Chapter 5

Potential Radiation Doses

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THIS chapter presents the potential doses to offsite individuals and the surrounding population from the 2002 Savannah River Site (SRS) atmospheric and liquid radioactive releases. Also documented are potential doses from special-case exposure scenarios—such as the consumption of deer meat, creek mouth fish, and goat milk.

Unless otherwise noted, the generic term "dose" used in this report includes both the committed effective dose equivalent (50-year committed dose) from internal deposition of radionuclides and the effective dose equivalent attributable to sources external to the body. Use of the effective dose equivalent allows doses from different types of radiation and to different parts of the body to be expressed on the same basis.

Descriptions of the effluent monitoring and environmental surveillance programs discussed in this chapter can be found in chapter 3, "Effluent Monitoring," and chapter 4, "Environmental Surveillance." A complete description of how potential doses are calculated can be found in section 1108 of the *Savannah River Site Environmental Monitoring Section Plans and Procedures*, WSRC–3Q1–2, Volume 1 [SRS EM Program, 2001]. All potential dose calculation results are presented in data tables on the CD accompanying this report.

Applicable dose regulations can be found in appendix A, "Applicable Guidelines, Standards, and Regulations," of this document.

Calculating Dose

Potential offsite doses from SRS effluent releases of radioactive materials (atmospheric and liquid) are calculated for the following scenarios:

- hypothetical maximally exposed individual
- 80-km (50-mile) population

Because the U.S. Department of Energy (DOE) has adopted dose factors only for adults, SRS calculates maximally exposed individual and collective doses as if the entire 80-km population consisted of adults [DOE, 1988]. For the radioisotopes that constitute most of SRS's radioactive releases (i.e., tritium and cesium-137), the dose to infants would be approximately two to three times more than to adults. The dose to older children becomes progressively closer to the adult dose.

For dose calculations, unspecified alpha releases were assigned the plutonium-239 dose factor, and unspecified nonvolatile beta releases were assigned the strontium-90 factor. Accounting for the alpha and beta emitters in this way generates an overestimated dose attributed to releases from SRS because

Dose to the Hypothetical Maximally Exposed Individual

When calculating radiation doses to the public, SRS uses the concept of the maximally exposed individual; however, because of the conservative lifestyle assumptions used in the dose models, no such person is known to exist. The parameters used for the dose calculations are

For airborne releases: Someone who lives at the SRS boundary 365 days per year and consumes large amounts of milk, meat, and vegetables produced at that location

For liquid releases: Someone who lives downriver of SRS (near River Mile 118.8) 365 days per year, drinks 2 liters of untreated water per day from the Savannah River, consumes a large amount of Savannah River fish, and spends the majority of time on or near the river

To demonstrate compliance with the DOE Order 5400.5 all-pathway dose standard of 100 mrem per year, SRS conservatively combines the airborne pathway and liquid pathway dose estimates, even though the two doses are calculated for hypothetical individuals residing at different geographic locations.

- plutonium-239 and strontium-90 have the highest dose factors among the common alpha- and beta-emitting radionuclides
- a part of the unidentified activity probably is not from SRS operations but from naturally occurring radionuclides, such as potassium-40 and radon progeny

SRS also uses adult consumption rates for food and drinking water and adult usage parameters to estimate intakes of radionuclides. These intake values and parameters were developed specifically for SRS based on a regional survey [Hamby, 1991].

Dose Calculation Methods

To calculate annual offsite doses, SRS uses transport and dose models developed for the commercial nuclear industry [NRC, 1977]. The models are described in SRS EM Program, 2001.

Meteorological Database

For 2002, all potential offsite doses from releases of radioactivity to the atmosphere were calculated with quality-assured meteorological data for A-Area (used for A-Area and M-Area releases) and H-Area (used for releases from all other areas). The meteorological databases used were for the years 1997–2001, reflecting the most recent 5-year compilation period.

Population Database and Distribution

Collective, or population, doses from atmospheric releases are calculated for the population within a 80-km radius of SRS. Within this radius, the total population was 713,500, based on 2000 census data.

Some of the collective doses resulting from SRS liquid releases are calculated for the populations served by the City of Savannah Industrial and Domestic Water Supply Plant, near Port Wentworth, Georgia, and by the Beaufort-Jasper Water Treatment Plant, near Beaufort, South Carolina. According to the treatment plant operators, the population served by the Port Wentworth facility during 2002 was approximately 11,000 persons, while the population served by the Beaufort-Jasper facility (including some residents of Hilton Head Island) was approximately 105,000 persons.

River Flow Rate Data

Although flow rates are recorded at U.S. Geological Survey (USGS) gauging stations at the SRS boat dock and near River Mile 118.8 (U.S. Highway 301 bridge), these data are not used directly in dose calculations. This is because weekly river flow rates fluctuate widely (i.e., short-term dilution varies from week to week). Used instead are “effective” flow rates, which are calculated by dividing the total curies of tritium measured in transport at River Mile 118.8 by the

- average tritium concentration measured at River Mile 118.8 (to determine the maximally exposed individual dose)
- average tritium concentrations measured in finished drinking water at the two downriver treatment plants (to determine drinking water population doses)

For 2002, the River Mile 118.8 calculated (effective) flow rate of 5,355 cubic feet per second was used. The effective flow rate was 6,564 cubic feet per second for the Beaufort-Jasper facility and 6,988 cubic feet per second for the Port Wentworth facility.

Uncertainty in Dose Calculations

Radiation doses are calculated using the best available data. If adequate data are unavailable, then site-specific parameters are selected that would result in a conservative estimate of the maximum dose.

All radiation data and input parameters have an uncertainty associated with them, which causes uncertainty in the dose determinations. For example, there is uncertainty in the assumed maximum meat consumption rate of 81 kg (179 pounds) per year for an individual. Some people will eat more than 81 kg, but most probably will eat less. Uncertainties can be combined mathematically to create a distribution of doses rather than a single number. While the concept is simple, the calculation is quite difficult.

Dose Calculation Results

Liquid Pathway

Liquid Release Source Terms

The 2002 radioactive liquid release quantities used as source terms in SRS dose calculations are presented in chapter 3 and summarized by radionuclide in table 5–1.

The total curies of tritium released is based on the measured tritium concentration at River Mile 118.8. This total (4,830 curies) includes contributions from Georgia Power Company’s Vogtle Electric Generating Plant (1,700 curies) and from other background sources (780 curies).

Radionuclide Concentrations in Savannah River Water and Fish

For use in dose determinations and model comparisons, the concentrations of tritium in

Table 5–1
2002 Radioactive Liquid Release Source Term and 12-Month Average Downriver Radionuclide Concentrations Compared to EPA's Drinking Water Maximum Contaminant Levels (MCLs)

		12-Month Average Concentration (pCi/mL)			
Nuclide	**Curies Released**	**Below SRS[a]**	**Beaufort-Jasper[b]**	**Port Wentworth[c]**	**EPA MCL**
H-3[d]	4.83E+03	1.01E+00	8.24E–01	7.74E–01	2.00E+01
Sr-90	3.45E–02	7.24E–06	5.89E–06	5.53E–06	8.00E–03
Tc-99	1.94E–02	4.06E–06	3.31E–06	3.11E–06	9.00E–01
I-129	7.82E–02	1.64E–05	1.33E–05	1.25E–05	1.00E–03
Cs-137[e]	7.63E–02	1.60E–05	1.30E–05	1.22E–05	2.00E–01
U-234	2.76E–04	5.77E–08	4.71E–08	4.42E–08	1.87E+02
U-235	1.09E–05	2.28E–09	1.86E–09	1.75E–09	6.48E–01
U-238	2.89E–04	6.04E–08	4.93E–08	4.63E–08	1.01E–02
Pu-238	1.15E–05	2.40E–09	1.96E–09	1.84E–10	1.50E–02
Pu-239	2.57E–06	5.39E–10	4.38E–10	4.12E–10	1.50E–02
Am-241	1.05E–05	2.20E–09	1.79E–09	1.68E–09	1.50E–02
Cm-244	1.97E–06	4.12E–10	3.36E–10	3.16E–10	1.50E–02
Alpha	2.44E–02	5.12E–06	4.16E–06	3.91E–06	1.50E–02
Nonvolatile Beta	3.79E–02	7.95E–06	6.47E–06	6.07E–06	8.00E–03
Sum of the Ratios =		6.92E–02	5.64E–02	5.30E–02	

a Near Savannah River Mile 118.8, downriver of SRS at the U.S. Highway 301 bridge
b Beaufort-Jasper, South Carolina, finished drinking water
c Port Wentworth, Georgia, finished drinking water
d Curies released based on measured tritium concentrations at Savannah River Mile 118.8
e Curies released based on measured cesium-137 levels in Savannah River fish

Savannah River water and cesium-137 in Savannah River fish are measured at several locations along the river. The amounts of all other radionuclides released from SRS are so small that they usually cannot be detected in the Savannah River using conventional analytical techniques.

Radionuclide Concentrations in River Water and Treated Drinking Water The measured concentrations of tritium in the Savannah River near River Mile 118.8 and at the Beaufort-Jasper and Port Wentworth water treatment facilities are shown in table 5–1, as are the calculated concentrations for the other released radionuclides.

The 12-month average tritium concentration measured in Savannah River water near River Mile 118.8 (1.01 pCi/mL) was slightly less than the 2001 concentration of 1.02 pCi/mL. The concentrations at the Beaufort-Jasper (0.824 pCi/mL) and Port Wentworth (0.774 pCi/mL) water treatment plants remained below the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 20 pCi/mL.

The MCL for each radionuclide released from SRS during 2002 is provided in table 5–1. The table indicates that all individual radionuclide concentrations at the two downriver community drinking water systems, as well as at River Mile 118.8, were below the MCLs.

Because more than one radionuclide is released from SRS, the sum of the ratios of the observed concentration of each radionuclide to its corresponding MCL must not exceed 1.0.

As shown in table 5–1, the sum of the ratios was 0.0530 at the Port Wentworth facility and 0.0564 at the Beaufort-Jasper facility. These are below the 1.0 requirement.

For 2002, the sum of the ratios at the River Mile 118.8 location was 0.0692. This is provided here only for comparison because River Mile 118.8 is not a community water system location.

Radionuclide Concentrations in River Fish At SRS, an important dose pathway for the maximally exposed individual is from the consumption of fish.

Table 5–2
Potential Dose to the Maximally Exposed Individual from SRS Liquid Releases in 2002

	Committed Dose (mrem)	Applicable Standard (mrem)	Percent of Standard
Maximally Exposed Individual			
Near Site Boundary (all liquid pathways)	0.12	100[a]	0.12
At Port Wentworth (public water supply only)	0.05	4[b]	1.25
At Beaufort-Jasper (public water supply only)	0.06	4[b]	1.50

a All-pathway dose standard: 100 mrem per year (DOE Order 5400.5)
b Drinking water pathway standard: 4 mrem per year (DOE Order 5400.5)

Fish exhibit a high degree of bioaccumulation for certain elements. For the element cesium (including radioactive isotopes of cesium), the bioaccumulation factor for Savannah River fish is approximately 3,000. That is, the concentration of cesium found in fish flesh is about 3,000 times more than the concentration of cesium found in the water in which the fish live [Carlton et al., 1994].

Because of this high bioaccumulation factor, cesium-137 is more easily detected in fish flesh than in river water. Therefore, the fish pathway dose from cesium-137 is based directly on the radioanalysis of the fish collected near Savannah River Mile 118.8, which is the assumed location of the hypothetical maximally exposed individual. The fish pathway dose from all other radionuclides is based on calculated concentrations. Some fraction of this estimated dose is due to cesium-137 from worldwide fallout and from neighboring Plant Vogtle; however, that amount is difficult to determine and is not subtracted from the total.

The dose determinations are accomplished by substituting a cesium-137 release value that would result in the measured concentration in river fish, assuming the site-specific bioaccumulation factor of 3,000. A weighted average concentration (based on the number of fish in each composite analyzed) of cesium-137 in River Mile 118.8 fish was used for maximally exposed individual and population dose determinations.

Dose to the Maximally Exposed Individual

As shown in table 5–2, the highest potential dose to the maximally exposed individual from liquid releases in 2002 was estimated at 0.12 mrem (0.0012 mSv). This dose is 0.12 percent of DOE's 100-mrem all-pathway dose standard for annual exposure and was slightly less than the 2001 dose of 0.13 mrem (0.0013 mSv).

Approximately 39 percent of the dose to the maximally exposed individual resulted from the ingestion of cesium-137, mainly from the consumption of fish, and about 40 percent resulted from the ingestion (via drinking water) of tritium. About 15 percent of the dose was attributed to unspecified alpha emitters, which are conservatively assigned the dose factor for plutonium-239 in the dose calculations (chapter 3).

Drinking Water Pathway Persons downriver of SRS may receive a radiation dose by consuming drinking water that contains radioactivity as a result of liquid releases from the site. In 2002, tritium in downriver drinking water represented the majority of the dose (about 68 percent) received by persons at downriver water treatment plants.

The maximum potential drinking water doses during 2002 were 0.06 mrem (0.0006 mSv) at the Beaufort-Jasper Water Treatment Plant and 0.05 mrem (0.0005 mSv) at the City of Savannah Industrial and Domestic Water Supply Plant (Port Wentworth).

As shown in table 5–2, the maximum dose of 0.06 mrem (0.0006 mSv) is 1.50 percent of the DOE

standard of 4 mrem per year for public water supplies. The 2002 maximum potential drinking water dose was slightly less than the 2001 maximum dose of 0.07 mrem (0.0007 mSv).

The "Potential Dose" section of appendix A, "Applicable Guidelines, Standards, and Regulations," explains the differences between the DOE and EPA drinking water standards.

Collective (Population) Dose

The collective drinking water consumption dose is calculated for the discrete population groups at Beaufort-Jasper and Port Wentworth. The collective dose from other pathways is calculated for a diffuse population that makes use of the Savannah River. However, this population cannot be described as being in a specific geographical location.

In 2002, the collective dose from SRS liquid releases was estimated at 3.9 person-rem (0.039 person-Sv). This was 9 percent less than the 2001 collective dose of 4.3 person-rem (0.043 person-Sv).

Potential Dose from Agricultural Irrigation

Based on surveys of county agricultural extension agencies, there are no known large-scale uses of river water downstream of SRS for agricultural irrigation purposes. However, the potential for irrigation does exist, so potential doses from this pathway are calculated for information purposes only but are not included in calculations of the official maximally exposed individual or collective doses.

For 2002, a potential offsite dose of 0.11 mrem (0.0011 mSv) to the maximally exposed individual and a collective dose of 7.7 person-rem (0.077 person-Sv) were estimated for this exposure pathway.

As in previous years, collective doses from agricultural irrigation were calculated for 1,000 acres of land devoted to each of four major food types—vegetation, leafy vegetation, milk, and meat. It is assumed that all the food produced on the 1,000-acre parcels is consumed by the 80-km population of 713,500.

Air Pathway

Atmospheric Source Terms

The 2002 radioactive atmospheric release quantities used as the source term in SRS dose calculations are presented in chapter 3.

In 2002, krypton-85 accounted for about 40 percent of the radioactivity released to the atmosphere from SRS. Because krypton is an inert noble gas, it causes a relatively small amount of dose to humans (less than 1 percent of the maximally exposed individual dose in 2002).

Estimates of unmonitored diffuse and fugitive sources were considered, as required for demonstrating compliance with NESHAP regulations.

Atmospheric Concentrations

Calculated radionuclide concentrations are used for dose determinations instead of measured concentrations. This is because most radionuclides released from SRS cannot be measured, using standard methods, in the air samples collected at the site perimeter and offsite locations. However, the concentrations of tritium oxide at the site perimeter locations usually can be measured and are compared with calculated concentrations as a verification of the dose models, as shown in data tables on the CD accompanying this report.

Dose to the Maximally Exposed Individual

In 2002, the estimated dose to the maximally exposed individual was 0.06 mrem (0.0006 mSv), which is 0.6 percent of the DOE Order 5400.5 ("Radiation Protection of the Public and the Environment") standard of 10 mrem per year. This dose is about the same as the final (revised) 2001 dose. For complete revised results, refer to the "Errata" folder on the CD accompanying this report.

Table 5–3 compares the maximally exposed individual's dose with the DOE standard.

Tritium oxide releases accounted for about 50 percent of the dose to the maximally exposed individual. Iodine-129 emissions accounted for about 18 percent of the maximally exposed individual dose, and plutonium-239 emissions accounted for about 14 percent. Nearly all the plutonium-239 releases were estimated to be from diffuse and fugitive sources (chapter 3).

The potential dose to the maximally exposed individual residing at the site boundary for each of the 16 major compass point directions around SRS can be seen in the "SRS Maps" appendix (figure 15) on the CD accompanying this report. For 2002, the due-north sector of the site was the location of the highest dose to the maximally exposed individual.

The major pathways contributing to the dose to the maximally exposed individual from atmospheric releases were inhalation (41 percent) and the consumption of vegetation (45 percent), cow milk (9 percent), and meat (3 percent).

Additional calculations of the dose to the maximally exposed individual were performed substituting goat

Table 5–3
Potential Dose to the Maximally Exposed Individual from SRS Atmospheric Releases in 2002

	MAXDOSE–SR	CAP88 (NESHAP)
Calculated dose (mrem)	0.06	0.04
Applicable standard (mrem)	10[a]	10[b]
Percent of standard	0.6	0.4

a DOE: DOE Order 5400.5, February 8, 1990
b EPA: (NESHAP) 40 CFR 61 Subpart H, December 15, 1989

milk for the customary cow milk pathway. The potential dose using the goat milk pathway also was estimated at 0.06 mrem (0.0006 mSv).

Collective (Population) Dose

In 2002, the collective dose was estimated at 3.0 person-rem (0.30 person-Sv)—less than 0.01 percent of the collective dose received from natural sources of radiation (about 214,000 person-rem).

Tritium oxide releases accounted for 56 percent of the collective dose. The 2002 collective dose was about 6 percent less than the 2001 final (revised) collective dose of 3.2 person-rem (0.032 person-Sv). For complete revised results, refer to the "Errata" folder on the CD accompanying this report.

NESHAP Compliance

To demonstrate compliance with NESHAP regulations, maximally exposed individual and collective doses were calculated, and a percentage of dose contribution from each radionuclide was determined using the CAP88 computer code [EPA, 1999a]. The dose was estimated at 0.04 mrem (0.0004 mSv), which is 0.4 percent of the 10-mrem-per-year EPA standard, as shown in table 5–3. Tritium oxide releases accounted for about 85 percent of this dose.

The CAP88-determined collective dose was estimated at 5.5 person-rem (0.055 person-Sv). Tritium oxide releases also accounted for about 85 percent of this dose.

The CAP88 code estimates a higher dose for tritium oxide than do the MAXDOSE–SR and POPDOSE–SR codes. Most of the differences occur in the tritium dose estimated from food consumption. The major cause of this difference is the CAP88 code's use of 100-percent equilibrium between tritium in air moisture and tritium in food moisture, whereas the MAXDOSE–SR and POPDOSE–SR codes use 50-percent equilibrium values, as recommended by the Nuclear Regulatory Commission [NRC, 1977]. A site-specific study indicated that the 50-percent value is correct for the atmospheric conditions at SRS [Hamby and Bauer, 1994].

Because tritium oxide dominates the doses determined using the CAP88 code, and because the CAP88 code is limited to a single, center-of-site release location, other radionuclides (such as plutonium-239) are less important—on a percentage-of-dose basis—for the CAP88 doses than for the MAXDOSE–SR and POPDOSE–SR doses.

All-Pathway Dose

To demonstrate compliance with the DOE Order 5400.5 all-pathway dose standard of 100 mrem per year (1.0 mSv per year), SRS conservatively combines the maximally exposed individual airborne pathway and liquid pathway dose estimates, even though the two doses are calculated for hypothetical individuals residing at different geographic locations.

For 2002, the potential maximally exposed individual all-pathway dose was 0.18 mrem (0.0018 mSv)—0.06 mrem from airborne pathway plus 0.12 mrem from liquid pathway, which is 0.18 percent of the 100-mrem-per-year DOE dose standard. This dose is slightly less than the 2001 final (revised) all-pathway dose of 0.19 mrem (0.0019 mSv). For complete revised results, refer to the "Errata" folder on the CD accompanying this report.

Figure 5–1 shows a 10-year history of SRS's all-pathway doses (airborne pathway plus liquid pathway doses to the maximally exposed individual).

Sportsman Dose

DOE Order 5400.5 specifies radiation dose standards for individual members of the public. The dose

standard of 100 mrem per year includes doses a person receives from routine DOE operations through all exposure pathways. Nontypical exposure pathways, not included in the standard calculations of the doses to the maximally exposed individual, are considered and quantified separately. This is because they apply to low-probability scenarios, such as consumption of fish caught exclusively from the mouths of SRS streams, or to unique scenarios, such as volunteer deer hunters.

In addition to deer and fish consumption, the following exposure pathways were considered for an offsite hunter and an offsite fisherman—both on a privately owned portion of the Savannah River Swamp (Creek Plantation):

- External exposure to contaminated soil
- Incidental ingestion of contaminated soil
- Incidental inhalation of resuspended contaminated soil

In the 1960s, an area of the Savannah River Swamp on Creek Plantation was contaminated by SRS operations (chapter 4).

Onsite Hunter Dose

Deer and Hog Consumption Pathway The estimated dose from consumption of the harvested deer or hog meat is determined for every onsite hunter.

During 2002, the maximum potential dose that could have been received by an actual onsite hunter was estimated at 39.5 mrem (0.395 mSv), or 39.5 percent of DOE's 100-mrem all-pathway dose standard (table 5–4). This dose was determined for a hunter who in fact harvested two deer during the 2002 hunts. The hunter-dose calculation is based on the conservative assumption that this hunter individually consumed the entire edible portion—approximately 62 kg (137 pounds)—of the deer he harvested from SRS.

Offsite Hunter Dose

Deer Consumption Pathway The deer consumption pathway considered was for a hypothetical offsite individual whose entire intake of meat during the year was deer meat. It was assumed that this individual harvested deer that had resided on SRS, but then moved off site.

Based on these low-probability assumptions and on the measured average concentration of cesium-137 (4.0 pCi/g) in all deer harvested from SRS during 2002, the potential maximum dose from this pathway was estimated at 12.2 mrem (0.122 mSv). A background cesium-137 concentration of 1 pCi/g is subtracted from the onsite average concentration before calculating the dose. The background concentration is based on previous analyses of deer harvested 80 km from SRS (table 33, *SRS Environmental Data for 1994*, WSRC–TR–95–077).

Savannah River Swamp Hunter Soil Exposure Pathway The potential dose to a recreational hunter exposed to SRS legacy contamination in Savannah River Swamp soil on the privately owned Creek Plantation in 2002 was estimated using the RESRAD

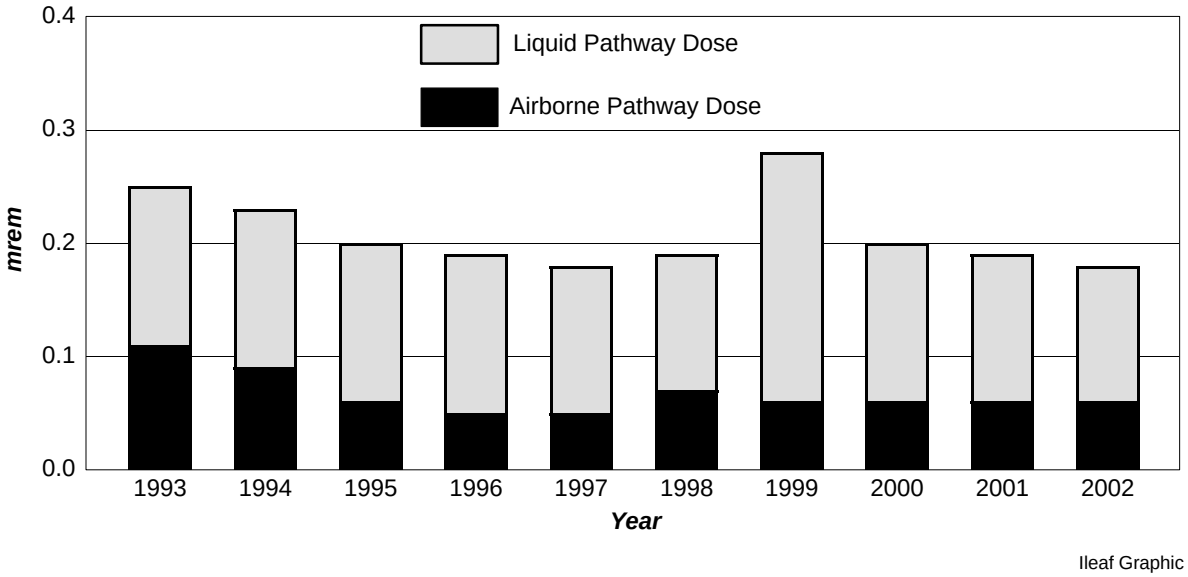

Figure 5–1 Ten-Year History of SRS Potential All-Pathway Doses to the Maximally Exposed Individual (Airborne plus Liquid Pathways)

Table 5–4
2002 Maximum Potential All-Pathway and Sportsman Doses Compared to the DOE All-Pathway Dose Standard

	Committed Dose (mrem)	Applicable Standard[a] (mrem)	Percent of Standard
Maximally Exposed Individual Dose			
All-Pathway (Liquid Plus Airborne Pathway)	0.18	100	0.18
Sportsman Doses			
Onsite Hunter	39.5	100	39.5
Creek Mouth Fisherman[b]	0.35	100	0.35
Savannah River Swamp Hunter			
Offsite Deer Consumption	12.2		
Soil Exposure[c]	4.4		
Total Offsite Hunter Dose	16.6	100	16.6
Savannah River Swamp Fisherman			
Steel Creek Fish Consumption	0.08		
Soil Exposure[d]	0.54		
Total Offsite Fisherman Dose	0.62	100	0.62

a All-pathway dose standard: 100 mrem per year (DOE Order 5400.5)
b In 2002, the maximum fisherman dose was caused by the consumption of bass from the mouth of Lower Three Runs.
c Includes the dose from a combination of external exposure to—and incidental ingestion and inhalation of—the worst-case Savannah River Swamp soil
d Includes the dose from a combination of external exposure to—and incidental ingestion and inhalation of—Savannah River Swamp soil near the mouth of Steel Creek

dosimetry code (DOE Order 5400.5). It was assumed that this recreational sportsman hunted for 120 hours during the year (8 hours per day for 15 days) at the location of maximum radionuclide contamination.

Using the worst-case radionuclide concentrations from the most recent comprehensive survey—conducted in 2000—the potential dose to a hunter from a combination of (1) external exposure to the contaminated soil, (2) incidental ingestion of the soil, and (3) incidental inhalation of resuspended soil was estimated to be 4.4 mrem (0.044 mSv).

As shown in table 5–4, the offsite deer consumption pathway and the Savannah River Swamp hunter soil exposure pathway were conservatively added together to obtain a total offsite hunter dose of 16.6 mrem (0.0166 mSv). This potential dose is 16.6 percent of the DOE 100-mrem all-pathway dose standard.

Offsite Fisherman Dose

Creek Mouth Fish Consumption Pathway For 2002, analyses were conducted of fish taken from the mouths of five SRS streams, and the subsequent estimated doses.

As shown in table 5–4, the maximum potential dose from this pathway was estimated at 0.35 mrem (0.0035 mSv) from the consumption of bass collected at the mouth of Lower Three Runs. This hypothetical dose is based on the low-probability scenario that, during 2002, a fisherman consumed 19 kg of bass caught exclusively from the mouth of Lower Three Runs. About 98 percent of this potential dose was from cesium-137.

Savannah River Swamp Fisherman Soil Exposure Pathway The potential dose to a recreational fisherman exposed to SRS legacy contamination in Savannah River Swamp soil on the privately owned Creek Plantation in 2002 was estimated using the RESRAD dosimetry code. It was assumed that this

recreational sportsman fished on the South Carolina bank of the Savannah River near the mouth of Steel Creek for 250 hours during the year.

During the comprehensive survey of the Savannah River Swamp conducted in 2000, the location on Creek Plantation that was closest to the South Carolina bank of the Savannah River and the mouth of Steel Creek was on trail 1, at a distance of 0 feet from the Savannah River.

Using the radionuclide concentrations measured at this location, the potential dose to a fisherman from a combination of 1) external exposure to the contaminated soil, 2) incidental ingestion of the soil, and 3) incidental inhalation of resuspended soil was estimated to be 0.54 mrem (0.0054 mSv).

As shown in table 5–4, the maximum Steel Creek mouth fish consumption dose (0.084 mrem) and the Savannah River Swamp fisherman soil exposure pathway were conservatively added together to obtain a total offsite creek mouth fisherman dose of 0.62 mrem (0.0062 mSv). This potential dose is 0.62 percent of the DOE 100-mrem all-pathway dose standard.

Potential Risk from Consumption of SRS Creek Mouth Fish

During 1991 and 1992, in response to a U.S. House of Representative Appropriations Committee request for a plan to evaluate risk to the public from fish collected from the Savannah River, SRS developed—in conjunction with EPA, the Georgia Department of Natural Resources (GDNR), and the South Carolina Department of Health and Environmental Control (SCDHEC)—the *Westinghouse Savannah River Company/Environmental Monitoring Section Fish Monitoring Plan*, which is summarized in SRS EM Program, 2001. Part of the reporting requirements of this plan are to perform an assessment of radiological risk from the consumption of Savannah River fish, and to summarize the results in the annual *SRS Environmental Report*.

Risk Comparisons For 2002, the maximum potential radiation doses and lifetime risks from the consumption of SRS creek mouth fish for 1-year, 30-year, and 50-year exposure durations are shown in table 5–5 and are compared to the radiation risks associated with the DOE Order 5400.5 all-pathway dose standard of 100 mrem (1.0 mSv) per year.

The potential risks were estimated using the cancer morbidity risk coefficients from Federal Guidance Report No. 13 [EPA, 1999b].

The maximum recreational fisherman dose was caused by the consumption of bass collected at the mouth of Lower Three Runs. About 98 percent of the dose was attributed to cesium-137.

Table 5–5
Potential Lifetime Risks from the Consumption of Savannah River Fish Compared to Dose Standards

	Committed Dose (mrem)	Potential Risk[a] (unitless)
2002 Savannah River Fish		
1-Year Exposure	0.35	2.6E–07
30-Year Exposure	10.5	7.8E–06
50-Year Exposure	17.5	1.3E–05
Dose Standard		
100-mrem/year All Pathway		
1-Year Exposure	100	7.3E–05
30-Year Exposure	3,000	2.2E–03
50-Year Exposure	5,000	3.7E–03

a It should be noted that all radiological risk factors are based on observed and documented health effects to actual people who have received high doses (more than 10,000 mrem) of radiation, such as the Japanese atomic bomb survivors. Radiological risks at low doses (less than 10,000 mrem) are theoretical and are estimated by extrapolating the observed health effects at high doses to the low-dose region by using a linear, no-threshold model. However, cancer and other health effects have not been observed consistently at low radiation doses because the health risks either do not exist or are so low that they are undetectable by current scientific methods.

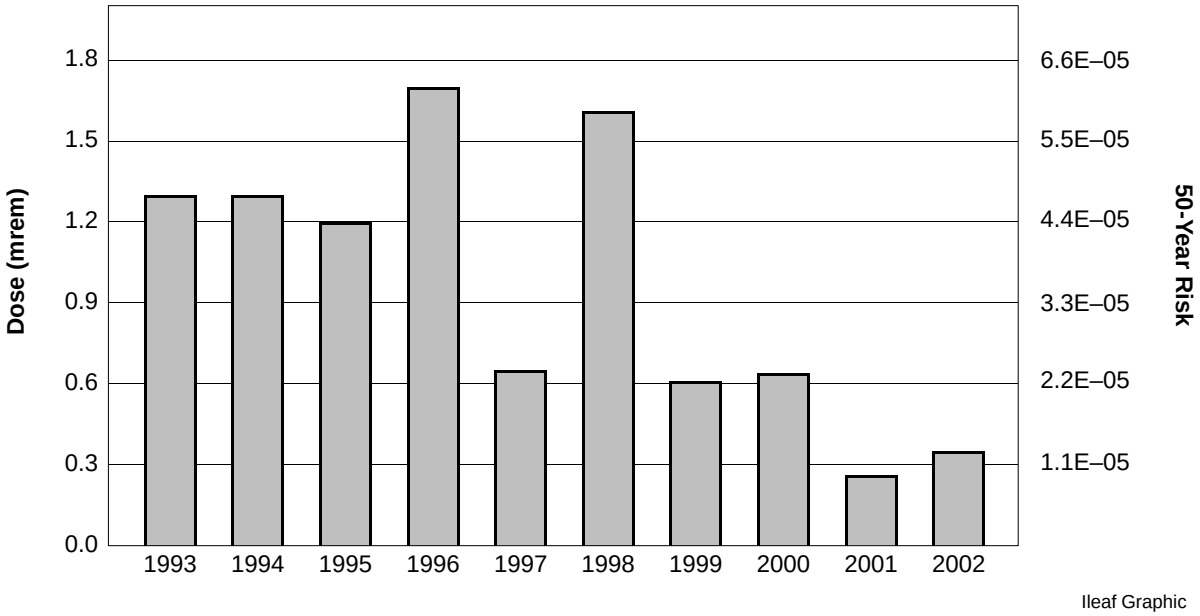

Figure 5–2 Ten-Year History of Annual Potential Radiation Doses and 50-Year Potential Risks from Consumption of Savannah River Creek Mouth Fish.

Figure 5–2 shows a 10-year history of the annual potential radiation doses from consumption of Savannah River fish. No apparent trends can be discerned from these data. This is because there is large variability in the annual strontium-90 and cesium-137 concentrations measured in fish from the same location due to differences in

- the size of the fish collected each year
- their mobility and location within the stream mouth from which they are collected
- the time of year they are collected
- variability in the amount of strontium-90 and cesium-137 available in the water and sediments at the site stream mouths—caused by annual changes in stream flow rates (turbulence) and water chemistry

As indicated in figure 5–2, the 50-year maximum potential lifetime risk from consumption of SRS creek mouth fish was 1.3E–05, which is below the 50-year risk (3.7E–03) associated with the 100-mrem-per-year dose standard.

According to EPA practice, if a potential lifetime risk is calculated to be less than 1.0E–06 (i.e., one additional case of cancer over what would be expected in a group of 1,000,000 people), then the risk is considered minimal and the corresponding contaminant concentrations are considered negligible. If a calculated risk is more than 1.0E–04 (one additional case of cancer in a population of 10,000), then some form of corrective action or remediation usually is required. However, if a calculated risk falls between 1.0E–04 and 1.0E–06, which is the case with the maximum potential lifetime risks from the consumption of Savannah River fish, then the risks are considered acceptable if they are kept as low as reasonably achievable (ALARA).

At SRS, the following programs are in place to ensure that the potential risk from site radioactive liquid effluents (and, therefore, from consumption of Savannah River fish) are kept ALARA:

- radiological liquid effluent monitoring program (chapter 3)
- radiological environmental surveillance program (chapter 4)
- environmental ALARA program [SRS EM Program, 2001]

Dose to Aquatic and Terrestrial Animal Organisms

DOE Order 5400.5 establishes an interim dose standard for protection of native aquatic animal organisms. The absorbed dose limit to these organisms is 1 rad per day (0.01 Gy per day) from exposure to radioactive material in liquid effluents released to natural waterways.

Initial Screening of Biota Doses Using DOE Biota Concentration Guides

For 2002, a screening of biota doses at SRS was performed using the DOE Biota Concentration Guides (BCGs) listed in the proposed DOE standard entitled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* [DOE, 2002].

The aquatic systems evaluation includes exposures to primary (herbivores) and secondary (predators) aquatic animals, and the BCGs are based on the 1.0-rad-per-day dose limit. Aquatic plants are not considered.

The terrestrial systems evaluation includes exposures to terrestrial plants and animals and is based on a 10-rad-per-day dose limit for plants and a 0.1-rad-per-day dose limit for animals.

For the aquatic systems evaluation portion of the BCGs, an initial screening was performed using maximum radionuclide concentration data for the 12 EMS stream sampling locations from which co-located water and sediment samples are collected. An exception to this was made for sample location FM–2B (located on Fourmile Branch between F-Area and H-Area) because of its historically high cesium and tritium concentration levels. This location was included in the initial screening even though no co-located sediment sample was collected there.

The combined water-plus-sediment BCG sum of the ratios was used for the aquatic systems evaluation. A sum-of-the-ratios value less than one indicates the sampling site has passed the initial pathway screen.

For the terrestrial systems evaluation portion of the BCGs, an initial screening was performed using concentration data from the five EMS onsite radiological soil sampling locations. Only one soil sample per year is collected from each location.

For 2002, stream sampling locations R–1—located adjacent to R-Reactor near the center of SRS—and FM–2B failed the initial aquatic systems screen. All other locations, including the five soil sampling locations, passed.

For the two locations that failed, an additional assessment was performed using annual average radionuclide concentrations. Sample location FM–2B passed this secondary screen (the sum of the ratios of each was less than 1.0), but R–1 did not because of elevated cesium-137 concentrations in water and sediment samples. The potential overexposure at R–1 was to a riparian animal (raccoon) that was assumed to have lived, and have consumed all of its food, at this location. Additional sampling and analysis will be performed in the vicinity of R–1 in 2003 to determine the extent of the potential problem.