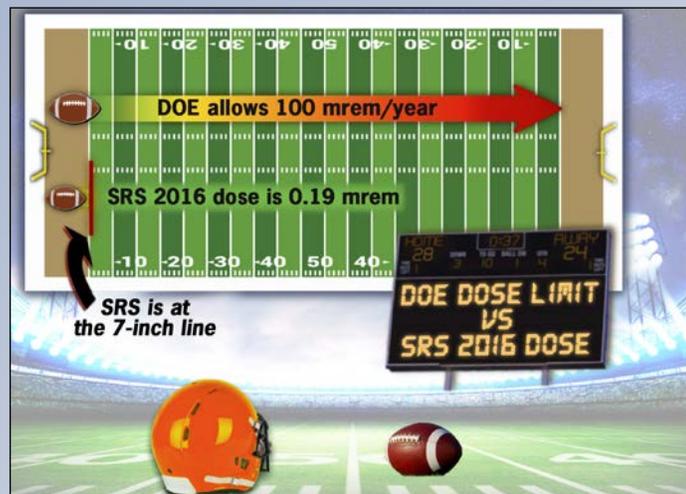


Department of Energy (DOE) Order 458.1, *Radiation Protection of the Public and the Environment*, establishes dose limits for the public and onsite plants and animals. These dose limits protect the public and environment from the effect of radiation released during some DOE activities. To ensure that radiation exposure does not exceed the DOE public dose standard of 100 mrem/year (yr), the Savannah River Site (SRS) calculates the potential dose to the public from radioactive releases in air and water through all reasonable exposure pathways (direct, ingesting, absorbing, inhaling). SRS also considers and quantifies exposure pathways that are nontypical and not included in the standard dose calculations to the representative person. These apply to conservative and unlikely scenarios such as a member of the public eating fish caught only from the mouths of SRS streams or to special scenarios such as hunters who participate in onsite hunts. In addition, DOE Order 458.1 establishes authorized surface contamination limits, which allow SRS to release personal and real property unconditionally. SRS performs radiological surveys on all equipment considered for release and follows applicable procedures.

2016 Highlights

Dose to the Offsite Representative Person—The dose to the offsite representative person was 0.15 mrem from SRS liquid releases and 0.038 mrem from SRS air releases. To comply with the DOE all-pathway dose standard of 100 mrem/yr, SRS conservatively adds these two doses for a total representative person dose of 0.19 mrem, which is 0.19% of the 100 mrem/yr DOE dose standard.



Comparison of DOE's 100 mrem/year (yr) Dose Standard to SRS's 2016 All-Pathway Dose of 0.19 mrem

2016 Highlights (continued)

Sportsman Doses

- **Onsite Hunter**—SRS conducts annual hunts to control onsite deer and wild hog populations. SRS determines the estimated dose from eating harvested deer or hog meat for every onsite hunter. The maximum potential dose for an onsite hunter was 13.5 mrem, or 13.5% of the 100 mrem/yr DOE dose standard.
- **Creek Mouth Fisherman**—SRS estimated the maximum potential dose from fish consumption from bass collected at the mouth of Fourmile Branch at 0.22 mrem. This dose is 0.22% of the 100 mrem/yr DOE dose standard. SRS bases this hypothetical dose on the low probability that, during 2016, a fisherman consumed 53 pounds (lbs) of bass caught exclusively from the mouth of Fourmile Branch.

Release of Material Containing Residual Radioactivity—SRS did not release any real property (land or buildings) in 2016. SRS unconditionally released 11,516 items of personal property (such as tools) from radiological areas. Most of these items did not leave the Site, but were reused elsewhere on the Site. However, all of these items required no additional radiological controls post-survey, as they met DOE Order 458.1 release criteria.

Radiation Dose to Aquatic and Terrestrial Biota—SRS evaluates plant and animal doses for water and land systems. For 2016, all SRS water, sediment, and soil locations passed their Level 1 (using maximum measured concentrations) or Level 2 (using average measured concentrations) screenings and did not require further assessments.

6.1 INTRODUCTION

Routine SRS operations release controlled amounts of radioactive materials to the environment through air and water. These releases could expose people offsite to radiation. To confirm that this exposure is below public dose limits, SRS calculates annual dose estimates using environmental monitoring and surveillance data, combined with relevant Site-specific data (such as weather conditions, population characteristics, and river flow). SRS also confirms that the potential doses to plants and animals (biota) living onsite remain below the DOE biota dose limits. This chapter explains radiation doses, describes how SRS calculates doses, and presents the estimated doses from SRS activities for 2016.

[Radiological Impact of 2016 Operations at the Savannah River Site](#) (Jannik, Minter, and Dixon 2017a) details SRS dose calculation methods and results.

To calculate the potential doses to the public, SRS used the data from the monitoring programs Chapter 5, *Radiological Environmental Monitoring Program*, describes.

6.2 WHAT IS RADIATION DOSE?

Radiation dose to a person is the amount of energy absorbed by the human body from a radiation source located either inside or outside of the body. SRS typically reports dose in millirem (mrem), which is one-thousandth of a rem. A rem is a standard unit used to measure the amount of radiation deposited in human tissue.

Humans, plants, and animals potentially receive radiation doses from natural and man-made sources. The average annual background dose for all people living in the United States is 625 mrem; this includes an average background dose of 311 mrem from naturally occurring radionuclides found in our bodies, in the earth, and from cosmic radiation, such as from the sun. Man-made sources and their doses include medical procedures (300 mrem), consumer products (13 mrem), and industrial and occupational exposures from facilities such as SRS (less than 1 mrem).

DOE has established dose limits to the public so that DOE operations will not contribute significantly to this average annual exposure. DOE Order 458.1 (DOE 2013) establishes 100 mrem/yr (1 mSv/yr) as the annual dose limit to a member of the public. Exposure to radiation primarily occurs through the following pathways, which Figure 6-1 illustrates:

- Inhaling air
- Ingesting water and food
- Absorbing through skin
- Direct (external) exposure to radionuclides in soil, air, and water

6.3 CALCULATING DOSE

To comply with DOE Order 458.1, dose can be calculated to the maximally exposed individual (MEI) or to a representative person. Since 2012, SRS has used the representative person concept for the DOE public dose limit.

SRS calculates the representative person dose using site-specific reference person parameters. The SRS representative person falls at the 95th percentile of national and regional data. The applicable national and regional data used are from the U.S. Environmental Protection Agency's (EPAs) *Exposure Factors Handbook*, 2011 Edition (EPA 2011).

The reference person is weighted based on gender and age. The International Commission on Radiation Protection Publication 89, (ICRP 2002) groups these ages as: Infant (0 years), 1 year, 5 years, 10 years, 15 years, and Adult (17 years and older). The reference person accounts for the fact that younger people are, in general, more sensitive to radioactivity than older people. SRS also developed human usage parameters at the 50th percentile for calculating dose to a "typical" person when determining population doses.

Chapter 6—Key Terms

Exposure pathway is the way that releases of radionuclides into the water and air could impact a person.

Reference person is a hypothetical person with average physical and physiological characteristics—including factors such as age and gender—used internationally to standardize radiation dose calculations.

Representative person is a hypothetical individual receiving a dose that is representative of highly exposed individuals in the population. The calculations incorporate age, gender, food and water consumption, and breathing rate. At SRS, the representative person equates to the 95th percentile of applicable national human-use radiation exposure data.

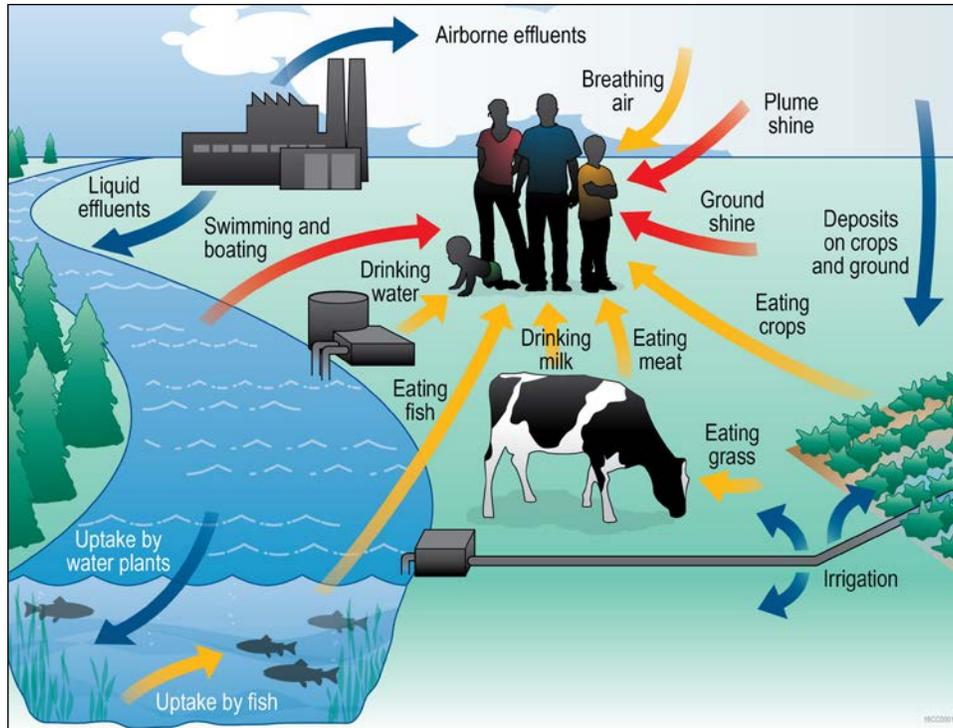


Figure 6-1 Exposure Pathways to Humans from Air and Liquid Effluents

The SRS report *Site-Specific Reference Person Parameters and Derived Concentration Standards for SRS* (Stone and Jannik 2013) documents SRS-specific reference and typical person usage parameters. The SRS report *Land and Water Use Characteristics and Human Health Input Parameters for Use in Environmental Dosimetry and Risk Assessments at the Savannah River Site* (Jannik et al. 2016) documents all other applicable land- and water-use parameters in the dose calculations. These parameters include local characteristics of food production, river recreational activities, and other human usage parameters required in SRS models to calculate radioactive dose exposure.

To determine the Site is complying with DOE public dose requirements, SRS calculates the potential offsite doses from Site effluent releases of radioactive materials (air and liquid) for the following scenarios:

- Representative person living near the SRS boundary
- Population living within a 50-mile (80-kilometer [km]) radius of SRS

For all routine environmental dose calculations, SRS uses environmental transport and dose models based on codes the Nuclear Regulatory Commission (NRC) developed (NRC 1977). The NRC-based transport models use DOE-accepted methods, consider all significant exposure pathways, and permit detailed analysis of the effects of routine operations. The SRS report *Environmental Dose Assessment Manual* (Jannik, Minter, and Dixon 2017b) describes the specific models SRS uses.

At SRS, the dose to a representative person is based on the following:

- 1) SRS-specific reference person usage parameters at the 95th percentile of appropriate national or regional data (Stone and Jannik 2013).
- 2) Reference person (gender- and age-averaged) ingestion and inhalation dose coefficients from the

DOE Derived Concentration Technical Standard, DOE-STD-1196-2011 (DOE 2011).

- 3) External dose coefficients from the DC_PAK3 toolbox, (accessed at <http://www.epa.gov/rpdweb00/federal/techdocs.html>). Currently, there are no age-specific external dose factors available.

6.3.1 Weather Database

Complete and accurate weather (meteorological) data are important to determine offsite contamination levels. SRS calculated potential offsite doses from radioactive releases to the air with quality-assured weather data from 2007 to 2011 (Viner 2013).

Figure 6-2 presents the H-Area wind rose plot for 2007-2011 and shows the direction and frequency the wind blows. As shown, the wind blows the most towards the East-Northeast sector (about 9% of the time), but there is no strongly prevalent wind direction.

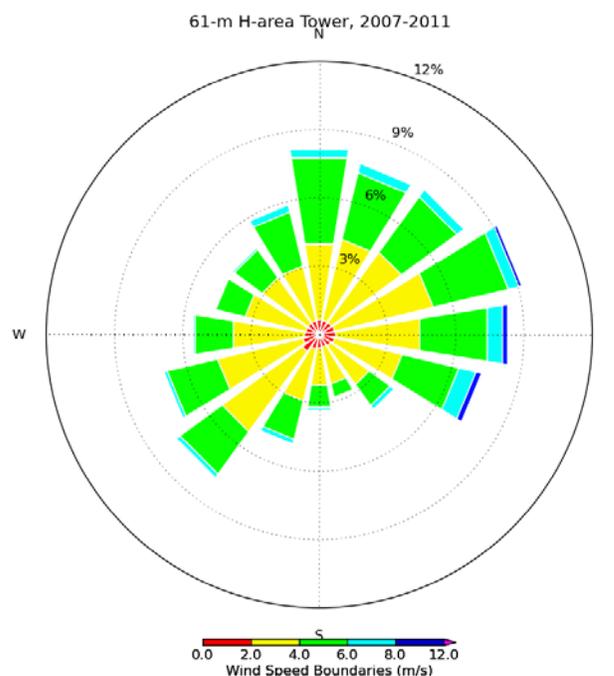


Figure 6-2 2007–2011 Wind Rose Plot for H Area (Showing Direction and Frequency Toward Which the Wind Blows)

6.3.2 Population Database and Distribution

SRS calculates the collective (population) doses from air releases for the population within a 50-mile radius of the Site. Based on the U.S. Census Bureau's 2010 data, the population within a 50-mile radius of the center of SRS is 781,060 people. This translates to about 104 people per square mile outside the SRS boundary, with the largest concentration in the Augusta metropolitan area.

Table 6-1 presents the collective doses from SRS liquid releases to the populations that three downriver drinking water supply plants serve.

The total population dose from routine SRS liquid releases is the sum of the following five contributing categories:

- 1) Beaufort-Jasper Water and Sewer Authority (BJWSA) water consumers
- 2) City of Savannah Industrial and Domestic (I&D) water consumers
- 3) Consuming fish and invertebrates of Savannah River origin
- 4) Recreational activities on the Savannah River
- 5) Irrigating foodstuffs with river water near River Mile (RM) 118.8 (U.S. Highway 301 bridge)

Table 6-1 Regional Water Supply Service

Water Supply Plant	Nearest City	Population Served
City of Savannah Industrial and Domestic Water Supply Plant (City of Savannah I&D)	Port Wentworth, Georgia	35,000 people
Beaufort-Jasper Water and Sewer Authority's (BJWSA) Chelsea Water Treatment Plant	Beaufort, South Carolina	83,700 people
BJWSA Purrysburg Water Treatment Plant	Beaufort, South Carolina	64,800 people

6.3.3 River Flow Rate Data

The annual rate of flow in the Savannah River, which varies greatly from year to year, is an important criterion for determining down-river concentrations of the contaminants SRS releases. The U.S. Geological Survey (USGS) measures Savannah River flow rates down river of SRS at its RM 118.8 gauging station, located near the U.S. Hwy 301 Bridge.

Figure 6-3 provides the river flow rates measured at this location from 1954 to 2016. It also shows that the average river flow rate for these years is about 10,000 cubic feet per second (cfs). However, recently, there has been a downward trend in these data with an average measured flow rate of just 7,567 cfs during the past 10 years.

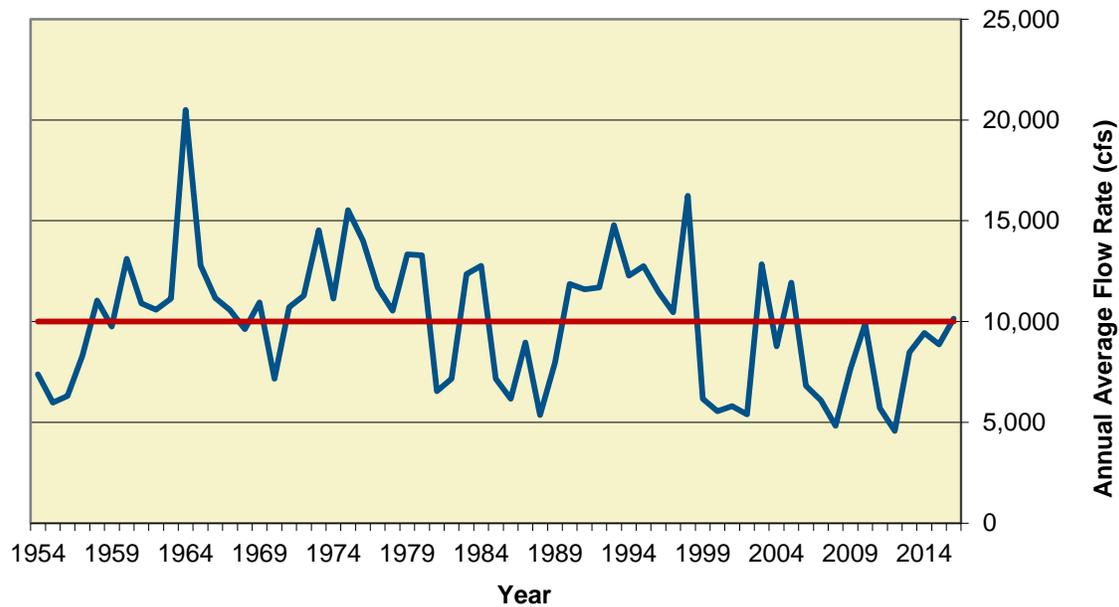


Figure 6-3 Savannah River Annual Average Flow Rates at River Mile 118.8

For 2016, SRS used a calculated “effective” Savannah River flow rate of 6,426 cfs in the dose calculations. The 2016 effective flow rate is about 8% more than the 2015 effective flow rate of 5,972 cfs. This effective flow rate (based on actual measured tritium concentrations in the river) is more conservative than the 2016 USGS measured flow rate of 10,150 cfs (based on daily flow rates). By using a conservative method, the calculated effective flow rate assumes radioactive material is less diluted and, therefore, increases the estimated potential dose.

6.4 OFFSITE REPRESENTATIVE PERSON DOSE CALCULATION RESULTS

To determine the Site is complying with DOE public dose requirements, SRS calculates the potential offsite doses from Site effluent releases of radioactive materials in air and liquid pathways for a representative person living near the SRS boundary. SRS calculates the pathways individually and then adds the two results to obtain the representative person dose.

6.4.1 Liquid Pathway

6.4.1.1 Liquid Release Source Terms

Table 6-2 shows, by radionuclide, the amount of radioactivity in liquid form that SRS released in 2016. SRS uses these release amounts in the dose calculations. Discussions of the sources of these data are in Chapter 5, *Radiological Environmental Monitoring Program*.

Tritium accounts for more than 99% of the total amount of radioactivity released from the Site to the Savannah River. In 2016, SRS released a total of 731 curies of tritium to the river, a 7% decrease from the 2015 amount of 786 curies. For compliance dose calculations, SRS used the stream transport measurement (731 curies), which was higher than the direct release (668 curies). Refer to Chapter 5, *Radiological Environmental Monitoring Program*, Section 5.4.5 for details concerning these measurements.

During 2016, in addition to the 731 curies SRS released, the Georgia Power Company’s Vogtle Electric Generating Plant (VEGP) released 992 curies of tritium to the Savannah River, and 56 curies migrated from the Barnwell Low-Level Disposal Facility (BLLDF) for an overall total of 1,779 curies of tritium (SRS plus VEGP plus BLLDF). This is slightly more than the total of 1,698 curies measured in the Savannah River near RM 118.8, as Chapter 5 reports. The 2016 total of 1,779 curies is a 31% decrease from the combined total of 2,565 curies in 2015.

Table 6-2 2016 Radioactive Liquid Release Source Term and 12-Month Average Downriver Radionuclide Concentrations Compared to the EPA's Drinking Water Maximum Contaminant Levels (MCL)

Nuclide	Curies Released	12-Month Average Concentration (pCi/L)		
		Below SRS ^a	at BJWSA Purrysburg Plant ^b	EPA MCL ^c
H-3 ^d	7.31E+02	3.10E+02	2.14E+02	2.00E+04
C-14	5.82E-04	1.01E-04	7.00E-05	2.00E+03
Sr-90	1.95E-02	3.40E-03	2.34E-03	8.00E+00
Tc-99	1.88E-02	3.27E-03	2.26E-03	9.00E+02
I-129	1.82E-02	3.17E-03	2.19E-03	1.00E+00
Cs-137	4.79E-02	8.34E-03	5.76E-03	2.00E+02
U-234	3.30E-02	5.75E-03	3.97E-03	1.03E+01
U-235	1.04E-03	1.81E-04	1.26E-04	4.67E-01
U-238	3.68E-02	6.41E-03	4.42E-03	1.00E+01
Np-237	2.78E-06	4.84E-07	3.34E-07	1.50E+01
Pu-238	2.60E-04	4.53E-05	3.13E-05	1.50E+01
Pu-239	1.37E-05	2.39E-06	1.65E-06	1.50E+01
Am-241	1.80E-03	3.13E-04	2.16E-04	1.50E+01
Cm-244	1.54E-04	2.68E-05	1.85E-05	1.50E+01
Alpha	1.98E-02	3.45E-03	2.38E-03	1.50E+01
Beta	1.36E-01	2.37E-02	1.63E-02	8.00E+00

Notes:

^a Near Savannah River Mile 118.8, downriver of SRS at the U.S. Highway 301 bridge^b Beaufort-Jasper Water and Sewer Authority, drinking water at the Purrysburg Water Treatment Plant^c MCLs for uranium based on radioisotope specific activity X 30 µg/L X isotopic abundance^d The actual measurements of the Savannah River water at the various locations are the basis for the tritium concentrations and source term. They include contributions from VEGP and the Barnwell Low-Level Disposal Facility. SRS uses the effective or measured river flow rate to calculate all other radionuclide concentrations.

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

SRS measures the tritium concentrations in the river water and cesium-137 in fish at several locations along the Savannah River. SRS uses these direct measurements to make dose determinations. The amounts of all other radionuclides SRS released are so small that their concentration in the Savannah River usually cannot be detected using conventional analytical techniques. SRS calculates the concentrations in the river based on the annual release amounts and river flow rates.

Radionuclide Concentrations in River Water and Treated Drinking Water—Table 6-2 shows the measured concentrations of tritium in the Savannah River near RM 118.8 and at the BJWSA Purrysburg Water Treatment Facility, which is representative of the BJWSA Chelsea and the City of Savannah I&D water treatment plants. These downriver tritium concentrations include tritium releases from SRS and the VEGP and BLLDF. Table 6-2 also provides the calculated concentrations for the other released radionuclides and a comparison of these concentrations to the Safe Drinking Water Act, 40 CFR 141 (EPA 2000) maximum contaminant level (MCL) for each radionuclide.

In 2016, the 12-month average tritium concentration measured in Savannah River water near RM 118.8 was 310 picocuries per liter (pCi/L). This reflects a 36% decrease from the 481 pCi/L measured in 2015. SRS attributes this decrease to the 30% decrease in the combined (SRS plus VEGP plus BLLDF) total of tritium released to the Savannah River in 2016 and to the 8% increase in the effective river flow rate from 2015 to 2016, which caused more dilution to occur.



SRS Samples Savannah River Water at RM 118.8, Near the U.S. Highway 301 Bridge. SRS Uses the Tritium Concentrations Measured at this Location in the Annual Dose.

Radionuclide Concentrations in Fish—Consuming fish is an important dose pathway for the representative person. Fish exhibit a high degree of bioaccumulation for certain elements. For cesium (including radioactive isotopes of cesium, such as cesium-137), the bioaccumulation factor for Savannah River fish is 3,000, meaning that the cesium concentration 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, SRS can detect cesium-137 more easily in fish flesh than in river water. Therefore, when conservative to do so, SRS bases the fish pathway dose from cesium-137 directly on analyzing the fish collected near RM 118.8, the assumed location of the hypothetical representative person. In 2016, SRS analyzed fish in the river to determine the cesium-137 release value of 0.0479 Ci, which was a small (2%) increase from the 2015 value of 0.0468 Ci.

6.4.1.3 Dose to the Representative Person

The 2016 potential dose to the representative person from all liquid pathways (including irrigation) was estimated at 0.15 mrem (0.0015 mSv), which was the same as the comparable dose in 2015. Table 6-3 shows that the total liquid pathway dose is 0.15% of the DOE public dose standard of 100 mrem/yr (1 mSv/yr).

Table 6-3 Potential Dose to the Representative Person from SRS Liquid Releases in 2016

	Committed Dose (mrem)	Applicable Standard (mrem)	Percent of Standard (%)
Near Site Boundary (All Liquid Pathways)			
All Liquid Pathways Except Irrigation	0.05		
Irrigation Pathways	0.10		
Total Liquid Pathways	0.15	100 ^a	0.15%

Note: ^aDOE dose standard: 100 mrem/yr (DOE Order 458.1)

About 66% of the 2016 total dose to the representative person is from consuming meat, milk, and vegetables that have been raised using Savannah River water from RM 118.8. The fish consumption pathway accounted for 23%, and the drinking water pathway accounted for 11%. As Figure 6-4 shows, unidentified beta emitters (23%) and cesium-137 (21%) contributed the most to the liquid dose.

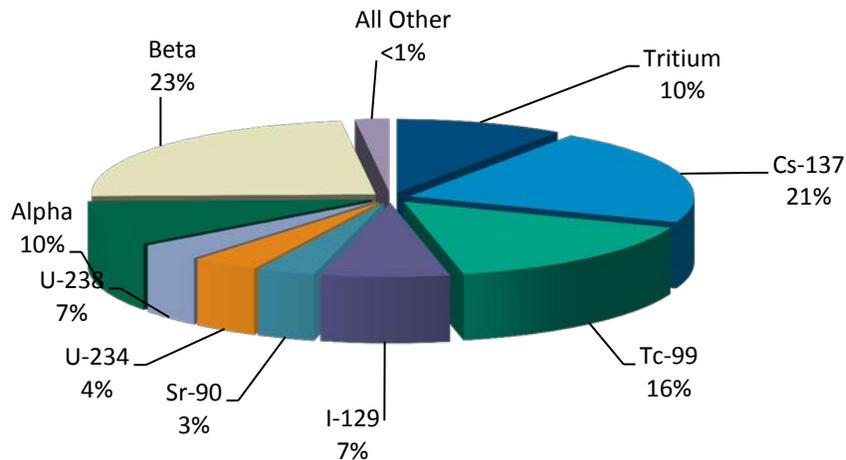


Figure 6-4 Radionuclide Contributions to the 2016 SRS Total Liquid Pathway Dose of 0.15 mrem (0.0015 mSv)

6.4.1.4 Drinking Water Pathway Dose

People living downriver of SRS may receive some dose by drinking water that contains radioactive releases from the Site. Tritium in downriver drinking water represented the highest percentage of the dose (about 46%) received by customers of the three downriver water treatment plants.

In 2016, SRS-only releases were responsible for a maximum potential drinking water dose of 0.012 mrem (0.00012 mSv). This dose is 25% less than the 2015 dose of 0.016 mrem (0.00016 mSv). SRS attributes this drop to the decrease in tritium releases and to the increase in the estimated Savannah River flow rate during 2016. There is not a separate drinking water dose standard, but the EPA Maximum Contamination Levels (MCL), defined in 40 CFR 141 (EPA 2000), assume a potential dose of about 4 mrem/yr for beta and gamma emitters.

6.4.1.5 Collective (Population) Dose

SRS calculates the collective drinking water consumption dose for the separate population groups that are customers of the BJWSA and City of Savannah I&D water treatment plants. Calculations of collective doses from agricultural irrigation assume that 1,000-acre parcels of land are used for each of the major food types grown in the SRS area (vegetables, milk, and meat), with the population within 50 miles of SRS consuming all the food produced on these 1,000-acre parcels.

In 2016, the collective dose from all liquid pathways was 3.5 person-rem (0.035 person-Sv). SRS calculates the collective dose in person-rem as the average dose per typical person multiplied by the number of people exposed. DOE Order 458.1 requires that SRS calculate and report a collective dose, but there is not a separate collective dose standard for comparison.

6.4.2 **Air Pathway**

6.4.2.1 Air Release Source Terms

Chapter 5, *Radiological Environmental Monitoring Program*, documents the 2016 radioactive air release quantities used as the source term in SRS dose calculations. Tritium accounts for a majority of the dose from SRS air releases. As discussed in Chapter 5, SRS tritium releases increased about 14% from 2015 to 2016, which increased the 2016 SRS air pathway doses.

6.4.2.2 Air Concentrations

SRS uses calculated radionuclide concentrations instead of measured concentrations for dose determinations because conventional analytical methods do not detect most of the radionuclides SRS released in the air samples collected at the Site perimeter and offsite locations. However, SRS can routinely measure tritium concentrations at locations along the Site perimeter and compare these results with the calculated concentrations to confirm the dose models. In 2016, this comparison showed that the dose models used at SRS were about 1.5 to 4 times more conservative than the actual measured tritium concentrations.

6.4.2.3 Dose to the Representative Person

The 2016 estimated dose from air releases to the representative person was 0.038 mrem (0.00038 mSv), 0.38% of the EPA 40 Code of Federal Regulations (CFR) 61 air pathway standard of 10 mrem per year. Table 6-4 compares the representative person dose with the EPA standard. The 2016 dose was about 19% more than the 2015 dose of 0.032 mrem (0.00032 mSv). SRS attributes this increase to the 14% increase in tritium releases during 2016 (See Chapter 5, *Radiological Environmental Monitoring Program*.)

Table 6-4 Potential Doses to the Representative Person and to the MEI from SRS Air Releases in 2016 and Comparison to the Applicable Dose Standard

	MAXDOSE-SR	CAP88-PC (EPA NESHAP)
Calculated dose (mrem)	0.038	0.024
Applicable Standard (mrem)	10 ^a	10 ^b
Percent of Standard (%)	0.38	0.24

Notes:

^a DOE: DOE Order 458.1

^b EPA: (NESHAP) 40 CFR 61, Subpart H

As Figure 6-5 shows, tritium releases were nearly 94% of the dose to the representative person. Iodine-129 and cesium-137 were about 2% each. No other individual radionuclide was more than 1% of the representative person dose.

The major ways a representative person received radiation dose from air releases were inhalation (37%), consuming vegetables (36%), and consuming cow milk (24%).

6.4.2.4 Collective (Population) Dose

SRS calculates the air-pathway collective dose for all 781,060 members of the population living within 50 miles of the center of the Site. In 2016, SRS estimated the airborne-pathway collective dose to be 1.4 person-rem (0.014 person-Sv).

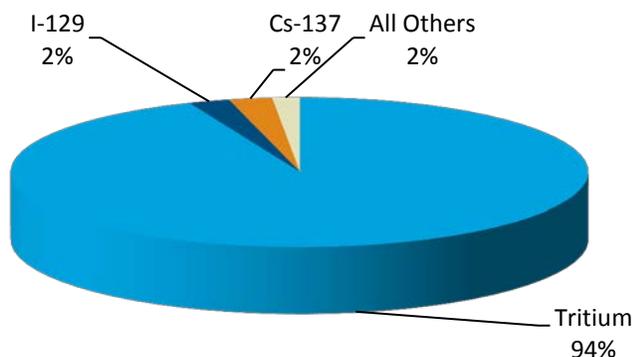


Figure 6-5 Radionuclide Contributions to the 2016 SRS Air Pathway Dose of 0.038 mrem (0.00038 mSv)

6.4.2.5 National Emission Standards for Hazardous Air Pollutants (NESHAP) Compliance

To demonstrate the Site is complying with NESHAP regulations (EPA 2002), SRS calculated maximally exposed individual (MEI) and collective doses using the following three methods:

- 1) The CAP88 PC version 4.0.1.17 computer code
- 2) The 2016 airborne-release source term
- 3) Site-specific input parameters

EPA requires using the MEI concept and not the reference person concept at this time. It specifies most of the input parameters in the CAP88 PC program. The EPA requires specific approval for any changes to these parameters.

For 2016, SRS used CAP88 PC (version 4.0.1.17, dated September 2014) to demonstrate it complied with EPA's 10 mrem/yr (0.1 mSv/yr) public dose standard for airborne emissions from DOE sites. SRS estimated the MEI dose at 0.024 mrem (0.00024 mSv), or 0.24% of the 10-mrem/yr EPA standard, as Table 6-4 shows.

Tritium oxide releases accounted for about 88% of the MEI dose, elemental tritium accounted for 6.5%, and cesium-137 accounted for 3.6%. The 2016 NESHAP compliance dose (MEI dose) was about 10% more than the 2015 dose of 0.022 mrem (0.00022 mSv). Again, SRS attributes this increase to the 14% increase in tritium releases during 2016. (See Chapter 5, *Radiological Environmental Monitoring Program*.)

6.4.3 All-Pathway Doses

6.4.3.1 All-Pathway Representative Person Dose

As stated in DOE Order 458.1, the all-pathway dose standard to a member of the public is 100 mrem/yr. SRS ensures a conservative estimate by combining the representative person airborne all-pathway and liquid all-pathway dose estimates, even though the two estimated doses are for hypothetical individuals living in different geographic locations.

For 2016, the potential representative person all-pathway dose was 0.19 mrem (0.0019 mSv), calculated as 0.15 mrem from liquid pathways plus 0.038 mrem from air pathways. As Table 6-5a shows, the all-pathway representative person dose is 0.19% of the 100 mrem/yr (1 mSv/yr) DOE dose standard. The all-pathway total dose is about 6% more than the 2015 total dose of 0.18 mrem (0.0018 mSv). SRS attributes this small increase to the 14% increase in airborne tritium releases during 2016.

Figure 6-6 shows a 10-year history of SRS's all-pathway (airborne pathways plus liquid pathways) doses to MEI and representative populations.

6.4.3.2 All-Pathway Collective (Population) Dose

DOE Order 458.1 requires that SRS calculate and report a collective dose, but there is not a separate collective dose standard for comparison. For 2016, the total potential collective all-pathway dose was 4.9 person-rem (0.049 person-Sv), calculated as 3.5 person-rem from liquid pathways plus 1.4 person-rem from air pathways. To compare, the annual collective dose from natural sources of radiation that the population within the 50-mile radius surrounding SRS receives is about 243,000 person-rem (781,060 people X 0.311 rem/yr). As Table 6-5b shows, the SRS all-pathway collective dose of 4.9 person-rem is less than 0.01% of the annual collective background dose.

Table 6-5a Potential Dose to the Representative Person from all Standard Pathways in 2016

Pathways	Committed Dose (mrem)	Applicable Standard (mrem)	Percent of Standard (%)
Near Site Boundary (All Pathways)			
Total Liquid Pathways	0.15	100 ^a	0.15%
Total Air Pathways	0.038	10 ^{a,b}	0.38%
Total All Pathways	0.19	100 ^a	0.19%

Notes:

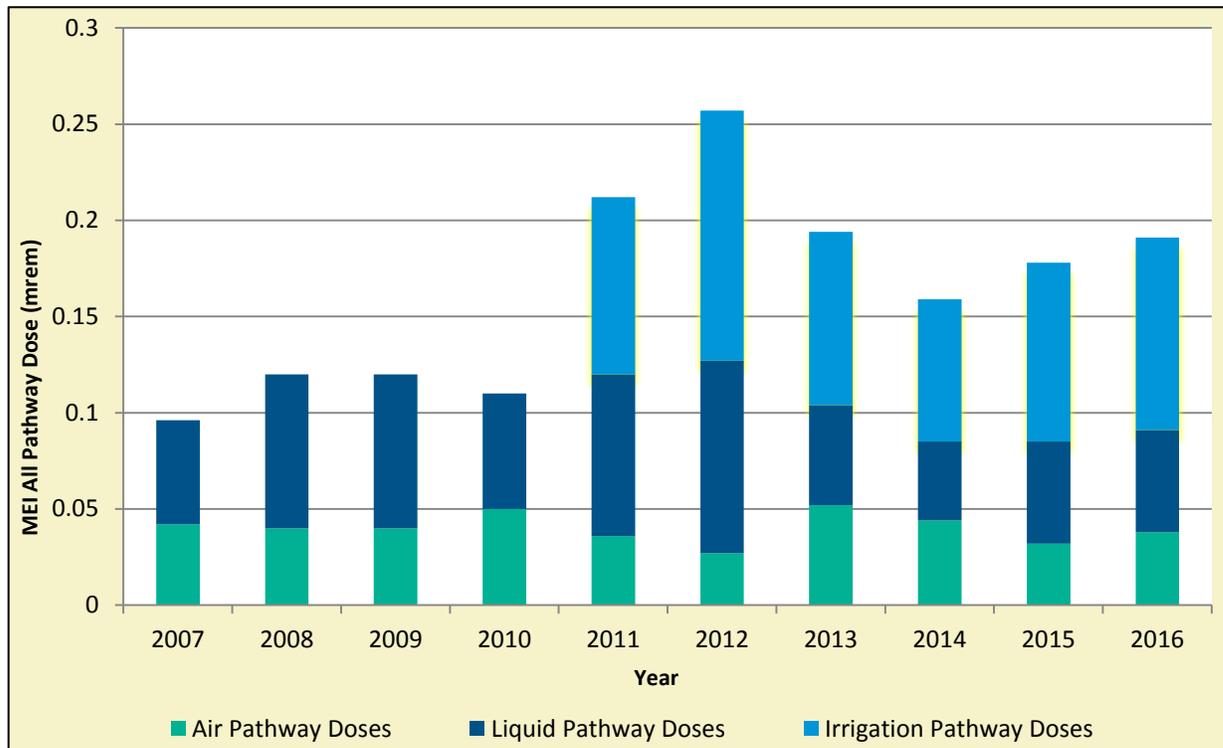
^a DOE: DOE Order 458.1

^b EPA: (NESHAP) 40 CFR 61, Subpart H

Table 6-5b Potential Collective Dose to the 50-Mile Population Surrounding SRS, Including the People Served by the Downriver Drinking Water Plants (Based on Dose to a Typical Person from all Standard Pathways in 2016)

Pathways	Collective Dose (person-rem)	Natural Background Dose (person-rem)	Percent of Natural Background (%)
50-mile Population Dose (All Pathways)			
Total Liquid Pathways	3.5	Not Applicable	Not Applicable
Total Air Pathways	1.4	Not Applicable	Not Applicable
Total All Pathways	4.9	243,000 ^a	< 0.01%

Note: ^a Calculated as 781,060 people (surrounding SRS population) times 311 mrem (0.311 rem) per person per year



Notes:

1. Beginning in 2011, the irrigation pathway dose is included in the liquid pathway dose. Previous years do not include the irrigation pathway dose.
2. Beginning in 2012, SRS began using the representative person dose instead of the Maximally Exposed Individual dose.

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

6.5 SPORTSMAN DOSE CALCULATION RESULTS

DOE Order 458.1 specifies radiation dose standards for individual members of the public. The dose standard of 100 mrem/yr includes the dose a person receives from routine DOE operations through all exposure pathways. Additionally, SRS considers and quantifies nontypical exposure pathways that are not included in the standard calculations of the doses to the representative person. This is because they apply to unlikely scenarios such as eating fish caught only from the mouths of SRS streams (“creek-mouth fish”) or to special scenarios such as hunters who volunteer to participate in an onsite hunt.

SRS also considered the following exposure pathways for a hypothetical offsite hunter and offsite fisherman on Creek Plantation, a neighboring, privately owned portion of the Savannah River Swamp:

- Ingesting deer meat or fish harvested on Creek Plantation
- Receiving external exposure to contaminated soil
- Incidentally ingesting contaminated soil
- Incidentally inhaling resuspended contaminated soil

6.5.1 Onsite Hunter Dose

Deer and Hog Consumption Pathway—SRS holds annual hunts for the public to control the Site’s deer and wild hog populations and to reduce animal-vehicle accidents. The estimated dose from consuming

harvested deer or hog meat is determined for every onsite hunter. Table 6-6 presents the maximum potential dose an onsite hunter received in 2016 as 13.5 mrem (0.135mSv), or 13.5% of DOE’s 100 mrem/yr dose standard. This dose is for an actual hunter who harvested two deer during the hunts. For the hunter-dose calculation, SRS conservatively assumes that this hunter individually consumed the entire edible portion, about 40 kilogram (kg) (89 lbs).

Turkey Consumption Pathway—SRS hosts a special turkey hunt in April for hunters with mobility impairments. Hunters harvested 25 turkeys in 2016. SRS measured all of the turkeys for radiation. Because none of them measured above the background value, SRS did not assign a dose to these hunters.

Table 6-6 2016 Sportsman Doses Compared to the DOE Dose Standard

	Committed Dose (mrem)	Applicable Standard (mrem) ^a	Percent of Standard (%)
Sportsman Dose			
Onsite Hunter	13.5	100	13.5
Creek-Mouth Fisherman ^b	0.22	100	0.22
Savannah River Swamp Hunter			
Offsite Hog Consumption	2.24		
Offsite Deer Consumption	6.36		
Soil Exposure ^c	2.90		
Maximum Offsite Hunter Dose (Deer + Soil Exposure)	9.26	100	9.26
Savannah River Swamp Fisherman			
Steel Creek Fish Consumption	0.14		
Soil Exposure ^d	0.67		
Total Offsite Fisherman Dose (Fish + Soil Exposure)	0.81	100	0.81

Notes:

^a DOE dose standard; 100 mrem/yr (DOE Order 458.1)

^b In 2016, the maximum dose to a hypothetical fisherman resulted from consuming bass from the mouth of Fourmile Branch

^c Includes the dose from combining external exposure and incidentally ingesting and inhaling the worst-case Savannah River swamp soil

^d Includes the dose from combining external exposure and incidentally ingesting and inhaling Savannah River swamp soil near the mouth of Steel Creek.

6.5.2 Hunter Dose

Deer and Hog Consumption Pathway—The deer and hog consumption pathways considered were for hypothetical offsite individuals whose entire intake of meat (81 kg [179 lbs]) during the year was either deer or hog meat. SRS assumes that these individuals harvest deer or hogs that had lived on SRS during the year but then moved offsite prior to hunting season.

Based on these unlikely assumptions and on the measured average concentration of cesium-137 in all deer

(2.06 pCi/g) and hogs (1.05 pCi/g) harvested from SRS during 2016, the potential maximum doses from this pathway were estimated to be 6.4 mrem (0.064 mSv) for the offsite deer hunter and 2.2 mrem (0.022 mSv) for the offsite hog hunter.

Savannah River Swamp Hunter Soil Exposure Pathway—SRS estimated the potential dose to a recreational hunter exposed to SRS legacy contamination on the privately owned Creek Plantation. The potential dose assumed that this person hunted for 120 hours during the year (8 hours a day for 15 days) at the location of maximum radionuclide contamination. SRS estimated this offsite-hunter soil exposure dose to be 2.9 mrem.

As Table 6-6 shows, the offsite deer consumption pathway dose (6.4 mrem) and the Savannah River Swamp hunter soil exposure pathway dose (2.9 mrem) were conservatively added together to obtain a total maximum offsite hunter dose of about 9.3 mrem (0.093 mSv). This potential dose is 9.3% of the DOE 100 mrem/yr dose standard.

6.5.3 Hypothetical Offsite Fisherman Dose

Creek-Mouth Fish Consumption Pathway—For 2016, SRS analyzed three species of fish (panfish, catfish, and bass) taken from the mouths of four SRS streams. Using these concentrations, SRS estimated the maximum potential dose from fish consumption to be 0.22 mrem (0.0022 mSv) from bass it collected at the mouth of Fourmile Branch. SRS bases this hypothetical dose on the low probability scenario that during 2016, a fisherman consumed 24 kg (53 lb) of bass caught exclusively from the mouth of Fourmile Branch. About 86% of this potential dose was from cesium-137.

Savannah River Swamp Fisherman Soil Exposure Pathway—SRS calculated the potential dose to a recreational fisherman exposed to SRS legacy contamination in Savannah River Swamp soil on the privately owned Creek Plantation using the RESidual RADioactivity (RESRAD) code (Yu et al., 2001). SRS assumes 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, SRS estimated 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 renewed suspension soil to be 0.67 mrem (0.0067 mSv).

As Table 6-6 shows, the maximum Steel Creek fish consumption dose (0.14 mrem) and the Savannah River Swamp fisherman soil exposure dose (0.67 mrem) were added to conservatively obtain a total offsite fisherman dose of 0.81 mrem (0.0081 mSv). This potential dose is 0.81% of the DOE 100 mrem/yr dose standard.

6.5.4 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 a fish monitoring plan in conjunction with EPA, the Georgia Department of Natural Resources, and SCDHEC. This plan includes assessing radiological risk from consuming Savannah River fish and requires that SRS summarize the results in the annual *SRS Environmental Report*. For 2016, SRS estimated the maximum potential lifetime risk of developing fatal and nonfatal cancer from consuming SRS creek-mouth fish to be

1.7E-07. That is, if 10 million people each received a dose of 0.22 mrem, there is a potential for 1.7 extra cancer incidents.

6.6 RELEASE OF MATERIAL CONTAINING RESIDUAL RADIOACTIVITY

DOE Order 458.1 establishes authorized surface contamination limits, which in turn allow unconditional release of personal and real property. This order defines personal property as “property of any kind, except for real property” and defines real property as “land and anything permanently affixed to the land such as buildings, fences and those things attached to the buildings, such as light fixtures, plumbing and heating fixtures, or other such items, that would be personal property if not attached.” SRS handles the unconditional release of real property on an individual basis that requires specific approval from DOE. SRS did not release any real property in 2016, so the following discussion is associated with release of personal property from SRS. DOE Order 458.1 specifies that the Site must prepare and submit an annual summary of cleared property to the DOE-SR Manager.

6.6.1 Property Release Methodology

SRS uses procedures to govern unconditionally releasing equipment. SRS can release the item after it has a radiological survey if it meets specific documented limits. For items meeting unconditional release criteria, SRS generates a form and attaches it electronically to the applicable radiological survey via the Visual Survey Data System (VSIDS). In some areas, SRS documents equipment and material release directly on the radiological survey form. SRS subsequently compiled these VSIDS and survey forms and coordinated a site-wide review to determine the amount of material and equipment SRS released from its facilities in 2016. These measures ensure that radiological material releases from SRS are consistent with DOE Order 458.1 requirements.

SRS unconditionally released 11,516 items of personal property from radiological areas in 2016. Most of these items did not leave the Site and were reused elsewhere on the Site. However, all of these items required no additional radiological controls post-survey as they met DOE Order 458.1 release criteria (The recently implemented DOE Order 458.1 allows the use of DOE Order 5400.5-derived supplemental limits for unconditionally releasing equipment and materials.)

In 2003, DOE approved a SRS request to use supplemental limits to release material from the Site with no further DOE controls. These supplemental release limits, provided in Table 31 of *Radiological Environmental Dose Assessment Methods and Compliance Dose Results for 2016 Operations at the Savannah River Site* (Jannik, Minter, and Dixon 2017a), are dose-based and are such that if any member of the public received any exposure, it would be less than 1 mrem/yr. The supplemental limits include both surface and volume concentration criteria. The volume criteria allow SRS the option to dispose of potentially volume-contaminated material in Three Rivers Landfill, an onsite sanitary waste facility. In 2016, SRS did not release any material from the Site using the supplemental release limits volume concentration criteria.

6.7 RADIATION DOSE TO AQUATIC AND TERRESTRIAL BIOTA

DOE Order 458.1 requires that SRS conduct Site operations in a manner that protects the local biota from adverse effects due to radiation and radioactive material releases. To demonstrate it is complying with this requirement, SRS uses the approved DOE Standard, DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002).

The biota dose rate limits specified in this standard are the following:

- Aquatic animals: 1.0 rad/day (0.01 gray/day)
- Riparian animals: 0.1 rad/day (0.001 gray/day)
- Terrestrial plants: 1.0 rad/day (0.01 gray/day)
- Terrestrial animals: 0.1 rad/day (0.001 gray/day)

6.7.1 DOE Biota Concentration Guides

SRS evaluates plant and animal doses for water and land systems using the RESRAD Biota model (version 1.5) (SRS EDAM 2012), which directly implements the DOE (2002) guidance. The RESRAD Biota model uses a graded approach consisting of three increasingly more detailed steps of analysis:

- Level 1 Screening—uses maximum measured concentrations and conservative default model input parameters
- Level 2 Screening—uses average concentrations or site-specific input parameters, as appropriate
- Level 3 Analysis—uses site-specific biota parameters or measured concentrations in the actual biota living at the assessed location

For water systems (animals who live in the water or along riverbanks), the RESRAD Biota model performs a combined water-plus-sediment evaluation. SRS performed initial (Level 1) screenings in 2016 using maximum radionuclide concentration data from SRS's 14 onsite stream and sediment sampling locations. A sum of the fractions less than 1.0 indicates the sampling site has passed its initial pathway screening, which means that the sampling site did not exceed its biota dose rate limits, and SRS does not have to assess the location further. All but one SRS aquatic system location passed the initial screening and did not require further assessment. The Z-Area Basin sampling location failed the Level 1 screening with a sum of the fractions of 1.05, requiring the performance of a Level 2 screening. The Site performed a Level 2 screening at this location using average concentrations, and it passed. Therefore, SRS did not have to assess this location further.

To evaluate land-based systems, SRS performed initial screenings using concentration data from the five onsite radiological soil sampling locations. Typically, SRS collects and analyzes only one soil sample per year from each location. For 2016, all land-based locations passed their initial pathway screenings.