Potential Radiation Doses

CHAPTER 6

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This chapter presents the potential doses to offsite individuals and the surrounding population from the 2009 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, 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 SRS effluent monitoring and environmental surveillance programs discussed in this chapter can be found in chapter 4, "Effluent Monitoring," and chapter 5, "Environmental Surveillance." A complete description of how potential doses are calculated can be found in section 1108 of the Savannah River Site Environmental Monitoring Program, WSRC–3Q1–2, Volume 1, Revision 4 [SRS EM Program, 2002a].

All dose calculation results are presented in data tables on the CD housed inside the back cover of this report.

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 living at the SRS boundary
- population living within an 80-km (50-mile) radius of SRS

Because the U.S. Department of Energy (DOE) has

Dose to the Hypothetical Maximally Exposed Individual

When calculating radiation doses to the public, SRS uses the concept of the hypothetical 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 as follows:

For airborne releases - Someone who lives at the SRS boundary 365 days per year and consumes 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 19 kg (42 pounds) per year 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.

adopted dose factors only for adults [DOE, 1988], SRS calculates maximally-exposed-individual and collective doses as if the entire 80-km population consists of adults. For the radioisotopes that contribute the most to SRS's estimated maximum individual doses (i.e., tritium and cesium-137), the dose to infants could be approximated as two to three times more than the adult dose. The dose to older children becomes progressively closer to the adult dose.

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].

For dose calculations, the unspecified alpha releases were conservatively treated as plutonium-239, and the unspecified beta releases were treated as strontium-90. These radionuclides have the highest dose factors of the alpha- and beta-emitters, respectively, that are commonly measured in SRS waste streams.

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, 2002a.

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 (for combined releases from C-Area, K-Area, and L-Area), and H-Area (for combined releases from all other areas). The meteorological databases were for the years 2002–2006, reflecting the most recent 5-year compilation period.

To show compliance with U.S. Environmental Protection Agency (EPA) regulations, only the H-Area database was used in the calculations because the EPA-required dosimetry code (CAP88, Mainframe version 1.0, henceforth referred to simply as CAP88) is limited to a single release location.

Population Database and Distribution

Collective (population) doses from atmospheric releases are calculated for the population within an 80-km radius of SRS. Within this radius, the total population is 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 (Savannah I&D), near Port Wentworth, Georgia, and by the Beaufort-Jasper Water and Sewer Authority's (BJWSA) Chelsea and Purrysburg Water Treatment Plants, near Beaufort, South Carolina. According to the treatment plant operators, the population served by the Savannah I&D facility during 2009 was 26,300 persons, while the population served by the BJWSA Chelsea facility was 77,000 persons and by the BJWSA Purrysburg facility, 58,000 persons.

River Flow Rate Data

Savannah River flow rates—recorded at a gauging station near River Mile 118.8 (U.S. Highway 301 bridge)—are based on the measured water elevation. However, these data are not used directly in SRS dose calculations. Used instead are "effective" flow rates, which are based on (1) the measured annual release of tritium and (2) the annual average tritium concentrations measured at River Mile 118.8 and at the three downriver water treatment plants. The use of effective river flow rates in the dose calculations generally is more conservative than the use of measured flow rates because it accounts for less dilution.

For 2009, the River Mile 118.8 calculated (effective) flow rate of 6,324 cubic feet per second (cfs) was used in the dose calculations. This flow rate was nearly 46 percent more than the 2008 effective flow rate of 4,340 cfs, which was the lowest annual average river flow rate since the startup of SRS operations in 1954. For comparison, the 2009 annual average flow rate (as measured by the U.S. Geological Survey) was 7,666 cfs. This flow rate is still well below the 1954–2009 mean annual flow rate of 10,228 cfs—likely because of persistent drought conditions in the Central Savannah River Area.

The 2009 calculated effective flow rates were 8,807 cfs for the Savannah I&D facility, 8,226 cfs for the BJWSA Chelsea facility, and 7,873 cfs for the BJWSA Purrysburg facility.

Dose Calculation Results

Liquid Pathway

Liquid Release Source Terms (Table)

The 2009 radioactive liquid release quantities used as the source term in SRS dose calculations are discussed in chapter 4 and shown by radionuclide in table 6–1. Tritium accounts for more than 99 percent of the total amount of radioactivity released from the site to the Savannah River. In 2009, a total of 1,559 curies of tritium were released from SRS to the river. In the recent past, the total amount of tritium used in SRS dose calculations was based on the measured tritium concentration at River Mile 118.8. However, the total from this location includes the tritium releases from Georgia Power Company's Vogtle Electric Generating Plant (VEGP). Since 2006, maximally-exposed-individual doses have been calculated and documented in this report using SRS-only releases.

Data from continuously monitored liquid effluent discharge points are used in conjunction with site seepage basin and Solid Waste Disposal Facility migration release measurements to quantify the total tritium released from SRS. A separate dose calculation is performed (for information only) that includes the total amount of tritium (SRS plus VEGP) measured at River Mile 118.8, which in 2009 was 2,784 curies.

Radionuclide Concentrations in Savannah River Water, Drinking Water, and Fish

The concentrations of tritium in Savannah River water and cesium-137 in Savannah River fish are measured at several locations along the river for use in dose determinations and model comparisons. 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. Therefore, their concentrations in the river are calculated using the LADTAP XL code, based on the annual release amounts and on the applicable effective flow rate.

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 Savannah I&D and BJWSA water treatment facilities are shown in table 6–1, as are the calculated concentrations for the other released radionuclides. These downriver tritium concentrations include the tritium releases from SRS and the neighboring VEGP.

In 2009, the 12-month average tritium concentration measured in Savannah River water near River Mile 118.8 (493 pCi/L) was 28 percent less the 2008 concentration of 686 pCi/L. This decrease is attributed to the 46 percent increase in river flow from 2008 to 2009. The 2009 concentrations at the BJSWA Chelsea (379 pCi/L) and Purrysburg (396 pCi/L) facilities, and at the Savannah I&D (354 pCi/L) water treatment plant, were proportionately lower than in 2008, and remained below the EPA drinking water maximum contaminant level (MCL) of 20,000 pCi/L.

The drinking water MCL for each radionuclide released from SRS during 2009 is provided in table 6–1. The table indicates that all individual radionuclide concentrations at the three 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 reported concentration of each radionuclide to its corresponding MCL must not exceed 1.0. The sums of the fractions were 0.0257 at the BJSWA Chelsea facility, 0.0268 at the BJSWA Purrysburg facility, and 0.0240 at the Savannah I&D facility. These are below the 1.0 sum-of-the-fractions requirement.

For 2009, the sum of the fractions at the River Mile 118.8 location was 0.0334. This is provided 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].

Table 6–1
2009 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]**	**BJWSA Chelsea[b]**	**BJWSA Purrysburg[b]**	**Savannah I&D[c]**	**EPA MCL**
H-3[d]	2.78E+03	4.93E+02	3.79E+02	3.96E+02	3.54E+02	2.00E+04
Zn-65	5.51E-04	9.76E-05	7.50E-05	7.84E-05	7.01E-05	3.00E+02
Sr-90	4.02E-02	7.12E-03	5.47E-03	5.72E-03	5.11E-03	8.00E+00
Tc-99	1.96E-02	3.47E-03	2.67E-03	2.79E-03	2.49E-03	9.00E+02
I-129	3.55E-02	6.29E-03	4.83E-03	5.05E-03	4.51E-03	1.00E+00
Cs-137	9.15E-02	1.62E-02	1.25E-02	1.30E-02	1.16E-02	2.00E+02
U-234[e]	1.62E-04	2.87E-05	2.21E-05	2.30E-05	2.06E-05	1.03E+01
U-235[e]	2.17E-06	3.84E-07	2.95E-07	3.09E-07	2.76E-07	4.67E-01
U-238[e]	1.16E-04	2.05E-05	1.58E-05	1.65E-05	1.47E-05	1.00E+01
Np-237	9.07E-06	1.61E-06	1.23E-06	1.29E-06	1.15E-06	1.50E+01
Pu-238	2.28E-03	4.04E-04	3.10E-04	3.24E-04	2.90E-04	1.50E+01
Pu-239	1.55E-04	2.74E-05	2.11E-05	2.20E-05	1.97E-05	1.50E+01
Am-241	1.05E-04	1.86E-05	1.43E-05	1.49E-05	1.33E-05	1.50E+01
Cm-244	2.92E-05	5.17E-06	3.97E-06	4.15E-06	3.71E-06	1.50E+01
Alpha	1.77E-02	3.13E-03	2.41E-03	2.52E-03	2.25E-03	1.50E+01
Beta	5.48E-02	9.70E-03	7.46E-03	7.79E-03	6.97E-03	8.00E+00

[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] The tritium concentrations and source term are based on actual measurements of the Savannah River water at the various locations. They include contributions from the VEGP. All other radionuclide concentrations are calculated based on the effective river flow rate.

[e] MCL for uranium in natural water, based on radioisotope-specific activity X 30 μg/L X isotopic abundance

Because of this high bioaccumulation factor, cesium-137 is detected more easily in fish flesh than in river water. Therefore, the fish pathway dose from cesium-137 normally is based directly on the radio-analysis of the fish collected near Savannah River Mile 118.8, which is the assumed location of the hypothetical maximally exposed individual. However, in 2009, the LADTAP XL dose model calculated

concentration of cesium-137 in fish, which is based on measured effluent releases, was determined to be more than the actual measured concentration in fish. To be conservative, this higher calculated cesium-137 concentration in fish was used in the 2009 dose determinations.

Dose to the Maximally Exposed Individual

As shown in table 6–2, the highest potential dose to the maximally exposed individual from liquid releases in 2009 was estimated at 0.08 mrem (0.0008 mSv). This dose is 0.08 percent of the DOE Order 5400.5 ("Radiation Protection of the Public and the Environment") 100-mrem all-pathway dose standard for annual exposure. The 2009 dose is the same as the 2008 dose.

Approximately 61 percent of the 2009 dose to the maximally exposed individual resulted from the ingestion of cesium-137, mainly from the consumption of fish. About 17 percent of the dose resulted from the ingestion of tritium (mainly via drinking water), an additional 14 percent from the ingestion of unspecified alpha emitters. Every other radionuclide contributed less than 3 percent to the dose.

Using the 2009 total Savannah River tritium source term (which includes SRS and VEGP releases) of 2,784 curies, the maximally-exposed-individual dose was calculated to be 0.09 mrem (0.0009 mSv). This dose, which is provided here for information only, is the same as the equivalent 2008 dose.

Drinking Water Pathway Dose

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 2009, tritium in downriver drinking water represented the majority of the dose (about 46 percent) received by persons at the three downriver water treatment plants. Unspecified alpha-emitters accounted for about 36 percent, and iodine-129 releases, about 5 percent. All other individual radionuclides contributed 3 percent or less to the dose.

Based on SRS-only releases, the maximum potential drinking water dose during 2009 was determined to be 0.02 mrem (0.0002 mSv)—about 50 percent less than the 2008 dose of 0.04 mrem (0.0004 mSv). This decrease is attributed primarily to the 46 percent increase in Savannah River flow rate from 2008 to 2009. As shown in table 6–2, the maximum dose of 0.02 mrem is 0.5 percent of the DOE standard of 4 mrem per year for public water supplies.

Using the SRS-plus-VEGP total tritium source term of 2,784 curies, the maximum drinking water dose

Table 6–2
Potential Dose to the Maximally Exposed Individual from SRS Liquid Releases in 2009

	Committed Dose (mrem)	Applicable Standard (mrem)	Percent of Standard
Maximally Exposed Individual			
Near Site Boundary (all liquid pathways)	0.08	100[a]	0.08
At BJSWA Chelsea (public water supply only)	0.02	4[b]	0.50
At BJSWA Purrysburg (public water supply only)	0.02	4[b]	0.50
At Savannah I&D (public water supply only)	0.02	4[b]	0.50

[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)

was calculated to be 0.03 mrem (0.0003 mSv) in 2009.

Collective (Population) Dose

The collective drinking water consumption dose is calculated for the discrete population groups served by the BJWSA and Savannah I&D water treatment plants. 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 2009, the collective dose from SRS liquid releases was estimated at 2.2 person-rem (0.022 person-Sv). This is about 42 percent less than the 2008 collective dose of 3.8 person-rem (0.038 person-Sv). Again, this decrease is attributed mainly to the higher Savannah River flow rate during 2009.

Using the SRS-plus-VEGP total tritium source term of 2,784 curies, the collective dose was calculated to be 2.9 person-rem (0.029 person-Sv) in 2009.

Potential Dose from Agricultural Irrigation

Based on discussions with personnel in the Georgia Department of Natural Resources (GDNR) and the South Carolina Department of Health and Environmental Control (SCDHEC), there are no known large-scale uses of Savannah River water downstream of SRS for agricultural irrigation purposes. However, the potential for agricultural irrigation does exist, so potential doses from this pathway are calculated for informational purposes only, but are not included in calculations of the official maximally-exposed-individual or collective doses.

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

For 2009, a potential offsite dose of 0.06 mrem (0.0006 mSv) to the maximally exposed individual and a potential collective dose of 3.9 person-rem (0.039 person-Sv) were estimated for this exposure pathway.

Air Pathway

Atmospheric Source Terms

The 2009 radioactive atmospheric release quantities used as the source term in SRS dose calculations are discussed in chapter 4. Estimates of unmonitored diffuse and fugitive sources were included in the atmospheric source term, as required, for demonstrating compliance with National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations.

Atmospheric Concentrations

Calculated radionuclide concentrations instead of measured concentrations are used for dose determinations. This is because most radionuclides released from SRS cannot be measured (using conventional analytical 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.

Dose to the Maximally Exposed Individual

In 2009, the estimated dose from atmospheric releases to the maximally exposed individual (calculated with MAXDOSE–SR) was 0.04 mrem (0.0004 mSv), which is 0.4 percent of the DOE Order 5400.5 air pathway standard of 10 mrem per year. Table 6–3 compares the maximally-exposed-individual dose with the DOE standard. The 2009 dose was the same as the dose for 2008.

Tritium oxide releases accounted for about 80 percent of the dose to the maximally exposed individual, and iodine-129 releases accounted for about 10 percent of the dose. No other individual radionuclide accounted for more than 5 percent of the maximally-exposed-individual dose.

The major pathways contributing to the maximally-exposed-individual dose from atmospheric releases were inhalation (41 percent), vegetation consumption (39 percent), and meat and milk consumption (17 percent). For 2009, the due north sector of the site was the location of the highest dose to the maximally exposed individual.

Table 6–3
Potential Dose to the Maximally Exposed Individual from SRS Atmospheric Releases in 2009

	MAXDOSE–SR	CAP88 (NESHAP)
Calculated dose (mrem)	0.04	0.04
Applicable Standard	10[a]	10[b]
Percent of Standard	0.40	0.40

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

Additional calculations of the dose to the maximally exposed individual again were performed substituting goat milk for the customary cow milk pathway. The potential dose to the maximally exposed individual using the goat milk pathway instead of the cow milk pathway was estimated at 0.05 mrem (0.0005 mSv).

Collective (Population) Dose

In 2009, the airborne-pathway collective dose (calculated with POPDOSE–SR) was estimated at 2.0 person-rem (0.020 person-Sv)—less than 0.01 percent of the annual collective dose received from natural sources of radiation (about 214,000 person-rem). Tritium oxide releases accounted for about 82 percent of the collective dose. The 2009 collective dose was about 11 percent more than the 2008 collective dose of 1.8 person-rem (0.018 person-Sv).

NESHAP Compliance

To demonstrate compliance with NESHAP regulations [EPA, 2002a], maximally-exposed-individual and collective doses were calculated using (1) the CAP88 computer code, (2) the 2009 airborne-release source term, and 3) site-specific input parameters [SRS EM Program, 2002a]. The CAP88 code estimates a higher dose for tritium oxide than do the MAXDOSE–SR and POPDOSE–SR codes, which are used for demonstrating compliance with DOE environmental orders. 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, other radionuclides (such as iodine-129) are less important—on a percentage-of-dose basis—for the CAP88 doses than for the MAXDOSE–SR and POPDOSE–SR doses.

For 2009, the maximally-exposed-individual 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 6–3. Tritium oxide releases accounted for about 96 percent of this dose. The 2009 NESHAP compliance dose of 0.04 mrem (0.0004 mSv) was the same as the dose for 2008.

For NESHAP, the dose from diffuse and fugitive releases is required to be reported separately. For 2009, the maximally-exposed-individual dose from diffuse and fugitive releases was estimated to be 0.01 mrem (0.0001 mSv), which accounts for slightly less than half the total maximally-exposed-individual dose.

The CAP88-determined collective dose was estimated at 5.0 person-rem (0.05 person-Sv). Tritium oxide releases accounted for about 96 percent of this dose.

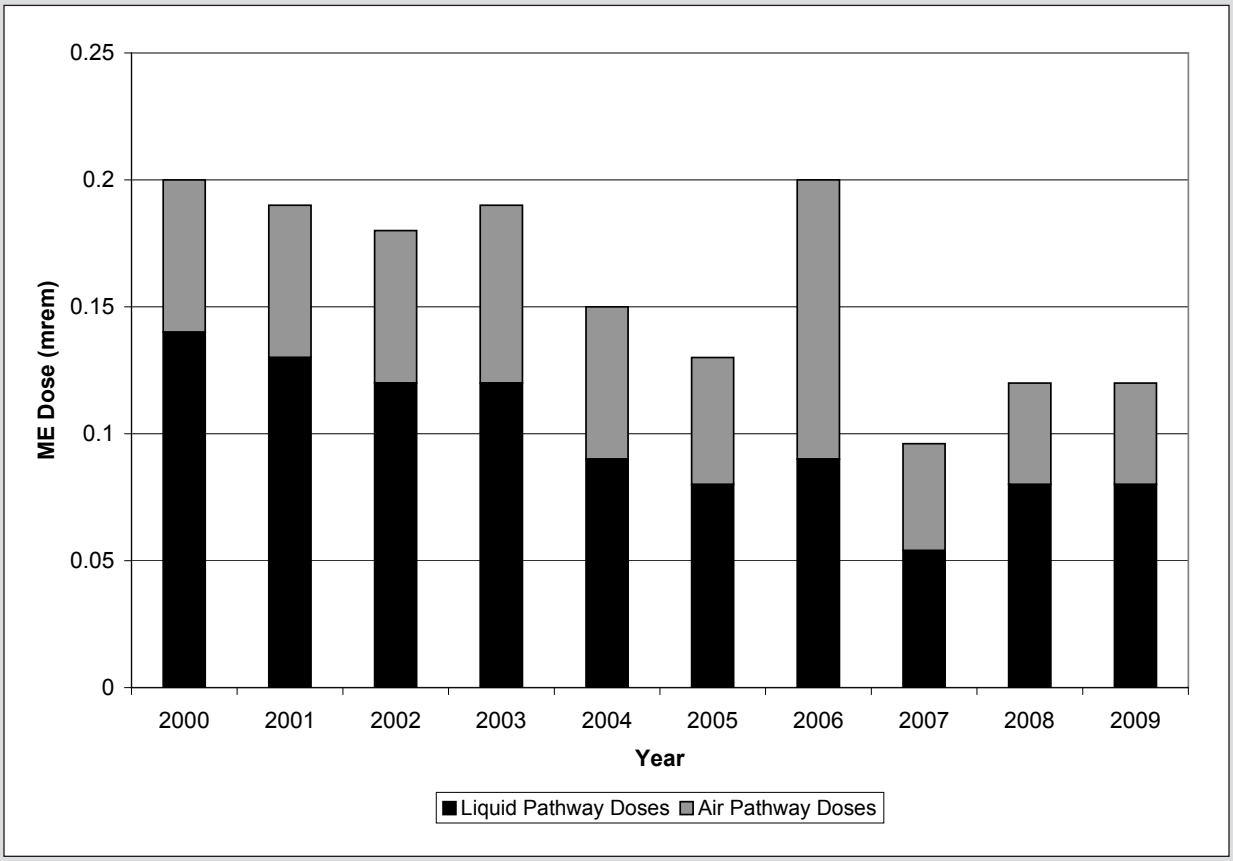

Figure 6–1 Ten-Year History of SRS Maximum Potential All-Pathway Doses

All-Pathway Dose

To demonstrate compliance with the DOE Order 5400.5 all-pathway dose standard of 100 mrem (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 2009, the potential maximally-exposed-individual all-pathway dose was 0.12 mrem (0.0012 mSv)—0.04 mrem from air pathways plus 0.08 mrem from liquid pathways. The all-pathway dose is 0.12 percent of the 100-mrem-per-year DOE dose standard. The 2009 all-pathway dose is the same as the 2008 dose.

Figure 6–1 shows a 10-year history of SRS's all-pathway (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 5):

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

Onsite Hunter Dose

Deer and Hog Consumption Pathway Annual hunts, open to members of the general public, are conducted at SRS to control the site's deer and feral hog populations and to reduce animal-vehicle accidents. The estimated dose from the consumption of harvested deer or hog meat is determined for every onsite hunter. During 2009, the maximum dose that could have been received by an actual onsite hunter was estimated at 8.4 mrem (0.084 mSv), or 8.4 percent of DOE's 100-mrem all-pathway dose standard (table 6–4). This dose was determined for

Table 6–4
2009 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)	0.12	100	0.12
Sportsman Dose			
Onsite Hunter	8.40	100	8.40
Creek-Mouth Fisherman[b]	0.35	100	0.35
Savannah River Swamp Hunter			
Offsite Hog Consumption	0.24		
Offsite Deer Consumption	1.54		
Soil Exposure[c]	2.90		
Total Offsite Deer Hunter Dose	4.44	100	4.44
Savannah River Swamp Fisherman			
Steel Creek Fish Consumption	0.10		
Soil Exposure[d]	0.28		
Total Offsite Fisherman Dose	0.38	100	0.38

[a] All-pathway dose standard: 100 mrem per year (DOE Order 5400.5)

[b] In 2009, the maximum dose to a hypothetical fisherman 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

an actual hunter who in fact harvested seven animals (4 deer and 3 hogs) during the 2009 hunts. The hunter-dose calculation is based on the conservative assumption that this prolific hunter individually consumed the entire edible portion—approximately 168 kg (370 pounds)—of the animals 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 (1.38 pCi/g) and hogs (1.06 pCi/g) harvested from SRS during 2009, the potential maximum doses from this pathway were estimated at 1.54 mrem (0.0154 mSv) for the offsite deer hunter and 0.24 mrem (0.0024 mSv) for the offsite 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 at least 80 km from SRS (table 33, SRS Environmental Data for 1994) [SRS Data, 1995].

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 2009 was estimated using the RESRAD code [Yu et al., 2001]. 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 2007—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 2.9 mrem (0.029 mSv).

As shown in table 6–4, 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 4.44 mrem (0.0444 mSv). This potential dose is 4.44 percent of the DOE 100-mrem all-pathway dose standard.

Offsite Fisherman Dose

Creek-Mouth Fish Consumption Pathway For 2009, radioanalyses were conducted of three species of fish (panfish, catfish, and bass) taken from the mouths of the five SRS streams, and the resulting estimated doses were calculated. SRS reports the maximum dose from this combination of fish and creek mouths. As shown in table 6–4, 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 2009, a fisherman consumed 19 kg of bass caught exclusively from the mouth of Lower Three Runs. About 91 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 2007 (year of last comprehensive swamp survey; refer to chapter 5) was estimated using the RESRAD code [Yu et al., 2001]. 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.

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 0.28 mrem (0.0028 mSv) in 2009.

As shown in table 6–4, the maximum Steel Creek-mouth fish consumption dose (0.10 mrem) and the Savannah River Swamp fisherman soil exposure pathway were conservatively added together to obtain a total offsite creek-mouth fisherman dose of 0.38 mrem (0.0038 mSv). This potential dose is 0.38 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

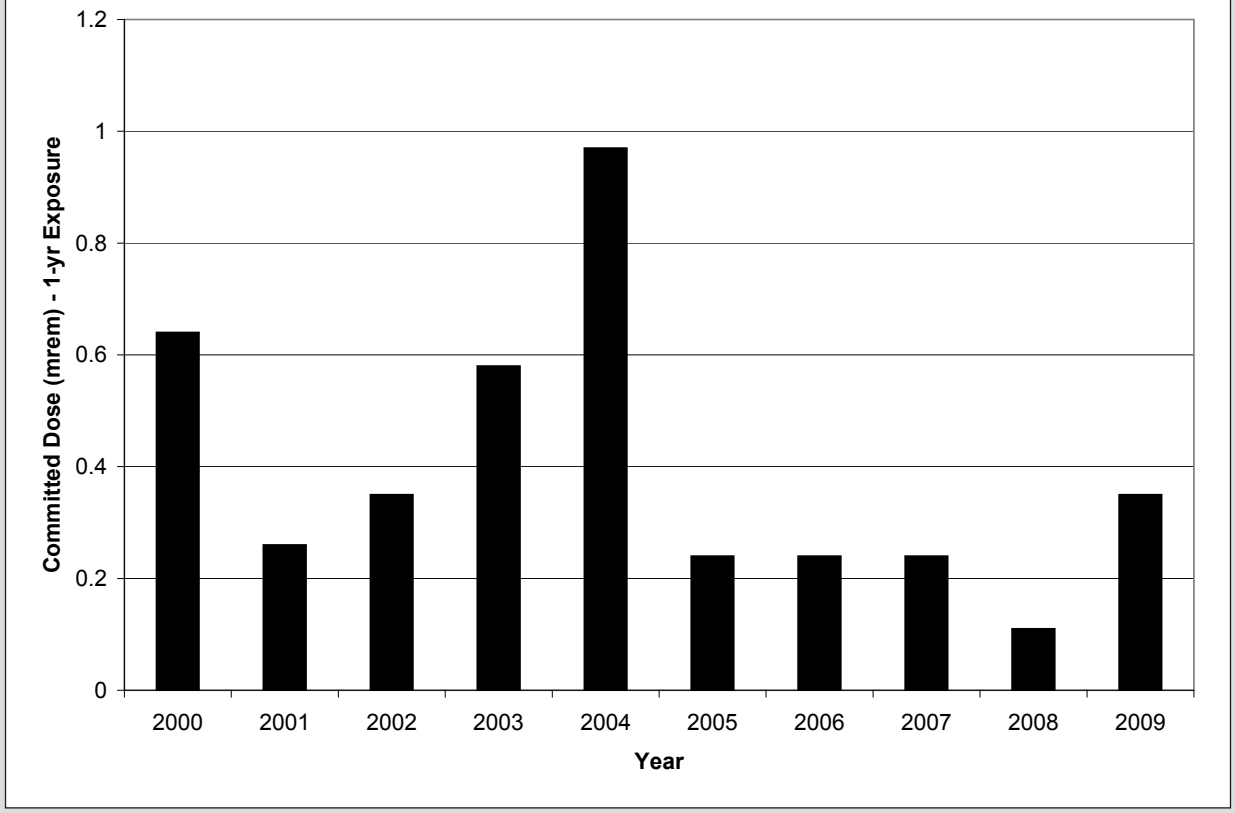

Figure 6–2 Ten-Year History of SRS Creek-Mouth Fisherman's Doses

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, 2002. 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 2009, 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 6–5, 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, 1999a].

For 2009, the maximum recreational fisherman dose was caused by the consumption of bass collected at the mouth of Lower Three Runs. Figure 6–2 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 of large variability in the 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
- the amount of cesium-137 (and other radionuclides) available in the water and sediments at the SRS stream mouths—caused by annual

Table 6–5
Potential Lifetime Risks from the Consumption of Savannah River Fish Compared to Dose Standards

	Committed Dose (mrem)	Potential Risk[a] (unitless)
2009 Savannah River Fish		
1-Year Exposure	0.35	2.8E-07
30-Year Exposure	10.50	7.8E-06
50-Year Exposure	17.50	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.

changes in stream flow rates (turbulence) and water chemistry

As indicated in table 6–5, the 50-year maximum potential lifetime risk from consumption of SRS creek-mouth fish was 4.1E-06, which is below the 50-year risk (3.7E-03) associated with the 100-mrem-per-year dose standard.

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 risk may be deemed acceptable if it is kept as low as reasonably achievable (ALARA), although actions to further reduce this risk can be considered. At SRS, the environmental ALARA program [SRS EM Program, 2002a] is in place to ensure that the potential risk from site radioactive liquid effluents (and, therefore, from consumption of Savannah River fish) is kept ALARA.

Release of Material Containing Residual Radioactivity (Table)

No materials containing residual radioactivity were released from SRS during 2009. DOE issued a moratorium in January 2000 prohibiting the release of volume-contaminated metals, and suspended the release of metals from DOE radiological areas in July 2000 for recycling purposes. No volume-contaminated metals or

metals for recycling purposes were released from SRS in 2009.

DOE approved an SRS request in 2003 to use supplemental limits for releasing material from the site with no further DOE controls. These supplemental release limits are dose-based, and are such that if any member of the public received any exposure, it would be less than 1 mrem/year. The supplemental limits include both surface and volume concentration criteria. The surface criteria are very similar to those used in previous years. The volume criteria allow the disposal of potentially volume-contaminated material in SRS's Three Rivers Landfill, an onsite sanitary facility. In 2009, no material was released from the site using the SRS Supplemental Release Limits volume concentration criteria.
These measures ensure that radiological releases of material from SRS are consistent with the requirements of DOE Order 5400.5.

Radiation Dose to Aquatic and Terrestrial Biota

DOE Order 5400.5 establishes an interim dose standard for protection of native aquatic animals. 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.

DOE Biota Concentration Guides

At SRS, the evaluations of biota doses for aquatic and terrestrial systems are performed using the RESRAD-Biota model (version 1.21), 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 biota concentration guides (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, initial screenings were performed in 2009 using maximum radionuclide concentration data from the 10 SRS Environmental Monitoring (EM) 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 fractions was used for the aquatic systems evaluation. A sum of the fractions less than 1.0 indicates the sampling site has passed its initial pathway screening.

For the terrestrial-systems evaluation, initial screenings were performed using concentration data from the five EM onsite radiological soil sampling locations. Only one soil sample per year is collected and analyzed for radioactivity from each location.

For 2009, all terrestrial locations and all but one aquatic location passed their initial pathway screenings. Location FM–2B failed the initial screening but passed the secondary screening using average concentrations in lieu of the maximum concentrations.