Chapter 5

Potential Radiation Doses

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THIS chapter presents the potential doses to offsite individuals and the surrounding population from the 2003 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 contribute the most to SRS's estimated maximum individual doses (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 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

- 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

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.

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

To show compliance with DOE environmental orders, potential offsite doses from releases of radioactivity to the atmosphere were calculated with quality-assured meteorological data for A-Area, K-Area (used for releases from C-Area, K-Area, and L-Area) 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.

To show compliance with EPA regulations, only the H-Area database was used in the calculations because the dosimetry code that EPA requires to be used is limited to a single release location. The H-Area meteorological database is provided on the CD accompanying this report.

Population Database and Distribution

Collective, or population, doses from atmospheric releases are calculated for the population within an 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 2003 was approximately 11,000 persons, while the population served by the Beaufort-Jasper facility (including some residents of Hilton Head Island) was approximately 112,000 persons.

River Flow Rate Data

Although flow rates are recorded at a gauging station 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 2003, the River Mile 118.8 calculated (effective) flow rate of 11,138 cubic feet per second was used. This flow rate was over 100 percent more than the 2002 effective flow rate of 5,355 cubic feet per second because of substantially more rainfall during 2003 than in 2002. The effective flow rate was 14,792 cubic feet per second for the Beaufort-Jasper facility and 13,904 cubic feet per second for the Port Wentworth facility.

Dose Calculation Results

Liquid Pathway

Liquid Release Source Terms

The 2003 radioactive liquid release quantities used as source terms in SRS dose calculations are presented in chapter 3 and shown 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 (7,450 curies) includes contributions from Georgia Power Company’s Vogtle Electric Generating Plant (1,900 curies) and from other sources (1,540 curies).

Radionuclide Concentrations in Savannah River Water and Fish

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

Table 5–1
2003 Radioactive Liquid Release Source Term and 12-Month Average Downriver Radionuclide Concentrations Compared to EPA's Drinking Water Maximum Contaminant Levels (MCL)

		12-Month Average Concentration (pCi/mL)			
Nuclide	**Curies Released**	**Below SRS[a]**	**Beaufort-Jasper[b]**	**Port Wentworth[c]**	**EPA MCL**
H-3[d]	7.45E+03	7.49E-01	5.64E-01	6.00E-01	2.00E+01
Sr-90	9.67E-02	9.72E-06	7.32E-06	7.79E-06	8.00E-03
I-129	7.82E-02	7.86E-06	5.92E-06	6.30E-06	1.00E-03
Cs-137	2.10E-01	2.11E-05	1.59E-05	1.69E-05	2.00E-01
U-234	6.97E-04	7.01E-08	5.28E-08	5.61E-08	1.87E+02
U-235	2.43E-05	2.44E-09	1.84E-09	1.96E-09	6.48E-01
U-238	7.05E-04	7.09E-08	5.34E-08	5.68E-08	1.01E-02
Pu-238	1.52E-04	1.53E-08	1.15E-08	1.22E-08	1.50E-02
Pu-239	8.48E-05	8.52E-09	6.42E-09	6.83E-09	1.50E-02
Am-241	1.32E-04	1.33E-08	9.99E-09	1.06E-08	1.50E-02
Cm-244	1.05E-04	1.06E-08	7.95E-09	8.46E-09	1.50E-02
Alpha	3.58E-02	3.60E-06	2.71E-06	2.88E-06	1.50E-02
Beta	1.46E-01	1.47E-05	1.11E-05	1.18E-05	8.00E-03
Sum of the Fractions of MCLs =		4.87E-02	3.67E-02	3.90E-02	

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

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 (0.749 pCi/mL) was about 25 percent less than the 2002 concentration of 1.01 pCi/mL. This reduction occurred because of the more than 100-percent increase in the Savannah River flow rate in 2003 compared to 2002, which caused more dilution. The concentrations at the Beaufort-Jasper (0.564 pCi/mL) and Port Wentworth (0.600 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 2003 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 fractions 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 fractions was 0.0390 at the Port Wentworth facility and 0.0367 at the Beaufort-Jasper facility. These are below the 1.0 sum-of-the-fractions requirement.

For 2003, the sum of the fractions at the River Mile 118.8 location was 0.0487. 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.

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 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

Table 5–2
Potential Dose to the Maximally Exposed Individual from SRS Liquid Releases in 2003

	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)	0.04	4[b]	1.0
At Beaufort-Jasper (public water supply only)	0.04	4[b]	1.0

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)

river water. Therefore, the fish pathway dose from cesium-137 normally 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. However, in 2003, the calculated concentration of cesium-137 in fish, which is based on measured effluent releases, was determined to be more than the actual measured concentrations in fish. To be conservative, the higher calculated cesium-137 concentrations were used in the 2003 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 2003 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 is the same as the 2002 dose.

Approximately 55 percent of the dose to the maximally exposed individual resulted from the ingestion of cesium-137, mainly from the consumption of fish, and about 44 percent resulted from the ingestion (via drinking water) of tritium.

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 2003, 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 2003 were determined to be about 0.04 mrem (0.0004 mSv) for both the Beaufort-Jasper Water Treatment Plant and the City of Savannah Industrial and Domestic Water Supply Plant (Port Wentworth). The 2003 maximum dose was about 33 percent less than the 2002 dose of 0.06 mrem (0.0006 mSv), primarily because of the increase in Savannah River flow rate.

As shown in table 5–2, the maximum dose of 0.04 mrem (0.0004 mSv) is 1.0 percent of the DOE standard of 4 mrem per year for public water supplies. For comparison, in table 5–1, the Port Wentworth sum of the fractions equated to 3.9 percent of the EPA MCLs. The difference between the DOE and EPA drinking water standards is explained in the "Potential Dose" section of appendix A.

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 2003, the collective dose from SRS liquid releases was estimated at 2.9 person-rem (0.029 person-Sv). This was 25 percent less than the 2002 collective dose of 3.9 person-rem (0.039 person-Sv). Again, this reduction was caused by the substantial increase in the Savannah River flow rate.

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 2003, a potential offsite dose of 0.08 mrem (0.0008 mSv) to the maximally exposed individual and a collective dose of 5.9 person-rem (0.059 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 2003 radioactive atmospheric release quantities used as the source term in SRS dose calculations are presented in chapter 3.

In 2003, krypton-85 accounted for about 55 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 2003).

Estimates of unmonitored diffuse and fugitive sources were included in the atmospheric source term, 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 2003, the estimated dose to the maximally exposed individual was 0.07 mrem (0.0007 mSv), which is 0.7 percent of the DOE Order 5400.5 ("Radiation Protection of the Public and the Environment") standard of 10 mrem per year. This dose was slightly higher than the 2002 dose of 0.06 mrem (0.0006 mSv). This increase is attributed to higher iodine-129 releases from H-Area, caused by increased operations in H-Canyon during 2003. Table 5–3 compares the maximally exposed individual's dose with the DOE standard.

Tritium oxide releases accounted for 39 percent of the dose to the maximally exposed individual. Iodine-129 emissions accounted for 33 percent of the maximally exposed individual dose, and plutonium-239 emissions accounted for 12 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 found in the "Maps" appendix (figure 12) on the CD accompanying this report. For 2003, 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 (34 percent) and the consumption of vegetation (52 percent), cow milk (10 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 2003

	MAXDOSE–SR	CAP88 (NESHAP)
Calculated dose (mrem)	0.07	0.05
Applicable standard (mrem)	10[a]	10[b]
Percent of standard	0.7	0.5

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 was estimated at 0.08 mrem (0.0008 mSv).

Collective (Population) Dose

In 2003, the collective dose was estimated at 3.6 person-rem (0.036 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 47 percent of the collective dose. The 2003 collective dose was about 20 percent more than the 2002 collective dose of 3.0 person-rem (0.030 person-Sv).

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 0.05 mrem (0.0005 mSv), which is 0.5 percent of the 10-mrem-per-year EPA standard, as shown in table 5–3. Tritium oxide releases accounted for about 80 percent of this dose.

The CAP88-determined collective dose was estimated at 5.7 person-rem (0.057 person-Sv). Tritium oxide releases also accounted for about 82 percent of this dose.

The CAP88 code estimates a higher dose for tritium oxide than do the MAXDOSE–SR and POPDOSE–SR codes, which are used for showing compliance with DOE environmental orders [SRS EM Program, 2001]. 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 2003, the potential maximally exposed individual all-pathway dose was 0.19 mrem (0.0019 mSv)—0.07 mrem from airborne pathway plus 0.12 mrem from liquid pathway—and is 0.19 percent of the 100-mrem-per-year DOE dose standard. This dose is slightly more than the 2002 all-pathway dose of 0.18 mrem (0.0018 mSv).

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, hog, and fish consumption, the following exposure pathways were considered for an offsite hunter and an offsite fisherman—both on Creek Plantation, a privately owned portion of the Savannah River Swamp, which was contaminated by SRS operations in the 1960s (chapter 4):

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

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 2003, the maximum potential dose that could have been received by an actual onsite hunter was

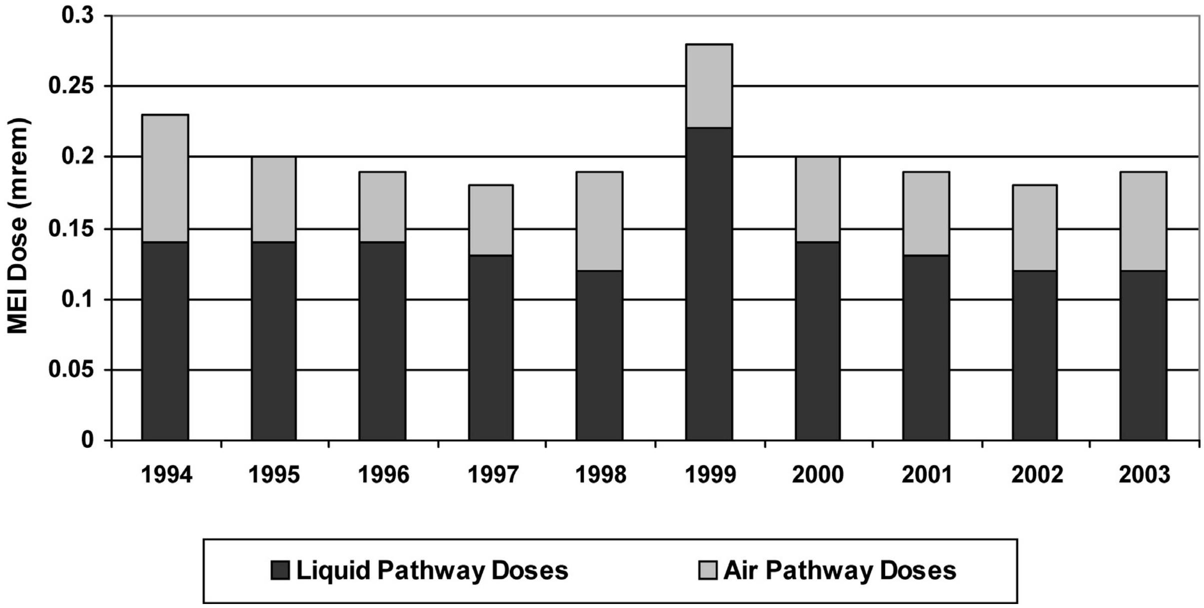

Figure 5–1 Ten-Year History of SRS Maximum Potential All-Pathway Doses

estimated at 15.6 mrem (0.156 mSv), or 15.6 percent of DOE's 100-mrem all-pathway dose standard (table 5–4). This dose was determined for a hunter who in fact harvested one deer during the 2003 hunts. The hunter-dose calculation is based on the conservative assumption that this hunter individually consumed the entire edible portion—approximately 54.4 kg (120 pounds)—of the deer he harvested from SRS.

Offsite Hunter Dose

Deer and Hog Consumption Pathway The deer and hog consumption pathway considered was for hypothetical offsite individuals whose entire intake of meat during the year was either deer or hog meat. It was assumed that these individuals harvested deer or hogs 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 in all deer (1.3 pCi/g) and hogs (1.2 pCi/g) harvested from SRS during 2003, the potential maximum doses from this pathway were estimated at 1.2 mrem (0.012 mSv) for the deer hunter and at 0.81 mrem (0.0081 mSv) for the hog hunter.

A background cesium-137 concentration of 1 pCi/g is subtracted from the onsite average concentrations before calculating the doses. 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 2003 was estimated using the RESRAD 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 5.6 mrem (0.056 mSv). This potential dose is 5.6 percent of the DOE 100-mrem all-pathway dose standard.

Offsite Fisherman Dose

Creek Mouth Fish Consumption Pathway For 2003, radioanalyses were conducted of fish taken from the mouths of five SRS streams, and the subsequent estimated doses were calculated.

Table 5–4
2003 Maximum Potential All-Pathway and Sportsman Doses Compared to the DOE All-Pathway Dose Standard

	Committed Dose (mrem)	Applicable Standard (mrem)[a]	Percent of Standard
Maximally Exposed Individual Dose			
All-Pathway (Liquid Plus Airborne Pathway)	0.19	100	0.19
Sportsman Doses			
Onsite Hunter	15.6	100	15.6
Creek Mouth Fisherman[b]	0.58	100	0.58
Savannah River Swamp Hunter			
Offsite Deer Consumption	1.2		
Offsite Hog Consumption	0.81		
Soil Exposure[c]	4.4		
Total Offsite Deer Hunter Dose	5.6	100	5.6
Savannah River Swamp Fisherman			
Steel Creek Fish Consumption	0.12		
Soil Exposure[d]	0.54		
Total Offsite Fisherman Dose	0.66	100	0.66

a All-pathway dose standard: 100 mrem per year (DOE Order 5400.5)
b In 2003, the maximum fisherman dose was caused by the consumption of bass from the mouth of Four Mile Creek.
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

As shown in table 5–4, the maximum potential dose from this pathway was estimated at 0.58 mrem (0.0058 mSv) from the consumption of bass collected at the mouth of Four Mile Creek. This hypothetical dose is based on the low-probability scenario that, during 2003, a fisherman consumed 19 kg of bass caught exclusively from the mouth of Four Mile Creek. About 94 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 2003 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 (0.12 mrem) and the Savannah River Swamp fisherman soil exposure pathway were conservatively added together to obtain a total offsite creek mouth fisherman dose of 0.66 mrem (0.0066 mSv). This potential dose is 0.66 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 Representatives 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, and the South Carolina Department of Health and Environmental Control—the *Westinghouse Savannah River Company/Environmental Monitoring Section Fish Monitoring Plan*, which is summarized in SRS EM Program, 2001. Among the reporting requirements of this plan are (1) assessing radiological risk from the consumption of Savannah River fish and (2) presenting a summary of the results in the annual *SRS Environmental Report*.

Risk Comparisons For 2003, 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].

For 2003, the maximum recreational fisherman dose was caused by the consumption of bass collected at the mouth of Four Mile Creek.

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 table 5–5, the 50-year maximum potential lifetime risk from consumption of SRS creek mouth fish was 2.4E-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

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

	Committed Dose (mrem)	Potential Risk[a] (unitless)
2003 Savannah River Fish		
1-Year Exposure	0.58	4.4E-07
30-Year Exposure	17.4	1.3E-05
50-Year Exposure	29.0	2.4E-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.

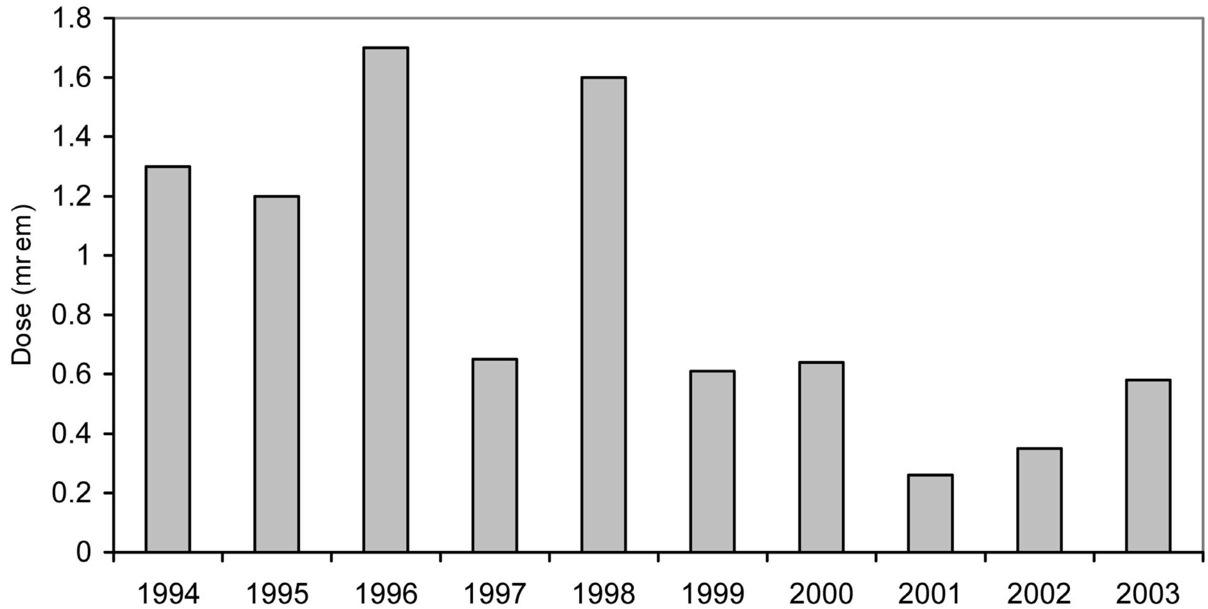

Figure 5–2 Ten-Year History of Savannah River Site Creek Mouth Fisherman's Dose

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) is 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 1.0 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 2003, a screening of biota doses at SRS was performed using the RESRAD-Biota model, which is based on the 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 Four Mile Creek 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 is collected there.

The combined water-plus-sediment BCG sum of the ratios was used for the aquatic systems evaluation. A sum of the ratios 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 2003, stream sampling locations R–1 (located adjacent to R-Reactor near the center of SRS), FM-A7, FM-2, and FM–2B failed the initial aquatic systems screen. All other locations, including the five soil sampling locations, passed.

For the four locations that failed, an additional assessment was performed using annual average radionuclide concentrations measured in the water and sediment samples. All locations passed this secondary screen (the sum of the ratios of each was less than 1.0).