two-year study. The seven major program elements addressed in the report are water quality, radionuclide and heavy metal transport, wetlands, aquatic ecology, ecology of Par Pond, endangered species, and waterfowl.

The water quality of onsite streams at SRP has been influenced primarily by the elevated temperatures and flow rates associated with reactor operation. During reactor operation, heated cooling water discharges at temperatures ranging from 32°C to about 70°C are discharged to onsite streams, in which mean annual temperatures range from 15 to 19°C. Although substantial cooling occurs during passage through the streams and swamp, thermal stream water reaches the Savannah River at temperatures ranging from 9 to 41°C, compared to 4 to 26°C in the ambient river.

The large volumes of reactor cooling water discharges (2.5 to 11.3 m^3/s) relative to natural discharges of the receiving streams (less than 1 m^3/s) result in thermal stream water chemistries more similar to Savannah River water chemistry than to Coastal Plain stream water chemistries. The river and associated thermal streams have higher nutrient concentrations than the ambient streams. In addition, high flow rates induce erosion in the thermal stream channels and create elevated suspended solid loads that are removed as water passes across the stream deltas and through the SRP Savannah River swamp.

Aquatic releases of radionuclides associated with SRP operations are low and, except for tritium, are largely contained within the SRP boundaries. Radionuclide releases, substantially reduced since the early 1970s, remain well within DOE and EPA concentration guidelines.

Physical factors associated with the release of reactor cooling water, such as flooding, elevated temperatures, erosion and sedimentation, continue to eliminate cypress-tupelo swamp forest canopy in the river swamp. The trend of canopy loss may be reversed by long-term reductions in thermal effluent flows and temperatures. As shown by studies in the post-thermal Steel Creek, stream corridor and delta areas are rapidly recolonized by herbaceous and shrub-scrub species after reactor operations cease. However, sedimentation and altered flow paths may retard or prohibit recovery of the original cypress-tupelo swamp forest.

When the reactors are operating, thermal streams and sedimentary deltas are largely devoid of fish and aquatic insects, except for thermally tolerant species. These areas are rapidly invaded by aquatic species when reactors are not operating. Limited spawning takes place in thermal streams, and may occur earlier than in nonthermal streams. In contrast, ambient temperature tributaries to thermal effluent streams appear to support self-sustaining communities of aquatic organisms typical of SRP nonthermal streams of similar size.

In the vicinity of SRP, the Savannah River contains an abundant, diverse fish population. In general, the fish are attracted to thermal plumes in the winter, but there is no evidence that river populations are adversely affected by SRP cooling water discharges. Neither impingement of adult and juvenile fish nor entrainment of fish eggs and larvae had significant effect on the Savannah River during the CCWS period. Impingement rates were low, averaging less than 18 fish per day. Entrainment at the SRP cooling water intakes on the Savannah River

affected approximately 8.3% of the fish eggs and larvae that drifted past the intakes in 1984, and 12.1% in 1985. Because natural mortality rates of fish eggs and larvae are high, the entrainment losses had no apparent adverse effects on the Savannah River fishery.

Overall, the CCWS determined that reactor operations have no adverse impact on the Par Pond system. The flora and fauna continue to flourish, and communities remain diverse, balanced, and representative of the region.

Four threatened or endangered species use areas that could be affected by SRP cooling water withdrawal or release. Shortnose sturgeon spawn in the Savannah River near the SRP. This species has not been found in impingement or entrainment collections at the SRP cooling water intakes, and physical properties of the shortnose sturgeon make impingement or entrainment unlikely.

Wood storks from a colony near Millen, GA forage on the SRP site, primarily in the Steel Creek delta and Beaver Dam Creek. High cooling water effluent flows probably limit wood stork use of the SRP site, but replacement foraging sites constructed at Kathwood Lake provide substantial new habitat for wood storks and more than compensate for foraging sites lost after the L-Reactor restart.

Bald eagle sightings at SRP have increased over the last decade. The eagles are seen primarily on the Par Pond system, L Lake, and the Savannah River swamp, and one pair nested south of Par Pond in 1986 and 1987. The pair fledged two juveniles successfully in both years. The bald eagle probably benefits from the large fish population of Par Pond and the protective nature of the SRP reservation.

The American alligator, listed as an endangered species during the CCWS period and subsequently downgraded to "threatened by similarity of appearance," is found on the SRP site, predominantly in the Beaver Dam Creek delta, Par Pond, and the Steel Creek area. Although elevated temperatures restrict use of portions of thermal streams, the mildly thermal habitats promote alligator use in winter months.

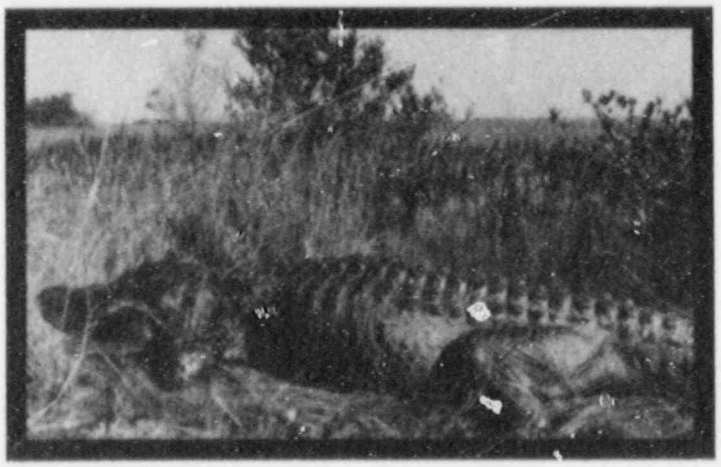
Almost every SRP body of water serves as a waterfowl habitat. During the CCWS period, midwinter waterfowl numbers increased 73% on the SRP site, while they decreased 33% in the Atlantic flyway and 70% in South Carolina. These trends indicate the importance of SRP as a waterfowl wintering refuge area.

Waste Management and Groundwater Protection

Waste Management and Groundwater Protection Environmental Impact Statement. An environmental impact statement (EIS) on waste management activities for groundwater protection at SRP has been prepared and was issued in December 1987. The three issues addressed in the EIS are (1) closure of waste disposal sites, (2) construction of new waste management facilities for low-level radioactive and hazardous materials, and (3) disposal of tritiated waste water. Technical support on the environmental analyses of waste-site closure options has been provided by the SRL Environmental Sciences and Environmental Technology Divisions.

A total of 77 waste sites at 45 distinct geographical locations around SRP were analyzed for impacts on human health and the ecology resulting from postulated closure actions.

Twenty-six environmental information documents (EID) encompassing the 77 waste sites have been completed. These EIDs describe the waste disposal sites at SRP and contain detailed evaluations of the closure options considered for each site. Each document describes the nature of the waste deposited at the site, discusses the geohydrologic setting, defines the waste site characteristics, identifies alternative closure options, and estimates



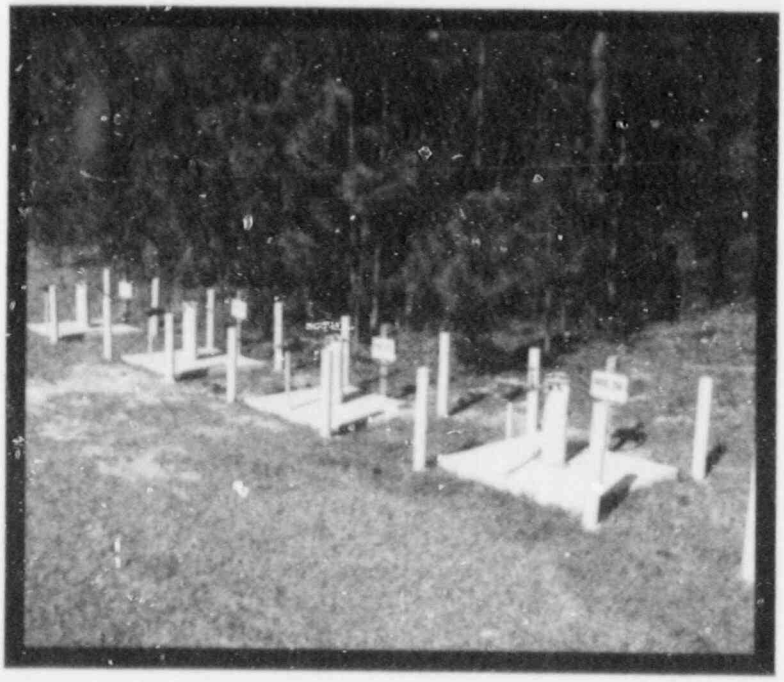
SRP is home to American alligator

the impacts to human health and the environment for postulated options identified. Five supplemental documents describe geochemical parameters, waste inventories, health effects parameters, modeling methodologies, and quality assurance reviews associated with this environmental analysis.

The results of the environmental analysis of waste disposal sites at SRP indicate that the risk to human health and the ecology is quite low. For many sites, no remedial action is needed. For others, backfilling and capping the waste site provide the required protection. At one site and possibly two, removal of the waste may be required to reduce the calculated risk to the human population.

Waste Site Characterization. SRP is required to close all waste sites in a manner consistent with protecting human health and the environment and complying with applicable environmental regulations. The first step in this closure procedure is to develop waste site characterization requirements. These requirements are based on technical considerations and specifications for RCRA and CERCLA facility investigations developed by the EPA.

Recommendations for characterizing all waste disposal sites at SRP have been developed. A total of 166 individual waste sites were evaluated according to the type of waste deposited. Historical records and previously obtained data were examined. Existing data and environmental standards for soil and groundwater concentrations were compared to determine whether additional data would be required. If additional information for a site was required, strategies for collecting samples for chemical and physical parameters were specified. For several waste sites for which characterization activities have already been conducted and the data for developing acceptable closure plans exist, no further action is recommended. For many sites, additional characterization is recommended using soil gas surveys, ground-penetrating radar, soil samples, groundwater monitoring wells, and geologic borings. Over 200 soil cores to nominal depths of 3 to 6 m are recommended. Installation of over 100 groundwater monitoring wells, mostly to the water table, is suggested. Use of ground-penetrating radar to define backfilled waste site boundaries is specified for 26 individual waste sites. Soil gas surveys for the presence of volatile organic materials are recommended at 17 specific waste sites. These recommendations will provide the basis for collecting the data necessary to develop closure plans for all SRP waste sites.



Cluster of groundwater monitoring wells

Soil Cleanup by Vacuum Extraction. In-situ vacuum extraction has been shown to remove significant amounts of trichloroethylene and tetrachloroethylene from the vadose zone (the zone of soil located above the permanent water table) of SRP soils contaminated with these solvents. In a pilot study conducted in M Area, almost 1,500 pounds of solvent was removed over a three-week test period. Three parallel efforts to further develop and apply vacuum extraction technologies at SRP are planned. These include research studies to determine flow rates of gases in the vadose zone during vacuum extraction and the degree of removal of volatile organic compounds (VOCs), field tests using horizontal wells to demonstrate vacuum extraction of VOCs from the vadose zone alone and in combination with injection of air into the underlying groundwater, and full-scale application of vacuum extraction to remove VOCs from the vadose zone in a facility to be constructed near Outfall A-14. Applications are being prepared for permits required by SCDHEC for these activities.

Baseline Hydrogeologic Investigation. The SRP Baseline Hydrogeologic Investigation for providing hydrogeologic data over the entire site was completed in 1987. This is the first program at SRP to obtain continuous geologic cores of the unconsolidated Coastal Plain sediments underlying the plant from the ground surface through the Middendorf Formation (formerly called the lower Tuscaloosa Aquifer).

Eighteen clusters of observation wells were installed at key locations across the plant site to provide detailed information on lithology, stratigraphy, and groundwater hydrology. These observation wells also provided the means to monitor groundwater quality, hydraulic head relationships, gradients, and flow paths. In all, a total of 129 wells were installed in accordance with SCDHEC regulations. The program was divided into three phases. Phase I, completed in 1984, included installation of 20 observation wells at three cluster sites. Phase II, completed in 1985, comprised installation of 56 observation wells at eight cluster sites. Phase III, completed in 1987, included installation of 53 observation wells at seven cluster sites. Phase I and Phase II concentrated on collection of data from areas of the SRP site for which little or no data previously existed. Phase III was designed to supplement data gaps and provide observation points for the major groundwater extraction areas of the plant. The program established a high quality geologic and hydrogeologic database for the site where all of the data have been consistently collected and evaluated.

Water-level measurements from this program have been used to construct an updated map of the head reversal across the Ellenton Formation which separates the Black Creek-Middendorf and Congaree Formations beneath SRP. The reversal should provide a barrier to water flow into the Black Creek-Middendorf Formations from overlying sediments. A head reversal is the presence of a higher pressure below a confining unit than above, creating the potential for upward flow. Since the early days of SRP operation, a head reversal was thought to exist over much of the plant area. This condition does not occur in the A/M Area and the east-central zone of the site. Continued work on this program will assure that future plant operations, such as new production wells and increased pumping from the Black Creek-Middendorf Formations, do not adversely affect the head reversal. These tasks include numerical modeling, the search for alternatives to withdrawal of Black Creek-Middendorf water, and collection of additional water-level data.

Groundwater Flow Modeling Program. Development of a validated, documented regional three-dimensional flow model that simulates the groundwater flow system at SRP continued in 1987. The model is being developed to provide a hydrologic management tool that allows assessment of onsite and offsite impacts of pumpage and that can be coupled with a transport simulator to consider convective, dispersive, adsorptive, and decay processes.

The general approach used in modeling the regional groundwater consists of three main phases: system conceptualization, model calibration, and simulation. Preliminary calibration of the model for a region of SRP was completed in 1987. The model is now being compared with other numerical models. Calibration of the model for the entire SRP site is expected to be completed in 1988. Upon completion, this program will provide a management tool for assessing alternative uses of groundwater resources at SRP.

Use of Herbicide-Impregnated Polymer Matrix to Exclude Plant Roots from Buried Waste. Radionuclides and some toxic wastes can move from burial in the ground to the surface through uptake by plant roots. Roots have the potential not only to remove waste but also to penetrate physical barriers and disrupt the waste containment systems. Since living roots have been found at more than 100 ft below the surface, there has been a great deal of interest in systems to limit root growth. The herbicide trifluralin (Treflan) is a root retardant (prevents roots from penetrating the soil layer). Because it is biodegradable, trifluralin alone is undesirable for long-term exclusion of roots. Research scientists at Batelle Northwest Laboratories have overcome this problem by incorporating trifluralin in a slow release matrix and bonding the matrix to the geofabric material Typar® for ease of handling.

Several characteristics make the bonding of trifluralin and Typar® promising for use in waste sites. Trifluralin is released at a rate that should keep it active for as long as 100 years. Because trifluralin is biodegradable and adheres strongly to soil, the zone of action is about 4 in below the retardant layer and trifluralin is not transported to the groundwater. Trifluralin retards root growth, but is not a systemic

herbicide and will not kill plants growing above the retardant layer. The last characteristic is important, since vegetation is often used to stabilize the overburden of waste sites.

The root retardant system is being manufactured by Reemay, Inc. of Old Hickory, TN. Because of its potential as a barrier to root penetration into radioactive and/or hazardous waste, SRL and SREL have begun a series of tests of the root barrier in the SREL rhizotron. The rhizotron facility is designed to study root growth by visually inspecting the roots through specially constructed soil-filled cells with glass inspection portals. A number of configurations of the root barrier (horizontal, vertical, and stair-stepped) have been placed in the soil to see the reaction of roots growing around edges and in corners. Two vegetation types have been used, soybean and Bermuda grass. Results to date indicate that the root barrier is functioning and the roots are not penetrating the material. However, the roots are growing around and about 6 in under the barrier. This means an effective root barrier will have to surround the volume of soil from which roots are to be excluded.

Activities Supporting Alternative Cooling Water Systems Environmental Impact Statement. Several activities were performed in support of the Alternative Cooling Water Systems (ACWS) Final Environmental Impact Statement (FEIS). In one, the potential effects on wildlife associated with the proposed cooling water alternatives for C-and K-Reactors and D-Area power plant were evaluated using a Habitat Evaluation Procedures (HEP) assessment. (The HEP analysis was developed by the U. S. Fish and Wildlife Service [USFWS] and modified by SRL for the SRP environment.)

The potential wildlife impacts and benefits of once-through and recirculating cooling towers located at C-and K-Reactors were evaluated for near-term (30-year) and long-term (100-year) periods. Results from these analyses were compared with the projected effects of current reactor operations. For the representative wildlife species selected, HEP analysis results showed that both the once-through and the recirculating cooling tower designs would improve overall aquatic habitat suitability by substantially reducing water temperatures from the present conditions. Neither cooling tower design could be clearly identified as the best thermal mitigation alternative; the lower temperatures associated with the recirculating towers counterbalanced the greater stream area available with the once-through tower.

Five information documents were also developed by SRL to support the ACWS FEIS. Four of these documents addressed the potential environmental impacts of recirculating and once-through cooling towers for C-and K-Reactors. Studies indicated that both cooling tower options would significantly reduce the temperature of cooling water discharged to site streams, thereby improving conditions for aquatic life. Recirculating towers would also reduce peak effluent flows to about 7% of the present volume. Similarly, recirculating towers would dampen the flow fluctuations induced by reactor cycles, consequently enhancing fish spawning and alligator nesting in the stream corridors and wood stork foraging in the deltas.

The fifth information document assessed effects of the "increased flow and mixing" thermal mitigation alternative for the D-Area power plant. Studies indicated that the additional water pumped to the powerhouse during extreme summer weather conditions would keep discharge temperatures below the 90°F limit. However, the environmental benefits obtained by the reduced temperatures might be offset by increased and fluctuating flows.

NATIONAL ENVIRONMENTAL RESEARCH PARK PROGRAM

Under the National Environmental Research Park (NERP) program, scientific investigators from universities and other organizations are encouraged to use the SRP site as an outdoor laboratory for studies of the environmental impact of man's activities. Since the site was designated as the nation's first NERP in 1972, many visiting scientists have worked there in cooperation with SRL, the Savannah River Ecology Laboratory, and the Savannah River Forest Station.

During 1987, approximately 15 NERP program research projects were conducted, with baseline studies providing information on the variability of plant and animal communities. The site was surveyed for plants listed by state or federal agencies as endangered, threatened, or of special concern. Other scientists surveyed soil organisms, shallow pond protozoa, stream insects and forest vines.

Many of the SRP studies started in 1987 are comparative, as is apparent from the following examples:

- Wetland bacteria of the Okefenokee Swamp (Georgia and Florida) are being compared with bacteria of thermally-impacted swamps at SRP.
- The feeding behavior of wading birds at SRP and of those at the Okefenokee and the Belle Baruch Long Term Ecologic Research Site at North Inlet, SC, is being compared.
- A regional study of forested wetlands of the Gulf and Atlantic Coastal Plains is examining community structure, factors controlling productivity, and stress responses. Similar data are being taken at SRP.
- The cesium-binding capacities of SRP, Los Alamos, and Bikini Atoll soils are being compared.

Wood storks nesting at rookery near Millen, GA

Two highlights of the 1987 NERP program were:

- A NERP-sponsored SRP meeting at which scientists from across the country learned about opportunities to study microorganisms found in the sedimentary rocks hundreds of feet beneath the SRP.
- A workshop held on the ecology and conservation of storks to share the results of SRP research activities.

SAVANNAH RIVER ECOLOGY LABORATORY PROGRAMS

Division of Biogeochemical Ecology

Environmental Chemistry of Sodium Tetraphenylboron. The Savannah River Ecology Laboratory (SREL) has conducted research for the past several years on understanding the environmental chemistry of sodium tetraphenylboron (NaTPB), an organo-borate compound that will be used in the new Defense Waste Processing Facility (DWPF) to precipitate radiocesium from high-level nuclear wastes.

In general, the mobility and fate of nonvolatile organic compounds in soil and aquatic environments are largely determined by sorption and degradation reactions. Previous research has shown that tetraphenylboron degrades in the soil to form diphenylborinic acid and biphenyl as initial degradation products. Other research has shown that tetraphenylboron is not readily degraded by microorganisms. During the past year, the effects of various abiotic soil parameters on the degradation rate of TPB were examined. These studies showed that the reaction rates are inversely related to soil water content and directly related to humic acid concentration.

Biogeochemical Cycling in L Lake. Microcosm studies were conducted to investigate the influence of oxidation-reduction status on the potential remobilization of metals and nutrients from L-Lake sediments. Previous research indicated that only iron and manganese concentrations were probably high enough to present a toxicological threat from remobilization.

Efforts during the past year focused on determining the bioavailable fractions of the total iron and manganese present, as well as the mobilization potentials of these two metals in L-Lake sediments. Under reducing conditions of -150 mV, all labile manganese fractions were mobilized after 72 hr, while only 6% of the labile iron was released after 75 hr. The results suggest that during conditions comparable

to those occurring in the anoxic hypolimnion of L Lake, there is a potential for rapid and complete mobilization of labile manganese fractions. Additional data are being collected to calculate potential ranges of iron and manganese concentrations resulting from remobilization processes under varying redox conditions.

Separate field and laboratory studies have focused on the bacterial processes involved in dissimilation of the particulate and dissolved organic matter from blue-green algal blooms, and from vascular plant-derived lignocellulosic detritus. This research involved following the rates of degradation of radiolabelled organic matter prepared to be similar to that in the lake itself. Results have shown that, although reactor operations may increase rates of primary production, there does not appear to be a consequent accumulation of organic matter, owing to the adaptability of the degrative microbial community in L Lake to the higher temperatures.

Biogeochemical Cycling in Pond B. To understand the long-term effects of radionuclide contamination in an aquatic ecosystem, SREL has been studying the aquatic chemistry, aquatic macrophytes, benthic invertebrates and waterfowl of the Pond B reservoir. Recent research has focused on determining radiocesium levels in various biotic components of the reservoir. Results indicate that less than 0.6% of the total inventory of radiocesium in Pond B is found in the biota. Approximately 99% of the radiocesium is found in the sediments, with the remainder being in the water column. Of the radiocesium found in the biota, over 99% is incorporated into the biomass of the macrophytes.

Biogeochemistry of D-Area Coal Pile and Ash Basins. Recent research has focused on understanding the chemical speciation, solubility and mobility of selenium, a potential contaminant of soils and groundwater that can be released from coal piles and runoff basins. Thermodynamic data were used to develop equilibrium reactions and constants for 83 selenium minerals and solution species that may be present in soils, surface waters, and groundwater. Studies of the solubilities of 17 metal-selenite minerals suggest that manganese selenite is the only selenite mineral that might persist in strongly acid soils, such as those that occur on the SRP site. Of the 17 metal selenides, cuprous selenide is the most stable mineral in acid soils.

The solubility and movement of selenium in soils and waters are closely associated with the chemical species in solution. The major factors controlling these chemical species are the redox potential and pH. At high redox potential, selenate (SeO_4^{2-}) is the predominant species. At moderate redox, both biselenite ($HSeO^{3-}$) and selenite (SeO_3^{2-}) are important. At low redox conditions, mono-hydrogen selenide (HSe^-) is the most important species.

Statistical Variance in Mercury Concentrations of Fish. Research was initiated to define the variance structure for mercury concentrations within a dominant fish species population, the dusky shiner (*Notropis cummingsae*), in Upper Three Runs Creek. A nested analysis of variance was used to define the structure of variance within the mainstream of Upper Three Runs Creek. Sources of variance were reaches within the stream, sites within each reach, schools within sites, and sample error. After size normalization of mercury concentrations, only means between stream reaches were identified as significantly different. Baseline data were collected prior to the introduction of mercury to Upper Three Runs Creek from the proposed F/H Area Effluent Treatment Facility. The results provide a statistical benchmark for similar surveys after facility operations begin.

Division of Stress and Wildlife Ecology

Life History Patterns of Mosquitofish (*Gambusia affinis*) in Thermal and Ambient Environments. Reproductive patterns of mosquitofish (*Gambusia affinis*) from both ambient and thermally stressed habitats on the Savannah River Plant were compared to determine short-term evolutionary changes imposed by thermal stress. Previous studies of thermally stressed ecosystems have demonstrated profound effects of elevated temperature on community attributes such as species diversity, biomass, and general condition. Such changes would in turn affect community structure. Somatic and reproductive data were analyzed from monthly samples at each location. The two populations were significantly different in annual reproductive cycle, fecundity and somatic condition (Fig. 12-1, Vol. II). Other studies have demonstrated genetic differences between thermal and ambient populations of mosquitofish, implying a possible genetic basis for life history differences (Fig. 12-2, Vol. II). Further research should emphasize genetic versus

environmental components of life history differences in these populations to determine if thermal stress has resulted in evolutionary change of life history characters.

Effects of Overhead Forest Canopy on Leaf Decomposition Dynamics in an SRP Blackwater Stream. Effects of overhead forest canopy on rates of leaf breakdown were estimated in regions of open and closed forest canopy on a second-order SRP coastal plain stream (Tinker Creek). Six sets of leaf packs placed in each habitat over a period of one year showed differences in the rates of decomposition that were linked to riparian characteristics, temperature, and macroinvertebrate community structure. Leaf decomposition was faster in the closed canopy habitat than in the open canopy habitat. Microbial processing was similar between habitat types, accounting for approximately 30 to 40% loss of dry weight. Observed differences between open and closed habitats were apparently the result of macroinvertebrate processing. Since leaf packs are temporary resources that function as both food resource and habitats, it was anticipated that microbial and macroinvertebrate responses should vary through time. Temporal differences in rates of processing were related to changes in water temperature. They were also affected by changes in macroinvertebrate population and community structure within and between sets of leaf packs.

Natural Variation in Stream and Wetland Ecosystems and the Effects of Defense Waste Processing Facility (DWPF) Construction. Density manipulations of marbled salamander larvae in field pens within a Carolina bay revealed that larval density may affect a suite of larval characters. Individuals in low-density pens grew faster, attained larger body size at metamorphosis, and exhibited higher survival. These density-dependent effects were consistent during FY 1986 and FY 1987. However, the density effects can be mediated by abiotic factors, presumably hydroperiod, as was evident by significant year effects. This research illustrates that intraspecific interactions in the larval environment can affect adult characters related to fitness (e.g. body size and fecundity) and ultimately the population dynamics of amphibians that breed in SRP wetlands.

The construction of the DWPF eliminated a 1-hectare Carolina bay (Sun Bay). To partially mitigate the effects of the loss of the bay, SREL constructed three artificial refuge or breeding ponds peripheral to the construction area and is conducting an experiment in them. Data from the experiment suggest that interactions among hydroperiod, predation, and competition may be important determinants of amphibian reproductive success at these sites. Salamanders first colonized the refuge ponds in appreciable numbers during FY 1986 and FY 1987 (Table 12-1, Vol. II). Two species, the red-spotted newt, *Notophthalmus viridescens*, and the mole salamander, *A. talpoideum*, have established breeding populations at the refuge ponds. Nearly half of the *A. talpoideum* that have entered the refuge ponds to breed have been marked animals from Sun Bay. Mole salamanders normally return to the site where they were born to breed; however, some individuals of these species responded to the elimination of Sun Bay and other construction disturbances by migrating to the refuge ponds.

DWPF Peripheral Stream Water Quality Studies. Mean total suspended solids (TSS) levels in McQueen Branch (one of the main creeks draining the DWPF site) increased for FY 1987, but not significantly. Other streams showed a mixture of nonsignificant increases and decreases in TSS concentrations for FY 1987. Rainfall one day prior to sampling was two times greater in FY 1987 than in FY 1986, which may account for some of the increases in TSS. McQueen Branch showed a nonsignificant increase in turbidity in FY 1987, while other streams showed a mixture of nonsignificant increases and decreases in turbidity. TSS loadings for McQueen Branch (construction impacted stream) were higher than Tinker Creek (unimpacted stream) for both FY 1986 and FY 1987. For both years, TSS loading rates were not statistically different either within or among streams.

For FY 1987 (as in past years), there were indications that during periods of rainfall, inputs from McQueen Branch were sufficient to increase (in one case slightly for FY 1987) the TSS levels in Upper Three Runs Creek below its confluence with McQueen Branch. Two TSS increases associated with McQueen Branch were observed in Upper Three Runs Creek for FY 1987 and were supported by similar increases in turbidity levels, specific conductance, and percent ash weight data. The combined TSS loadings from Tinker Creek and McQueen Branch appear to account for six other times during FY 1987 when increases were observed in Upper Three Runs Creek below the confluences of Tinker and McQueen.

Crouch Branch is a second creek draining the DWPF site. Mean TSS concentrations observed in Crouch Branch were significantly higher than those in all other streams for FY 1987 for five of the 12 months. Crouch Branch appears to have increased (in some cases slightly) the TSS load in Upper Three Runs Creek for five of the 12 months in FY 1987. Data for turbidity, specific conductance, and percent ash weight, all support these five observed TSS concentration increases.

Flow Cytometric Analysis of the Effects of Low-level Radiation Exposure on Natural Populations of Slider Turtles (*Pseudemys scripta*). Aquatic turtles inhabiting seepage basins that contain low concentrations of radioactive and nonradioactive contaminants possess significantly greater variation in DNA content in blood cells than turtles from a control population. This variation, measured on a flow cytometer as the coefficient of variation of the cells in G1 of the cell cycle, is positively correlated with plastron length and estimated age of the turtles. Multiple peaks indicative of aneuploid mosaicism (a condition in which distinct "populations" of cells contain substantially different amounts of nuclear DNA) also were observed. It is concluded that radiation or some unidentified chemical in the seepage basins likely acts as a clastogenic agent that causes chromosomal rearrangements leading to deletions and duplications that have the effect of increasing DNA content variation in blood cells. The proliferation of a mutant cell line leads to aneuploid mosaicism and the observation of multiple peaks in the DNA histograms.

Biomass Productivity of Turtles in Freshwater Wetlands. Adults of six turtle species examined at Ellenton Bay ranged from 93 to 264 mm in maximum plastron length and from 298 to 10,000 g in maximum body mass (Table 12-2, Vol. II). The ratio of the minimum to maximum plastron lengths and body masses of adult turtles among the six species in Ellenton Bay were approximately 3 and 35, respectively. Standing crop biomass (SCB) and biomass production (BP) of soma and eggs were highest in *T. scripta*, the numerically dominant species, and lowest for *S. odoratus*, a species of small-bodied individuals occurring at low densities in this location. The second highest SCB and BP were found in *C. serpentina*, large-bodied turtles that occur at relatively low densities and produce large clutches of eggs. For most species BP of soma was greater than that of eggs. However, for *S. odoratus* BP of soma and eggs were approximately equal. Biomass production of eggs represented approximately 20% of the total production by all six species in Ellenton Bay.

Mature populations are generally thought to have high standing crop biomass relative to biomass production rates. Turtles seem to follow this pattern as the ratio of total BP to SCB for Ellenton Bay is 0.13. BP to SCB rates for primary producers range from 25 to 42 in aquatic habitats and from 0.4 to 0.65 in terrestrial communities. If the total primary BP of wetland habitats averages 2,500 g/m^2/year, then total BP of the entire turtle communities represents 3.88×10^{-2}% at Ellenton Bay.

BP of eggs compared to soma is high within turtle populations, presumably because turtles are relatively long-lived animals and growth rates of older individuals are very low. BP ratios of eggs to soma ranged from 0.18 to 1.0 among the six turtle species from Ellenton Bay. Although these figures are rough estimates calculated from cumulative data that do not reveal annual variability, they provide evidence that the proportion of total BP resulting from turtle egg production can be relatively high in freshwater wetland habitats.

Wood Storks at Kathwood Artificial Foraging Ponds. The United States breeding population of wood storks (*Mycteria americana*) has decreased over the last 30 years, and in 1984 the U. S. Fish and Wildlife Service listed that population as endangered. The decrease in numbers has been attributed largely to loss of foraging habitat. When DOE decided to restart the L-Reactor at the Savannah River

Wood storks foraging at Kathwood Lake

Kathwood Lake

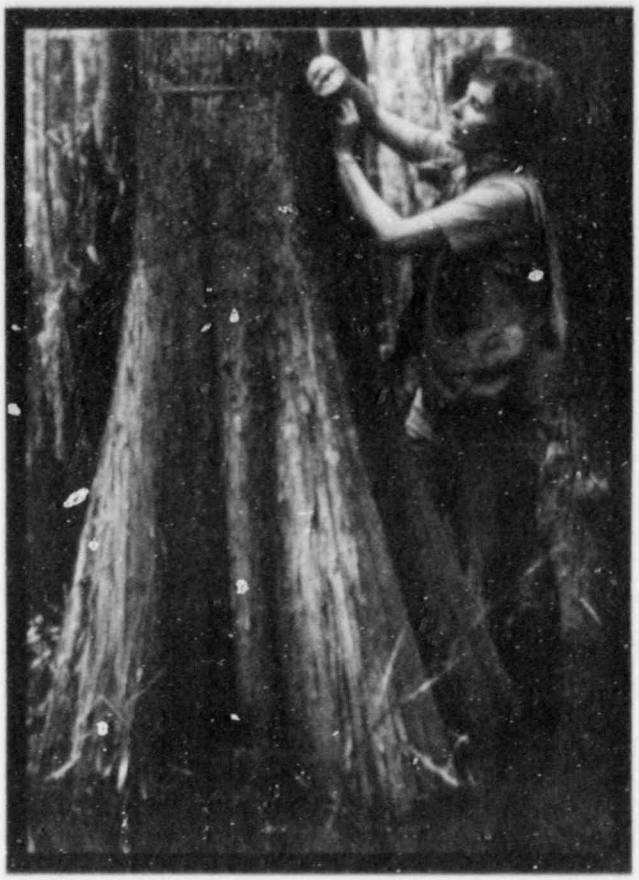
Plant, there was concern that reactor cooling water would increase the water level in the Steel Creek delta and make this area unavailable to wood storks that nest in a rookery near Millen, GA, and fly to SRP to feed on fish. To replace the potentially lost foraging habitat, DOE created 14 hectares of ponds at the site of Kathwood Lake on the National Audubon Society's Silver Bluff Plantation Sanctuary in 1985. These ponds were stocked with aquatic prey and managed specifically for wood storks.

DOE is providing research funds to SREL to assure continued availability of adequate forage for this endangered species. In 1986, wood storks foraged on the ponds for over two months and 97 storks were counted feeding at one time; this number increased to 150 in 1987. The patterns of numbers of storks at the ponds in 1986 (Fig. 12-3, Vol. II) suggest that the artificial ponds do indeed present appropriate foraging habitat. In the future it is hoped that fish reproduction will make restocking unnecessary as the ponds become self-sustaining; however, as a precautionary measure the ponds were stocked with fish in early 1987 and 1988.

Factors Affecting Variation in the Egg and Duckling Components of Wood Ducks. Three eggs from each of 35 female wood ducks (*Aix sponsa*) were collected. Fresh-egg mass averaged 44.2 g and consisted of 53.1% albumen, 36.4% yolk, and 9.6% shell. Albumen and yolk contained 86.2% and 44.9% water, respectively. Lipids comprised 65.1% of the dry yolk. All egg components except dry albumen increased in direct proportion to fresh-egg mass. Variation among females explained 52 to 80% of the total variation in mass and composition of eggs (Fig. 12-4, Vol. II). Body mass of hens during early incubation was correlated with estimates of pre-egg-laying lipid reserves ($r_s = 0.66$); therefore, body mass was a good measure of female quality. Body mass of females was independent of age and structural size and was positively related to mean egg mass, egg composition, energy content of eggs (kJ/g), and clutch mass, but not to clutch size of time of nesting. Female body mass explained more variation in albumen components than in yolk or shell components. These results support Drobney's (1980) hypothesis that prebreeding conditions of female wood ducks is important because it allows hens to accumulate exogenous protein for egg synthesis. The data do not support predictions based on optimal egg size theory.

The body mass of ducklings averaged 23.7 g (n = 43); there were no intersexual differences in mass or composition. Ducklings contained 65.9% water and 32.5% lipids (dry mass). Components of ducklings increased in direct proportion to fresh-egg mass, but egg mass was a poor predictor of duckling lipid content.

Factors Affecting Productivity of a White-Tailed Deer Herd. Reproductive and demographic data on female white-tailed deer (*Odocoileus virginianus*) were collected from 1965 to 1984. Intensive either-sex hunting has resulted in a shift towards a younger age structure in the herd. Mean fetal number varies according to female age (0.5<1.5<2.5<3.5 or greater years). Does of all age classes have significantly lower fetal numbers in the swamp than in the uplands, but there is little annual variation in mean fetal number (Table 12-3, Vol. II). Conception dates for fawns are significantly later than those of older females. Mean conception date for all females on the site has remained relatively constant over time at November 20 ± 3.4 days with no significant habitat differences. The percentage of breeding fawns varies from 16 to 69% from year to year with an average of 39% (Table 12-4, Vol. II). There was also significant temporal variation in fawn breeding between habitat types. The overall productivity of the herd has remained essentialiy constant at 126 fetuses per 100 does of any age. The relative consistency of the reproductive rate is maintained in both the swamp and upland habitats but at different levels.



Bald cypress measured for ecology studies

Division of Wetlands Ecology

Dynamics of Wetland Forest Species. The population dynamics of bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) and the potential regeneration of these forests on the Savannah River floodplain near SRP are influenced by changes in the hydrologic regime. SREL studies show that the production and dispersal of viable seeds differ between the species and between years. Seed viability is generally low in bald cypress (7 to 14% viable) and higher in water tupelo (40 to 50%). Once shed from the trees during the late fall and winter months, seeds are dispersed by water and may be moved great distances by winter and early spring floods. Emergent structures such as stumps, logs, and tree bases are critical in trapping the seeds of these species and in providing safe sites for germination and seedling establishment. Extensive inundation of the floodplain decreases this seed trapping and reduces availability of microsites for seedling establishment. Floods during the growing season may additionally cause high mortality of tree seedlings. Factors that have modified floodplain hydrology, such as cooling water discharge from SRP reactors and upstream control of Savannah River flows, may effectively limit bald cypress and water tupelo regeneration in the floodplain forest.

Using Plants, Soils, Soil Chemistry and Flooding Regime to Delineate a Wetland Boundary. SREL and Louisiana State University are involved in a cooperative research effort to understand the complex relationships between flooding, wetland plants and wetland soils. This work is of considerable interest to wetland managers and scientists concerned with delineation of wetland boundaries as required by the Clean Water Act Section 404.

Transects were established on the SRP which represent a wide range in flooding frequency. Probes and wells were installed at sites along each transect and used to monitor flooding depth, soil oxygen content and soil reduction/oxidation (redox) potential. Soils at each site were classified, and plant communities were described using sampling plots.

Flooding in the rooting zone often caused anoxic conditions to develop. However, soils did remain aerobic when saturated for short periods of time. All the sites that were flooded in the rooting zone during the growing season had hydric soils. However, one site with hydric soils was not flooded during the growing season because of altered hydrology.

Most sites were dominated by facultative wetland species. Because facultative species are as likely to occur in nonwetlands as in wetlands, the vegetation on these sites would not be useful for delineating a boundary. Identification of soils would have been required in most cases. Army Corps of Engineers' methods for wetland delineation would have correctly identified soils at 90% of the sites assuming field personnel were properly trained in soil identification.

Growth and Photosynthesis in Chinese Tallow Tree, American Sycamore, and Cherrybark Oak Seedlings Subjected to Different Light Regimes. Net photosynthesis and dry-weight production were measured for first-year seedlings of the exotic Chinese tallow tree (*Sapium sebiferum*) and two native bottomland hardwoods, American sycamore (*Platanus occidentalis*) and cherrybark oak (*Quercus falcata* var. *pagodifolia*). Plants were grown in 3% and 100% full sunlight to simulate

forest understory and open environments. In 3% light, tallow tree exceeded sycamore and oak in net photosynthesis and dry-weight accumulation, while in full sunlight, both tallow tree and sycamore exceeded oak (Fig. 12-5, Vol. II). Compared to the other species, tallow tree allocated less dry weight to leaves, more to stems, and an intermediate amount to roots. These results show that the exotic species may grow faster and regenerate better than co-occurring native bottomland hardwood species in select situations.

SRP Threatened and Rare Plant Species. An ongoing National Environmental Research Park (NERP) project has located and identified 30 plant species categorized by the federal and South Carolina governments as threatened or rare. Of these plants, eight are candidate species possibly appropriate for the proposed federal list. Of those listed by South Carolina, one is nationally threatened, three are regionally threatened, seven are threatened statewide, and 16 are considered rare (final status unresolved). About two-thirds of these 30 plant species are associated with wetland habitats.

Some results of the project are:

- Nine locations of a species new to SRP were found;
- 34 new locations of plants already known to occur on the SRP site were found;
- DOE has begun to use the inventoried populations in the overall management of the SRP.

Some of the recommendations of the project are:

- consider adding eight new sites to the set-aside program;
- continue field surveys for certain priority plant species;
- begin detailed studies on selected populations that have federal status.

Studies are being initiated to study the population dynamics of two of the federally listed plants: *Echinacea laevigata* (Fig. 12-6, Vol. II) and *Croton elliottii*.

Zooplankton Community Development in L Lake. SREL research to assess the effects of thermal stress and elevated nutrients on the zooplankton at L Lake continues, and the sampling program has been expanded to include stations at the upper end of the lake. The cladoceran *Diaphanosoma* and the calanoid copepod *Diaptomus dorsalis* are major components of the zooplankton community when blue-green algae dominate the phytoplankton; other crustacean species, including *Daphnia parvula*, are important only when the blue-greens are absent. The patterns suggest a strong trophic component to the determinants of community composition. In addition to the ongoing analysis and modeling of the zooplankton community, SREL is beginning feeding experiments to determine which food resources are used by the major zooplankton species.

Revegetation of Steel Creek Corridor and Delta. A survey of the vegetation in the Steel Creek floodplain and delta, conducted 17 years after thermal discharges to Steel Creek ceased, demonstrated continued revegetation of this highly disturbed wetland system. There has been very limited regeneration by bald cypress and water tupelo, co-dominants of the undisturbed swamp forest. Limited establishment of other early successional hardwood species (e.g., red maple, sweetgum) is evident near adjacent uplands. Much of the Steel Creek delta is still dominated by freshwater marsh and shrub communities (the latter comprised primarily of willow and buttonbush). The early stages of revegetation resemble patterns of old-field succession in that dominance proceeds from annual to perennial herbs to shrubs. Because this system is unique, the final stages of succession (increasing dominance by trees) cannot be predicted; however, it appears unlikely that bald cypress or water tupelo will regain dominance.

Wetland vegetation established in L Lake

Establishment of Littoral/Wetland Vegetation at L Lake. Littoral/wetland vegetation was established in L Lake during the period January-August 1987. Over 125,000 individuals representing over 50 species along 5400 m of shoreline were either transplanted from Par Pond or acquired from nurseries. In August 1987, vegetation from planted and unplanted sites was sampled to (1) evaluate establishment success of the planted vegetation and (2) compare the rate of vegetation establishment between planted and unplanted areas. Difference in coverage between unplanted and planted areas was greatest in the emergent zone (9% and 32%). Submersed vegetation was slow to become established and coverage in both areas was low (0% and 3%). Species which increased most in density following planting include *Eleocharis equisetoides*, *E. quadrangulata*, *Polygonum* sp. and *Typha latifolia*. The planting project was successful in establishing diverse plant communities and wildlife habitat.

Bald eagles find refuge at SRP

U. S. FOREST SERVICE SAVANNAH RIVER FOREST STATION PROGRAMS

Forest Management

In response to the need for the DOE to make the best use of public lands under its control, a program of forest management has been conducted on the 300 square miles of the SRP site since 1952. This program is conducted through an interagency agreement with the U. S. Department of Agriculture Forest Service. In addition to producing timber, the forest management program contributes to enhancing environmental diversity, protecting endangered species, providing quality habitats for native wildlife, protecting soil and watershed values, and providing a healthy forest for environmental research.

Planning for forest management is enhanced by preparing timber compartment prescriptions for one-tenth of the forest area each year. Prescriptions include a comprehensive collection of data required for vegetative manipulation, road maintenance, and coordination with other programs. The DOE Site Use Approval system includes more than 800 activities using SRP land for such programs as operations and research. Data include timber stand types and condition, and inventories of areas especially valuable for wildlife. Based on the prescriptions, timber sales are prepared and the trees to be sold are marked.

Timber cut during 1987 brought the federal government nearly $2.3 million for 27 million board feet. Cut-over land was reforested as soon as possible. Before reforestation, the land was cleared by burning, shearing and raking, drum chopping, or by herbicide application. Pine seedlings were planted on over 2,200 acres during FY 1987.

On 560 of these acres, the Savannah River Forest Station (SRFS) planted longleaf pine. Although difficult to grow, longleaf pine was the native pine of SRP sandhill habitats and is preferred by the endangered red cockaded woodpecker. Superior tree seedlings are needed for successful survival of planted longleaf pines. The South Carolina Forestry Commission Nursery is under contract to DOE to use the most advanced technology identified by U. S. Forest Service (USFS) researchers to grow seedlings for planting at the SRP in future years. The promising new technology is being closely watched by nurserymen, the forest industry and regional tree farmers. A workshop of the new techniques (sponsored by SRFS, the Southeastern Forest Experiment Station [SEFES], and the South Carolina Forestry Commission) brought participants to the nursery and to planting demonstrations on SRP.

SRFS thinned noncommercial stems on 200 acres using heavy-duty brush saws to allow the remaining trees to produce more valuable timber. On more than 700 acres, the competition of undesirable vegetation was reduced by application of selective herbicides.

Secondary roads used for the timber harvest are being upgraded to handle the large trucks used for hauling tree length sawtimber and pulpwood. During FY 1987 nearly four miles of secondary roads were upgraded. The road banks were seeded with plants that provide food for wildlife and control erosion. Routine road maintenance was performed on over 160 miles of roads.

Under a continuing program of reclaiming eroding land, approximately seven acres of bare areas were reshaped, subsoiled, and planted with legumes, grasses, hardwoods, and other wildlife food plants. The plants also control erosion. The areas stabilized in 1986 were fertilized to improve their value for wildlife and erosion control.

Endangered species receive special consideration as forests are managed. Southern bald eagles returned to SRP to nest in 1987. For the second year, two eaglets were raised to fledging. A buffer zone established by SRFS prevented disturbance of the nesting birds. The SRFS developed an eagle habitat management plan to improve possible nesting sites for other eagles. The plan will be used as a model for Southern Forests.

The very small SRP population of endangered red cockaded woodpeckers is the subject of an intensive research program testing the feasibility of translocating a few red cockaded woodpeckers to the SRP forests to counteract possible inbreeding in the local population. In 1987, SEFES scientists successfully experimented with cross fostering chicks. Two chicks were removed from a nest at Francis Marion National Forest, transported to SRP, and substituted for two chicks of the same age in an SRP nest. The SRP chicks were then placed in the nest at Francis Marion Forest. All of the swapped chicks were accepted and reared by their foster parents. This technique increases the genetic diversity of the woodpecker population in both forests. Cavity competitors, such as flying squirrels, were removed from the colonies. Artifical cavities, installed to make room for an increased population of woodpeckers, have yet to be used by the endangered birds. In 1987, all three pairs of red cockaded woodpeckers nested successfully. They produced seven fledglings, increasing the known SRP population to 14 birds.

Habitat was improved for the red cockaded woodpeckers on more than 300 acres of older pine forest by applying herbicide to weed out the competing scrub oak. Prescribed burning of 222 acres had a similar effect. On more than 660 acres, noncommercial and commercial thinning opened up the longleaf pine forest to the parklike condition the bird prefers for foraging and nesting.

Several wildlife species require control to protect forests, roads, and research sites. During FY 1987, trapping contractors removed 170 wild hogs and 84 beavers from locations where they were causing damage.

Prescribed burning of 4,300 acres stimulated growth of vegetation on the forest floor for wildlife food. The cool burns conducted each winter under carefully selected weather conditions also reduce fuel on the forest floor to protect the forest against wildfires. The wet winter in 1987 limited prescribed burning opportunities. Fire danger was high during the spring and summer of 1987, but effective wildfire suppression by Du Pont and USFS held 22 wildfires to only 90 acres.

At DOE request, the USFS is writing a plan for long-term management of natural resources at SRP. The plan will coordinate USFS activities with Du Pont activities outlined in the Environmental Implementation Plan. During 1987, the USFS planners met with the other organizations using the SRP site. They identified the various interests to be considered in the plan to be written in 1988.

The SRFS designed a walking trail that was constructed to support the DOE wellness program. The safe, attractive trail is available to the several thousand workers in the Administrative Area.

The detailed mapping of SRP soils was completed during 1987. The Soil Conservation Service staff on site described soils on about 16,000 acres and completed the maps and manuscript for the Soil Survey Report scheduled for publication in 1989. The soil scientist also provided specific information needed at SRP for plans for forest management, environmental research, environmental assessment, and facility siting.

Forest Management Research

Units of SEFES are conducting numerous studies that are anticipated to improve the overall forest management activities conducted at SRP.

Techniques for producing seedlings for more successful reforestation are being tested at SRP.

- Trees grow better if their feeder roots develop a symbiotic relationship with mycorrhizal fungi to facilitate absorption of water and nutrients. If seedlings in the nursery beds are innoculated with superior, selected fungi, then field performance will be enhanced.

- Seedlings with more lateral roots show better field performance. Scientists use genetic selection to obtain families that have a higher percentage of lateral roots. Pruning the roots in the nursery bed also improves root morphology.

During 1987, 27 field studies varying in age from one to 12 years and involving over 20,000 trees of longleaf pine, loblolly pine, sweetgum, and black walnut were measured and the data analyzed. Results were published in 14 research articles.

Five new studies were established in 1987. Pines grown from seed from a new seed orchard of resistant trees are being exposed at SRP to the very abundant fusiform rust in a field test. Another study examines the differences in sweetgum grown from seed collected from swamp trees compared to sweetgum with upland parents.

In two large pine field studies, certain common nursery practices, i.e. seedbed densities and top pruning, are being studied to determine the effect of these practices on lateral root development and mycorrhizal development as they influence survival and early growth. Another study will measure what effect removing pine straw from the forest floor has on the growth and nutrition of the trees. If there are changes, the scientists will determine if fertilization can compensate for the nutrients removed. Also in 1987, USFS administrators from Washington, D.C., Atlanta, GA, and Asheville, NC, favorably reviewed the cooperative research/management program at SRP.

1987 HIGHLIGHTS

SRP Environmental Management Programs

- A comprehensive SRP Environmental Implementation Plan was completed and will be presented to Congress in 1988.
- A large and intensive environmental audit of SRP by EPA revealed no major problems.
- In response to SARA Title III, SRP conducted a workshop for local emergency planning commissions and provided surrounding counties with 8000 MSDSs for chemicals and chemical products.
- SRP received a five-year RCRA Part B Permit for hazardous waste facilities from South Carolina Department of Health and Environmental Control (SCDHEC). A task team will perform RCRA Facility Investigations for 65 solid waste management units covered under the EPA portion of permit. The permit includes radioactive wastes jointly regulated by EPA and DOE.
- An Environmental Awareness/Training Coordinator was designated to promote employee commitment to protecting the environment.
- The SRP NEPA group reviewed 289 SRP/SRL activities for early consideration of environmental factors.
- Two environmental impact statements were issued: DOE/EIS-0120 (protection of groundwater) and DOE/EIS-0121 (alternative cooling water systems).
- The National Environmental Research Park program conducted 15 research projects, sponsored a meeting on microorganisms in deep sedimentary rocks, and held a workshop on the ecology and conservation of storks.

SRL Environmental Management and Research Programs

Programs following the dispersion and effect of SRP pollutants included the following studies:

- Mass spectrometry methods were improved for measuring Pu in body fluids, the nonradioactive fission-product isotopes of Kr and Xe at ultra low levels in the environment, and very low concentrations of environmental tritium.
- Construction and testing began in 1988 of a prototype aqueous effluent tritium monitor that will detect 1 Ci/hr releases from 400-D Area within five minutes.
- Pre- and post-operational environmental surveys for the Vogtle 1 Nuclear Power Plant showed consistency with Vogtle measurements.
- Measurements of ^{14}C emissions from the stack of P Reactor were made in the fall of 1987, and a comprehensive report on measurements of ^{129}I in surface waters and groundwater was issued.

- Development of remote sensing techniques continued as a cost-effective means for environmental monitoring of large areas.

- Tomato, pepper, and pine plant exposures to tritium in a controlled environmental chamber indicated that the plants' intake of tritium is from tritiated water, probably by photosynthesis.

- An ongoing study of the microbiology of the deep subsurface has shown that microorganisms occur in great diversity and densities at depths down to 851 ft. The long-term goal of this study is to use active microorganisms to degrade organic contaminations.

- Sitewide seismic surveys were conducted to obtain a three-dimensional representation of the geologic structure beneath the SRP for use in environmental studies.

Programs to develop and implement procedures to comply with regulations and to conduct pollution abatement activities included the following:

- The emergency response system was upgraded by linking its tritium monitors to the WIND system computer and the VANTAGE data management system, by installing new instrumentation and data acquisition/transmission systems on meteorological monitoring towers, by installing a Geographic Information System in the Weather Center Analysis Laboratory, by adding computer hardware in the SRP Emergency Operating Center, and by adding two NaI detectors on the TRAC vehicle to identify (at a distance) localized land masses contaminated with radioactivity.

- A ^{137}Cs transport monitoring program showed that restart of L-Reactor had only a minor effect on offsite concentrations of ^{137}Cs.

- Dye tracers in L Lake showed that the construction of a new canal substantially increased the flow time to the middle of the lake and thereby slightly improved the production of L Reactor. Remote thermal imagery studies of SRP's cooling ponds are under way.

- A STABLE program (a study of the stable planetary boundary layer [SBL] of warm night air just above the ground) was initiated to study the potential dispersal of contaminants via SBL turbulence and diffusion.

- Calculations of offsite radiation doses with the EPA-approved CAAC Code (Clean Air Act Code) were performed to demonstrate NESHAPS compliance (National Emission Standards for Hazardous Air Pollutants).

Activities to meet permit or environmental impact statement requirements included the following:

- Monitoring and maintenance of L Lake showed that the lake had dissolved oxygen content and pH values, inshore vegetative macrophyte growth, and insect and fish populations similar to those in other southeastern reservoirs.

- A final report on the Comprehensive Cooling Water Study initiated in 1983 to evaluate environmental effects associated with SRP cooling water withdrawals and discharges shows that no large permanent adverse effects are presently occurring, and, in fact, some animal species are benefiting from the effects.

- An environmental impact statement on waste management activities for groundwater protection has progressed to the point that 26 environmental information documents (EIDs) encompassing the 77 waste sites have been completed, all indicating that the risk to human health and ecology is low.

- As a first step in characterizing 166 individual waste sites (a preclosure requirement) historical records were examined and for some sites recommendations were made that further investigative activities be initiated (i.e., soil gas surveys, ground-penetrating radar, soil sample, groundwater monitoring wells, and geologic borings).

- In a pilot study, 1,500 pounds of the solvents trichloroethylene and tetrachloroethylene contaminating SRP soils above the permanent water table were removed by in-situ vacuum extraction.

- The SRP Baseline Hydrogeologic Investigation for providing hydrogeologic data over the entire SRP site was completed. Water-level measurements from this program were used to construct an updated map of the head reversal across the Ellenton Formation that separates the Tuscaloosa and Congaree Formations beneath SRP.

- Development of a validated, documented regional three-dimensional flow model that simulates the groundwater flow system at SRP continued. Upon completion, the model will be used for assessing alternative uses of groundwater resources at SRP.

- SRL and SREL have begun tests in which the herbicide trifluralin (Treflan) — an effective plant root retardant — is incorporated in a slow-release matrix that could prevent plant roots from penetrating into radioactive and/or hazardous waste and transporting contaminants to the surface.

- Evaluations supporting the Alternative Cooling Water Systems Environmental Impact Statement indicated that the potential effects on wildlife of the proposed systems would be positive and that the temperatures discharged into site streams would be significantly reduced.

Savannah River Ecology Laboratory Programs

Biogeochemical ecology studies included the following:

- Continued research on the environmental chemistry of sodium tetraphenylboron (NaTPB), an organo-borate compound to be used in the new Defense Waste Processing Facility, included examination of the effects of various abiotic soil parameters on the degradation rate of TPB.

- Microcosm studies to investigate the potential remobilization of metals and nutrients from L-Lake sediments showed that under reducing conditions all labile manganese fractions were mobilized after 72 hr but only 6% of the labile iron was released after 75 hr. Other research indicates that elevated temperatures in the lake do not increase the accumulation of organic matter.

- Radiocesium deposits in Pond B reservoir are largely retained in sediments, with less than 0.6% of the total inventory being found in the biotic components of the reservoir.

- The solubility and movement of selenium, a potential contaminant of soils and groundwater that can be released from coal piles and runoff basins, are closely associated with the chemical species in solution, the major factors controlling the species being the redox potential and pH.

- The variance structure for mercury concentrations within a dominant fish species population, the dusky shiner *(Notropis cummingsae)*, in Upper Three Runs Creek was defined and will serve as a statistical benchmark.

Stress and wildlife ecology studies encompassed the following:

- Water quality studies of streams peripheral to the DWPF showed some increases in the concentrations of total suspended solids and in turbidity levels.

- Research indicates that aquatic turtles inhabiting seepage basins containing low concentrations of radioactive and nonradioactive contaminants possess significantly greater variation in DNA content in blood cells than turtles from a control population.

- A study of the biomass productivity of adults from six turtle species in freshwater wetlands showed large variations in the ratios of minimum to maximum plastron lengths and body masses.

- To replace a potentially lost foraging habitat for wood storks with the restart of L-Reactor, SRP created 14 hectares of ponds at the site of Kathwood Lake and stocked them with aquatic prey. The number of wood storks foraging at the ponds increased substantially in 1987.

- Examination of reproductive and demographic data on female white-tailed deer collected over a 20-year period shows that a relative consistency of the reproductive rate is maintained in both the swamp and upland habitats, but that those in the swamp have significantly lower fetal numbers.

Wetlands ecology research included the following:

- Studies of the dynamics of wetland forest species show that factors that modify the Savannah River floodplain hydrology, such as cooling water discharge from SRP reactors and upstream control of river flows, may effectively limit bald cypress and water tupelo regeneration in the floodplain forest because of the removal of safe sites for seed germination and seedling establishment.

- SREL and Louisiana State University are engaged in research to understand the complex relationships between flooding, wetland plants and wetland soils on the SRP site. This work will be used to delineate wetland boundaries as required by the Clean Water Act Section 404.

- NERP Project inventories of plant species categorized by the federal and South Carolina governments as threatened or rare are being used by DOE in the overall management of the SRP site and studies of the population dynamics of two of the federally listed plants have been initiated.

- SREL research to assess the effects of thermal stress and elevated nutrients on the zooplankton community development in L Lake has been expanded to include additional stations and feeding experiments to determine the food resources used by major zooplankton species.

- Revegetation of the highly disturbed wetland system in the Steel Creek floodplain and delta (17 years after thermal discharges ceased) is continuing, but it appears unlikely that the bald cypress and water tupelo, co-dominants of the undisturbed swamp forest, will regain dominance.

- Littoral/wetland vegetation planting project in L Lake during 1987 was successful in establishing diverse plant communities and wildlife habitat.

U.S. Forest Service Savannah River Forest Station Programs

- Timber cut during 1987 brought the federal government nearly $2.3 million for 27 million board feet.

- Pine seedlings were planted on over 2,200 acres during FY1987, including longleaf pines preferred by the endangered red cockaded woodpecker.

- The South Carolina Forestry Commission Nursery is under contract to DOE to use the most advanced technology identified by the U.S. Forest Service to grow seedlings for planting at SRP.

- Secondary roads were upgraded and seven acres of bare areas were planted with wildlife food plants.

- A buffer zone established for nesting Southern bald eagles was utilized.

- The translocation of a few red cockaded woodpeckers to SRP forests to counteract possible inbreeding in the small local population was successful.

- Steps were taken to control the population of wild hogs and beavers from locations where they were causing damage.

- A detailed mapping of SRP soils was completed for use in a soil survey report scheduled for publication in 1989.

- Techniques for producing seedlings for more successful reforestation were tested.

- The results of 27 field studies on over 20,000 trees were published in 14 research articles.

- Five new studies were initiated on the germination and growth of pines and sweetgum under varying conditions and nursery practices.

References

CAAC86 Radiation Shielding Information Center, 1986, "Code System for Implementation of Atmospheric Dispersion Assessment Required by the Clean Air Act," *Report CCC*-476, Oak Ridge, National Laboratory, Oak Ridge, TN.

Du84 Dukes, E.K., 1984, *The Savannah River Plant Environment*, Report DP-1642, Savannah River Laboratory, Aiken, SC.

Ec80 Eckerman, K.F., et al, June 1980, *Users Guide to GASPAR Code*, Report NUREG-0597, U.S. Nuclear Regulatory Commission.

ENV Envirodyne Engineers, Inc., *Handbook for Analytical Quality Control,* St. Louis, MO.

EPA75 U.S. Environmental Protection Agency, 1975, "National Interim Primary Drinking Water Regulations," Title 40, *Code of Federal Regulations*, Part 141, Washington, DC.

EPA82, EPA83 U.S. Environmental Protection Agency, 1982 and 1983, *Environmental Radiation Data*, Reports 31-33 (Sept., Dec. 1982 and Mar. 1983). USEPA 520/5-83, -015 and -016, Washington, DC.

EPA85 U.S. Environmental Protection Agency, 1985, "National Emission Standards for Hazardous Air Pollutants: Standards for Radioactivity," Title 40, *Code of Federal Regulations*, Part 61, Washington, DC.

EPA86 U.S.Environmental Protection Agency, 1986. "Proposed Rules," Title 40, *Code of Federal Regulations*, Part 141, Washington, DC.

EPA87 U.S. Environmental Protection Agency, 1987. "National Primary Drinking Water Regulations," Title 40, *Code of Federal Regulations*, Part 141, Washington, DC.

HPS80 Health Physics Society, 1980, "Upgrading Environmental Radiation Data," *Health Physics Society Committee Report HPSE*-1, prepared for the Office of Radiation Programs, U.S. Environmental Protection Agency, EPA 520/1-80-012, Washington, DC.

ICRP59 International Commission on Radiological Protection, 1959, *ICRP Publication* 2, (Oxford: Pergamon Press).

ICRP65 International Commission on Radiological Protection, 1965, "Principles of Environmental Monitoring Related to the Handling of Radioactive Materials," *ICRP Publication* 7, (New York: Pergamon Press).

ICRP68 International Commission on Radiological Protection, 1968, *ICRP Publication* 10, (Oxford: Pergamon Press).

ICRP77 International Commission on Radiological Protection, 1977, *ICRP Publication* 26, *Annals of the ICRP* 1(3).

ICRP79 International Commission on Radiological Protection, 1979, "Limits for Intake of Radionuclides by Workers," *ICRP Publication* 30, *Annals of the ICRP* **3**(4).

ICRP81 International Commission on Radiological Protection, 1981, "Limits of Inhalation of Radon Daughters by Workers," *ICRP Publication* 32, *Annals of the ICRP* **6**(1).

Ka87 Kantelo, M.V., 1987, "Summary of I-129 Measurements in Ground and Surface Waters," Report DPST-87-820, Savannah River Laboratory, Aiken, SC.

Ku87 Kurzeja, R.J.; Taylor, R.W.; Sharma, J.; Buckhalter, L.T. 1987, "Environmental Effects of the July 31, 1987 Tritium Release From the Savannah River Plant," *Report DP*-1758, Savannah River Laboratory, Aiken, SC.

Mar84 Marter, W.L., 1984, "Environmental Dosimetry for Normal Operation at SRP," *Report DPST* 83-270 Rev. 1, Aiken, SC.

Mi80 Michel, J.; Moore, W.S. 1980, "Ra-228 and Ra-226 Content of Groundwater in Fall line Aquifers," *Health Physics, Vol.* 38, pp. 663-671.

NCRP78 National Council on Radiation Protection and Measurements, 1971, "A Handbook of Radioactivity Measurements Procedures, *NCRP No.* 58, Washington DC.

NCRP79 National Council on Radiation Protection and Measurements, 1979, "Tritium in the Environment," *NCRP Report No.* 62, Washington, DC.

NCRP87a National Council on Radiation Protection and Measurements, 1987, "Ionizing Radiation Exposure of the Population of the United States,"*NCRP Report No.* 93, Washington, DC.

NCRP87b National Council on Radiation Protection and Measurements, 1987, "Recommendations on Limits for Ionizing Radiation Exposure," *NCRP Report No.* 91, Washington, DC.

NUREG84 Office of Nuclear Reactor Regulations, 1984, *Lower Limit of Detection: Definition and Elaboration of a Proposed Position for Radiological Effluent and Environmental Measurements*, prepared by the National Bureau of Standards for the Division of Systems Integration, Office of Nuclear Reactor Regulations, U.S Nuclear Regulatory Commission, NCR FIN B8615.

Sa77 Sagendorf, J.F.; Goll, J.T., 1977, *XOQ/DOQ Program for Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations*, U.S. Nuclear Regulatory Commission, Washington DC., NUREG-0324 (Draft).

SCDHEC81 South Carolina Department of Health and Environmental Control, 1981, *Water Classification Standards System for the State of South Carolina*, Columbia, SC.

SCDHEC85 South Carolina Department of Health and Environmental Control, 1985, "Savannah River Plant, Aiken, Allendale, and Barnwell Counties," NPDES Permit 0000175, Columbia, SC.

Si80 Simpson, D.B; McGill, R.L., 1980, *Users Manual for LADTAP II - A Computer Program for Calculating Radiation Exposure to Man from Routine Release of Nuclear Reactor Liquid Effluents*, Oak Ridge National Laboratory, Oak Ridge, TN, NUREG/CR-1276 (ORNL/NUREG/TOMC-1).

St83 Stone, J.A., 1983, "Technical Summary of Groundwater Quality Protection Program at Savannah River Plant," *Report DPST*-83-829, Volume II, Savannah River Laboratory, Aiken, SC.

Tu83 Turcotte, M.D.S., 1983, "Georgia Fishery Study: Implications for Dose Calculations," *Report DPST*-83-319, Rev.1, Savannah River Laboratory, Aiken, SC.

USNRC71 U.S. Nuclear Regulatory Commission, 1971, *Calculations of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50*, Appendix I, Regulatory Guide 1.109, Washington, DC.

USNRC73 U.S. Nuclear Regulatory Commission, 1973, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," *Regulatory Guide* 1.111, Washington, DC.

USNRC79 U.S. Nuclear Regulatory Commission, 1979, "NUREG 172," prepared by Battelle Pacific Northwest Laboratory for the U. S Nuclear Regulatory Commission.

Ze87 Zeigler, C.C.; Lawrimore, I.B.; Heath, E.M.; Till, J.E., 1986, *U.S. Department of Energy Savannah River Plant Environmental Report for 1986, Report DPSPU*-86-30-1, Savannah River Plant, Aiken, SC.

Glossary

activity. See radioactivity.

alpha particle. A positively charged particle emitted from the nucleus of an atom having the same charge and mass as that of a helium nucleus (2 protons, 2 neutrons).

atom. Smallest particle of an element capable of entering into a chemical reaction.

beta particle. A negatively charged particle emitted from the nucleus of an atom having a mass and charge equal to that of an electron.

biota. The animal and plant life of a particular region considered as a total ecological entity.

Central Savannah River Area (CSRA). A 13-county area in Georgia and South Carolina surrounding Augusta, GA. SRP is included in the CSRA.

contamination. The deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or personnel.

concentration. The amount of a specified substance or amount of radioactivity in a given volume or mass.

cosmic radiation. Radiation of many types with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.

counter. A general designation applied to radiation detection instruments or survey meters that detect and measure radiation.

curie (Ci). Unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are in common usage:

kilocurie (kCi) – 10^{3}Ci, one thousand curies; 3.7×10^{13} disintegrations per second.

millicurie (mCi) – 10^{-3} Ci, one-thousandth of a curie; 3.7×10^{7} disintegrations per second.

microcurie (μCi) – 10^{-6} Ci, one-millionth of a curie; 3.7×10^{4} disintegrations per second.

nanocurie (nCi) – 10^{-9} Ci, one-billionth of a curie; 37 disintegrations per second.

picocurie (pCi) – 10^{-12} Ci, one-trillionth of a curie; 0.037 disintegrations per second.

femtocurie (fCi) – 10^{-15} Ci, one-quadrillionth of a curie; 0.000037 disintegrations per second.

attocurie (aCi) – 10^{-18} Ci, one-quintillionth of a curie; 0.000000037 disintegrations per second.

decay, radioactive. The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.

Derived Concentration Guide (DCG). The standards applicable to concentrations of radionuclides in air and water as given in DOE Order 5480.1A.

diatoms. Unicellular or colonial algae of the class Bacillariophyceae, having siliceous cell walls with two overlapping, symmetrical parts. Diatoms represent the predominant periphyton (attached algae) in most waterbodies and have been shown to be reliable algal indicators of water quality.

diatometer. Diatom collection equipment consisting of a series of microscope slides in a holder.

disintegration, nuclear. A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus.

dose, absorbed. The amount of energy deposited by radiation in a given amount of material. The unit of absorbed dose is the rad.

dose commitment. The radiation dose received from major pathways of exposure, both internal and external, throughout a specified lifetime of an individual (generally 50 years).

dose equivalent. A modification to absorbed dose which expresses the biological effects of all radiations on a common scale. The unit of dose equivalent is the rem.

exposure. A measure of the ionization produced in air by x- or gamma radiation. The special unit of exposure is the roentgen (R).

gamma ray. High-energy short-wavelength electromagnetic radiation emitted from the nucleus. Gamma radiation frequently accompanies the emission of alpha or beta particles. Gamma rays are identical to x-rays except for the source of the emission.

half-life, radioactive. The time required for a given radionuclide to lose half of its activity by radioactive decay. Each nuclide has a unique half-life.

half-life, biological. The time required for a biological system, such as that of a human, to eliminate by natural processes half the amount of a substance (such as a radioactive material) that has entered it.

isotopes. Forms of an element having the same number of protons in their nuclei and differing in the number of neutrons.

milli-roentgen (mR). A measure of x- or gamma radiation.

minimum detectable concentration (MDC). The smallest amount or concentration of a radioelement that can be distinguished in a sample by a given measurement system in a preselected counting time at a given confidence level.

natural radiation. Radiation arising from cosmic sources and from naturally occurring radionuclides (such as radon) present in the human environment.

outfall. The place where a storm sewer or effluent line discharges to the environment.

part per million (ppm). Concentration unit equivalent to mg/L.

parts per billion (ppb). Concentration unit equivalent to ng/mL or µg/L.

person-rem. Collective dose to a population group. For example, a dose of one rem to 10 individuals results in a collective dose of 10 person-rem.

quality factor. The factor by which the absorbed dose (Rad) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than others.

rad. The unit of absorbed dose.

radioactivity. The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope.

radionuclide. A species of atom characterized by the constitution of its nucleus, i.e., by the numbers of neutrons and protons it contains.

rem. The unit of dose equivalent. Dose equivalent is frequently reported in units of millirem (mrem) which is one-thousandth of a rem.

sievert (Sv). International Standards Organization (S.I.) Unit for radiation dose, 1 Sv = 100 rem.

thermoluminescent dosimeters (TLDs). A device used to measure external radiation levels.

tritium (H-3). The hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low energy beta particle (0.0186 MeV max).

uncontrolled area. Any area to which access is not controlled for the purpose of protecting individuals from exposure to radiation and radioactive materials. The area beyond the boundary of the Savannah River Plant is an uncontrolled area.

watershed. The region draining into a river, river system or body of water.

worldwide fallout. Radioactive debris from atmospheric weapons tests that is either airborne and cycling around the earth or has been deposited on the earth's surface.

Appendix A: Listing of Environmental Monitoring Reports

ONSITE REPORTS

Reports of the routine environmental monitoring program at SRP have been prepared periodically since before SRP startup. The monitoring report numbering system and titles have been changed several times over the years to reflect the evolving progress in the concepts of environmental monitoring. The amount of detailed information contained in the reports also varies from time to time and probably reflects the relative importance and emphasis given to topics by different authors.

Except for July–December 1953, reports were issued semi-annually from 1951 to 1962 and annually beginning in 1963. Attempts to find a report for July–December 1953 have been unsuccessful. The onsite report was discontinued in 1985 when the onsite and offsite reports were merged into a single publication.

Some of the monitoring reports originally contained secret information, primarily radioactive release values that could be related to production rates. The secret information in these reports was deleted in the mid-1970s and a deleted version (DEL) of the report was issued.

Listed below are onsite environmental reports since 1951.

Number	Period	Title
DP27	Jun 1951–Jan 1953	Natural Radioactivity Content of the Savannah River Plant
DPSPU 54-11-12	Jan–Jul 1953	Works Technical Department Data Record, Health Physics Site Survey Data
No report	Jul–Dec 1953	
DP92	Jan–Jul 1954	Radioactivity in the Environment of the Savannah River Plant
DPSP 55-25-34	Jul–Dec 1954	Semi-Annual Progress Report-Regional
DPSP 56-25-13	Jan–Jun 1955	
DPSP 56-25-54 (DEL)	Jul–Dec 1955	Health Physics Regional Monitoring
DPSP 56-25-4 (DEL)	Jan–Jun 1956	
DPSP 57-25-15 (DEL)	Jul–Dec 1956	
DPSP 57-25-43 (DEL)	Jan–Jun 1957	
DPSP 58-25-17 (DEL)	Jul–Dec 1957	
DPSP 58-25-38 (DEL)	Jan–Jun 1958	
DPSPU 59-11-23	Jul–Dec 1958	
DPSPU 59-11-30	Jan–Jun 1959	
DPSPU 60-11-9	Jul–Dec 1959	
DPSP 60-25-26 (DEL)	Jan–Jun 1960	
DPSP 61-25-4 (DEL)	Jul–Dec 1960	
DPSP 62-25-2 (DEL)	Jan–Jun 1961	
DPSP 62-25-9 (DEL)	Jul–Dec 1961	
DPSP 63-25-3 (DEL)	Jan–Jun 1962	
DPSP 63-25-10 (DEL)	Jul–Dec 1962	
DPSPU 64-11-12	Jan–Dec 1963	Environmental Monitoring at the Savannah River Plant
DPST 65-302	Jan–Dec 1964	
DPST 66-302	Jan–Dec 1965	
DPST 67-302	Jan–Dec 1966	

Number	Period	Title
DPST 68-302	Jan–Dec 1967	
DPST 69-302	Jan–Dec 1968	
DPST 70-302	Jan–Dec 1969	
DPST 71-302	Jan–Dec 1970	
DPSPU 72-302	Jan–Dec 1971	
DPSPU 73-302	Jan–Dec 1972	
DPSPU 74-302	Jan–Dec 1973	
DPSPU 75-302	Jan–Dec 1974	
DPSPU 76-302	Jan–Dec 1975	
DPSPU 77-302	Jan–Dec 1976	
DPSPU 78-302	Jan–Dec 1977	
DPSPU 79-302	Jan–Dec 1978	
DPSPU 80-302	Jan–Dec 1979	
DPSPU 81-302	Jan–Dec 1980	
DPSPU 82-302	Jan–Dec 1981	
DPSPU 83-302	Jan–Dec 1982	
DPSPU 84-302	Jan–Dec 1983	
DPSPU 85-302	Jan–Dec 1984	

DEL–reissue of reports with secret information deleted.

OFFSITE "PUBLIC" REPORTS

Results of the environmental monitoring program that affected the offsite environment have been reported to the public since 1959. These reports contained data from the site boundary and beyond. The offsite report was discontinued in 1985 when the onsite and offsite reports were merged into a single publication. A listing of the offsite reports follows:

Number	Period	Title
No document number	Jan–Dec 1959	The Effect of the Savannah River Plant on Environmental Radioactivity
	Jan–Mar 1960	
	Apr–Jun 1960	
	Jul–Sep 1960	
	Oct–Dec 1960	
	Jan–Mar 1961	
	Apr–Jun 1961	
	Jul–Sep 1961	
DPSPU 62-30-11	Oct–Dec 1961	
DPSPU 62-30-24	Jan–Jun 1962	
DPSPU 63-30-12	Jul–Dec 1962	
DPSPU 63-30-1	Jan–Jun 1963	
DPSPU 64-30-1	Jul–Dec 1963	
DPSPU 64-30-2	Jan–Jun 1964	
DPSPU 65-30-1	Jul–Dec 1964	
DPST 65-30-2	Jan–Jun 1965	
DPST 66-30-1	Jul–Dec 1965	
DPST 66-30-2	Jan–Jun 1966	

Number	Period	Title
DPST 67-30-1	Jul–Dec 1966	
DPST 67-30-2	Jan–Jun 1967	
DPST 68-30-1	Jul–Dec 1967	
DPST 68-30-2	Jan–Jun 1968	
DPST 69-30-1	Jul–Dec 1968	
DPST 69-30-2	Jan–Jun 1969	
DPST 70-30-1	Jul–Dec 1969	
DPST 70-30-2	Jan–Jun 1970	
DPST 71-30-1	Jul–Dec 1970	
DPST 71-30-16	Jan–Jun 1971	
DPSPU 72-30-1	Jan–Dec 1971	Environmental Monitoring in the Vicinity of the Savannah River Plant
DPSPU 73-30-1	Jan–Dec 1972	
DPSPU 74-30-1	Jan–Dec 1973	
DPSPU 75-30-1	Jan–Dec 1974	
DPSPU 76-30-1	Jan–Dec 1975	
DPSPU 77-30-1	Jan–Dec 1976	
DPSPU 78-30-1	Jan–Dec 1977	
DPSPU 79-30-1	Jan–Dec 1978	
DPSPU 80-30-1	Jan–Dec 1979	
DPSPU 81-30-1	Jan–Dec 1980	
DPSPU 82-30-1	Jan–Dec 1981	
DPSPU 83-30-1	Jan–Dec 1982	
DPSPU 84-30-1	Jan–Dec 1983	
DPSPU 85-30-1	Jan–Dec 1984	Savannah River Plant Environmental Report

ENVIRONMENTAL REPORTS (COMBINED ONSITE AND OFFSITE)

In 1985, the onsite and offsite environmental monitoring reports were merged into a single publication. A listing of these reports follows:

Number	Period	Title
DPSPU 86-30-1	Jan–Dec 1985	Savannah River Plant Environmental Report
DPSPU 87-30-1	Jan–Dec 1986	

Appendix B: Groundwater Monitoring Sites

A-AREA METALS BURNING PIT

The **A-Area Metals Burning Pit (731-4A)**, placed in service about 1960, is west of Road D, about halfway between A Area and Road 2 (Fig. 4-22, Vol. II). The materials deposited at this site consisted mainly of lithium-aluminum alloy, aluminum pieces, plastic pipe, metal drums, and other metal scraps. They were deposited in open piles and burned periodically. In 1974, the solid materials remaining in the pit were covered with soil, and the site was regraded.

The basin is monitored by the four wells of the ABP series. The tops of the screens in wells ABP 1A, 2A, and 4 are below the water table, making interpretation of the upgradient and downgradient positions of the wells difficult.

ACID/CAUSTIC BASINS

The Acid/Caustic Basins, unlined earthen depressions approximately 15 m by 15 m by 2 m deep, were used for disposal of dilute sulfuric acid and sodium hydroxide solutions employed to regenerate ion exchange units in the water purification processes at the reactor and separations areas. Other wastes discharged to the basins included water rinses from the ion exchange units, steam condensate, and any rain that collected in the storage tanks spill containment enclosures.

The basins were constructed between 1952 and 1954. The R-Area basin was abandoned in 1964; the L-Area basin was abandoned in 1968; the other basins remained in service until the in-process neutralization facilities became operational in 1982. The basins are uncovered and abandoned in place. Most of the basins are dry during dry weather and contain up to approximately 1 m of water during periods of prolonged precipitation.

The **F-Area Acid/Caustic Basin (904-74G)** is east of F Area, on a slope that leads to an unnamed tributary of Upper Three Runs Creek (Fig. 4-4, Vol. II). The site is monitored by the four wells of the FAC series. Wells FAC 1, 2, and 3 are near the basin, with well FAC 3 in an upgradient position, well FAC 2 in a sidegradient position, and well FAC 1 in a downgradient position. Well FAC 4 is sidegradient and at a greater distance from the basin than the other wells.

The **K-Area Acid/Caustic Basin (904-80G)** is on the northeast side of K Area a few hundred meters from a tributary of Pen Branch (Fig. 4-18, Vol. II). The basin is monitored by the four wells of the KAC series. Wells KAC 1, 2, and 3 are near the basin, with well KAC 3 in an upgradient position, well KAC 2 in a sidegradient position, and well KAC 1 in a downgradient position. Well KAC 4 is a greater distance from the basin than the other wells and is screened below the water table.

The **L-Area Acid/Caustic Basin (904-79G)** is southeast of L Area adjacent to the L-Area Oil and Chemical Basin (904-83G) on a slope leading to Steel Creek (Fig. 4-19, Vol. II). The site is monitored by the four wells of the LAC series. Wells LAC 1, 3, and 4 are downgradient of the basin, and well LAC 2 is upgradient of the basin.

The **P-Area Acid/Caustic Basin (904-78G)** is northeast of P Area and Road F on a slope that leads to a tributary of Par Pond (Fig. 4-20, Vol. II). The site is monitored by the four wells in the PAC series. Wells PAC 3 and 4 are near the basin, with PAC 3 in a downgradient position and PAC 4 in an upgradient position. Wells PAC 1 and 2 are a greater distance from the basin, with PAC 1 in an upgradient position and PAC 2 in a sidegradient position.

The **R-Area Acid/Caustic Basin (904-77G)** is south of R Area, just south of Road G. The site is monitored by the four wells of the RAC series. Well RAC 1 is upgradient of the basin, and wells RAC 2, 3, and 4 are downgradient of the basin.

BACKGROUND WELLS

The **A-Area Background Well Near the Firing Range**, a single well (ABW 1) installed to serve as a background well for A Area, is located approximately 700 m northeast of the SRL Seepage Basins. The screen in this well was placed below the water table in the Congaree Aquifer. The well is downgradient from the SRL Seepage Basins and the A-1 outfall.

The **Background Well Near Hawthorne Fire Tower** is in the north-central part of SRP between Upper Three Runs Creek and Tinker Creek. Well GBW 1 was installed at this remote site to provide background groundwater quality information.

BURNING/RUBBLE PITS

The Burning/Rubble Pits were shallow excavations, commonly 3 m deep, where burnable waste was collected continuously beginning in 1951. Waste collected included paper, plastics, wood, rubber, rags, cardboard, oil, degreasers, and drummed organic solvents. The collected waste was then burned, usually monthly. Disposal of chemically contaminated oils was not permitted at the burning pits.

When burning of waste in the pits was discontinued in October 1973, a layer of soil was placed over the remaining burning pit waste, and the pits were opened to receive nonsalvageable rubble such as concrete, bricks, tile, asphalt, plastics, wallboard, rubber, and nonreturnable empty drums. As each pit reached its capacity, it was closed and backfilled with soil to grade. All Burning/Rubble Pits were inactive by 1981, and all are covered except for Pit 131-1R in R Area, which was not backfilled.

The **A-Area Burning/Rubble Pits (731-A and 731-1A)** are west of Road D to the north of the A-Area Metals Burning Pit (Fig. 4-22, Vol. II). The site is monitored by the four wells of the ARP series. Well ARP 3 is upgradient from the pits, well ARP 1A is downgradient, and wells ARP 2 and 4 are sidegradient.

The **C-Area Burning/Rubble Pit (131-C)** is approximately 300 m west of C Area (Fig. 4-17, Vol. II). The site is monitored by the four wells of the CRP series. Relative to the pit, well CRP 1 is upgradient, well CRP 3 is downgradient, and wells CRP 2 and 4 are both sidegradient. Elevated conductivity and pH levels in well CRP 3 indicate that this well has been affected by leaching of the well grout.

The **Central Shops Burning/Rubble Pits (631-1G and 631-5G)** are about 500 m north of Central Shops between Road C and Road 5 (Fig. 4-24, Vol. II). The site is monitored by the four wells of the CSR series. All of the wells are either upgradient or sidegradient from the site.

The **D-Area Burning/Rubble Pits (431-D and 431-1D)** are approximately 300 m west of D Area (Fig. 4-26, Vol. II). The site is monitored by the four wells of the DBP series. Wells DBP 1 and 3 are upgradient, well DBP 4 is sidegradient, and well DBP 2 is downgradient.

The **F-Area Burning/Rubble Pits (231-F and 231-1F)** are northwest of the intersection of Road C and the F-Area entrance road (Fig. 4-5, Vol. II). The site is monitored by the four wells of the FBP series. Well FBP 2A is downgradient, well FBP 3A is sidegradient, and wells FBP 1A and 4 are upgradient of the basin. Upgradient well FBP 1A may be affected by the old pipeline to the F-Area Seepage Basins.

The **K-Area Burning/Rubble Pit (131-K)** is approximately 60 m northeast of K Area (Fig. 4-18, Vol. II). The site is monitored by the four wells of the KRP series. Well KRP 2 is upgradient of the basin, wells KRP 1 and 3 are sidegradient, and well KRP 4 is downgradient. KRP 4 is deeper than the other wells, which may result in a lower water-level elevation in this well.

The **L-Area Burning/Rubble Pit (131-L)** is northwest of L Area, between Road 7-1 and the steam-line road (Fig. 4-19, Vol. II). The site is monitored by the four wells of the LRP series. Relative to the pit, well LRP 2 is upgradient, well LRP 1 is sidegradient, and wells LRP 3 and 4 are downgradient.

The **P-Area Burning/Rubble Pit (131-P)** is west of P Area, south of Road C-7 (Fig. 4-20, Vol. II). The site is monitored by the four wells of the PRP series. Well PRP 4 is upgradient of the pit, wells PRP 2 and 3 are sidegradient, and well PRP 1A is downgradient.

The **R-Area Burning/Rubble Pits (131-R and 131-1R)** are southeast of R Area, southeast of Road F-8. The site is monitored by the four wells of the RRP series. Relative to the pits, well RRP 1 is upgradient, well RRP 2 is sidegradient, and wells RRP 3 and 4 are downgradient.

CHEMICALS, METALS, AND PESTICIDES (CMP) BURIAL PITS

The **Chemicals, Metals, and Pesticides Burial Pits (080-17G, -17.1G, -18G, -18.1G, -18.2G, -18.3G, and -19G)** are southwest of Road C at the top of a hill near the head of Pen Branch (Fig. 4-25, Vol. II). The CMP Pits were used to dispose of waste from 1971

through 1979. The waste consisted of drummed oil and organic solvents, as well as small amounts of pesticides and toxic metals. Detailed inventories of the wastes disposed of in each pit are not available. In 1984, the pits were completely excavated, backfilled, and capped. During excavation, much of the liquid waste was recovered in drums.

The site is monitored by the 20 wells of the CMP series. Wells CMP 8, 9C, 10, 11, 12, 13, 14C, 15C, and 16C monitor the water table. The remaining wells monitor lower aquifers. The water table flows away from the pits on three sides so that all of the wells are downgradient except CMP 10, which is sidegradient or upgradient.

COAL PILE RUNOFF CONTAINMENT BASINS

Coal has been stored in open piles at seven locations at SRP. The coal is generally moderate-to-low sulfur coal (1–2% S). Surface runoff from these piles is directed into coal pile runoff containment basins via gravity flow ditches and sewers. Work on the A and D basins was completed in October 1978, and the F, C, K, P, and H basins were completed in March 1981. All of the basins are active except for those in C and F areas. The C- and F-Area basins still collect rainwater, but no coal remains at either area.

The **A-Area Coal Pile Runoff Containment Basin (788-3A)** is east of Road D and southeast of the A-Area coal storage facility (Fig. 4-22, Vol. II). The site is monitored by the four wells of the ACB series. The horizontal gradients in the area are very low, making the terms *upgradient* and *downgradient* inappropriate at this site.

The **C-Area Coal Pile Runoff Containment Basin (189-C)** is southeast of C Area approximately 200 m southeast of the C-Area coal storage facility (Fig. 4-17, Vol. II). The C-Area coal pile was removed in 1985. The basin still receives rainfall runoff from the coal pile area. The site is monitored by the four wells of the CCB series. Relative to the basin, well CCB 4 is upgradient, wells CCB 1 and 3 are sidegradient, and well CCB 2 is downgradient.

The **D-Area Coal Pile Runoff Containment Basin (489-D)** is south of D Area (Fig. 4-26, Vol. II) and is monitored by the wells of the DCB series. Well DCB 2A is upgradient, well DCB 3A is sidegradient, and wells DCB 4A and 5A are downgradient. Well DCB 1A is sidegradient to the coal pile runoff containment Basin but is directly downgradient of the coal pile itself. Seven new wells (DCB 6 through 12) were installed in the area in August 1987 for a SRL research project.

The **F-Area Coal Pile Runoff Containment Basin (289-F)** is southeast of F Area (Fig. 4-6, Vol. II). The coal pile in F Area was removed in 1985, and the basin, although no longer in use, still receives rainfall runoff from the coal pile area. The basin is monitored by the four wells of the FCB series. Wells FCB 1 and 2 are upgradient of the basin, FCB 4 is sidegradient, and FCB 3 is downgradient. Elevated conductivity and pH levels in well FCB 1 indicate this well has been affected by leaching of the well grout.

The **H-Area Coal Pile Runoff Containment Basin (289-H)** is east of H Area (Fig. 4-11, Vol. II). The site is monitored by the four wells of the HCB series. Relative to the basin, well HCB 3 is upgradient, well HCB 4 is downgradient, and wells HCB 1 and 2 are sidegradient.

The **K-Area Coal Pile Runoff Containment Basin (189-K)** is southwest of K Area, between the ash disposal basin and the reactor seepage basin (Fig. 4-18, Vol. II). The site is monitored by the four wells of the KCB series. Relative to the basin, well KCB 1 is upgradient, wells KCB 2 and 4 are sidegradient, and well KCB 3 is downgradient.

The **P-Area Coal Pile Runoff Containment Basin (189-P)** is southeast of the coal pile and south of P Area (Fig. 4-20, Vol. II). The site is monitored by the four wells of the PCB series. Horizontal groundwater gradients in this area are low, making interpretation of groundwater flow direction difficult, but well PCB 1A appears to be upgradient, wells PCB 2A and 4A sidegradient, and well PCB 3A downgradient.

D-AREA OIL DISPOSAL BASIN

The **D-Area Oil Disposal Basin (631-G)** is north of D Area between Roads A-4.4 and A-4.5 (Fig. 4-27, Vol. II). The basin was constructed in 1952 and began receiving waste oil products from D Area that were unacceptable for incineration in the powerhouse boilers. These waste oils may have contained hydrogen sulfide, chlorinated organics, or other chemicals. In 1975, the oil basin was removed from service and backfilled with soil. The basin is monitored by the four wells of the DOB series. The

horizontal gradient in this area is very low, and at least two major flow direction reversals have occurred since mid-1984. The flat water table and resultant fluctuations in flow direction make characterization of the hydrologic regime difficult.

DISASSEMBLY BASINS

The disassembly basins were constructed adjacent to each reactor at SRP for storing irradiated assemblies prior to their shipment to the separations areas. The disassembly basins are concrete-lined tanks containing 10 m of water. The irradiated assemblies are rinsed, but some radioactivity is transferred from the irradiated assemblies to the water in the basins. Sand filters are used to maintain the clarity of the disassembly basin water and remove radioactive particulates. The basin water is circulated through deionizers to reduce ion concentrations. The deionizers are regenerated, then the basin water is purged through the deionizers and replaced with clean water. The basin water is periodically purged to reduce radiation exposure to operating personnel from the accumulation of tritium in the basin.

Wells CDB 1 and 2 monitor the **C-Area Disassembly Basin** (Fig. 4-17, Vol. II). There is insufficient information to determine the horizontal groundwater gradient at this site.

Wells KDB 1, 2, and 3 monitor the **K-Area Disassembly Basin** (Fig. 4-18, Vol. II). Relative to the basin well KDB 2 is downgradient, and wells KDB 1 and 3 are sidegradient.

Wells LDB 1 and 2 monitor the **L-Area Disassembly Basin** (Fig. 4-19, Vol. II). There is insufficient information to determine the horizontal groundwater gradient at this site.

Wells PDB 2 and 3 monitor the **P-Area Disassembly Basin** (Fig. 4-20, Vol. II). Both wells are screened below the water table, making interpretation of the site hydrology difficult.

F-AREA A LINE AND CANYON BUILDING

The **F-Area Canyon Building (221-F)** is in the center of F Area. The **A-Line Uranium Recovery Facility (221-1F)** is east of the south end of the Canyon Building (Fig. 4-3, Vol. II). At the A-Line Building, uranium is processed in the form of uranyl nitrate. At the Canyon Building, target rods from the reactors are dissolved using nitric acid, and the desired radionuclides are separated from the other fission products.

The groundwater at these buildings is monitored by the two wells of the FAL series and six wells of the FCA series. Eight other shallow wells of the FCA series, which are usually dry, monitor the Canyon Building base slab. The results of this monitoring are reported in Chapter 8. These buildings are near the groundwater divide between Upper Three Runs Creek and Four Mile Creek. Horizontal gradients in the water table are low, making it difficult to determine which wells are upgradient or downgradient.

F-AREA SEEPAGE BASINS

The **F-Area Seepage Basins (904-41G, -42G, and -43G)** are on either side of Road C-4, south of Road C (Fig. 4-7, Vol. II). Since 1955, the basins have received wastewater from F Area containing low-level radioactivity and chemicals, including nitric acid, mercury, and sodium hydroxide. They are currently operating under Resource Conservation and Recovery Act (RCRA) interim status. A RCRA Part B application was filed with the South Carolina Department of Health and Environmental Control (SCDHEC) on February 6, 1985.

It is believed that two unconfined aquifers are underneath the F-Area Seepage Basins. The first is a perched groundwater table 3 to 78 m below the ground surface. The second is the normal water table, which is 18 to 20 m below the ground surface. Both of these unconfined aquifers discharge into Four Mile Creek about 500 m to the southeast.

Three other aquifers are monitored under the F-Area Seepage Basins. The McBean Aquifer is between 40 and 50 m mean sea level (msl), the Upper Congaree Aquifer is between 25 and 35 m msl, and the Lower Congaree Aquifer is between 8 and 18 m msl. The vertical groundwater gradient is downward from the water table to the Upper Congaree Aquifer. The vertical gradient is upward to neutral between the Upper Congaree Aquifer and the Lower Congaree Aquifer. The McBean Aquifer flows south toward Four Mile Creek. The Upper and Lower Congaree Aquifers flow west toward Upper Three Runs Creek.

The F-Area Seepage Basins are monitored by nine wells of the F series and 48 wells of the FSB series. During 1987, 31 wells in the FSB 88 through FSB

110 clusters were installed. Well F 10 is the only currently active well monitoring the perched water table. The remaining wells of the F series and the wells of the FSB series with a "D" or no letter designator after the well cluster number are screened in the water table. The water table is above the tan clay in the upper portion of the Dry Branch Formation and the Tobacco Road Formation. Between the tan clay and the green clay in the lower portion of the Dry Branch Formation and the Santee Formation are screened FSB wells with a "C" letter designator. Below the green clay in the upper portion of the Congaree Formation are screened wells FSB 76B, 78B, 79B, 87B, 96A, 97A, 98A, 99A, 100A, and 101A. Wells FSB 76A, 78A, 79A, and 87A are screened in the lower portion of the Congaree Formation.

F-AREA TANK FARM

The **F-Area Tank Farm**, at the southwest edge of F Area (Fig. 4-9, Vol. II), comprises 22 subsurface tanks containing aqueous radioactive wastes. These wastes consist of sludges, supernatant liquid of varying salt concentrations, and salt cake. The sludges are composed primarily of a mixture of oxides and hydroxides of manganese, iron, and aluminum and a small amount of uranium, plutonium, and mercury, with essentially all of the fission products of original irradiated fuel except cesium. The supernate is primarily a solution of sodium nitrate, sodium nitrite, sodium hydroxide, sodium aluminate, and all of the fission products including the major cesium isotopes. The solution is put in the tank farm evaporators, then stored in cool tanks to precipitate the sodium nitrate and sodium nitrite. This precipitate forms the salt cake. In 1961, Tank 8 was overfilled, causing soil contamination and subsequent groundwater contamination.

The site is monitored by the 27 wells of the FTF series. The tank farm is located on the groundwater divide between Upper Three Runs Creek and Four Mile Creek. The horizontal flow direction of the water table under most of the site is to the south, but in the north part of the site the flow is to the northwest.

F-AREA NAVAL FUELS FACILITY

The **Naval Fuels Facility (247-F)** began operating in 1986 (Fig. 4-3, Vol. II). The site is monitored by the five wells of the NBG series, which are placed between the Naval Fuel Facility and the other buildings in F Area. Because the wells are almost in a line, it is difficult to interpret the local groundwater flow direction, but it appears to be toward the east.

FIRE DEPARTMENT TRAINING FACILITY

The **Fire Department Training Facility (904-113G)** also known as the Central Shops Burnable Oil Basin, is at the southeast end of the Central Shops Area (Fig. 4-24), about 150 m north of the Ford Building (690-G). The site was used from 1979 to 1982 by the SRP Fire Department to train personnel to use firefighting equipment. The site is monitored by the two wells of the CSO series. CSO 1 is sidegradient of the basin, and CSO 2 is upgradient.

FORD BUILDING SEEPAGE BASIN

The **Ford Building Seepage Basin (904-91G)** is in the Central Shops Area (Fig. 4-24, Vol. II), approximately 30 m from the Ford Building (690-G). The basin received very low-level radioactive wastewaters from Ford Building operations (repairing heat exchangers) from 1964 to January 1984. The basin is monitored by the three wells of the HXB series. All of the HXB wells are screened below the water table. Relative to the basin, wells HXB 2 and 3 are upgradient, and well HXB 1 is sidegradient.

H-AREA CANYON BUILDING

The **H-Area Canyon Building (221-H)** is in the north-central part of the area (Fig. 4-10, Vol. II). At the building, target rods from the reactors are dissolved using nitric acid, and the desired radionuclides are separated from waste products.

The groundwater is monitored by the four wells of the HCA series. The 25 wells of the HCC series are dry wells monitoring the edges of the building base slab. The horizontal gradient in the groundwater in this area is low, but well HCA 2 is slightly upgradient compared to the other wells.

H-AREA RETENTION BASINS

The **H-Area Retention Basins (281-3H and 281-8H)** are southeast of the intersection of Road 4 and Road E (Fig. 4-12, Vol. II). A small, unlined earthen retention basin (281-3H) was used from 1955 to 1973 to provide temporary emergency storage for radioactively contaminated cooling water from the chemical separations process. The water contained radionu-

clides and possibly trace quantities of chemicals. A larger, rubber-lined retention basin (281-8H) replaced the original basin in 1973 and is still in use. The basins are adjacent to each other, and all of the elevated contaminant levels in the groundwater are probably due to the unlined 281-3H basin.

The basins are monitored by the six wells of the HR3 and HR8 series. Wells HR3 11 and 13 are upgradient of the basins and wells HR8 14 and 11 are sidegradient of the new basin, but HR8 14 is downgradient of the old basin, and wells HR8 12 and 13 are downgradient of both basins.

H-AREA SEEPAGE BASINS

The **H-Area Seepage Basins (904-44G, -45G, -46G, and -56G)** are southwest of H Area, southwest of the intersection of Road E and Road 4 (Fig. 4-13, Vol. II). Starting in 1955 the basins received wastewater from the H-Separations Area containing low-level radioactivity and chemicals, including nitric acid, mercury, chromium, and sodium hydroxide. Basins 1, 2, and 4 are currently operating under RCRA interim status, and a Part B application was filed on February 6, 1985. Basin 3 has been inactive since 1962.

At the H-Area Seepage Basins, the water table is 5 to 8 m below the ground surface and outcrops adjacent to Four Mile Creek 100 to 400 m from the basins. Below the water table are the McBean, Upper Congaree, and Lower Congaree Aquifers. Vertical groundwater gradients are predominantly downward from the water table to the Lower Congaree Aquifer. The McBean Aquifer flows south toward Four Mile Creek. The Upper Congaree Aquifer flows toward Upper Three Runs Creek to the west.

The H-Area Seepage Basins are monitored by the 28 wells of the HSB series and 16 wells of the H series. The H series wells and wells HSB 65, 65C, 66, 67, 68, 69, 70, 71, 83D, 84D, 85C, 86C, and 86D monitor the water table, which is above the tan clay in the upper portion of the Dry Branch Formation and the Tobacco Road Formation. Below the tan clay in the Dry Branch Formation are screened wells HSB 68C, 83C, and 84C. In the Santee Formation above the green clay are screened HSB wells with "B" designators. The HSE wells with "A" designators are screened in the upper portion of the Congaree Formation below the green clay.

H-AREA TANK FARM

The **H-Area Tank Farm**, at the south end of H Area (Fig. 4-14, Vol. II), comprises 29 subsurface tanks containing aqueous radioactive wastes. These wastes consist of sludges, supernatant liquid of varying salt concentrations, and salt cake. The sludges are composed primarily of a mixture of oxides and hydroxides of manganese, iron, and aluminum and a small amount of uranium, plutonium, and mercury, with essentially all of the fission products of original irradiated fuel except cesium, which remains in the supernate. The supernate is primarily a solution of sodium nitrate, sodium nitrite, sodium hydroxide, sodium aluminate, and all of the fission products including the major cesium isotopes. The solution is put in the tank farm evaporators, then stored in cool tanks to precipitate the sodium nitrate and sodium nitrite. This precipitate forms the salt cake. Tank 16 was known to leak prior to the removal of the waste from that tank in 1972. A spill occurred at Tank 13 in 1984.

The site is monitored by the 32 wells of the HTF series. The site is located on the groundwater divide between Upper Three Runs Creek and Four Mile Creek. Well 241-H is a 1.8-m-deep well between Tanks 9 and 11.

HAZARDOUS WASTE STORAGE FACILITY AT CENTRAL SHOPS

The **Hazardous Waste Storage Facility (709-G)** is west of the Central Shops Area (Fig. 4-24, Vol. II). The wastes are stored inside the building in drums placed on diked concrete floors designed to contain liquid spills. The facility is inspected routinely for container leakage. The site is monitored by the two groundwater monitoring wells of the HWS series. Relative to the building, well HWS 2 is upgradient, and well HWS 1A is sidegradient.

HYDROFLUORIC ACID SPILL AREA

The **Hydrofluoric Acid Spill Area (631-4G)** is at the south end of the Central Shops Area, just north of the rail line to C Area (Fig. 4-24, Vol. II). It is uncertain whether a spill occurred at this site or contaminated soil or containers were buried here. The spill or burial occurred prior to 1970. This site is monitored by the four wells of the CSA series. Relative to the site, well CSA 2 is upgradient, wells CSA 1 and 3 are sidegradient, and well CSA 4 is downgradient.

K-AREA ASH BASIN

The **K-Area Ash Basin (188-K)** is southwest of K Area, about 100 m south of the coal pile (Fig. 4-18, Vol. II). The basin receives ash sluice water from the powerhouse in K Area and has been in service since 1951. The site is monitored by the four wells of the KAB series. Well KAB 2 is upgradient of the basin, wells KAB 1 and 3 are sidegradient, and well KAB 4 is downgradient. Wells KAB 1, 2, and 4 are downgradient of the K-Area coal pile.

L-AREA OIL AND CHEMICAL BASIN

The **L-Area Oil and Chemical Basin (904-83G)** is southeast of L Area (Fig. 4-19, Vol. II), between the reactor seepage basin (904-64G) and the acid/caustic basin (904-79G). From 1961 to 1979, the basin received small quantities of radioactive oil and chemical waste from throughout the plant. The purpose of the facility was to dispose of small volumes of wastes that were not appropriate for discharge to effluent streams, regular seepage basins, or the 200-Area waste management system. The waste came primarily from the reactor areas. The basin has been inactive since 1979. The vegetation inside the basin perimeter fence is removed and the area kept bare.

The basin is monitored by the four wells of the LCO series. Relative to the basin, wells LCO 2 and 3 are upgradient, and wells LCO 1 and 4 are downgradient. Wells LCO 3 and LCO 4 are downgradient of the nearby L-Area Acid/Caustic Basin and may be affected by constituents released there.

M-AREA GROUNDWATER PLUME DEFINITION WELLS

Groundwater beneath A and M Areas is contaminated with halogenated organics as a result of past operations. Since the discovery of the contamination in June 1981, significant progress has been made in assessing the extent of the contamination and in establishing a remediation program. The inventory of organics in the groundwater is estimated to be 450,000 lb with peak concentrations of 300 mg/L.

A Groundwater Remediation Program is under way to clean up the groundwater contamination. In February 1983, a 20-gal/min air stripper began operation. In January 1984, two recovery wells were installed along with a 50-gal/min air stripper. A full-scale recovery system, which replaced the previous air strippers in April 1985, consists of 11 recovery wells and a 400-gal/min air stripper. Through December 1987, 143,000 lb of organics have been removed from 482,000,000 gal of water.

Besides the groundwater monitoring in A and M areas conducted for the waste-site monitoring wells (Fig. 4-22, Vol. II), groundwater is also monitored for organics by approximately 200 M-Area plume definition wells, which include the MSB wells not under the waste-site monitoring program, the ASB 8 well cluster, and the AC well series. During 1987, 19 plume definition wells were added to the MSB well series.

Several water-bearing zones are monitored within the contaminant plume. The water table in the area is relatively flat with drainage toward Tims Branch and the Savannah River. Upper and Lower Congaree sands drain to the southeast toward Upper Three Runs Creek. Water in Cretaceous sediments below the Ellenton Formation drains to the south toward the Savannah River.

M-AREA HAZARDOUS WASTE MANAGEMENT FACILITY (HWMF)

The M-Area Hazardous Waste Management Facility (HWMF) consists of the **M-Area Settling Basin (904-51G)**, south of the M-Fuel Fabrication Area and west of Road D, and **Lost Lake (904-112G)** (Fig. 4-22, Vol. II). The unlined basin received wastewater containing metal cleaning solvents, uranium, and other chemicals and metals from the M-Fuel Fabrication Area. In operation from 1958 until 1985, the basin overflowed into Lost Lake to the south. The basin is currently uncovered, contains water, and is undergoing RCRA closure.

The M-Area HWMF is monitored by wells MSB 1A, 2A, 3A, 4A, 5A, 6A, 7A, and 8A. Because several sources of contamination exist in M Area and because the water-table aquifer has a low gradient, most wells are downgradient of a source of contamination or are affected by contamination dispersion from nearby sources. Therefore, designation of upgradient and downgradient wells at this site is inappropriate. Instead, wells MSB 29B, 29C, 29D, 43A, 43B, and 43D to the north of the 700-A Administration Area are used to establish background water quality for the area.

METALLURGICAL LABORATORY SEEPAGE BASIN

The **Metallurgical Laboratory Seepage Basin (904-110G)** at the east edge of A Area (Fig. 4-22, Vol. II), received wastewater effluent from the Metallurgical Laboratory Building (723-A) from 1956 until 1985. Wastewater released to the basin consisted of small quantities of laboratory wastes from metallographic sample preparation (degreasing, cleaning, etching) and corrosion testing of stainless steels and nickel-based alloys. The volumes of wastewater from the lab were small (5 to 10 gal/day) and consisted mostly of rinsewater. Noncontact cooling water (approximately 900 gal/day) was also discharged. The basin is currently inactive and contains rainwater.

The basin is monitored by the three wells of the AMB series. The groundwater surface in this area is flat, making the terms *upgradient* and *downgradient* inappropriate.

MISCELLANEOUS CHEMICAL BASIN

The **Miscellaneous Chemical Basin (731-5A)** is west of Road D near the A-Area Metals Burning Pit. The basin was in operation by 1956 and was closed and the site graded in 1974. There are no records of the materials disposed of at this site. Soil gas investigations revealed halogenated organics in the near-surface soils at the site. During 1987, wells MCB 2, 4, 5, and 6 were installed to monitor the groundwater.

MOTOR SHOP OIL BASIN

The **Motor Shop Oil Basin (904-101G)** is at the south edge of A Area, by the 716-A Motor Shop (Fig. 4-22, Vol. II). This unlined basin was placed in service in 1977 to receive liquid waste from the Motor Shop. Effluent discharges from the Motor Shop included waste engine oil, grease, kerosene, ethylene glycol, and soapy water. All wastes passed through an oil skimmer prior to discharge into the basin. In August 1983, all discharges to the oil basin were terminated. The site is currently inactive but collects rainwater during periods of heavy precipitation.

The basin is monitored by the two wells of the AOB series. It is in an area of low horizontal groundwater gradients, making the terms *upgradient* and *downgradient* inappropriate. The basin is near the NPDES Outfall A-14, a known source of halogenated organics.

NEW TNX SEEPAGE BASIN

The **New TNX Seepage Basin (904-102G)** has been in operation since 1980 and is in the east section of the TNX facility, across River Road from the TNX process area (Fig. 4-29, Vol. II). The basin receives waste from pilot-scale tests conducted at TNX. The basin will be closed when the TNX Effluent Treatment Plant begins operation in the second quarter of 1988. The depth of water in the large section of the basin ranges from 1.8 to 3.0 m, depending upon rainfall and the number of processes discharging to the basin.

The basin is monitored by the four wells of the YSB series. Well YSB 2A is upgradient, wells YSB 1A and 3A are sidegradient, and well YSB 4A is downgradient of the basin.

OLD F-AREA SEEPAGE BASIN

The **Old F-Area Seepage Basin (904-49G)** is northwest of the F-Area perimeter security fence and north of Building 221-F (Fig. 4-8, Vol. II). The first seepage basin constructed in the area, it was used for disposal of wastewater from Building 221-F from November 1954 until mid-May 1955, when it was abandoned in place. During operation, the seepage basin received a variety of wastewaters, including evaporator overheads, laundry wastewater, and an unknown amount of chemicals. Currently the basin is open and contains some rainwater.

The basin is monitored by the four wells of the FNB series. Well FNB 4 is upgradient of the basin, wells FNB 3 and FNB 1 are sidegradient, and well FNB 2 is downgradient.

OLD TNX SEEPAGE BASIN

The **Old TNX Seepage Basin (904-76G)**, in the southwest corner of the TNX facility (Fig. 4-29, Vol. II), was in operation from 1958 to 1980 and received waste from pilot-scale tests conducted at TNX. In 1981, the west wall of the basin was breached to drain the impounded water, and the basin was backfilled with a sand and clay mixture and the top capped with clay.

The basin is monitored by the seven wells of the XSB series. Wells XSB 1, 2, 3A, and 4 are adjacent to the

basin with well XSB 2 upgradient, wells XSB 1 and 3A sidegradient, and well XSB 4 downgradient. Wells XSB 5, 5A, and 3T are downgradient of the basin and are screened to monitor deeper aquifers.

REACTOR SEEPAGE BASINS

Reactor seepage basins receive water from the reactor disassembly basins. The water in the disassembly basins is periodically purged as described on p. 164. Monitoring of the purge water ensures that particulate radioactivity and ionic levels are within specified limits before release to the seepage basins. An environmental release report is issued for each purge.

The reactor seepage basins were constructed in 1957. Initially, purge water was pumped directly into the seepage basins. The use of mixed-bed deionizers and sand filters began in the 1960s. From 1970 to 1978, the seepage basins were bypassed, and the deionized purge water was discharged directly into plant streams. In 1978, the basins were reactivated and are currently in use.

The **C-Area Reactor Seepage Basins (904-66G, -67G, and -68G)** are about 200 m southwest of the reactor building (Fig. 4-17, Vol. II). The basins are connected in series, with water entering Basin 1 then moving to Basins 2 and 3. The basins are monitored by the six wells in the CSB series. Well CSB 1A maintains an upgradient position. Well CSB 6A is sidegradient, and wells CSB 2A, 3A, 4A, and 5A are downgradient. Elevated conductivity and pH levels in wells CSB 1A, 5A, and 6A indicate that these wells have been affected by leaching of well grout.

The **K-Area Retention Basin (904-88G)** is northwest of K Area, about 100 m from the perimeter fence (Fig. 4-18, Vol. II). It has been used since 1965 for disposal of purge water from the K-Area Disassembly Basin. The basin is monitored by the five wells of the KRB series. Well KRB 8 is upgradient of the basin, wells KRB 1 and 13 are sidegradient, and wells KRB 14 and 15 are downgradient.

The **K-Area Reactor Seepage Basin (904-65G)** is west of K Area (Fig. 4-18, Vol. II). The basin was used from 1957 until 1960. The basin is monitored by the four wells in the KSB series. Well KSB 1 is upgradient of the basin, KSB 2 and 4A are sidegradient, and KSB 3 is downgradient.

The **L-Area Reactor Seepage Basin (904-64G)** is southeast of L Area adjacent to the L-Area Oil and Chemical Basin (Fig. 4-19, Vol. II). The L-Area Reactor Seepage Basin was used from 1958 until 1969 and from 1985 to the present. The basin is monitored by the four wells in the LSB series. Relative to the basin, well LSB 3 is upgradient, well LSB 1 is downgradient, and well LSB 2 and 4 are sidegradient.

The **P-Area Reactor Seepage Basins (904-61G, -62G, and -63G)** are southwest of the reactor building (Fig. 4-20, Vol. II). The basins are connected in series with water entering Basin 1 then moving to Basins 2 and 3. The basins are monitored by the seven wells in the PSB series. Well PSB 5A is upgradient of Basin 3. Well PSB 6A is upgradient of Basin 2 but downgradient of part of Basin 1. Well PSB 7A is sidegradient to upgradient of Basin 1. Well PSB 1A is downgradient of the basins. Well PSB 4A is sidegradient of Basin 3.

The six **R-Area Reactor Seepage Basins (904-103G, -104G, and -57G through -60G)** are located just outside the perimeter fence northwest of R Area (Fig. 4-21, Vol. II). The basins received purge water from the R-Area Disassembly Basin from 1957 until 1964. Overflow was sequential via overflow channels from Basin 1 to Basin 2, to Basin 3, to Basin 4. Basin 5 received water directly from the disassembly basin. Basin 6 received water pumped from Basins 2, 3, and 4 and then was used for receiving water from the disassembly basin.

On November 8, 1957, an experimental fuel element failed during a calorimeter test in the emergency section of the R-Area Disassembly Basin. Following this incident, the seepage basins received approximately 2,700 Ci of radionuclides, including 200 Ci of ^{90}Sr and 1,000 Ci of ^{137}Cs. About half of the ^{90}Sr and ^{137}Cs has decayed since the incident. A large portion of the released radioactivity was contained in Basin 1, which was backfilled in December 1957. Basins 2 through 6 were placed in operation in 1957 and 1958 after the incident to assist in containing the radioactivity.

In 1960, Basins 2 through 5 were closed and backfilled. The ground surface above Basins 1 through 5 was treated with herbicide and covered with asphalt. In addition, a kaolinite dike (down to a clay layer) was constructed around Basin 1 and the northwest end of Basin 3 to minimize latera move-

ment of the radioactive contamination. Basin 6, which was active until 1964, was backfilled in 1977.

The R-Area Reactor Seepage Basins are monitored by the wells of the RSA, RSB, RSC, RSD, RSE, and RSF series. In 1975, a substantial increase in ^{90}Sr activity (3,400 pCi/L) occurred in groundwater monitoring well RSE 13 on the southeast side of Basin 1 outside the clay dike. Investigations revealed that the source of the contamination was migration through a sewer line that had been abandoned after completion of R-Reactor construction. Subsequently, eight groundwater monitoring wells (RSD 4 through RSD 11) were installed downgradient from well RSE 13. These wells are located on two lines, 15 to 46 m south and parallel to wells RSD 4, 5, and 6. During 1987, five new monitoring wells (RSE 24 and 25 and RSF 1, 2, and 3) were installed to monitor the R-Area Reactor Seepage Basins.

In general, the water-table gradient in the northwest part of the site is to the north. To the south of Basin 6, and in the vicinity of Basin 1 and the nearby abandoned sewer line, the water-table flow direction is to the southeast.

ROAD A CHEMICAL BASIN

The **Road A Chemical Basin (904-111G)** is approximately 800 m west of the intersection of SRP Road A (SC Rt. 125) and SRP Road 6 (about 3.2 km southeast of the D-Area Powerhouse) (Fig. 4-30, Vol. II). The basin was closed and backfilled in 1973. The basin received miscellaneous radioactive and chemical aqueous waste, but no data on the wastes are available.

The basin is monitored by the four wells of the BRD series. Well BRD 3 is upgradient, well BRD 2 is sidegradient, and wells BRD 1 and 4 are sidegradient to downgradient of the basin.

S AREA

The Defense Waste Processing Facility is under construction in S Area (Fig. 4-15, Vol. II). The six wells of the SBG series are located at the perimeter of the area and are screened below the water table. The groundwater flow direction appears to be to the northwest toward Upper Three Runs Creek. Wells SBG 1 and 2 are downgradient, wells SBG 4 and 5 are upgradient, and wells SBG 3 and 6 are sidegradient of the area. Well SBG 5 was installed in 1987.

SANITARY LANDFILL

The **Sanitary Landfill (740-G)** is south of Road C about midway down the slope from the Aiken Plateau to Upper Three Runs Creek (Fig. 4-28, Vol. II). The site was opened in 1973. At the landfill, material such as paper, plastics, rubber, wood, cardboard, and rags are placed in trenches, which are covered with soil daily. The landfill receives approximately 4,000 tons of waste per year. In addition to the waste already listed, the landfill receives pesticide bags, punctured and empty aerosol cans, food waste, and asbestos in bags. The landfill is operated under South Carolina Domestic Waste Permit No. 87A.

The landfill is monitored by the 31 wells of the LFW series. All of the wells monitor the water table. The horizontal groundwater flow direction is to the southeast toward Upper Three Runs Creek.

SAVANNAH RIVER LABORATORY SEEPAGE BASINS

The **Savannah River Laboratory (SRL) Seepage Basins (904-53G1, -53G2, -54G, and -55G)** are east of Road 1-A across from SRL (Fig. 4-22, Vol. II). These four basins, constructed between 1954 and 1960, received low-level radioactive wastewater through underground drains from laboratories in Buildings 735-A and 773-A. The basins were taken out of service in October 1982.

The basins are monitored by seven wells of the ASB series (1A, 2A, 3A, 4, 5A, 6A, and 7). The remaining wells in the ASB series are not adjacent to the basin. The gradients in this area are relatively flat, and changes in the flow direction and gradient have occurred. Generally, wells ASB 1A and 2A are upgradient. Wells ASB 4 and 6A are downgradient. Well cluster ASB 8 is near the NPDES Outfall A-1, which could be a source of contaminants. Well ASB 9 is 500 m southeast of the seepage basins.

SILVERTON ROAD WASTE SITE

The **Silverton Road Waste Site (731-3A)** is southwest of Road C-1.1, midway between Road 1 and Road D (Fig. 4-23, Vol. II). It was used for disposal of metal shavings, construction debris, tires, drums, tanks, and miscellaneous items. The site was probably used before construction of SRP, but the startup date is unknown, and no records of waste disposal activities have been kept. The site was closed in

1974. The waste material is presently covered with soil and vegetation.

The basin is monitored by the 30 wells of the SRW series. The wells monitor the water-table aquifer and deeper aquifers. The wells with an "A" or a "B" after the well number monitor the lower aquifers except for well SRW 3A, which is a water-table well. Well clusters SRW 1 through 6 are at the edge of the site, with wells SRW 1, 2 and 3A upgradient, well SRW 4 sidegradient, and wells SRW 5 and 6 downgradient. The remaining wells are farther from the site, with well cluster 16 upgradient, clusters 14 and 15 sidegradient, and the remaining wells downgradient.

SOLID WASTE STORAGE FACILITY (BURIAL GROUNDS)

The **Solid Waste Storage Facility** is between F and H Areas (Fig. 4-2, Vol. II) and is used for storage of radioactive solid waste produced at the plant and shipped from other U.S. Department of Energy facilities. The original area (643-G) began receiving waste in 1952 and was filled in 1972. Operations then shifted to an adjacent site, the 643-7G burial ground. Site 643-28G, an area within 643-7G, was defined in 1986. There are plans for the 643-7G site to be closed and capped.

The Burial Grounds are used for disposal of transuranic (TRU) alpha waste, low-level alpha and beta-gamma waste, intermediate-level beta-gamma waste, and waste generated offsite. Until 1965, TRU waste was buried in plastic bags and cardboard boxes in earthen trenches. Between 1965 and 1974, TRU waste was segregated according to TRU content into two categories. Waste containing less than 0.1 Ci per package was buried unencapsulated in trenches. Waste containing greater than 0.1 Ci per package was buried in retrievable concrete containers or encapsulated in concrete. Since 1974, transuranic wastes contaminated with greater than 10 nCi TRU/g have been stored in water-tight containers that can be retrieved intact for at least 20 years from the time of storage. Containers are stored on a concrete pad with a monitoring sump. Some bulky wastes are stored directly in shallow land burial trenches. Since mid-1984, newly generated low-level waste has been placed in metal boxes or metal drums and is currently stored in trenches covered with soil shortly after emplacement.

Mixed wastes (low-level radioactive waste containing hazardous waste) stored within the Radioactive Waste Burial Grounds include lead (used for shielding), cadmium (from control rods, safety rods, and shielding), tritiated pump oil, and mercury. Some of the waste is contained in welded stainless steel containers or metal drums and stored within concrete cylinders. Newly generated mixed waste is stored in Building 643-29G permitted by the SCDHEC and operating under interim status. Degraded solvents and tritiated pump oil are stored in tanks installed in 1975. A program is under way to incinerate the degraded solvents and tritiated oil. In March 1986, disposal operations for radioactive waste containing lead or any other listed hazardous substance were discontinued. A plan was implemented to ensure that all other wastes are certified to be free of hazardous materials.

The Burial Grounds are monitored by the wells of the BG, MGA, MGC, MGE, MGG, and MGI series. All of these wells are screened in the water table at a depth of 15 to 30 m. The naming of wells within the Burial Ground in this report is different from previous annual reports. The water table at the Burial Grounds generally flows toward the west except in the east corner, where the flow is to the east.

Z AND ZW WELLS

The Z and ZW wells were originally installed as piezometers in 1951 (Fig. 4-16, Vol. II). These piezometers, which range from 7 to 26 m deep, measure water-table elevations in the separations areas. These wells also monitor for groundwater contamination that might exist within a large radius of F and H areas.

Z AREA

Z Area, located north of the intersection of Road F and Road 4, is being developed for the disposal of saltstone. The saltstone will be made by mixing treated supernate from the high-level waste tanks with concrete. During 1987, three wells were installed in Z Area for groundwater monitoring. Wells ZBG 1 and 2 monitor the water table. Well ZBG 1P monitors a perched water zone.

Appendix C: Environmental Permits

Permit Number	Type	Title	Expiration Date
SC0000175	Wastewater (NPDES)	SCDHEC Water Pollution Control Permit	12/31/88
SC1890008989	Hazardous Waste	SCDHEC Office of Environmental Quality Control, Bureau of Solid and Hazardous Waste Management, Hazardous Waste Permit	9/30/92
SC1890008989	Hazardous Waste	Environmental Protection Agency RCRA Hazardous Waste Permit	11/1/92
0300-0015	Air	Permit to operate concrete batch plant, Steel Creek Dam construction project	
0080-0060-CE	Air	300 KW Emergency Diesel Generator, 654-T	
0080-0046-CJ	Air	455 KW Emergency Diesel Generator, 720-H	
0080-0042-CC	Air	455 KW Emergency Diesel Generator, 720-2A	
0080-0045-CJ	Air	455 KW Emergency Diesel Generator, 720-F	
0080-0060-CF	Air	1000 KW Emergency Diesel Generator, 654-1T	
0080-0045-CI	Air	Silos and baghouse facility for naval fuel	
0080-0042-01	Air	Boiler (71.7 mmBtu/hr) 784-A	5/31/89
0080-0042-02	Air	Boiler (71.7 mmBtu/hr) 784-A	5/31/89
0080-0042-03	Air	Diesel Generator (600 KW) 794-A	5/31/89
0080-0042-04	Air	Diesel Generator (400 KW) 773-A	5/31/89
0080-0042-05	Air	Diesel Generator (200 KW) 703-A	5/31/89
0080-0043-01	Air	Diesel Generator (150 KW) 108-4C	1/31/89
0080-0043-02	Air	Diesel Generator (150 KW) 108-4C	1/31/89
0080-0043-03	Air	Diesel Generator (1000 KW) 108-1C	1/31/89
0080-0043-04	Air	Diesel Generator (1000 KW) 108-2C	1/31/89
0080-0044-01	Air	Boiler (396 mmBtu/hr) 484-D	2/28/89
0080-0044-02	Air	Boiler (396 mmBtu/hr) 484-D	2/28/89
0080-0044-03	Air	Boiler (396 mmBtu/hr) 484-D	2/28/89
0080-0044-04	Air	Boiler (396 mmBtu/hr) 484-D	2/28/89
0080-0044-05	Air	Diesel Generator (150 KW) 501-D	2/28/89
0080-0044-06	Air	Reject System (1.1 T/hr) 484-D	2/28/89
0080-0044-07	Air	Coal Crusher (300 T/hr) 484-D	2/28/89
0080-0045-05	Air	U-Dissolution 221-F	2/28/89
0080-0045-06	Air	Diesel Generator (200 KW) 254-5F-1	2/28/89
0080-0045-07	Air	Diesel Generator (200 KW) 254-5F-2	2/28/89
0080-0045-08	Air	Diesel Generator (175 KW) 772-F-1	2/28/89
0080-0045-09	Air	Diesel Generator (175 KW) 772F-2	2/28/89
0080-0045-10	Air	Diesel Generator (350 KW) 241-19F	2/28/89
0080-0045-11	Air	Diesel Generator (350 KW) 235-F	2/28/89
0080-0045-12	Air	Diesel Generator (350 KW) 254-4F	2/28/89
0080-0045-13	Air	Diesel Generator (250 KW) 254-1F	2/28/89
0080-0045-14	Air	Diesel Generator (200 KW) 241-74F	2/28/89
0080-0045-15	Air	Diesel Generator (600 KW) 292-F	2/28/89
0080-0045-16	Air	Diesel Generator (600 KW) 247-1F	2/28/89
0080-0045-17	Air	Diesel Generator (315 KW) 221-FB	2/28/89
0080-0045-18	Air	Diesel Generator (415 KW) 772-1F	2/28/89
0080-0045-19	Air	Diesel Generator (300 KW) 292-2F	2/28/89
0080-0045-20	Air	Diesel Generator (300 KW) 254-9F	2/28/89
0080-0045-21	Air	Diesel Generator (1000 KW) 221-F	2/28/89

Blank indicates no expiration date.

Permit Number	Type	Title	Expiration Date
0080-0045-22	Air	Diesel Generator (600 KW) 254-10F	2/28/89
0080-0046-01	Air	Boiler (71.7 mmBtu/hr) 284-H	3/31/89
0080-0046-02	Air	Boiler (71.7 mmBtu/hr) 284-H	3/31/89
0080-0046-03	Air	Boiler (71.7 mmBtu/hr) 284-H	3/31/89
0080-0046-04	Air	BGI (400 lbs/hr)	3/31/89
0080-0046-05	Air	Separation Process 221-H	3/31/89
0080-0046-06	Air	Diesel Generator (200 KW) 234-4H	3/31/89
0080-0046-07	Air	Diesel Generator (200 KW) 299-1H	3/31/89
0080-0046-08	Air	Diesel Generator (200 KW) 241-7H	3/31/89
0080-0046-09	Air	Diesel Generator (250 KW) 254-1H	3/31/89
0080-0046-10	Air	Diesel Generator (275 KW) 254-3H	3/31/89
0080-0046-11	Air	Diesel Generator (300 KW) 221-HB	3/31/89
0080-0046-12	Air	Diesel Generator (300 KW) 254-5H-1	3/31/89
0080-0046-13	Air	Diesel Generator (300 KW) 254-5H-2	3/31/89
0080-0046-14	Air	Diesel Generator (300 KW) 232-H	3/31/89
0080-0046-15	Air	Diesel Generator (300 KW) 234-H	3/31/89
0080-0046-16	Air	Diesel Generator (500 KW) 232-H-2	3/31/89
0080-0046-17	Air	Diesel Generator (500 KW) 254-H	3/31/89
0080-0046-18	Air	Diesel Generator (600 KW) 292-H	3/31/89
0080-0046-19	Air	Diesel Generator (1000 KW) 221-H	3/31/89
0080-0047-01	Air	Boiler (194.5 mmBtu/hr) 184-K	3/31/89
0080-0047-02	Air	Boiler (194.5 mmBtu/hr) 184-K	3/31/89
0080-0047-03	Air	Diesel Generator (1000 KW) 108-1K	3/31/89
0080-0047-04	Air	Diesel Generator (1000 KW) 108-2K	3/31/89
0080-0047-05	Air	Diesel Generator (150 KW) 108-4K	3/31/89
0080-0047-06	Air	Diesel Generator (150 KW) 108-4K	3/31/89
0080-0047-07	Air	Diesel Generator (225 KW) 152-7K	3/31/89
0080-0049-01	Air	Diesel Generator (1000 KW) 108-1L	4/30/89
0080-0049-02	Air	Diesel Generator (1000 KW) 108 2L	4/30/89
0080-0049-03	Air	Diesel Generator (400 KW) 191-L	4/30/89
0080-0049-04	Air	Diesel Generator (150 KW) 108-4L	4/30/89
0080-0049-05	Air	Diesel Generator (150 KW) 108-4L	4/30/89
0080-0049-06	Air	Diesel Generator (225 KW) 152-7L	4/30/89
0080-0055-01	Air	U-Metal Cleaning 313-M	3/31/89
0080-0055-02	Air	Al-Tube Cleaning 321-M	3/31/89
0080-0055-03	Air	Diesel Generator (200 KW) 320-M	3/31/89
0080-0055-04	Air	Air Stripper (400 gpm)	3/31/89
0080-0048-01	Air	Boiler (194.5 mmBtu/hr) 184-P	4/30/89
0080-0048-02	Air	Boiler (194.5 mmBtu/hr) 184-P	4/30/89
0080-0048-03	Air	Diesel Generator (1000 KW) 108-1P	4/30/89
0080-0048-04	Air	Diesel Generator (1000 KW) 108-2P	4/30/89
0080-0048-05	Air	Diesel Generator (150 KW) 108-4P	4/30/89
0080-0048-06	Air	Diesel Generator (150 KW) 108-4P	4/30/89
0080-0048-07	Air	Diesel Generator (225 KW) 152-7P	4/30/89
0080-0066-01	Air	Cement Silo (540 T/hr)	5/31/89
0080-0066-02	Air	Fly Ash Silo (540 T/hr)	5/31/89
0080-0066-03	Air	Mixer (540 T/hr)	5/31/89
0080-0066-04	Air	New Cen Silo (84 T/hr)	5/31/89
0080-0060-01	Air	Diesel Generator (750 KW) 673-T	5/31/89
0080-0060-02	Air	Diesel Generator (300 KW) 672-T	5/31/89
0080-0060-03	Air	Diesel Generator (300 KW) 673-T	5/31/89
0080-0060-04	Air	Shiro Incinerator (20 lbs/hr)	5/31/89
0080-0060-05	Air	PHEF 682-T	5/31/89
LS-23-W	Domestic Water	DWPF TC emergency water supply	
200092	Domestic Water	Deep Wells, 905-104L, 904-105L	

Blank indicates no expiration date.

Permit Number	Type	Title	Expiration Date
48061	Domestic Water	Temporary water supply 905-104L, 904-105L	
402874	Domestic Water	Segregated domestic water supply, 300/700 Area, phase I	
403434	Domestic Water	Segregated domestic water supply, 300/700 Area, phase II	
LS-4-W	Domestic Water	Water line, office building, 703-41A	
LS-1-W	Domestic Water	Water line, tritium facilities support building, 235-H	
405184	Domestic Water	Water line, 773-41A, 773-42A	
LS-7-W	Domestic Water	Water line navel fuels material facility, 221-17F, 221-18F	
LS-8-W	Domestic Water	Water line, 703-4A, 703-6A, 703-34A	
LS-11-W	Domestic Water	Water line navel fuels material facility, 247-F	
208434	Domestic Water	Domestic water system, barricades, 701-8G, 701-12G, 701-13G	
209454	Domestic Water	TNX domestic water system and well	
409484	Domestic Water	Water line, reactor simulator facility, 707-C	
201715	Domestic Water	Domestic deepwell, railroad classification yard, 905-107G	
202915	Domestic Water	Polyphosphate feed system, TC S-Area well	
402925	Domestic Water	DWFF temporary domestic water	
202915	Domestic Water	Water supply and well system, DWPF construction support area	
LS-25-W	Domestic Water	Chemical feed facility water system, 100-C	
206575	Domestic Water	Domestic water deepwells and distribution line, A-Area	
207005	Domestic Water	Activated carbon treatment system, 3,700 Area	
408285	Domestic Water	Domestic water service for sanitary waste treatment facility, TNX	
LS-43-W	Domestic Water	Technical area water main bypass, 773-14A	
408595	Domestic Water	Domestic water line, construction office building, 300 M	
409955	Domestic Water	Helicopter facility domestic water line	
LS-54-W	Domestic Water	Domestic water line, 707-H	
LS-56-W	Domestic Water	Domestic water supply for chemical feed facilities in G&H Areas (H)	
LS-55-W	Domestic Water	Domestic water supply for chemical feed facilities in G&H Areas (G)	
LS-57-W	Domestic Water	Domestic water line relocation & service line install 735-11A	
411995	Domestic Water	Water distribution system, 340-M, 341-M	
208425	Domestic Water	ATTA domestic water system	
LS-61-W	Domestic Water	Domestic water line to feed DWPF sanitary treatment plant	
LS-60-W	Domestic Water	Domestic water line for 704-S administration building DWPF	
LS-59-W	Domestic Water	Water system DWPF ice house	
41225	Domestic Water	3/700 A-Area water line from new domestic wells	
212745	Domestic Water	DWPF domestic water wells 1 and 2	
401446	Domestic Water	Production control facility for 200 Area process 772-1F	
402186	Domestic Water	DWPF domestic water distribution system	
203786	Domestic Water	Drinking water well 905-114G, 681-3G	
LS-81-W	Domestic Water	Domestic water for construction office building, C-Area	

Blank indicates no expiration date.

Permit Number	Type	Title	Expiration Date
LS-82-W	Domestic Water	Domestic water for sanitary treatment facility, U-Area	
405556	Domestic Water	Domestic water system, 200-H	
405566	Domestic Water	Domestic water system, 200-F	
208866	Domestic Water	Domestic water well for Aiken barricade gate house 701-5G	
LS-106-W	Domestic Water	DWPF auxiliary pump pit water lines, S-511	
410406	Domestic Water	Drinking water system, 777-A	
LS-115-W	Domestic Water	Water line, crafts and engineers, CAB/Cantle Shop	
LS-118-W	Domestic Water	Water line, 719-4A	
111626	Domestic Water	Upgrade gaseous chlorination facility, D/G Areas	
LS-119-W	Domestic Water	Water line, 730-M	
400347	Domestic Water	Domestic water headers, TNX Area	
400367	Domestic Water	Fuel production facility water system, 225-H	
LS-139-W	Domestic Water	Replace tritium facility domestic water, 233-H, 249-H	
400737	Domestic Water	Water line DWPF, Z Area	
203427	Domestic Water	Sodium hypochlorite system, 280-F	
203467	Domestic Water	Sodium hypochlorite system, 280-H	
205217	Domestic Water	Upgrade instrumentation 280-1, F/H Areas	
205877	Domestic Water	Augusta barricade water well, 905-116G	
406137	Domestic Water	Int[illegible] storage and redrumming facility, dom[illegible]c water 709-1G, 709-2G	
208177	Domestic Water	Phos[illegible]ate feed system, B-Area	
LS-178-W	Domestic Water	Computer repair building domestic water, 722-5A	
LS-185-W	Domestic Water	Domestic water main, 901-A	
LS-187-W	Domestic Water	ETF-F lift station domestic water	
210 657	Domestic Water	Drinking water well and distribution system, 905-39F	
411357	Domestic Water	ETF-F lift station domestic water	
412917	Domestic Water	Drinking water system, ETF, 241-84H, 241-81H	
401118	Domestic Water	Domestic water for NWTF	
203638	Domestic Water	Replace Allendale barricade well	
203628	Domestic Water	Replace pistol range well	
204138	Domestic Water	Replace domestic deepwell, 905-94K	
204198	Domestic Water	Replace domestic deepwell, 905-66H	
404618	Domestic Water	705-C domestic water	
404608	Domestic Water	717-K domestic water	
LS-233-W	Domestic Water	Temporary domestic water for F&H ETF construction office	
LS-238-W	Domestic Water	Temporary domestic water for FPF & RTF facilities	
LS-238-W	Domestic Water	ECF/CAS security upgrade facilities, H Area	
411337	Domestic Water	Install sodium hypochlorite system, 780-A	
DWP-087A	Ind. Solid Waste	Sanitary landfill expansion	
IWP-210	Ind. Solid Waste	D-F steamline erosion control site	
IWP-211	Ind. Solid Waste	200-H erosion control site	
IWP-212	Ind. Solid Waste	Coal-ash waste landfill, 100-P Area	
IWP-219	Ind. Solid Waste	200-F erosion control site	
10,349	Ind. Wastewater	672-T TNX process sewer to outfall X-008	
10,389	Ind. Wastewater	M-Area drain line	
11,413	Ind. Wastewater	DWPF chemical treatment facility, S Area	
11,760	Ind. Wastewater	Wastewater for PCB clean-up, 320-M	
10,920	Ind. Wastewater	SREL wastewater disinfection facility	
7289	Ind. Wastewater	"As built" wastewater treatment facilities, A and M Areas	

Blank indicates no expiration date.

Permit Number	Type	Title	Expiration Date
7290	Ind. Wastewater	"As built" wastewater treatment facilities, F Area	
7291	Ind. Wastewater	"As built" wastewater treatment facilities, H Area	
7292	Ind. Wastewater	"As built" wastewater treatment facilities, P Area	
7293	Ind. Wastewater	"As built" wastewater treatment facilities, K Area	
7294	Ind. Wastewater	"As built" wastewater treatment facilities, C Area	
7295	Ind. Wastewater	"As built" wastewater treatment facilities, D Area	
7296	Ind. Wastewater	"As built" wastewater treatment facilities, CS Area	
9886	Ind. Wastewater	M Area 50 gpm air stripper	
9974	Ind. Wastewater	Concrete batch plant, S Area	
10,253	Ind. Wastewater	M Area 330 gpm air stripper	
10,287	Ind. Wastewater	Liquid effluent treatment facilities, 300-M	
10,358	Ind. Wastewater	S Area oil separator	
10,469	Ind. Wastewater	735-11A lab building process sewer system neutralization facility	
10,475	Ind. Wastewater	Non-contact cooling water diversion, 300-M Area	
10,696	Ind. Wastewater	Interim sludge storage tank M Area	
10,765	Ind. Wastewater	Wastewater neutralization facility, 704-U	
10,778	Ind. Wastewater	Wastewater treatment facility, naval fuels	
LS-42-S	Ind. Wastewater	Inert L facility loading dock sewer relocation, 234-H	
10,995	Ind. Wastewater	DWPF concrete batch plant wastewater treatment pond, S Area	
10,949	Ind. Wastewater	Trade waste flow equalization tank, 607-18A	
LS-53-S	Ind. Wastewater	Sanitary sewer line construction office line, M Area	
11,411	Ind. Wastewater	DWPF treated effluent line	
11,406	Ind. Wastewater	Fire brigade training facilities oil separator, 411-D	
11,498	Ind. Wastewater	Flow monitoring station for NPDES outfall L-007	
11,497	Ind. Wastewater	Production control facility sanitary/process sewer 772-1F	
11,588	Ind. Wastewater	Powerhouse effluent diversion to ash basins, D/H Areas	
11,589	Ind. Wastewater	Powerhouse effluent diversion to ash basins, K&P Areas	
11,971	Ind. Wastewater	Carbon bed piping for organics removal demonstration project TNX	
12,622	Ind. Wastewater	Organics removal facility, TNX	
10,633	Ind. Wastewater	Effluent treatment plant, TNX	
12,888	Ind. Wastewater	Metallurgical laboratory neutralization facility, 723-A	
12,973	Ind. Wastewater	P Area neutralization facility, 183-2P	
13,286	Ind. Wastewater	Portable chromium removal system, SRL	
13,354	Ind. Wastewater	D Area Neutralization facility, 483-1D	
13,355	Ind. Wastewater	F Area neutralization facility, 280-1F	
13,356	Ind. Wastewater	H Area neutralization facility, 280-H	
13,357	Ind. Wastewater	K Area neutralization facility, 183-2K	
13,431	Ind. Wastewater	Flume at M-0004 outfall	
13,456	Ind. Wastewater	L-Tank "as built"	
13,734	Ind. Wastewater	Industrial wastewater pH control system, 211-H	
13,735	Ind. Wastewater	Industrial wastewater pH control system, 211-F	
12,773	Ind. Wastewater	L Lake thermal barrier curtain	
12,683	Ind. Wastewater	Z Area saltstone mfg. facility	
12,782	Ind. Wastewater	Peplacement tritium facility process sewer	
12,070	Ind. Wastewater	Effluent treatment facility F/H Area	
12,894	Ind. Wastewater	Filtrate hold tank covers, M Area	

Blank indicates no expiration date.

Permit Number	Type	Title	Expiration Date
12,922	Ind. Wastewater	Naval fuel facility modifications	
13,105	Ind. Wastewater	ETF process sewer lines, F/H Area	
LS-'86-S	Ind. Wastewater	FPF process sewer line	
,154	Ind. Wastewater	Flow measurement device, L Area	
13,457	Ind. Wastewater	L Tank mercury removal	
LS-10-S	San. Waste	Sanitary sewer system, naval fuels material facility, 248-F	
14,443	San. Wastewater	Septic tank and tile field, H Area	
9256P	San. Wastewater	Septic tank and tile field landfill monitoring building 642-G	
8611-P	San. Wastewater	Septic tank and tile field CS Area 709-1G	
13,717	San. Wastewater	Wastewater treatment facility Z Area	
8881	San. Wastewater	Flow equalization basin, 700-A	
8928	San. Wastewater	FMF sanitary waste treatment plant	
9326	San. Wastewater	Sanitary wastewater treatment plant F,H, P&G Areas	
LS-3-S	San. Wastewater	Sanitary sewer system office building 703-41A	
LS-2-S	San. Wastewater	Sanitary sewer line tritium facilities support building 235-H	
9694	San. Wastewater	Sanitary sewer system, 773-41A, 773-42A	
9888	San. Wastewater	DWPF sanitary waste treatment plant	
9940	San. Wastewater	Sanitary sewer system, reactor simulator facility, 707-C	
9983	San. Wastewater	Sanitary treatment plan, 100-C Area	
10,236	San. Wastewater	Lift station, change station facility, 241-58H	
10,499	San. Wastewater	DWPF sanitary sewer system, 200S	
10,521	San. Wastewater	Chemical feed facility, A Area	
10,522	San. Wastewater	Chemical feed facility, F Area	
10,523	San. Wastewater	Chemical feed facility, H Area	
10,524	San. Wastewater	Chemical feed facility, P Area	
10,525	San. Wastewater	Chemical feed facility, G Area	
10,526	San. Wastewater	Chemical feed facility, D Area	
LS-32-S	San. Wastewater	Sanitary sewer line, Wackenhut building, TC/U Area	
10,530	San. Wastewater	TNX sanitary wastewater treatment plant 607-40-G	
LS-35-S	San. Wastewater	Sanitary sewer relocation, building 735-11A	
10,825	San. Wastewater	Sanitary sewer lift station, 607-19-A	
10,906	San. Wastewater	Sanitary sewer, 341-M	
LS-52-S	San. Wastewater	Sanitary sewer, 707-H	
11,407	San. Wastewater	Sanitary waste transfer station 321-M change room renovation	
11,442	San. Wastewater	Lift station force main, 241-82H	
LS-78-S	San. Wastewater	Sanitary sewer line for construction office building C Area	
LS-80-S	San. Wastewater	Sanitary sewer line receiving & stores warehouse construction central shops	
LS-79-S	San. Wastewater	Sanitary sewer line electrical office building construction central shops	
11,847	San. Wastewater	Effluent weir for sanitary treatment system, TNX	
11,847	San. Wastewater	Effluent weir, TNX	
LS-98-S	San. Wastewater	Sanitary sewer addition, S Area	
11,615	San. Wastewater	Sanitary treatment plant U Area	
LS-112-S	San. Wastewater	Fire training facility process sewer 904-D	
LS-129-S	San. Wastewater	Sanitary sewer, 719-4A	
LS-134-S	San. Wastewater	DWPF sanitary sewer line modification	

Blank indicates no expiration date.

Permit Number	Type	Title	Expiration Date
12,383	San. Wastewater	Fuel production facility sanitary sewer, 225H	
12,386	San. Wastewater	Sanitary sewer, 730-M	
12,453	San. Wastewater	Bromide feed system, 607-18F	
12,452	San. Wastewater	Bromide feed system, 607-19L	
12,498	San. Wastewater	F Area STP Phase II	
LS-149-S	San. Wastewater	Sanitary sewer, TNX-ETP	
LS-158-S	San. Wastewater	Sanitary sewer, 3/700 construction facility	
12,725	San. Wastewater	F Area STP Phase III	
12,910	San. Wastewater	Sanitary treatment facility, H Area	
13,155	San. Wastewater	Naval fuels flow measurement device outfall F-003(A)	
13,175	San. Wastewater	Flow equalization basin, building 607-22A	
LS-206 S	San. Wastewater	Sewer pipe and manhole, 704-1T TNX	
9998	San. Wastewater	Septic tank and drain field for F&H ETF	
10,131-P	San. Wastewater	Septic tank and drain field for RTF construction engineers office	
10,132-P	San. Wastewater	Septic tank and drain field for FTF construction engineers office	
LS-227-S	San. Wastewater	705-C sanitary sewer	
LS-228-S	San. Wastewater	717-K sanitary sewer	
LS-239-S	San. Wastewater	ECF/CAS security upgrade facilities, F Area	
LS-240-S	San. Wastewater	3/700 Area security upgrade, building 720-2A	
LS-244-S	San. Wastewater	ECF/CAS security upgrade facilities, H Area	
10,314	San. Wastewater	DWPF construction site sanitary sewer system	
LS-62-S	San. Wastewater	717-F sanitary sewer relocation for DWPF	
12,695	San. Wastewater	Replacement tritium facility sanitary sewer	
LS-168-S	San. Wastewater	A Area sanitary sewer	
13,156	San. Wastewater	716-2A sanitary sewer	
13,157	San. Wastewater	Computer repair building sanitary sewer, 722-5A	
13,173	San. Wastewater	Sanitary sludge land application, K Area and Par Pond borrow pits	
13,430	San. Wastewater	Sanitary sewage treatment facility, 607-21F	
12,076	Ind. Solid Waste	Sanitary sludge land application, F&H Area borrow pit	

Blank indicates no expiration date.

TRADITIONAL AND NEW RADIOLOGICAL UNITS

(Conventional units are in parentheses)

Quantity	Name	Symbol	Expression in Terms of Other Units
activity	becquerel	Bq	1 dps
	(curie)	Ci	3.7×10^{10} Bq
absorbed dose	gray	Gy	J/kg^{-1}
	(rad)	rad	10^{-2} Gy
dose equivalent	sievert	Sv	J/kg^{-1}
	(rem)	rem	10^{-2} Sv
exposure	coulomb per kilogram		C/kg^{-1}
	(roentgen)	R	2.58×10^{-4} C/kg^{-1}