PUBLIC HEALTH ASSESSMENT

EVALUATION OF OFF-SITE AIR CONTAMINATION

FROM THE SAVANNAH RIVER SITE (USDOE)

Savannah River Site

Aiken, South Carolina

USEPA Facility ID: SC1890008989

July 1, 2013

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Foreword

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. This law set up a fund to identify and clean up our country's hazardous waste sites. The U.S. Environmental Protection Agency, USEPA, and the individual states regulate the investigation and cleanup of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the USEPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by scientists from ATSDR and from states with which ATSDR has cooperative agreements. The public health assessment program allows flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations—the structure may vary from site to site. Whatever the form of the public health assessment, the process is not considered complete until public health issues at the site are addressed.

Exposure

As the first step in the evaluation, ATSDR scientists review environmental data to see what hazardous substances are present, where these substances were found, and how people might come into contact with them. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by USEPA, other government agencies, businesses, and the public. When environmental data do not allow ATSDR to fully evaluate exposure, the report will indicate what further sampling data are needed.

Health Effects

If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these exposures may result in harmful effects. ATSDR recognizes that developing fetuses, infants, and children can be more sensitive to exposures than are adults. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable than adults. Thus, when contact by children may be possible, the health impact to the children is considered first when evaluating exposure and the potential adverse effects to a community. The health impacts to other groups within the community (such as the elderly, chronically ill, and people engaging in high-exposure practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic, and epidemiologic studies and the data collected in disease registries, to determine the likelihood of health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain

substances is not available. In this case, this report suggests what further public health actions are needed.

Conclusions

This report presents conclusions about the public health threat, if any, posed by a site. Any health threats that have been determined for high-risk groups (such as children, the elderly, chronically ill people, and people engaging in high-risk practices) are summarized in the Conclusions section of the report. Ways to stop or reduce exposure are recommended in the Public Health Action Plan section.

ATSDR is primarily an advisory agency, so its reports usually identify what actions are appropriate to be undertaken by USEPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community

ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments

If, after reading this report, you have questions or comments, we encourage you to send them to us. Letters should be addressed as follows:

Agency for Toxic Substances and Disease Registry
ATTN: Records Center
4770 Buford Highway, NE (Mail Stop F-09)
Atlanta, GA 30341

Table of Contents

Table of Contents (Continued)

List of Tables

Table of Contents (Continued)

List of Figures

Acronyms and Abbreviations

AEC	Atomic Energy Commission
AEI	Air emissions inventory
ATG	Savannah River National Laboratory's Atmospheric Technologies Group
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	biomass cogeneration facility
Bq	becquerel (International System (SI) unit of radioactivity; 1 Bq = 27 pCi; 1 Bq = 1 disintegration per second)
Bq/kg	becquerel per kilogram (SI unit of radioactivity in soil)
Bq/m^3	becquerel per cubic meter (SI unit of radioactivity in air)
CAA	Clean Air Act, as amended
CAAA	1990 Clean Air Act Amendments
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CREGs	cancer risk evaluation guides
CV	ATSDR's comparison value
DOE	U. S. Department of Energy
EIS	Environmental impact statement
EM	(Savannah River Site) Environmental Management
EMEGs	Environmental media evaluation guides
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
GDNR	Georgia Department of Natural Resources
GDNR-EPD	GDNR's Environmental Protection Division
HAPs	Hazardous air pollutants
HECs	Human equivalent concentrations
ICRP	International Commission on Radiological Protection
LOAEL	lowest observed adverse effect level
MEI	maximally exposed individual
mg/kg/day	milligram per kilogram per day
mrem	millirem = 10^{-3} rem (a unit of radiation dose equivalent; the product of the absorbed dose [rad] and a weighting factor which accounts for the effectiveness of the radiation to cause biological damage)
mSv	millisievert = 10^{-3} Sv (SI unit of radiation dose equivalent; 1mSv = 100 mrem)
MOX	Mixed Oxide (facility)
MRL	ATSDR's Minimum Risk Level
NAAQS	National Ambient Air Quality Standard
NATA	(2005) National-scale Air Toxic Assessment
NCEH	CDC's National Center for Environmental Health
NCRP	National Council on Radiation Protection and Measurements
NEI	Nuclear Energy Institute
NERP	National Environmental Research Park
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NIOSH	National Institute of Occupational Safety and Health

Acronyms and Abbreviations (Continued)

NNSA	National Nuclear Security Administration
NOAEL	no observed adverse effect level
NPL	National Priorities List
ODS	ozone depleting substances
OSHA	Occupational Safety and Health Administration
PBPK	physiologically based pharmacokinetics
PCE	perchloroethylene (also known as tetrachloroethylene)
pCi	picocurie (standard unit of radioactivity; 1 pCi = 10^{-12} curie; 1 pCi = 0.037 Bq)
pCi/g	picocurie per gram (standard unit of radioactivity in soil)
pCi/L	picocurie per liter (standard unit of radioactivity in liquid)
pCi/m^3	picocurie per cubic meter (standard unit of radioactivity in air)
PHA	public health assessment
$PM_{2.5}$	particulate matter with aerodynamic particle size of 2.5 microns or less
PM_{10}	particulate matter with aerodynamic particle size of 10 microns or less
RCRA	Resource Conservation and Recovery Act
RfCs	reference concentrations
SCDHEC	South Carolina Department of Health and Environmental Control
SCDHEC-ESOP	SCDHEC's Environmental Surveillance and Oversight Program
SIPs	State implementation plans
SRARP	Savannah River Archeological Research Program
SREL	Savannah River Ecology Laboratory
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRP	Savannah River Plant
SRS	Savannah River Site
SRSCAB	Savannah River Site Citizens Advisory Board
SRSHES	Savannah River Site Health Effects Subcommittee
SVEUs	soil vapor extraction units
TCE	trichloroethylene
TLD	thermoluminescent dosimeter
TSP	total suspended particulates
TWA	time-weighted average
USDOE	U.S. Department of Energy
USDOE-SR	U.S. Department of Energy – Savannah River
USEPA	U.S. Environmental Protection Agency
USFS-SR	United States Forest Service – Savannah River
USNRC	US Nuclear Regulatory Commission
VEGP	Georgia Power's Vogtle Electric Generating Plant
VOCs	volatile organic compounds
WSRC	Westinghouse Savannah River Company
yr	year
µ	micro (10^{-6}); such as microcurie (µCi), microrem (µrem), etc.
$\mu g/m^3$	microgram per cubic meter (standard unit - chemical concentration in air)

Summary

Introduction

The Savannah River Site (SRS), owned by the U.S. Department of Energy (USDOE), encompasses 198,344 acres in a rural and remote area in the southwestern portion of South Carolina. The closest densely populated area is Augusta, Georgia, about 22.5 miles northwest of SRS. Construction of the SRS facility commenced in 1951, with the main purpose of the facility to support the country's defense program by producing basic materials used in the manufacturing of nuclear weapons. When initially built, the site contained five nuclear reactors, two large chemical separation plants, a tritium (hydrogen-3) processing facility, a heavy water (enriched in hydrogen-2) extraction plant, a uranium fuel processing facility, a fuel and target fabrication facility, and a waste management facility. During SRS operations, large amounts of radioactive, chemical, and mixed hazardous materials and wastes were processed, treated, and stored at the site. As a result, radioactive and chemical materials have been released to air, biota, groundwater, sediment, soil, and surface water. In 1988, all reactors were shut down and SRS discontinued its production of nuclear materials for the U.S. defense program but continued to process radionuclides for other purposes such as space exploration, nuclear medicine, and commercial uses. The K-reactor was started up briefly in 1991/1992 as part of a startup demonstration. By 1993, the site reactors were permanently shut down, significantly reducing air releases. Currently the site's primary missions include site remediation, meeting the needs of the U.S. nuclear weapons stockpile through the tritium programs, meeting the needs of the National Nuclear Security Administration's (NNSA) nuclear nonproliferation programs by storing and disposing of excess special nuclear materials, and supporting the needs of the Savannah River National Laboratory's science applications.

In 1992, the Centers for Disease Control and Prevention (CDC) initiated a Dose Reconstruction Project to closely examine the radionuclide and chemical releases that occurred at SRS during the site's main operating period from 1954 to 1992. The Dose Reconstruction determined that the available environmental monitoring data suggested there were significant releases of radionuclides to ambient air, but the release rates for chemicals and heavy metals were most likely overestimated and further research was needed to better define actual release rates.

To investigate the radionuclide and chemical air releases and potential exposures further, as well as address community concerns associated with air releases from SRS, the Agency for Toxic Substances and Disease Registry (ATSDR) has prepared this public health assessment to evaluate potential human exposures. This evaluation emphasizes the period of time following the CDC Dose Reconstruction Project (from 1993 through 2010).

In addition, potential off-site radionuclide soil and rainwater exposures are evaluated in this document, because radioactive pollutants released into ambient air can eventually be deposited in soil and rainwater and contribute to the public's exposures. Potential exposures from the uptake of contaminants by plants and animals and migration of contaminants to surface water and groundwater were evaluated in previously released ATSDR public health assessments.

Conclusions

ATSDR reached four main conclusions in this public health assessment:

Conclusion 1

Based on information reviewed by ATSDR, emissions *of radioactive materials* and *criteria pollutants* (carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide) from SRS were at levels unlikely to cause adverse health effects to the general population.

Basis for conclusion

Using maximum inhalation rates and maximum concentrations of radioactive materials detected offsite and maximum permitted (modeled) releases of criteria pollutants, ATSDR estimated hypothetical maximum exposures for offsite populations. These hypothetical exposures are at levels that are unlikely to harm people's health.

Next Steps

USDOE-SR should continue to monitor for airborne radioactive materials and model releases of criteria pollutants as long as release sources continue to be present at the Savannah River Site.

Conclusion 2

Due to limited information, ATSDR cannot make a public health conclusion for non-cancer health effects from *trichloroethylene* emissions from the Savannah River Site between 1997 and 2010.

Basis for conclusion

ATSDR had very limited information to use in determining potential offsite exposures from the releases of trichloroethylene from the Savannah River Site between 1997 and 2010. During this timeframe there were significant increases in the number of soil vapor extraction units being used to extract trichloroethylene from soils at the site.

Next Steps

USDOE-SR should conduct air modeling for trichloroethylene based on actual emissions between 1997 and 2010, which should include both short and long term averaging times.

Conclusion 3	Due to limited information, ATSDR cannot make a public health conclusion for potential cancer health effects from *toxic air pollutants* (257 air pollutants listed in South Carolina Standard No. 8 regulation) released from the Savannah River Site.
Basis for conclusion	ATSDR had very limited information to use in determining potential offsite exposures from the releases of toxic air pollutants from the Savannah River Site. Most of the information reviewed by ATSDR involved modeling estimated short term concentrations of toxic air pollutants, but potential cancer risks are best estimated from long term (annual) concentrations. Very little information on long term concentrations was available for ATSDR's review.
Next Steps	USDOE-SR should conduct air dispersion modeling for all carcinogenic South Carolina Standard No. 8 pollutants based on the actual emissions between 2004 and 2010. USDOE-SR should also consider ambient air sampling at the site boundary for South Carolina Standard No. 8 air pollutants to better understand the relationship between the modeled and actual concentrations of these pollutants.
Conclusion 4	Due to limited information, ATSDR cannot make a public health conclusion for potential adverse health effects in highly sensitive asthmatics from Savannah River Site's sulfuric acid emissions in 1994.
Basis for conclusion	Modeling based on the maximum permitted limits in 1994 indicate that the concentrations at the boundary could have been at levels to temporarily adversely affect highly sensitive asthmatics if the Savannah River Site operated at their maximum permitted capacity.
Next Steps	None. Modeling based on maximum permitted limits since 2000 has not shown levels of health concern at the site boundary.
FOR MORE INFORMATION	For further information about this public health assessment, please call ATSDR at 1-800-CDC-INFO and ask for information about the Savannah River Site, Aiken, SC site. If you have concerns about your health, you should contact your health care provider.

Purpose and Scope of Document

The Agency for Toxic Substances and Disease Registry (ATSDR) prepared this public health assessment (PHA) to evaluate radionuclides and chemicals released from SRS to off-site air from 1993 through 2010, to evaluate potential exposures associated with these releases, and to address community concerns related to these types of releases. ATSDR also evaluated radionuclide concentrations in offsite soil and rainwater because contaminants found in these media can be indicators of contaminants deposited from the air and can contribute to exposures to the public. This PHA will not include an evaluation of occupational or on-site exposures, or exposures via groundwater, surface water, or biota.

This document focuses only on exposures occurring since 1993: "current exposures" in this document are those that occurred between 1993 and 2010, and "future exposures" are those expected to occur in the future. "Past exposures" are defined as those that occurred prior to 1993. This document does not evaluate past exposures because they were already addressed in the CDC's Dose Reconstruction Project, which analyzed the community's past exposures to radioactive materials from 1954 through 1992. Since 1992, USDOE-SR and its contractors as well as the states of South Carolina and Georgia have collected a tremendous amount of air, soil, and rainwater sampling data. Although CDC's dose reconstruction primarily relied on conservative environmental models, ATSDR's assessment discussed herein involves a detailed evaluation of environmental air, soil, and rainwater sampling data.

For additional reference, this document includes a glossary of terms (Appendix A) and an overview of ATSDR's methodology for evaluating potential contaminants of concern (Appendix B).

Background

This section includes background information describing the site location, operational history, remedial and regulatory history, environmental setting, demographics, and public health activities. More detail for each of these sections is presented below.

Site Description and Operational History

SRS is a 310-square-mile (806-square-kilometer) U.S. Department of Energy (USDOE) owned and contractor operated facility. It encompasses 198,344 acres (80,267 hectares) in the southeastern coastal area of the United States in the southwest section of South Carolina (WSRC 2005). The site is located on the Aiken Plateau in the Upper Atlantic Coastal Plain about 20 miles southeast of the fall line that separates the Piedmont and Coastal Plain Provinces. SRS is bounded by the Savannah River for approximately 27 miles (43 kilometers) on its southwestern perimeter along the South Carolina and Georgia border (USDOE 2005a). The entire site covers approximately 1 percent of South Carolina (WSRC 1998a).

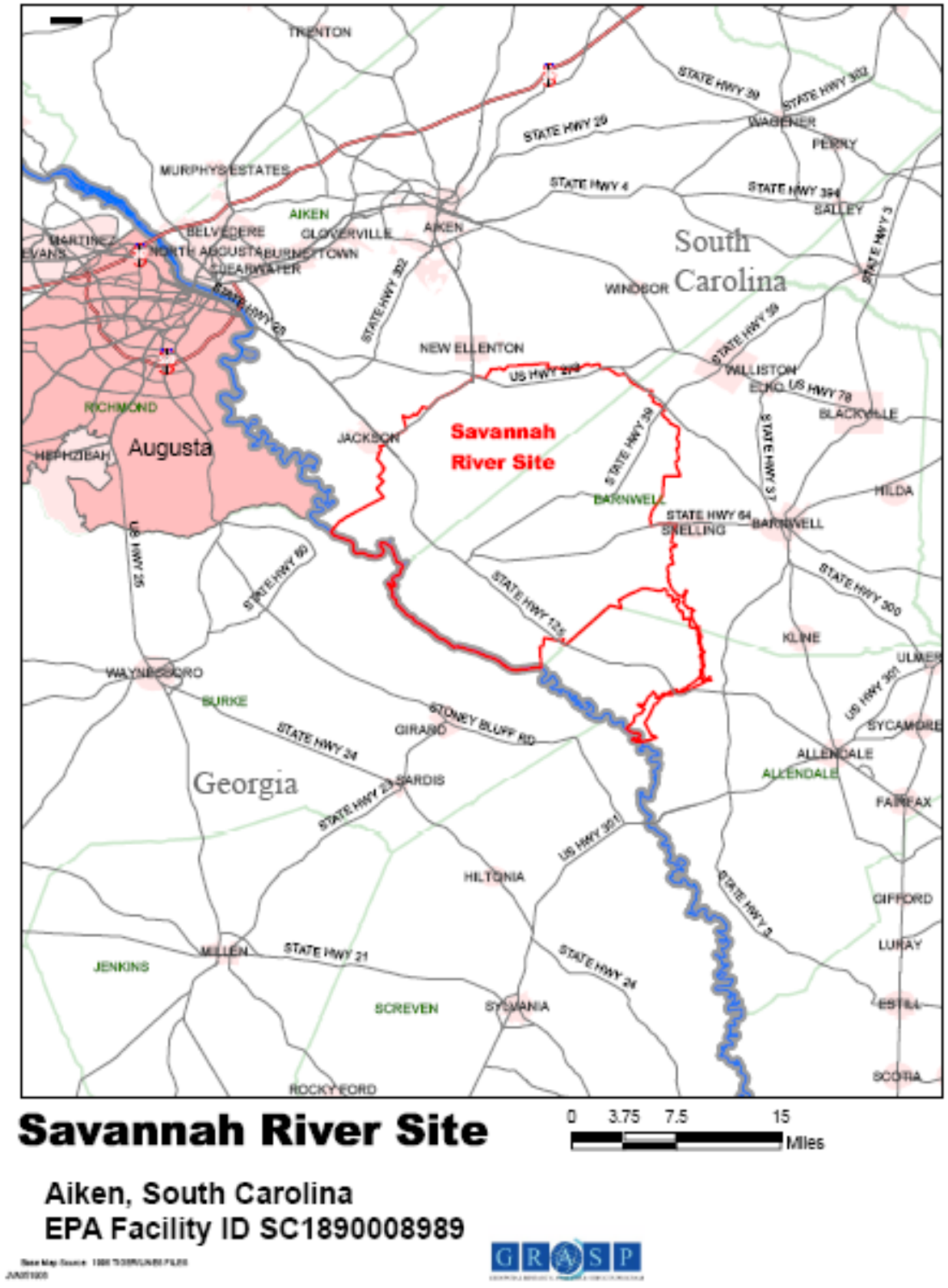
SRS lies in a rural, remote area (USDOE 2005a). The closest major population areas to the SRS are Aiken, South Carolina, which is 19.5 miles (31 kilometers) north of the SRS, and Augusta, Georgia, which is 22.5 miles (36 kilometers) northwest of the site. SRS includes portions of Allendale (4,155 acres; 1,681 hectares), Aiken (72,686 acres; 29,410 hectares), and Barnwell

(121,503 acres; 49,170 hectares) Counties in South Carolina. In South Carolina, the small towns of Jackson, New Ellenton, and Snelling are adjacent to the northwestern, northern, and eastern site boundaries, respectively (see Figure 1). There are no permanent residents on the site (CDC 2005; USFS-SR 2004; USDOE 2005a).

The former Atomic Energy Commission (AEC) contracted with the E.I. duPont de Nemours and Company, Inc. (DuPont) to construct the Savannah River Plant (SRP) in 1950 (WSRC 1994a). The primary mission of the plant was to support the United States defense program by producing basic materials used in the manufacturing of nuclear weapons (e.g., tritium [hydrogen 3] and plutonium-239) (USDOE 2005a). From 1951 to 1956, DuPont developed, designed, and constructed the SRP, which included five nuclear reactors, two large chemical separation plants, a tritium processing facility, a heavy water extraction plant, a uranium fuel processing facility, a fuel and target fabrication facility, and a waste management facility (WSRC 2005; USDOE 2000b). In accordance with the Energy Reorganization Act of 1974, the non-regulatory portion of the AEC became the Energy Research and Development Administration (ERDA) in 1975. By 1977, ERDA was replaced by USDOE, which is the federal agency that has overseen the site activities since that time (WSRC 1994a).

DuPont operated the plant until March 31, 1989. On April 1, 1989, Westinghouse Savannah River Company (WSRC) became the Management and Operations contractor, and SRP became SRS (WSRC 1994a). From this point onward, this document will refer to the site as SRS regardless of the referenced time frame. In December 2005, WSRC became Washington Savannah River Company (Gail Whitney, USDOE-SR, personal communication, September 22, 2006). On January 10, 2008, the contract to manage and operate the site for USDOE was awarded to Savannah River Nuclear Solutions (SRNS); SRNS took over the responsibilities as the Management and Operations contractor on August 1, 2008 (SRNS 2009). The current Period of Performance runs through September 30, 2016. SRNS is responsible for operating and managing three main SRS components: National Nuclear Security Administration (NNSA) activities, operations at the Savannah River National Laboratory (SRNL), and cleanup of environmental contamination. SRNS also handles administrative functions at the site (e.g., SRS infrastructure) (USDOE 2008). Other contractors at the site are responsible for liquid waste operations, security, construction and operation of the mixed oxide facility, and construction and operation of the salt waste processing facility (SRNS 2011c).

72 **Figure 1. Savannah River Site Area Map**



SRS is generally divided into several areas, based on production, land use, and other related characteristics. These areas are shown in Figure 2 and are described below (Denison 2011; SRNS 2011a, 2011b; SRSCAB 2000; USDOE 2000a, 2005a, 2006, 2009, 2010b, 2011a; USEPA 2009a, 2012a; USNRC 2010; WSRC 2001, 2008):

- **Administrative facilities**: *A-Area*, *B-Area* and part of *H-Area* have primarily administrative facilities that provide office space, training areas, and records storage. Over the last 10 years, most administrative functions have been transferred to *B-Area*. The addition to the administrative facilities, the Radiological Monitoring and Bioassay Laboratory, Health Protection Calibration, Whole Body Counting facilities and Wackenhut (security) facilities are located in *B-Area*. *A-Area*, along with *M-Area* described below, are undergoing some closure activities. The *A-Area* coal-fired steam plant was replaced with a new biomass steam plant which began operating in September 2008.

- **Heavy water reprocessing** (*D-Area*), now closed, had facilities for supporting heavy water coolant/moderator for the reactors, heavy water purification facilities, an analytical laboratory, and a powerhouse. Although the closure activities in this area were completed in 2006, the Waste Tank Mock-up facility continues to operate. The *D-Area* coal-fired powerhouse was replaced with a new biomass unit, referred to as the SRS Biomass Cogeneration Facility (BCF) which began operation in March 2012.

- **Non-nuclear facilities**: Central Shops (*N-Area*) house construction and craft facilities and the primary facilities for storage of construction materials. The *T-Area* or the *TNX-Area* contained non-nuclear facilities that tested equipment and developed new designs. Completion of all closure activities in this area was accomplished in 2006.

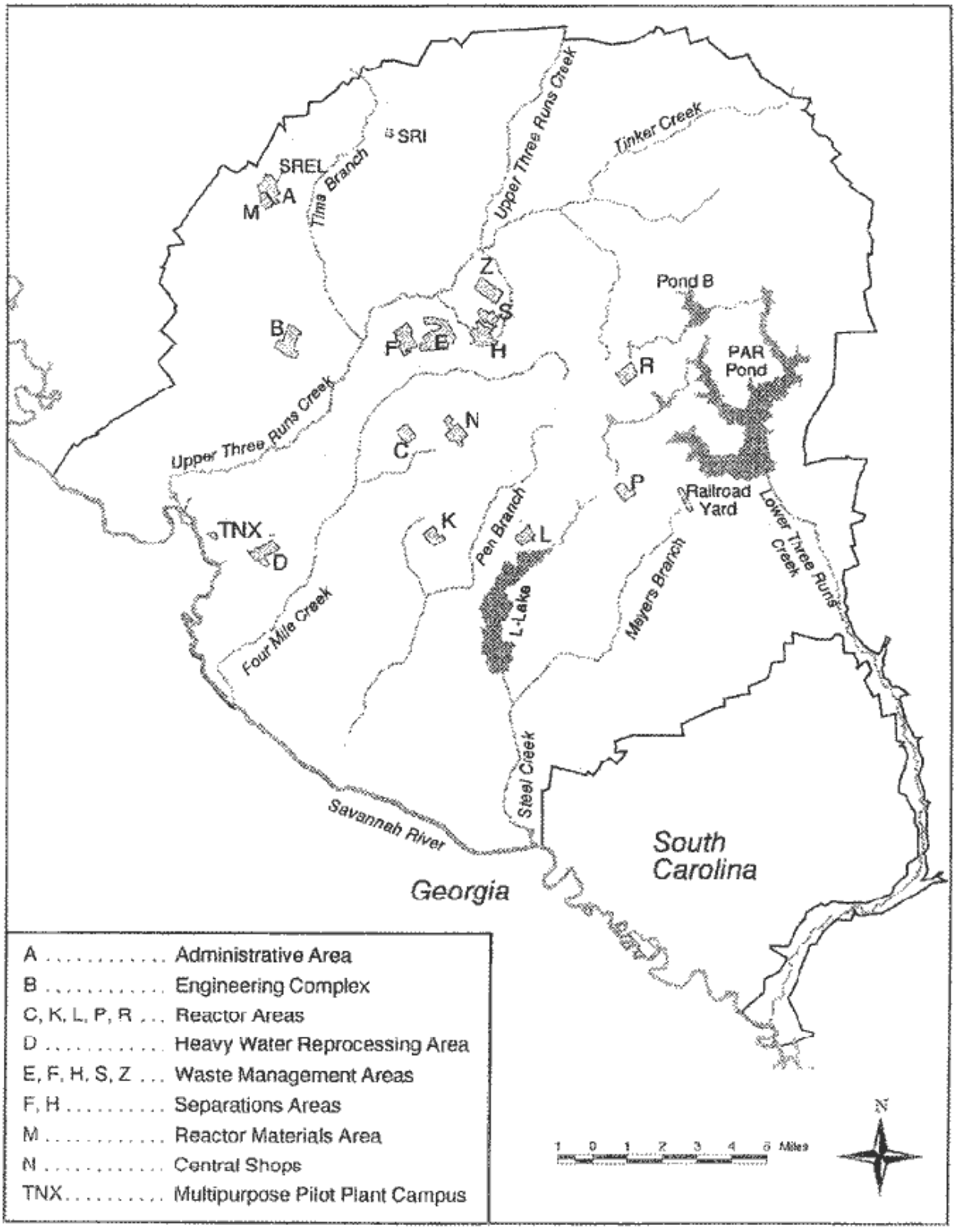
- **Nuclear/radiological facilities**: Fuel/Target Fabrication (*M-Area*) facilities housed the metallurgical/foundry operations for fabricating fuel and target elements for the SRS reactors. All operations have been shut down since the late 1980s. On October 20, 2010, USDOE-SR announced that the *M-Area* closure project was completed two years ahead of schedule. Closure activities included demolition of buildings as well as extensive soil remediation. Groundwater remediation activities continue.

- **Reactors**: *C, K, L, P,* and *R Areas* house the C, K, L, P, and R Reactors, respectively. These five reactors were used for nuclear production but are permanently shut down. Some of these facilities are in the process of being decommissioned while others are being used for other purposes. C, P, and R reactors are permanently closed and access has been sealed. Process area stack monitoring had continued for P and R Reactors until June 2010 when the main stacks were demolished and the monitoring equipment removed. Decontamination capability has been installed in the *C-Area.* Fuel storage basins at the L Reactor contain spent nuclear fuel awaiting disposition. Portions of the *K-Area* were converted to the K-Area Material Storage Facility. In terms of site cleanup, in situ decommissioning (e.g., keeping contaminants in place to prevent environmental releases, sealing buildings to eliminate access) with land use controls (e.g., warning signs, access controls) was selected as the remedial action for all five reactor areas.

- **Processing facilities**: At the *H-Area* facilities, nuclear materials are processed, stabilized, separated, and recovered. This work was previously performed at the *F-Area* facilities, but primary *F-Area* facilities (including the Plutonium Metallurgical Building and the Naval Fuel Facility) have been closed. The new Mixed Oxide (MOX) facility is being constructed in the *F-Area*. The *H-Area* contains the closed Receiving Basin for Off-Site Fuels. The tritium recycling facilities will continue operating in the *H-Area* of SRS and include tritium loading, unloading, and surveillance operations to support the active stockpile. The Tritium Extraction Facility became operational in 2007. High-level waste tanks are located in the *F- and H-Areas*. Waste Management Storage Buildings are also located in the *H-Area*. The Consolidated Incineration Facility was constructed in the *H-Area* to incinerate and reduce the volume of hazardous, radioactive and mixed waste. It began operations at the beginning of 1997 but only operated until mid-2000.

- **Waste management facilities**: Solid waste is centrally located in a 195-acre complex in the *G-* and *E-Areas*. These facilities store and dispose of radioactive solid wastes and include the Low Level Radioactive Waste Disposal Facility, Transuranic Waste Storage Pads, and the Mixed Waste Storage Buildings. *S-Area* facilities house the Defense Waste Processing Facility, which immobilizes the active portion of the high level waste in glass. SRS's primary radioactive waste storage and disposal facility is located in the *E-Area.* The Saltstone Processing Facility (which converts decontaminated liquid salt waste to solids) and the Saltstone Disposal Facility are located in the *Z-Area*. Several areas (i.e., F- and H-Areas) have permits for hazardous waste management facilities in conjunction with well networks for treating groundwater.

Figure 2. Location of Major Production Facilities and Reactors at Savannah River Site



Source: WSRC 2002a

Historically, irradiated materials were moved from the nuclear reactors to one of two chemical separation plants where the irradiated fuel and target assemblies were chemically processed to separate useful products from waste. Once refined, the useful materials were shipped to other AEC or USDOE sites for final application. Between 1953 and 1988, SRS produced approximately 36 metric tons of plutonium and other radionuclides (USEPA 2009a; WSRC 2005). Liquid and solid radioactive, chemical, and mixed wastes were also created and released into the ground, surface waters, and air during the period of SRS operations (CDC 2005). SRS ceased its nuclear material production for the US defense programs in 1988, but it continued to produce radionuclides for nuclear medicine, space exploration, research efforts, and commercial purposes (USDOE 2000; USEPA 2009a). By 1993, the site reactors were no longer operating.

The present and future missions of SRS include meeting the needs of the US nuclear weapons stockpile; storing, treating, and disposing of excess nuclear materials safely and securely; treating and disposing of legacy radioactive liquid waste from the Cold War; and cleaning up radioactive and chemical environmental contamination from previous site operations (WSRC 2008). The production and support facilities at SRS include buildings, construction areas, and parking lots. The original production facilities occupied less than 10 percent of the total land area with the major radioactive operations toward the center of the site (refer to Figure 2). This layout created a buffer zone aimed at reducing the risk of accidental exposure to the general public and providing security for the site (WSRC 1994a; USDOE 2005a). Eighty-five percent of the 198,344-acre (80,267-hectare) site consists of forest management lands (168,415 acres; 68,155 hectares). The remaining portions of the site consist of 7 percent (14,005 acres; 5,668 hectares) of lands made up of 30 separate research set-aside areas and 8 percent (15,924 acres; 6,444 hectares) designated for industrial activities (e.g., nuclear processing, research and development, waste management) (USFS-SR 2005c, 2010).

The transportation network at SRS consists of approximately 130 miles (209 kilometers) of primary roads, 1,220 miles (1,963 kilometers) of secondary roads, and 33 miles (53 kilometers) of railroad. Roads serve to provide access for employees; to enable shipment of radioactive and hazardous materials between areas; and to allow access to test wells, utility lines, research sites, and natural resource management activities. The railroad system supports the delivery of foreign fuel shipments, movement of nuclear material and equipment on site, and the delivery of construction materials for new projects (USDOE 2005a; USFS-SR 2005c).

The following organizations also have programs at the site:

- The Savannah River Ecology Laboratory (SREL), founded in 1951, has been located on site and was the first land stewardship program at SRS. The SREL has been operated by a research branch of the University of Georgia and was previously funded primarily by USDOE's Environmental Management Division, Savannah River Operations office; however, this funding was progressively reduced in 2006 and completely expended by June 2007. The SREL is now funded largely by specific projects for USDOE-SR, Savannah River Nuclear Solutions (SRNS), and other outside projects and grants. The SREL initially conducted baseline ecological studies and later became involved in waste management activities, release studies of various radioactive and non-radioactive elements, thermal effect studies of reactor effluent water on local ponds, and environmental assessments. SREL has provided independent evaluations of the

ecological effects of SRS operations through a program of ecological research, education, and outreach. This program has involved basic and applied environmental research, as well as evaluation of impacts of industrial and land-use activities on the environment. In addition, the SREL has provided knowledge about the behavior of environmental contaminants, especially in aquatic environments like the rivers, streams, and ponds at SRS (SREL 2001, ND; USDOE 2006; UGA 2009).

- In 1972, more than 14,000 acres (5,666 hectares) at SRS were designated by the Atomic Energy Commission as the first National Environmental Research Park (NERP). This designation allowed for ecologists, engineers, and land managers to study the impact of human activities on the environment, to develop methods to estimate or predict the environmental response to human activities, and to evaluate developed methods to minimize any adverse effects human activities may have on the environment. The SREL has managed NERP activities at SRS, including the 14,000 acres (5,666 hectares) of dedicated DOE Research-Set-Aside Areas (SREL 1998).

- The United States Forest Service–Savannah River (USFS-SR) has worked with SREL to conduct research on the basic aspects of ecological and environmental sciences. Research has focused on studying the fate and effects of contaminants in the environment, examining the biology of native species to improve remediation and restoration activities, and enhancing the management of natural resources (SREL 2001; USFS-SR 2004). Specifically, USFS-SR has conducted research in direct support of threatened, endangered, and sensitive species, and has examined methods to improve biological diversity (USFS-SR 2005a). USFS-SR has cut and sold timber and pine straw and has conducted annual prescribed burning operations to enhance wildlife habitat and reduce forest fuels (USFS-SR 2005b; WSRC 2005). Each year, an average of 20,000 acres (5,393 hectares) undergoes prescribed burning (USFS-SR, 2012). USFS-SR has also participated in waste site closure projects, provided aerial photo services, maintained secondary roads and site boundaries, managed soil erosion areas and watersheds, and engaged in community outreach. USFS-SR has been responsible for developing the SRS Natural Resources Management Plan which encompasses all natural resource operations, including management, education, and research programs (USDOE 2005a, 2006; USFS-SR 2005c).

- The University of South Carolina's Savannah River Archeological Research Program (SRARP) has made recommendations to USDOE-SR that facilitate management of cultural resources and has assisted with compliance activities involving site-use surveys, data recovery, coordination with major land users, and reconstruction of the site's environmental history (WSRC 2001).

Remedial and Regulatory History

Throughout its operation, large amounts of radioactive, non-radioactive, and mixed hazardous materials and wastes were processed, treated, and stored at SRS. During this time, radioactive and chemical materials have been released to groundwater, surface water, soil, sediment, air, and biota (USDOE 2005a). Initial cleanup activities of seepage basins, pits, piles, and landfills were started by USDOE-SR under a Resource Conservation and Recovery Act (RCRA) permit

submitted by SRS in 1985 and issued by the U.S. Environmental Protection Agency (USEPA) and the South Carolina Department of Health and Environmental Control (SCDHEC) in 1987. Since that time, USDOE-SR has begun and completed actions on several RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) responses that address contamination and disposal issues (USEPA 1989, 2012a; USDOE 2006).

SRS initiated the Environmental Management Program to address the closure of old burial grounds and seepage basins. The program objectives are to contain known contamination at inactive sites, assess the uncertain nature and extent of contamination, and clean up the inactive waste sites. SRS' Environmental Management Program activities include the stabilization of nuclear material and facilities, environmental restoration, and waste management (USDOE 2006). In 1989, SRS was officially listed on USEPA's National Priorities List (NPL) due to contamination of shallow groundwater with volatile organic compounds (VOCs), heavy metals, and radionuclides. Trichloroethylene (TCE) was detected in numerous on-site monitoring wells and soil. Additionally, the Savannah River Swamp had previously been found to be contaminated with heavy metals and radionuclides that overflowed into the area from an old seepage basin (USEPA 1989; USDOE 2006).

In 1992, CDC initiated a Dose Reconstruction Project to examine the release of chemicals and radionuclides from SRS during the main operating period from 1954 to 1992. Phase I of the Dose Reconstruction Project included a systematic review of available documentation of potential value to the project. Phase II developed an estimate of the releases of the most significant radionuclides and chemicals from various facilities at SRS from 1954 to 1992 (CDC 2001, 2002a, 2002b, 2005). Although Phase II summarizes the initial estimates of annual releases to air of selected chemicals, the report stated that the release rates were most likely an overestimate of the actual releases and further research was needed to better define actual release rates for chemicals and heavy metals. Based on the findings of Phase II, the final phase of the study—Phase III—estimated only the radiation doses and associated cancer risks for hypothetical persons (including families and children who were born during the years when the largest quantities of radioactive material were released in the environment) living near SRS and performing various activities (e.g., swimming, boating, fishing) on or near the site (CDC 2002a, 2002b, 2005).

In 2005, USDOE-SR, in collaboration with SRS stakeholders and regulators, developed the *SRS End State Vision* (i.e., USDOE 2005a). The goal of the *SRS End State Vision* is to permanently dispose of all environmental nuclear material and hazardous waste, decommission all environmental management facilities, and remediate all inactive waste units at SRS. The *SRS End State Vision* plan assumes that the entire site will continue to be owned and be the responsibility of the federal government once the cleanup is complete. The 2005 plan had a completion date of 2025. The *SRS End State Vision* plan became part of the SRS Environmental Management (EM) Program Management Plan issued in August 2007 with updates in January 2008 and July 2010. Due to policy changes and budget constraints, the original goals have been slightly modified and the cleanup completion date has been extended to 2038 which is consistent with other USDOE-SR documents such as SRS Comprehensive Plan and Ten Year Site Plan (FY 2012-2021) (SRNS-

The future objectives of the SRS call for the site boundaries to remain unchanged and residential use to remain prohibited.

RP-2011-0024).Once the EM Cleanup Project and mission at SRS is complete, the National Nuclear Security Administration will continue the nuclear industrial missions at this site (USDOE 2005a, 2010b, 2011b).

Current Regulatory Requirements Pertinent to Air Releases at SRS

In 1970, Congress passed the Clean Air Act (CAA), which allowed the USEPA to establish two types of standards relevant to this PHA: (1) National Ambient Air Quality Standards (NAAQS) for six principal pollutants called "criteria pollutants" – carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide, and (2) National Emissions Standards for Hazardous Air Pollutants (NESHAPs). In 1990, major amendments to the CAA were associated with these SRS-related standards, including (1) modification of maintenance and attainment of NAAQS provisions, (2) new provisions for protecting stratospheric ozone (Title VI), (3) establishment of the Title V air permitting program, and (4) expansion of NESHAPs (USEPA 2008, 2009b, 2010, 2012b; WSRC 2001; WSRC 2004).

These standards apply to SRS releases of airborne criteria pollutants. The standards are briefly summarized below, and discussed in more detail in the sections that follow.

- Primary and secondary NAAQS have been established for each criteria pollutant. Areas that meet the NAAQS are referred to as "attainment areas" and those not meeting them are called "nonattainment areas." Under the CAA, USEPA also requires states to develop plans (known as State Implementation Plans [SIPs]) that outline the steps they will take to reach levels at or lower than the NAAQS for all nonattainment areas (USEPA 2010). SCDHEC has also established ambient air quality standards for criteria pollutants in its Regulation 61-62.5, Standard No. 2.

- A NESHAP is a stationary source standard for hazardous air pollutants. Hazardous air pollutants (HAPs) are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects, birth defects, or adverse environmental effects (USEPA 2009e). Two NESHAPs apply to SRS:

    - Title 40 Code of Federal Regulations, Part 61 (40 CFR 61), Subpart H National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities, which requires that the effective dose equivalent of the maximally exposed individual not exceed 10 millirem per year. Subpart H also requires that all sampling must follow USEPA-approved procedures and that computer models used to calculate the effective dose equivalents must be approved by the USEPA. (The CAP88 computer code is an approved computer model.) (USEPA 1989, as amended)

    - 40 CFR 61. Subpart M, National Emission Standards for Asbestos, which addresses milling, manufacturing and fabricating operations, demolition and

renovation activities, waste disposal issues, active and inactive waste disposal sites and asbestos conversion processes. The Asbestos NESHAP requires facility owners and/or operators involved in demolition and renovation activities to control emissions of particulate asbestos (USEPA 2011a).

- Title VI requires the USEPA to establish regulations for phasing out the production and use of ozone-depleting substances (ODSs). Sections of Title VI are applicable to Savannah River Site as well as regulations established by the USEPA's Stratospheric Protection Regulations (40 CFR 82).

- Title V established a new regulatory program that requires operating permits for all major stationary sources such as SRS. SCDHEC authorizes the operation of SRS equipment and air emission sources through the Part 70 Air Quality Permit Program. The Title V permit for SRS was originally issued in 2003 (WSRC 2004). In September 2007, SRS transmitted a Title V renewal application to SCDHEC. The application was found to be complete, and the application shield was granted allowing SRS to continue operating under its expired Title V Permit which had expired on March 31, 2008. However, this permit did not cover the D-area Powerhouse. From 1996 to 2006, the D-Area Powerhouse was operated by a contractor for USDOE-SR. A Title V permit was issued to this contractor in 2001. In late 2006, SRS personnel began working with SCDHEC personnel to finalize a new Title V permit for the D-Area Powerhouse that replaced the facilities' existing Title V permit, which expired April 30, 2006. The D-Area Powerhouse continued operation under a Title V renewal from May 2007 until the facility closure and permit termination in May 2012 (WSRC 2007, 2008; USDOE 2013).

In addition to the USEPA's regulations, in 1991, SCDHEC established Air Pollution Control Regulation 61-62.5, Standard No. 8 to control emissions of various toxic air pollutants (USNRC 2005). This standard lists maximum allowable ambient air concentrations beyond the plant property line for most of the 257 toxic air pollutants listed in the standard. The pollutants listed in Standard No. 8 do not include radionuclides or asbestos (SCDHEC 2001a). SCDHEC requires sources, such as SRS, to use air modeling to show compliance with the concentrations listed in Standard No. 8 in accordance with established guidelines (SCDHEC 2001b). Modeling is based upon the maximum permitted limits and is reviewed by personnel in SCDHEC's Bureau of Air Quality.

SCDHEC's Regulation 61-62.1, Section III, requires SRS to compile and submit air emissions data inventory reports to the state (SCDHEC 2011a). The air emission inventory reports include estimates of the amount of criteria, hazardous, and toxic air pollutants emitted in one year. At times these emission inventories are able to provide insight into the results of the modeling efforts. For example, some of Standard No. 8 pollutants that SRS could have emitted based upon the modeling were not actually emitted according to the emission inventory data available in the annual environmental reports.

USDOE Order 5400.5, Radiation Protection of the Public and the Environment, establishes standards and requirements for USDOE and USDOE contractors with respect to protecting members of the public and the environment against undue risk from radiation. It requires compliance with the requirements of the Clean Air Act. For dose evaluations, SRS uses a USEPA model prescribed in 40 CFR 61, Subpart H but also uses a model for USDOE purposes using contemporary dosimetry. If a large site has multiple emission points, the collective public dose off-site may be estimated from a single point centrally located. To estimate the maximally exposed individual's dose, a single emission point may be used if the release points are close together and similar distance to the offsite locations. Otherwise, the estimate must take into consideration the actual locations of the releases with respect to off-site locations (USDOE 1990, as amended).

Environmental Setting

The environmental setting of SRS greatly influences how site contaminants move through the environment and how people living nearby could come into contact with contamination sources. The intent of the following sections is to identify features of the environmental setting at SRS that are most relevant to atmospheric releases of contaminants from on-site facility operations. Accordingly, ATSDR considered the following factors when evaluating air-related environmental health issues for SRS.

Land use on site and in the surrounding areas

The majority of the 198,344-acre SRS is undeveloped forest land, with only 8 percent of the site (15,924 acres) designated for industrial activities including nuclear processing, research and development, and waste management (SRNS 2009; USFS-SR 2005a, 2010). The small percentage of land used for on-site facilities, which is heavily industrialized and contains minimal natural vegetation, includes buildings, laydown yards, paved parking lots, and graveled construction areas (USDOE 1995). Lands around the site are primarily used for agricultural, light and heavy industrial, light residential, and recreational purposes. Major manufacturing facilities in the surrounding area include polystyrene foam and paper product plants; chemical processing facilities; textile mills; a commercial, low-level radioactive landfill (operated by Energy Solutions, formerly Chem-Nuclear Systems, LLC) in Barnwell, South Carolina; and a commercial nuclear power plant (Georgia Power's Vogtle Electric Generating Plant [VEGP]) across the Savannah River from SRS near Waynesboro in Burke County, Georgia (USDOE 2005a). Area farms generate a variety of products (e.g., dairy, livestock, soybeans) and hunting and fishing occur in areas on and near the site (Burger et al. 1997, 1998, 1999; Sanchez and Burger 1998; Toth and Brown 1997; USDA 2004, 2009). It is anticipated that land use in areas surrounding SRS will remain relatively consistent through at least 2025 (USDOE 2005a).

Site access

In general, public access to SRS is restricted to environmental/ecological research studies, guided tours, and controlled hunting activities (CDC 2005). Controlled hunting activities are conducted on specified dates and are monitored by SRS personnel and/or SCDHEC (James Heffner, WSRC, personal communication, June 4, 2007; SCDNR 2006). However, some illegal trespassing and onsite fishing have been reported (Burger et al. 1999).

Terrain

With the exception of main facility areas, SRS is heavily forested and terrain variation is minimal (O'Kula 2000). SRS lies on the Aiken Plateau of the Upper Atlantic Coastal Plain, approximately 25 miles (40 kilometers) southeast of the Fall Line dividing the Piedmont province from the Atlantic Coastal Plain. The Aiken Plateau, which contains steep-sided valleys, slopes at the Fall Line from an estimated 200-meter (650-feet) elevation to an estimated 75-meter (250-feet) on its southeast edge. Because SRS lies close to the Piedmont province, it is hillier than near-coastal areas, with site elevations varying from 27 to 128 meters (90 to 420 feet) above sea level (USDOE 1995). The Atlantic Ocean (about 160 river miles away) and Appalachian Mountains (to the north and northwest) are significant influences on wind direction at SRS (SRNL 2009; SRNS 2009; Weber et al. 2003). During spring and summer months, sea breezes come up from the coast to the Savannah River Channel. In fall months, northeasterly winds arise from high-pressure systems coming from the north and northwest (Weber et al. 2003).

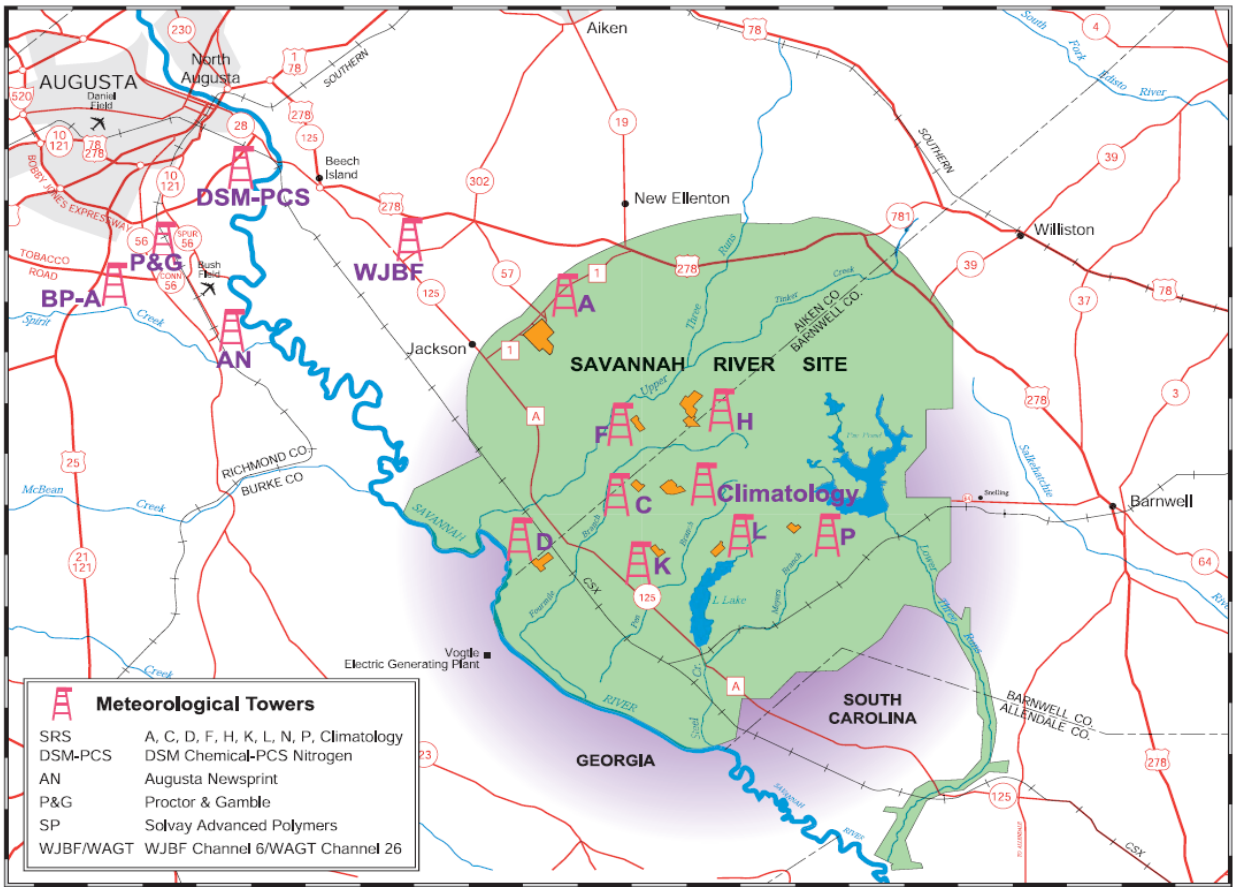
Climate

Overall, the climate at SRS is moderate, consisting of long humid summers and brief mild winters (Oliver and Fairbridge 1987). Usually, summer-type weather occurs from May through September, when the western extension of the Atlantic subtropical "Bermuda" high pressure system strongly influences the weather in the area. Humid summer conditions frequently result in thunderstorms during afternoons and evenings. In the fall, SRS weather is relatively dry with moderate temperatures. In wintertime, weather conditions change depending on influences from either the Gulf of Mexico region's moist subtropical air or cool dry polar air. The Appalachian Mountains, to the north and northwest of SRS, help moderate extremely cold temperatures caused by intermittent arctic air outbreaks. Snow and sleet typically do not occur in the SRS area. Generally, mild temperatures and windy conditions occur in the spring (Hunter 1990).

Additional insights on climate conditions from 1993 to 2010 can be gleaned from evaluating meteorological data collected at SRS by SRNL's Atmospheric Technologies Group (ATG). ATG uses a network of nine monitoring stations to collect meteorological data. Eight towers situated near all of SRS's major operations areas (A, C, D, F, H, K, L, and P areas) (see Figure 3) measure temperature, wind direction, dew point, and wind speed at a height of 61 meters above ground (measurements for dew point and temperature are also collected at 2 meters)[1] (SRNL 2011a). A ninth tower, the Central Climatology site, collects dew point, temperature, and wind measurements at four levels: 2 meters [4 meters for wind], 18 meters, 36 meters, and 61 meters. ATSDR obtained and reviewed monthly and annual average temperature data (see Table 1) collected at SRS during 1993–2010 by ATG's meteorological monitoring program (SRNL [ND], 2011a). Based on this data review, the overall annual average temperature for this 18-year time period was 63.6 degrees Fahrenheit. The lowest and highest observed monthly average temperatures were 38.2 (December 2000) and 83.6 (July 1993) degrees Fahrenheit, respectively.

[1] According to SRNL (2011a), a complete description of the SRS monitoring program is available in Parker MJ and Addis RP. 1993. Meteorological monitoring program at the Savannah River Site. WSRC-TR-93-016. Aiken, SC: Westinghouse Savannah River Company.

Figure 3. Savannah River Site Meteorological Monitoring Network (Source: SRNL-ATG [ND])



422

Table 1. Monthly and annual average temperatures at Savannah River Site in degrees Fahrenheit, 1993-2010

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1993	51.7	47.8	53.2	58.9	69.7	78.2	83.6	80.0	75.2	62.8	55.2	43.6	63.3
1994	41.5	50.1	60.2	68.0	71.2	82.3	81.8	81.2	77.4	67.2	62.3	53.3	66.4
1995	45.5	49.9	58.6	65.9	73.5	75.0	79.9	79.0	71.8	65.9	50.8	43.8	63.3
1996	44.6	50.1	50.6	61.6	72.9	76.5	79.3	76.0	72.7	62.1	51.6	48.8	62.2
1997	48.2	52.9	63.3	61.2	68.5	74.0	80.2	79.0	75.0	64.1	51.6	47.0	63.8
1998	49.7	51.1	53.6	62.7	74.6	82.1	82.6	80.3	75.8	66.9	60.5	53.6	66.1
1999	51.9	51.6	53.4	67.2	69.7	76.6	80.7	82.9	73.8	64.3	58.1	48.6	64.9
2000	44.4	50.2	58.5	60.7	75.1	78.0	79.9	77.6	71.7	62.5	53.1	38.2	62.5
2001	43.8	52.4	53.0	63.9	71.3	75.3	77.7	78.8	71.2	62.2	60.0	52.4	63.5
2002	47.3	48.0	57.6	68.1	70.2	77.5	80.5	78.4	75.4	66.7	51.7	44.5	63.8
2003	42.0	47.5	57.6	61.6	70.6	75.2	77.3	77.7	71.9	63.7	58.2	42.9	62.2
2004	43.7	45.2	58.5	63.4	74.0	77.7	80.1	77.3	73.2	66.2	56.1	45.8	63.4
2005	47.9	49.0	53.1	60.9	68.0	75.4	79.4	78.8	77.0	64.7	56.1	44.3	62.9
2006	50.8	47.3	55.3	66.3	70.1	76.2	80.3	80.5	72.9	62.4	53.6	50.6	63.9
2007	48.6	46.4	58.4	61.8	70.2	76.5	77.4	81.9	75.2	68.7	54.0	52.3	64.3
2008	43.8	51.1	55.3	61.8	70.2	80.1	78.7	77.9	73.7	61.1	50.0	52.1	63.0
2009	44.9	47.4	55.2	62.3	70.7	79.2	78.6	78.2	74.1	62.7	54.6	45.5	62.8
2010	40.8	41.4	51.9	64.6	73.7	80.0	81.0	80.0	76.2	64.0	54.0	39.2	62.2

Source: SRNL 2011a

Prevailing wind patterns

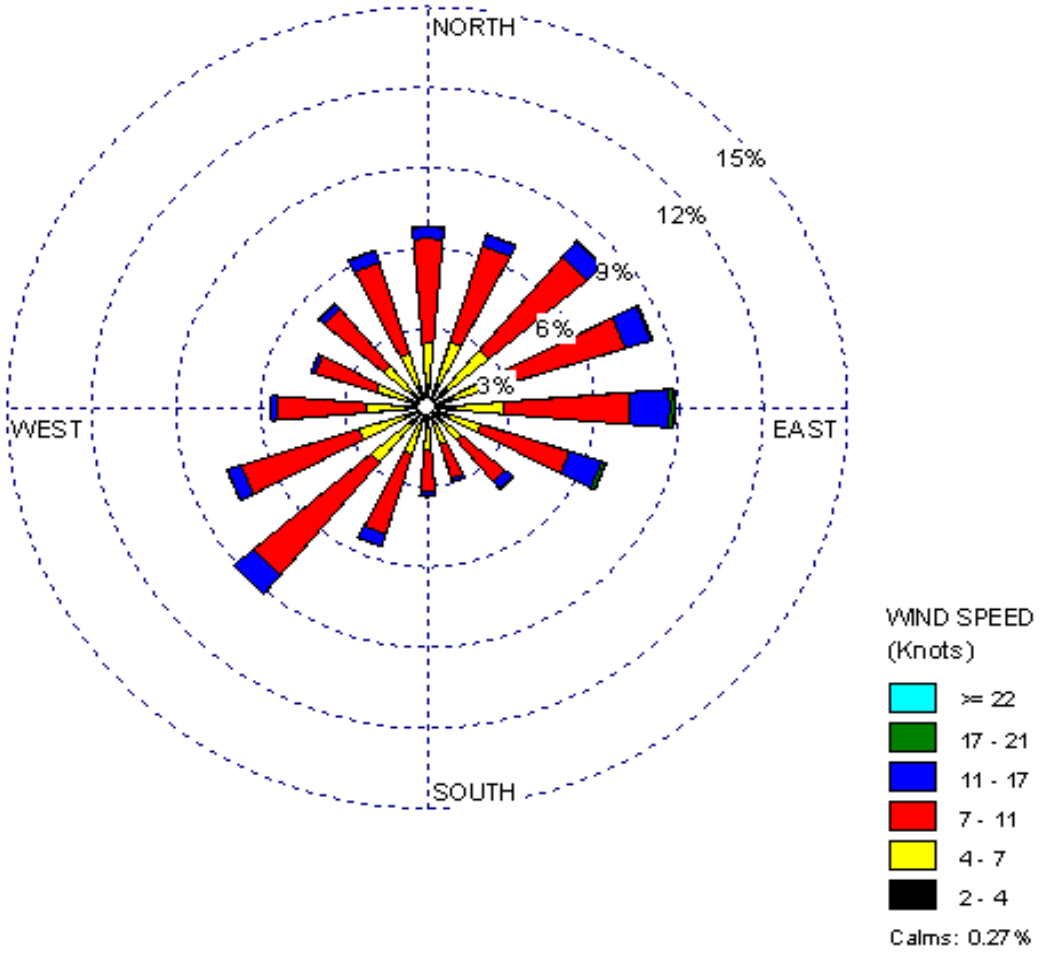
Based on historically-collected wind direction measurements, some sources conclude that there is no prevailing wind direction at SRS (WSRC 2002b). This information was demonstrated by composites of hourly averaged wind data from SRS meteorological tower network data from 1982 through 1986 and 1987 through 1991 (WSRC 1994a). The percentages of time the prevailing wind was blowing toward each of the 16 sectors at 61 meters above the ground were less than ten percent. The highest percent that the wind blew toward any direction from 1982 through 1986 was 9.6 percent toward the southwest, and from 1987 through 1991 was 9.1 percent toward the southwest. The least frequent direction was toward the south-southeast (2.9 percent from 1982 through 1986 and 3.1 percent from 1987 through 1991) (WSRC 1994a). To investigate these wind patterns further for the time period covered by this document, ATSDR obtained wind direction and wind speed data collected by SRNL's ATG from 1993–2006[2] at the SRS meteorological network of eight main towers[3] and combined the data into a format known as a "transport wind rose" (see Figure 4).

The "transport wind rose" displays the direction toward which the wind would transport an airborne contaminant release and the statistical distribution of wind speeds. This figure indicates a very low calm rate, with 0.27 percent of the wind observations classified as calm when all eight stations were combined. The average wind speed was 3.96 meters per second (8.86 miles per hour). As the figure illustrates, winds measured at 61 meters above ground flow toward all directions with winds fairly evenly distributed around the compass. The least frequent is toward the south and south-southeast. The figure also demonstrates the wind directions are similar to previous findings, with winds slightly more often toward the southwest, east, and northeast. This information shows that although there is a slight prevailing wind pattern, off-site areas in all directions could have been or could be affected by airborne releases from SRS.

[2] Wind direction and wind speed data for 2007 through 2010 were not available for inclusion at the time this PHA was prepared. SRNL's ATG will format these data as part of their 5-year data set (i.e., 2007–2011) in 2012. Based on the data evaluated from 1993–2006; however, ATSDR does not believe additional data would alter the observed trends in wind patterns at SRS.

[3] SRNL's ATG provided ATSDR with wind direction and wind speed data from the eight main towers, but not from the Central Climatology meteorological station.

Figure 4. "Transport Wind Rose" for the Savannah River Site Meteorological Network: 1993–2006



Source: SRNL's Atmospheric Technologies Group

Note: The "transport wind rose" displays the direction toward which the wind would transport an airborne contaminant release.

Surface soil

Radioactive pollutants released into ambient air via on-site processes can eventually be deposited in off-site surface soil by dry deposition or wet deposition (rainwater). Among off-site locations, the radionuclide concentrations detected in soil can differ quite a bit due to wind direction, rainfall patterns, variations in soil type, and the particular radionuclide which influence the transport and retention of the radionuclide in soil (Strebl et al. 2007; SRNS 2009; WSRC 1998a).

Typical for this region and SRS specifically, the majority of soils are clayey (i.e., a group containing soils with a clay, sandy clay, or silty clay texture; these soils are 35 percent or more clay and less than 35 percent rock fragment) or sandy over loamy (i.e., soil that contains less than 50 percent of fine sand or coarser sand) subsoil (CDC 2005; Soil Science Society of America 2010; Soil Survey Staff 2010). Generally speaking, cation exchange capacities,[4] pH levels, and clay contents can increase or decrease radionuclide mobility in soil. For instance, cesium-137 can affix itself strongly to clay-containing soil and tends to have low vertical mobility. Vertical movement of radionuclides in soil also depends on the water content in the soil that comes from sources such as rainwater and runoff (Strebl et al. 2007).

Over time, soil is the primary source for radionuclides entering groundwater or the food chain. ATSDR has discussed the groundwater and biota pathways previously in two SRS PHAs. For this document, ATSDR will evaluate potential exposure to contaminants in surface soil using the National Council on Radiation Protection and Measurement (NCRP) Report No. 129 which takes into account land use and potential exposure from inhalation, ingestion, and external sources (NCRP 1999). ATSDR also will review ambient radiation levels detected by thermoluminescent dosimeters from 1993 through 2010 in conjunction with this evaluation.

Rainfall

Although the amount of rainfall can have an effect on surface soil contaminants and the migration of contaminants in soil and plants, for this document, ATSDR will evaluate the concentration trends in rainwater samples and focus on rainwater as a potential source of drinking water from collection systems such as cisterns. South Carolina and Georgia have issued guidelines for installing cisterns but do not have laws or statutes for regulating or permitting their use. Concentrations of radioactive contaminants in collected rainwater are affected by all of the following: 1) characteristics of the original airborne emissions (type of radionuclide and particle size), 2) wind direction, and 3) the amount of rainfall. (Large amount of rainfall can affect the deposition rates for some radionuclides but not as much for others [Baskaran 2011].) ATSDR obtained and reviewed total monthly and annual rainfall data collected by the SRNL's ATG during 1993–2010 (see Table 2) (SRNL 2011a). Based on this data review, the annual average total rainfall from 1993 through 2010 was 45.9 inches and the average monthly rainfall from 1993 through 2010 was 3.8 inches. The lowest monthly recorded rainfall during this time period

[4] Cation exchange capacities (CECs) approximate the sum of negatively-charged sites on the soil surface. CECs are estimated by calculating the mass of a standard cation (e.g., ammonia) that causes another cation held by the soil to move. Typically, cations associated with percolating or flowing water will be present at these negatively-charged sites on the soil's surface, such as calcium, magnesium, potassium, and sodium (Piwoni and Keeley 1990).

was 0.02 inches in October 2000; the highest monthly rainfall of 11.0 inches occurred in June 2003 (SRNL 2009).

Table 2. Monthly and annual total rainfall in inches at Savannah River Site, 1993-2010

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1993	7.5	3.6	8.4	1.7	1.4	3.3	3.1	2.2	7.3	1.0	1.9	1.8	43.2
1994	4.8	3.9	6.4	1.1	1.5	5.1	7.5	3.5	1.0	10.0	3.1	4.6	52.3
1995	7.0	8.0	0.9	1.3	1.8	8.2	5.7	6.9	5.8	2.6	2.4	4.5	54.9
1996	3.7	2.4	6.6	2.4	3.0	3.0	5.6	6.9	3.7	2.2	2.3	3.2	45.0
1997	4.2	5.5	2.7	4.4	2.4	6.9	7.1	2.0	4.9	4.1	5.5	9.1	58.7
1998	7.7	8.9	6.7	7.4	4.1	4.7	5.3	2.9	4.8	0.8	0.8	1.8	55.7
1999	5.3	2.3	3.4	2.0	1.3	7.5	4.9	3.1	4.5	2.6	1.5	1.2	39.6
2000	5.8	0.7	4.0	1.3	1.4	4.7	2.5	4.5	7.7	0.0	3.5	1.5	37.6
2001	3.1	2.7	7.2	1.3	3.9	6.5	4.8	3.6	3.3	0.5	1.0	0.5	38.4
2002	2.9	2.1	3.9	2.6	1.7	2.3	6.0	5.5	3.5	3.2	4.0	3.6	41.1
2003	1.7	5.0	7.1	8.4	5.6	11.0	8.9	4.6	2.7	3.0	1.2	1.9	61.2
2004	2.9	6.7	0.8	1.3	3.5	6.4	1.2	3.0	10.3	1.0	3.2	2.7	42.9
2005	2.1	3.9	6.1	1.7	2.9	8.2	5.8	4.1	0.2	3.6	2.7	6.2	47.4
2006	3.4	2.9	1.8	2.4	1.8	6.9	5.2	2.2	2.5	1.7	3.0	4.6	47.4
2007	3.3	3.6	2.0	3.0	1.2	4.8	4.6	2.7	1.0	1.4	0.6	8.8	36.8
2008	3.7	5.4	3.0	2.4	1.8	1.4	5.4	5.4	0.9	4.1	5.1	2.9	41.6
2009	2.0	1.7	3.7	4.6	5.2	2.7	2.6	3.1	3.7	3.0	5.5	10.2	48.0
2010	4.8	2.4	3.0	1.5	2.6	5.7	2.7	5.2	2.9	0.3	1.3	1.3	33.7

Source: SRNL 2011a

General air quality

This section reviews the general air quality for the area which does not appear to be site related but may be instrumental in discussing the site impact later in the report. This initial discussion refers to the attainment status for *criteria pollutants* in this portion of South Carolina. For over 20 years, USEPA and state environmental agencies have evaluated general air quality based on ambient air concentration measurements of six common air pollutants (i.e., *criteria pollutants*). The criteria pollutants include the following:

- Carbon monoxide
- Lead
- Nitrogen dioxide
- Ozone
- Two forms of particulate matter
  - Particulate matter with aerodynamic particle size of 2.5 microns or less ($PM_{2.5}$)
  - Particulate matter with aerodynamic particle size of 10 microns or less (PM_{10})
- Sulfur dioxide

Various sources contribute to airborne levels of these pollutants, which are found throughout the United States.

USEPA has established a health-based National Ambient Air Quality Standard (NAAQS) for each criteria pollutant. In the event that air quality measurements do not meet the NAAQS, USEPA requires states to develop and implement plans to lower levels so the pollutant measurements are in attainment with the health-based standards.

For the state of South Carolina, SCDHEC is responsible for developing a sampling plan and for using samplers and monitors to collect measurements of these criteria pollutants.[5] ATSDR reviewed SCDHEC's sampling plan for 2010 (SCDHEC 2009c) to identify the most recent sampling plan during the time period of this PHA. For sampling, frequency of collection varies by pollutant, and occurs every day, every third day, every sixth day, and for some special project sites, every twelfth day. SCDHEC reports the sampling results as averages for the sample collection period. For monitoring, SCDHEC typically uses stationary analyzers to continuously sample the air, and then reports the results as hourly averages (SCDHEC 2009c). SCDHEC does not operate monitors in every county in South Carolina. Instead, SCDHEC focuses its monitoring efforts in areas expected to have elevated pollutant concentrations, such as larger populated areas. In order to ensure that the network accurately represents statewide air quality, SCDHEC also operates various monitors in smaller cities and towns. SCDHEC also periodically conducts special studies to address area- or pollutant-specific questions (SCDHEC 2011b).

ATSDR reviewed SCDHEC's ambient air monitoring data (SCDHEC 2012; USEPA 2011b, 2012b) to determine the general air quality for the counties that SRS lies within: Aiken, Allendale, and Barnwell Counties in South Carolina (SCDHEC 2009c). During the time period for this PHA (i.e., 1993–2010), SCDHEC operated air network monitoring stations in two of the three counties: Barnwell County (1993 to 2007) and Aiken County (1993 to 2010). The Aiken County monitor is located at Jackson Middle School (northwest of the site not far from the site perimeter) while the Barnwell County monitor was located along Road S-6-21(near the perimeter east of the site). SCDHEC monitored for four criteria pollutants in Barnwell County until 2007: nitrogen dioxide, sulfur dioxide, ozone, and PM_{10}. The criteria pollutants monitored in Aiken County have included nitrogen dioxide, ozone, lead, sulfur dioxide, PM_{10}, and $PM_{2.5}$; however, the number of pollutants monitored has decreased over time and as of 2010 the state was only monitoring for one criteria pollutant in Aiken County: ozone (USEPA 2012c). Based on these data, Aiken and Barnwell Counties met the NAAQS for all of the monitored criteria pollutants except for 8-hour averages of ozone. Barnwell County monitoring data show levels of ozone below the current 8-hour average NAAQS standard (i.e., 0.075 parts per million [ppm])[6] since 2002. Aiken County monitoring data, on the other hand, periodically exceeded the current 8-hour standard since 1993 (but did not exceed it during the most recent 3-year period from 2008 through 2010) (SCDHEC 2012, 2013; USEPA 2011b).

[5]SCDHEC examines air quality in the state of South Carolina by using samplers and monitors. Samplers collect pollutants, with subsequent analysis occurring in a laboratory. Monitors, on the other hand, continuously analyze and report the pollutant concentrations.

[6] The USEPA did not finalize an 8-hour NAAQS for ozone until 1997. In 2008, the USEPA changed the standard from 0.08 ppm to 0.075 ppm. Further information about the history of the ozone standard is available at: http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_history/html

During this time period, SCDHEC also monitored for acid rain (see text box) in Barnwell County. Acid rain data were collected from 1993 to 2007, with an average acid rain pH value of 4.59 during this time period. The pH value of 4.59 is consistent with the state-wide average for this same time period of 4.55 (SCDHEC 2012). Acid rain is more acidic than "normal rain," which has a pH of about 5.6 (USEPA 2007).

Acid rain is defined as hail, snow, fog, sleet, or rain, which is characterized by a low pH due to the presence of airborne pollutants, particularly nitrogen oxides and sulfur dioxide (SCDHEC 2006c). Acid rain forms when these air pollutants from various sources (e.g., vehicles, power plants) react with atmospheric oxidants, oxygen, and water (USEPA 2009d).

Like SCDHEC, GDNR maintains an ambient air monitoring network and does not monitor every county in Georgia. GDNR's Ambient Air Surveillance Reports are available on GDNR website for the years 1998 through 2010. These reports indicate that no ambient air sampling for criteria pollutants took place in Burke County, which is across the Savannah River from the site. A county is only designated as *nonattainment* if it does not meet (or contributes to ambient air quality in a nearby area that does not meet) the NAAQS for a criteria pollutant (Section 107 of the Clean Air Act). In the absence of monitoring data, the USEPA allows counties to be designated as *unclassifiable* (USEPA 1979). Burke County is designated as attainment/unclassifiable for all criteria pollutants (J. Johnston, GDNR. Personal communication, June 28, 2012).

ATSDR also reviewed the results of USEPA's RadNet monitoring system for *radioactive contaminants* detected at locations near SRS from 1993 through 2010. The RadNet system is a national network of ambient air monitoring stations distributed across 50 states and American territories to continuously monitor for radionuclides. RadNet's current database contains data collected since 1978 and includes results for air, precipitation, drinking water, and milk samples. The samples are analyzed by USEPA's National Air and Radiation Environmental Laboratory in Montgomery, Alabama (USEPA 2011c). ATSDR reviewed RADNET ambient air sampling data collected at two locations: Augusta, Georgia and Barnwell, South Carolina. Only limited air filter sampling results for 2008 and 2009 were available from the Augusta location, but results were available for 1993 through 2009 from the Barnwell location. Also, rainwater samples analyzed for tritium were available for the Barnwell location from 1993 until 2003. (A summary of the results for the Barnwell location is in Appendix C.) In 1993 and 1994, the Barnwell precipitation samples results occasionally appear to be slightly affected by the site due to its close proximity; however, the overall average concentrations are similar to other states as reported in RadNet and are well below USEPA's Safe Drinking Water standards (USEPA 2012d).

Demographics

The most densely populated area in proximity to the site is Augusta, Georgia—located about 22.5 miles northwest of SRS—with a population of 195,844. The total population within 1 mile of the site boundary is 3,899, within 10 miles is 82,359, and within 25 miles is 424,307 (see Figure 5). (US Census Bureau 2011a; SRNS 2011a).

ATSDR evaluated U.S. decennial census data for 1990, 2000, and 2010 to obtain demographic data for the three counties in which SRS lies: Aiken, Allendale, and Barnwell Counties (see Table 3). During this time, the percentage of people age 25 and older who have a high school diploma has consistently increased. The percent of the residents age 25 and older who have a high school diploma living in owner-occupied housing units in 2010 suggest a stable, non-transient population. The median household income for residents of these counties ranged from $20,081 to $44,468 in 2010 (US Census Bureau 1992a, 1992b,1992c, 2001, 2011b).

In these three counties, the largest portion of employment is through manufacturing as well as educational service, healthcare, and social assistance jobs. The percentages of people with government jobs are 18.7, 20.5, and 23.2 percent in Aiken, Allendale, and Barnwell counties, respectively (US Census Bureau 2011a). SRS is one of the largest employers in the area, employing approximately 12,000 federal, contractor, and subcontractor workers in 2009 (SRNS 2011c). SRS significantly contributes to the economies of South Carolina and Georgia through employment, purchasing, education, research, technology, business development, and community assistance programs (CDC 2005; USDOE 2005a).

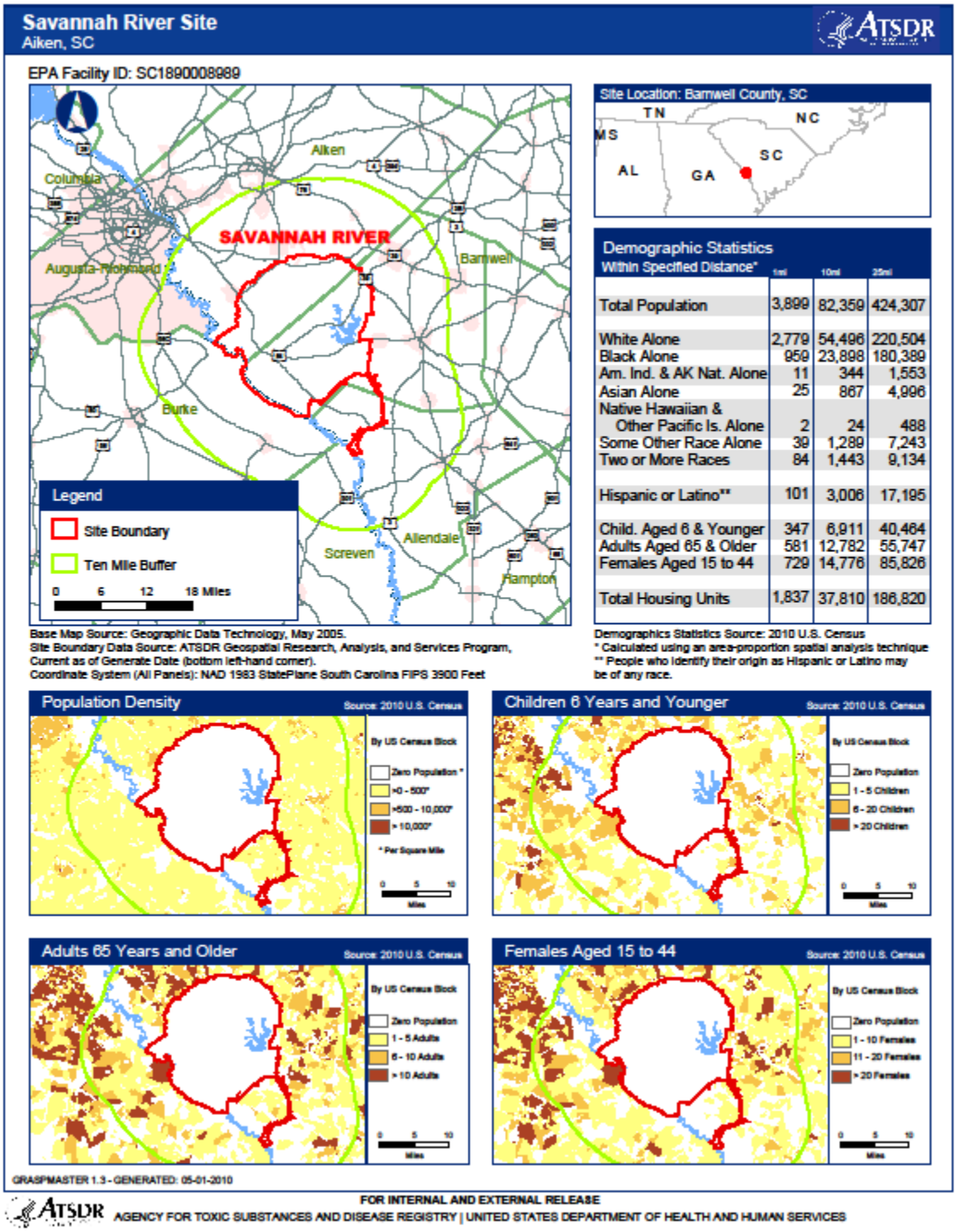
Table 3. Demographics in Aiken, Allendale, and Barnwell Counties: 1990 to 2010

County	1990	2000	2010
Aiken County			
Population	120,940	142,552	160,099
People aged 25 and older with a high school diploma (percentage of persons aged 25 and older with high school diploma)	53,894 (70.7%)	72,217 (77.7%)	88,618 (83.7%)
Live in owner-occupied housing (percentage of persons aged 25 and older with high school diploma living in owner-occupied housing)	33,491 (74.6%)	42,036 (75.6%)	45,491 (73.3%)
Median household income	$29,994	$37,889	$44,468
Allendale County			
Population	11,722	11,211	10,419
People aged 25 and older with a high school diploma (percentage of persons aged 25 and older with high school diploma)	3,601 (52.3%)	4,254 (60.0%)	5,256 (73.2%)
Live in owner-occupied housing (percentage of persons aged 25 and older with high school diploma living in owner-occupied housing)	2,584 (68.2%)	2,846 (72.7%)	2,042 (59.1%)
Median household income	$15,013	$20,898	$20,081
Barnwell County			
Population	20,293	23,478	22,621
People aged 25 and older with a high school diploma (percentage of persons aged 25 and older with high school diploma)	7,284 (59.9%)	9,976 (67.5%)	11,730 (78.2%)
Live in owner-occupied housing (percentage of persons aged 25 and older with high school diploma living in owner-occupied housing)	5,194 (73.2%)	6,810 (75.5%)	6,141 (72.9%)
Median household income	$23,501	$28,591	$33,816

Source: U.S. Census Bureau 1992a, 1992b,1992c, 2001, 2011b

602

Figure 5. Demographics Within Specified Distances from Savannah River Site Boundary



604

Summary of Public Health Activities

ATSDR Involvement

ATSDR is required by law to conduct a PHA at each of the sites on USEPA's NPL. As part of the PHA process, ATSDR conducted a site visit at SRS in September 2005 to collect information for identifying any potential public health hazards and health issues or community concerns related to environmental contamination. During the visit, ATSDR staff met with WSRC and USDOE-SR representatives, toured SRS and surrounding areas, and attended the final meeting of the Savannah River Site Health Effects Subcommittee (SRSHES). SRSHES was established to identify the needs of exposed and potentially exposed people and to advise the CDC on the adequacy of the agency's health research and public activities at SRS.

Since 1991, other ATSDR activities associated with SRS included oral and written consultations on various on-site remediation projects, including soil contamination at the Acid/Caustic Storage Basins, removal actions at the unlined trenches of the D-Area Seepage Basin, interim actions and remedial alternatives for the Metallurgical Laboratory Hazardous Waste Management Facility and the M-Area, and pump-and-treat processes for groundwater in the A&M-Area. SRS was also one of the USDOE sites included in ATSDR's Health Consultation on Tritium Releases and Potential Off-site Exposures issued in March 2002 (ATSDR 2002a).

In 2002, ATSDR conducted a three-phase health education/needs assessment, involving community leaders and individuals from 10 Georgia and South Carolina counties potentially affected by SRS activities, to assess community environmental health education needs and concerns. Phase 1 consisted of collecting information about the demographics, major employers, local medical services, religious institutions, educational centers, and local communication channels for the impacted counties. Phase 2 included conducting interviews with area health care providers to gather information on local environmental health concerns. Phase 3 consisted of conducting focus groups in selected communities within Georgia and South Carolina to gather information on each community's health and other concerns related to SRS, community data needs, and effective communication channels for the communities. As part of this process, ATSDR identified the following community concerns related to potential adverse health effects linked to SRS activities: respiratory illness, cancer, skin diseases, and birth defects. Focus group members also expressed concern about the extent of environmental degradation resulting from activities conducted at SRS (ATSDR 2002b).

In December 2007, ATSDR issued a final PHA titled "Evaluation of Off-Site Groundwater and Surface Water Contamination at the Savannah River Site (USDOE)" (see ATSDR 2007). Based on the information evaluated, under existing and normal operations, ATSDR scientists concluded that exposure to SRS-related contaminants in groundwater and surface water was not expected to harm the health of people living in the surrounding community.

On February 29, 2012, ATSDR issued a final PHA titled "Evaluation of Exposures to Contaminants in Biota Originating from the Savannah River Site (USDOE)" (see ATSDR 2012). Based on the information evaluated, ATSDR scientists concluded that the public's exposure to SRS-related radioactive contaminants in offsite plants and animals is not expected to harm the health of people consuming these products. However, due to mercury concentrations in some

fish species, persons consuming fish from the Savannah River should follow fish advisory guidance issued by South Carolina and Georgia. Also, there were not sufficient data available for non-radioactive, non-metal contaminants in biota to determine whether potential health effects were possible for persons consuming local fish and wildlife.

Community concerns associated with SRS

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. For this and other ATSDR PHAs for SRS, ATSDR gathered comments and other information from the people who live or work near the site and reviewed several documents identifying concerns. ATSDR is particularly interested in hearing from residents of the area, civic leaders, health professionals, and community groups. The SRS Citizens Advisory Board (SRS CAB), established in 1994 to advise USDOE-SR on environmental activities at SRS, is a non-partisan group comprised of 25 stakeholders from South Carolina and Georgia with diverse backgrounds and work histories (e.g., local government, academia, business). The full SRS CAB meets six times per year with committee meetings held more frequently (i.e., bimonthly) (USDOE 2010a). ATSDR has attended these meetings periodically.

Appendix E presents community concerns regarding SRS and ATSDR's responses to them. Some of the community concerns presented were obtained by reviewing online information (e.g., reports prepared by different organizations, articles posted by concerned individuals) as well as those obtained during ATSDR's health education/needs assessment project conducted in the 10-county area within 50 miles or downstream of SRS to help the agency develop environmental health education materials (ATSDR 2002b). ATSDR also obtained community concerns about SRS operations from WSRC (1992) that were identified via public meetings, public hearings, and the news media. In 1990, SRS representatives conducted 85 interviews with local elected officials, environmentalists, and citizens of Georgia and South Carolina to identify the public's concerns about SRS for the site's *Public Participation Plan* as required under CERCLA. WSRC compiled the questions and a summary of the interviewee responses, and provided them to ATSDR (WSRC 1992). In 2011 the USEPA and USDOE-SR began a series of environmental justice meetings held in neighboring locations in Georgia and South Carolina. Concerns have also been included from these meetings. In addition, ATSDR conducted online searches using basic terms (e.g., concerns about SRS) to identify information and documents that contained concerns associated with SRS.

Specifically addressed in this PHA are concerns about contamination in air and soil, which can generally be categorized into three groups: environmental releases and contamination, air quality and pollution, and potential health effects and health concerns. Note that ATSDR removed personal identifiers as well as any indication of direct quotations from the community concerns.

Quality assurance and quality control

In preparing this PHA, ATSDR scientists reviewed and evaluated environmental data provided in the citations presented in the References section. As shown in Table 4, the radiological environmental data presented in this PHA come from routine off-site radiological monitoring of ambient air, rainwater, soil, and direct radiation by USDOE-SR and its contractors, Georgia

Department of Natural Resources' Environmental Protection Division (GDNR-EPD), and the SCDHEC-ESOP. ATSDR obtained the data via direct electronic transfer from the agency or from published annual reports. With a few exceptions, ATSDR was able to obtain radiological data for these media during the entire time period of interest for this PHA. The validity of analyses and conclusions drawn in this PHA are based on the reliability of the information in the referenced sources. ATSDR has determined that the data quality reviewed for this PHA is adequate for making public health decisions.

Table 4. Radiological monitoring data collected off-site by GDNR-EPD, SCDHEC-ESOP, and USDOE-SR from 1993–2010

Data Collector	Media	Available Data for this PHA (1993–2010)
GDNR-EPD	Ambient air	1993–2010
	Direct radiation (TLDs)	1993–2009[b]
	Soil	1993–2010
	Rainwater	1993–2010
SCDHEC-ESOP	Ambient air	1997–2010
	Direct radiation (TLDs)	1997,[a] 1999–2010
	Soil	1993–2010
	Rainwater	1998–2010
USDOE-SR	Ambient air	1993–2010
	Direct radiation (TLDs)	1993–2010
	Soil	1993–2010
	Rainwater	1993–2010

Notes: PHA = public health assessment
GDNR-EPD = Georgia Department of Natural Resources' Environmental Protection Division
SCDHEC-ESOP = South Carolina Department of Health and Environmental Control's Environmental Surveillance and Oversight Program
TLD = thermoluminescent dosimeter
USDOE-SR = U.S. Department of Energy-Savannah River
[a]SCDHEC-ESOP did not report TLD data in 1998 because of equipment difficulty (SCDHEC 1999a).
[b]GDNR-EPD discontinued its site-related TLD monitoring in April 2009.

Evaluation of Environmental Contamination and Potential Exposure Pathways

The primary focus and majority of discussion in this section are ATSDR's evaluation of contaminants in off-site air. This section also summarizes radioactive contaminants found in off-site soil and rainwater because contaminant concentrations in these media are indicators of potential deposition of airborne pollutants and additional routes of exposure.

Introduction

ATSDR's public health assessment process emphasizes the importance of exposure pathways, or the different ways that people can come in contact with environmental contaminants. The release of a chemical or radioactive material into the environment does not always result in human exposure. Human exposure to a substance depends on whether a person comes in contact with the environmental contaminant through breathing, eating, drinking, or external exposure. If an individual does not have exposure with a contaminant, then resulting health effects cannot occur. Furthermore, the release of a contaminant from a site does not always mean that the substance will have a negative impact on the health of a member of the off-site community. However, even if the site is inaccessible to the general public, contaminants can move through the environment to locations where people could come into contact with them. Figure 6 illustrates the various exposure pathways that could result in exposure to contaminants released from SRS.

How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate site conditions to determine if people could have been or could be exposed to site-related contaminants. For this PHA, ATSDR identified whether exposure to contaminants has occurred, is occurring, or may occur in the future through inhalation. ATSDR identifies an exposure pathway as completed or potential, or eliminates the pathway from further evaluation. *Completed* exposure pathways exist if all five elements of a human exposure pathway are present. (See Elements of an Exposure Pathway text box.) A *potential* exposure pathway exists when one or more of the elements are missing but available information indicates human exposure is possible. An *incomplete* exposure pathway exists when one or more of the elements are missing and available information indicates that human exposure is unlikely to occur (ATSDR 2005a).

Elements of an Exposure Pathway

1.) The *source* is the place where the chemical or radioactive material is released.

2.) The *environmental medium* (such as groundwater, soil, surface water, or air) transports the contaminants.

3.) The *point of exposure* is the place where people come into contact with the contaminated medium.

4.) The *route of exposure* (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body.

5.) The *receptor population* is a population that is potentially exposed to contaminants at an exposure point.

As previously noted this PHA mainly focuses on human exposure to off-site air contamination but also discusses how radioactive contaminants in air emissions can affect contamination levels in off-site soil and rainwater. ATSDR scientists evaluated the potential for contaminants to be transported off the site by reviewing environmental sampling data from USDOE-SR, USDOE-SR contractors,

SCDHEC-ESOP, and GDNR-EPD. ATSDR scientists selected contaminants for further evaluation by comparing them to media-specific health-based screening levels as discussed in subsequent sections.

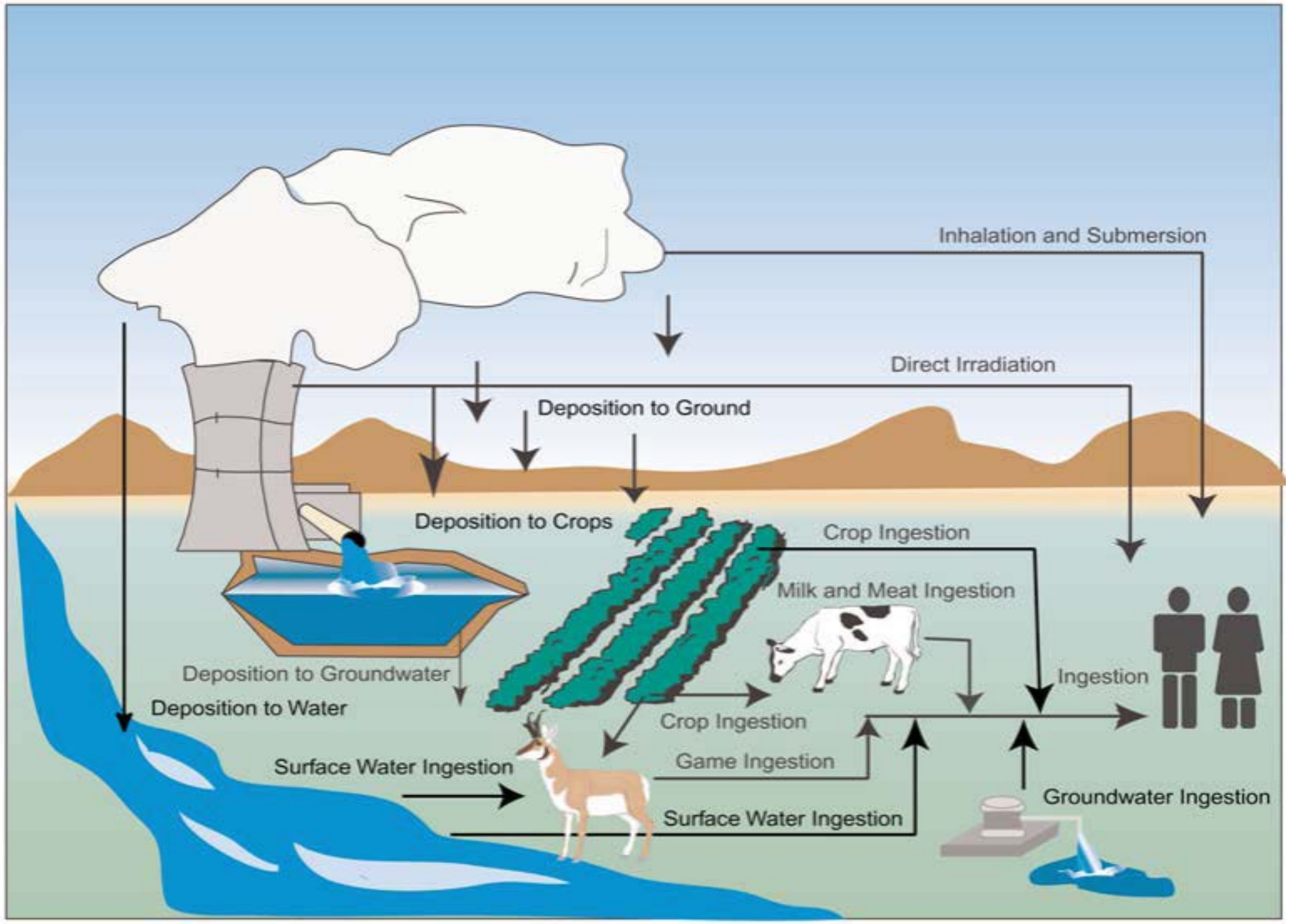
Screening values used by ATSDR are not thresholds for adverse health effects. Rather, these values represent concentrations in air emissions that are many times lower than levels expected to cause any health effects in members of the public. If contaminant concentrations are above screening values, ATSDR further analyzes exposure variables (for example, duration and frequency of exposure), the toxicology of the contaminant, other epidemiology studies, and the weight of evidence for health effects.

If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects a person can experience due to contact with an environmental contaminant depend on the exposure concentration (how much), the frequency (how often) and/or duration (how long) of exposure, the route or pathway of exposure (breathing, eating, drinking, or external exposure), and the multiplicity of exposure (combination of contaminants). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how the individual absorbs, distributes, metabolizes, and excretes the contaminant. Together, these factors and characteristics determine the health effects that may occur.

To account for the uncertainty in the precise level of exposure and to be protective of public health, ATSDR scientists often use worst-case exposure level estimates as the basis for determining whether adverse (harmful) health effects are possible. These estimates are usually much higher than the actual exposure level received by an individual. If adverse health effects are possible based on these worst-case scenarios, then ATSDR performs a more detailed review of the exposure pathway and consults the toxicologic and epidemiologic literature for information on the health effects from exposure to the radioactive and chemical materials of interest.

766 **Figure 6. Pathways of Exposure for Site-specific Contamination**



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768 Source: S.M. Stoller Corporation 2004

Radioactive Contaminants in Off-site Air, Rainwater, and Surface Soil

Radionuclides are present in air in the SRS region as a result of site operations, but also as a result of natural sources and worldwide fallout (USDOE 1994).

Evaluating residents' off-site exposures to SRS's air emissions of radioactive contaminants is detailed in the following sections. The first section discusses the routine and non-routine SRS operations that resulted in air releases of radioactive contaminants to off-site areas. The second section discusses air modeling performed by SRS to satisfy USDOE's Order 5400.5 and USEPA's 40 CFR 61, Subpart H (National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities) and the annual potential effective dose equivalent for a hypothetical maximally exposed individual and neighboring population if pollution control equipment did not exist but facilities operations were otherwise normal. The third section discusses off-site air monitoring programs (air and rainwater sampling) and available data from USDOE-SR, GDNR-EPD, and SCDHEC-ESOP and compares estimated radioactive concentrations from the second section at off-site locations to these data results. The fourth section discusses and evaluates the results from other sampling programs (soil and direct radiation) potentially related to SRS air releases.

On-site air emission sources for radioactive contaminants

Since construction of SRS began in 1951, an on-site surveillance program has been in place to monitor the impact of site releases of radioactive materials on the environment (CDC 2001; SRNS 2009; WSRC 1994a). Since operations began in 1952, SRS management has kept a comprehensive inventory of radioactive atmospheric releases resulting from facilities and other on-site sources (WSRC 1993, 1998a). Specifically during the time period for this PHA (1993–2010), SRS management has monitored on-site airborne releases from facilities that potentially emit radionuclides during routine and non-routine (e.g., equipment malfunction) operations using a combination of sample extraction and analysis, direct measurements, or calculating methods using process knowledge and existing analytical data (SRNS 2011a; WSRC 1994a, 2003). On-site radiological monitoring occurs at facilities' points of discharge (stacks or vents) at varying time periods depending on the facility (e.g., continuously, weekly, quarterly, annual). Some of these point sources have control devices (e.g., HEPA, sand and fiberglass filters with efficiencies ranging from 99% to greater than 99.9%) and some do not. SRS also includes in their estimations non-point sources such as seepage basins, burial grounds, open pits, etc. Radionuclide releases from these sources are not monitored, but estimates of these releases are calculated annually using USEPA's recommended methods from 40 CFR 61, Subpart H (SRNS 2009). SRS reports concentrations of on-site atmospheric radionuclide releases resulting from routine and non-routine operations from the following: 1) diffuse and fugitive sources;[7] 2) reactors; 3) separation, waste management, and tritium facilities; and 4) the Savannah River National Laboratory (SRNL) (SRNS 2011a; USDOE 2005b; WSRC 2002b). Prior to 1993, the majority of airborne radionuclide releases from SRS came from the five reactors (C, K, L, P, and R), the reprocessing

[7] SRS defines a "diffuse source" as an area source such as a disposal area; a "fugitive source" is defined as an undesignated localized source (e.g., a building that is naturally ventilated). These releases are not monitored at the source, but SRS management estimates the radionuclide concentrations emitted annually via these sources. Stations are also in place to monitor any unanticipated large fugitive and diffuse releases (SRNS 2011a).

area (F-Area and H-Area), and the tritium production area (CDC 2001). In 1993, the largest releases were attributed to the separation, tritium, heavy water (D-Area) and reactor facilities. Since 1993 most of the releases have been from the separation facilities and diffuse/fugitive sources (WSRC 1994a, 1995, 2001, 2006; SRNS 2009, 2010, 2011a).

Operations at SRS have resulted in the release of alpha-, beta-, and gamma-emitting radioactive materials (see text box for definitions) in both particulate and gas form (SRNS 2011a; WSRC 1994a). According to Phase III of the CDC's Dose Reconstruction, the key radionuclides released to air from SRS operations prior to 1993 included americium-241, argon-41, carbon-14, cesium-137, hydrogen-3 (tritium), iodine-129, iodine-131, plutonium-238, plutonium-239/240, ruthenium-103, ruthenium-106, strontium-89/90, and uranium (CDC 2005).[8] Based on monitoring performed from 1993 through 2010, radionuclides detected in ambient air on the site include radionuclides that are both naturally-occurring (e.g., radon) and manmade (e.g., tritium). Only a small number of these radionuclides can still be detected offsite. Since 1993, the predominant radionuclide released to air from SRS has been tritium. Most of the tritium releases have been in the form of tritium oxide. The total atmospheric tritium releases gradually decreased from approximately 200,000 curies[9] in 1993 to below 50,000 curies in 2000 (Whitney 2012; WSRC 1994a, 2001). However, tritium releases have remained relatively constant from 2000 through 2010 (generally between 30,000 and 40,000 curies per year with a maximum of 61,300 curies in one year) (Figure 7). Therefore, it is predicted that, in the future, tritium will continue to be a critical radionuclide released from the site as long as the Tritium Facility missions continue to remain constant (SRNL 2011b). Other radionuclides discussed in the

Alpha particle: A +2-charged particle with two neutrons and two protons emitted from some radionuclides during radioactive decay. It releases more energy than beta or gamma radiation, depositing that energy rapidly as it goes through matter. However, it cannot penetrate the outer dead layer of human skin. Uranium and plutonium are examples of alpha emitters.

Beta particle: A negatively-charged particle emitted from some radionuclides during radioactive decay. Most beta particles are stopped less quickly in matter than an alpha particle but more quickly than gamma radiation. Tritium and strontium-90 are examples of beta-emitting radionuclides, but each travels different distances and deposit energy very differently as they interact with matter. Beta particles from tritium are weak, can penetrate only about 6.0 mm of air, and are incapable of passing through the dead layer of human skin. Beta particles from strontium-90 have much more energy and can penetrate the dead layer of human skin.

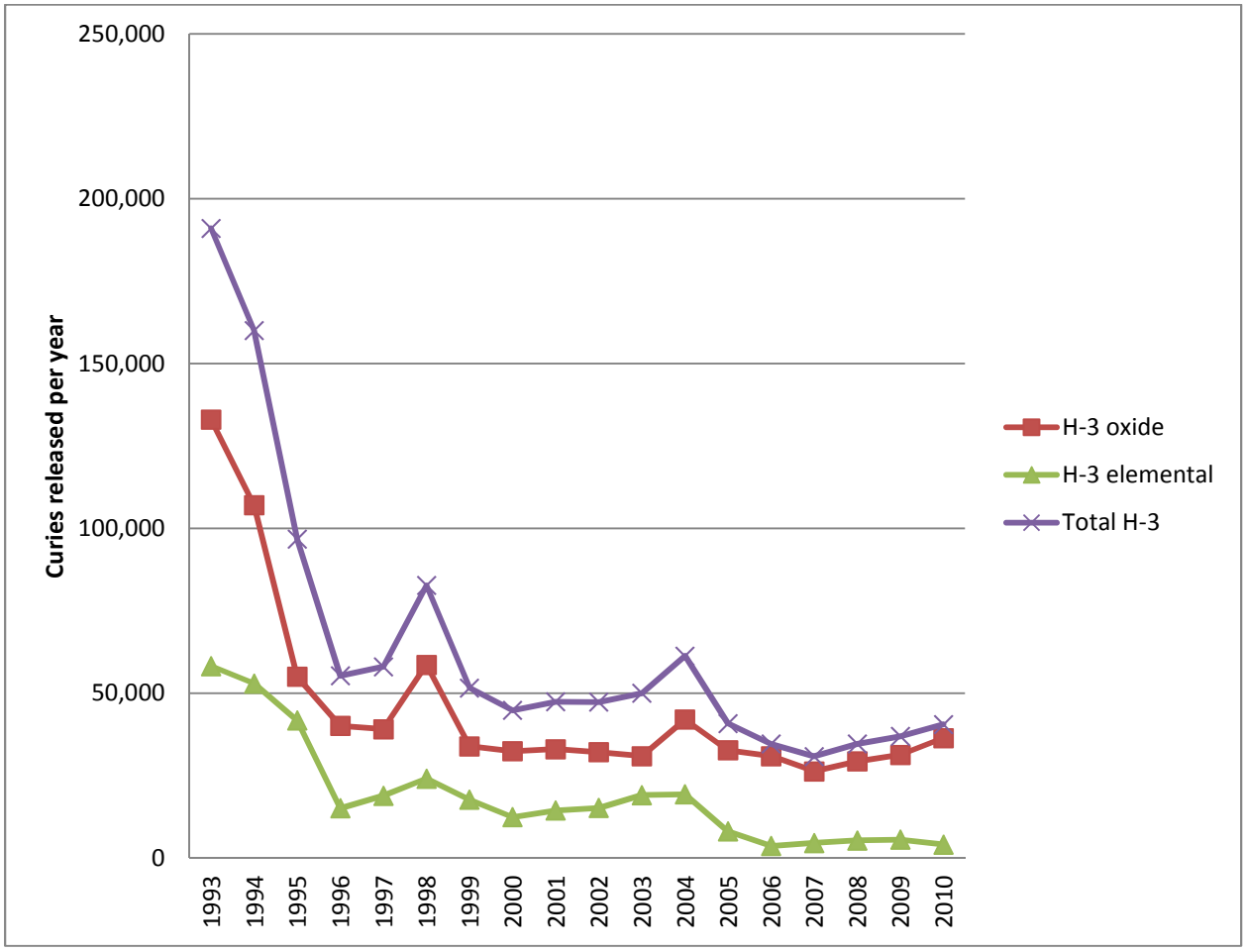
Gamma rays: Short wavelength electromagnetic radiation emitted during radioactive decay. They have a wide range of energies depending on the decaying atoms' characteristics. They can be hazardous from outside the body because they penetrate living tissue. However, when ingested or inhaled, they deposit less energy per gram of tissue and are less hazardous internally than alpha- or beta-emitting radionuclides. However, they often accompany an alpha or beta decay (i.e., neptunium-237 [alpha], molybdenum-99 [beta]) (USEPA 2009c; Schleien 1992).

[8] Based on an exposure pathway evaluation of radionuclides most likely to have traveled off site via air, only releases of iodine-129, iodine-131, tritium, argon-41, plutonium-239/240, and uranium required detailed analysis during the Dose Reconstruction (CDC 2005).

[9] One curie (Ci) is equal to 3.7×10^{10} disintegrations per second; one curie is equal to 3.7×10^{10} becquerels (Bq)

following sections have also been released and their potential contribution to an off-site exposure will be evaluated as well.

Figure 7. Tritium (H-3) releases from 1993 through 2010



(Source: SRS NESHAP reports submitted to USEPA)

Air modeling by SRS to satisfy the requirements of USDOE Order 5400.5 and USEPA 40 CFR 61, Subpart H

In accordance with USDOE Order 5400.5 and the Clean Air Act, as amended, SRS uses an EPA-approved model (CAP-88) prescribed in 40 CFR 61, Subpart H for dose evaluations but also uses other models for USDOE purposes using more site-specific information and contemporary dosimetry. SRS used the site-specific air model MAXIGASP until 1999 and then began using the site-specific air model MAXDOSE-SR for estimating chronic exposure to an off-site *maximally exposed individual* (MEI) from routine releases. The MEI is the person with the highest exposure in a given population. SRS used the air model POPGASP to estimate the collective population

dose until 2000 and then began using POPDOSE-SR[10]. The *collective population dose* is the amount of radiation received by a group of people measured in person-rem or person-sievert. For example, if 25 million people smoke cigarettes and each person receives an average exposure of 2 rem (0.02 sievert), the collective population dose would be 50 million person-rem or 0.5 million person-sievert. SRS reports the results from CAP-88 modeling as well as SRS modeling in their annual environmental reports.

The models are complex and use a variety of information for their calculations. Environmental release data obtained from monitored airborne release points in conjunction with calculated release estimates from unmonitored release points and unmonitored diffuse and fugitive sources are used to quantify the amount of radioactive materials released to the environment. For NESHAP reporting (CAP-88), all sources are modeled as if co-located at the same location in the center of the site (H-Area). USDOE-SR models calculate the maximally exposed individual (MEI) doses from the A-Area, H-Area, K-Area (from a combined C-, K-, and L-Area), and from the Center of the Site for all other release sources. The computer models use this information along with other information such as distances to offsite locations, release heights, meteorological data, deposition rates on ground surfaces, concentration factors in food products, and intakes rates by persons breathing air or consuming food products to estimate offsite concentrations in air in 16 sectors around the site and subsequent potential doses to members of the public. Variations in the results from these models are usually due to the way the model uses the information. For instance, Simpkins and Hamby compared annual average air concentrations of tritium calculated by the computer models CAP88, MAXIGASP, and AXAIRQ with measured average tritium concentrations taken over a 10 year period (1985 to 1994). The modeled concentrations were higher than the measured due to conservatism but were acceptable (ratios were less than two). The researchers concluded that the modeled result differences were primarily due to different wind speed averages used within each model (Simpkins and Hamby 1997). More recently USDOE-SR has been evaluating measured concentrations of tritium with the modeled results in their annual environmental reports.

ATSDR reviewed the 1993 through 2010 NESHAP reports submitted to USEPA. The estimated total effective dose equivalents from air releases include doses from inhalation, ingestion, and external exposure. The dose calculations use annual average concentrations for all released radionuclides. The 1993 through 2010 estimated total site effective dose equivalents from all air release sources were much less than 10 mrem (0.1 mSv) per year, as required by 40 CFR 61, Subpart H (Table 5). Offsite doses were estimated to be mostly from ingestion of food products contaminated with tritium (hydrogen-3).

ATSDR compared USDOE-SR modeling (MAXIGASP and MAXDOSE-SR) results for the maximally exposed individual doses to CAP-88 results. USDOE-SR models estimate a larger percentage of the total dose results from inhalation, especially when non-volatile beta and/or alpha emitters were released in that year (see Table 5).

[10] MAXIGASP and POPGASP used dose conversion factors and risk estimates from the International Commission on Radiological Protection (ICRP) Publication 30. MAXDOSE-SR and POPDOSE-SR use dose conversion factors and risk estimates from ICRP Publication 60.

USDOE-SR models assume 50 percent equilibrium between tritium in air moisture and tritium in food moisture. CAP-88 assumes 100 percent equilibrium. Because tritium dominates the dose calculated by CAP-88 (mainly from ingestion of food products), other radionuclides are less important on a percentage-of-dose basis. ATSDR compared CAP-88 results to MAXIGASP and MAXDOSE-SR results. The ratio of CAP-88 results to MAXIGASP results (1993 through 1998) averaged 1.36 (CAP-88 results slightly higher). The ratio of the CAP-88 results to the MAXDOSE-SR results (1999 through 2010) averaged 0.90 (MAXDOSE-SR results slightly higher). However, all results from MAXDOSE-SR and MAXIGASP have been much less than 10 mrem per year (0.1 mSv/yr).

Table 5. Maximally exposed individual modeled doses (1993 – 2010)

Year	Annual maximally exposed individual (MEI) doses in mrem/yr								CAP-88 compared to MAXIGASP/ MAXDOSE-SR[6]
	CAP-88 (NESHAP)				MAXIGASP/MAXDOSE-SR[6]				
	Total Dose [1,2,3,4,5] (percentage of dose from H-3)		Inhaled Dose (percentage of total dose)		Total Dose [1,2,3,4,5] (percentage of dose from H-3)		Inhaled Dose (percentage of total dose)		
1993	0.182	(98.4%)	0.0534	(29.3%)	0.108	(89%)	0.0511	(47.4%)	1.6852
1994	0.148	(98%)	0.0438	(29.6%)	0.0883	(88%)	0.0421	(47.7%)	1.6761
1995	0.0774	(95.9%)	0.0227	(29.3%)	0.0556	(77.5%)	0.0245	(44.1%)	1.3921
1996	0.0591	(91.7%)	0.0171	(29%)	0.0535	(68%)	0.0206	(38.5%)	1.1047
1997	0.0535	(93.8%)	0.0152	(28.4%)	0.0463	(71.3%)	0.0194	(41.9%)	1.1555
1998	0.0800	(94.3%)	0.0242	(30.3%)	0.0685	(66.8%)	0.0292	(42.6%)	1.1679
1999	0.0512	(86.5%)	0.0169	(33%)	0.0572	(27.8%)	0.0276	(48.3%)	0.8951
2000	0.0483	(87.6%)	0.0160	(33.1%)	0.0451	(49.5%)	0.0204	(45.7%)	1.0710
2001	0.0515	(85.4%)	0.0169	(33.6%)	0.0541	(51.2%)	0.023	(42.6%)	0.9519
2002	0.0449	(84.8%)	0.0148	(33%)	0.0564	(49.7%)	0.0231	(41%)	0.7961
2003	0.0473	(80.4%)	0.0156	(33%)	0.0742	(38.8%)	0.0249	(33.5%)	0.6375
2004	0.0560	(93.5%)	0.0168	(30%)	0.0561	(73.9%)	0.0243	(43.3%)	0.9982
2005	0.0459	(90.1%)	0.0144	(31.4%)	0.0507	(65.8%)	0.0217	(42.7%)	0.9053
2006	0.0583	(67.2%)	0.0241	(41.4%)	0.1100	(21.5%)	0.0457	(41.6%)	0.5300
2007	0.0377	(93.4%)	0.0108	(28.6%)	0.0421	(68.7%)	0.0173	(41.1%)	0.8955
2008	0.0406	(97%)	0.0118	(29%)	0.0387	(82%)	0.0167	(43.2%)	1.0491
2009	0.0437	(95.9%)	0.0122	(28%)	0.0419	(80.3%)	0.0172	(41.1%)	1.0430
2010	0.0567	(87.7%)	0.0192	(34%)	0.0535	(81.7%)	0.0251	(47%)	1.0598

Notes:
[1] Pathways evaluated in models – inhalation, ingestion, and external exposures
[2] All estimates are significantly below the NESHAP requirement of 10 mrem/yr (0.10 mSv/yr)
[3] CAP-88 results in higher H-3 (tritium) doses due to H-3 dose estimate from food consumption. CAP-88 assumes 100% equilibrium between H-3 in air and food moisture. MAXIGASP and MAXDOSE-SR assume 50%equilibrium as recommended by Hamby and Bauer (1994) and USNRC. Because H-3 dominates the dose using CAP-88, other radionuclides (non-volatile beta and alpha emitters) are less important on a percentage-of dose basis.
[4] CAP-88 uses atmospheric information from a central location on the site using H-Area meteorology. USDOE-SR models estimate MEI doses from A-Area, H-Area, K-Area (from combined C-, K-, and L-Areas), and the Center of the Site for all other releases sources.
[5] All doses are calculated for adults.
[6] USDOE-SR changed from MAXIGASP to MAXDOSE-SR. Average ratio of CAP-88 to MAXIGASP results from 1993 through 1998 is 1.3636. Average ratio of CAP-88 to MAXDOSE-SR results from 1999 through 2010 is 0.9027.
NESHAP = standard from National Emissions Standards for Hazardous Air Pollutants (40 CFR 61, Subpart H)
mrem/yr = millirem per year; mSv/yr = millisievert per year (1 mrem/yr = 0.01 mSv/yr)

Table 5. Maximally exposed individual modeled doses (1993 – 2010)

Year	Annual maximally exposed individual (MEI) doses in mrem/yr				CAP-88 compared to MAXIGASP/ MAXDOSE-SR[6]
	CAP-88 (NESHAP)		MAXIGASP/MAXDOSE-SR[6]		
	Total Dose [1,2,3,4,5] (percentage of dose from H-3)	Inhaled Dose (percentage of total dose)	Total Dose [1,2,3,4,5] (percentage of dose from H-3)	Inhaled Dose (percentage of total dose)	

H-3 = hydrogen-3 (also referred to as tritium)
% = percent
USNRC = U.S. Nuclear Regulatory Commission
USDOE-SR = U.S. Department of Energy – Savannah River

In 2007 SCDHEC-ESOP merged two reports (Dose Calculation Project and Critical Pathway Project) into one report (the Critical Pathway Dose Report) covering estimated exposures to the public from 1999 through 2007, based on monitoring results. Since 2007, this report has been included in their annual environmental reports. The reports cover two primary exposure pathways (atmospheric and liquid) subdivided into three exposure routes (inhalation, ingestion, and direct exposures by media).The information is presented such that someone can estimate their own potential exposures based on their lifestyles and activities. For the atmospheric pathway, all MEI doses were less than 10 mrem and less than the site's MEI inhalation dose estimate, mainly due to some modeled radionuclide concentrations being non-detectable offsite.

Off-site monitoring of radioactive materials in ambient air and rainwater

This section describes the off-site radiological air surveillance programs conducted by USDOE-SR, USDOE contractors, GDNR-EPD, and SCDHEC-ESOP and summarizes the off-site radiological air monitoring and rainwater data available for this evaluation. As shown in Table 4, ATSDR was able to obtain radiological air monitoring measurements data for 1993 through 2010 from GDNR-EPD and USDOE-SR, and for 1997 through 2010 from SCDHEC-ESOP. Table 6 summarizes the information available for ATSDR's evaluation and the variations in radiological parameters monitored. In general, gross alpha and gross beta were consistently reported by these agencies. Off-site atmospheric surveillance station locations for GDNR-EPD, SCDHEC-ESOP, and USDOE-SR are presented in Figure 8, Figure 9, and Figure 10, respectively.

USDOE-SR has ambient air surveillance stations at various locations throughout the site (e.g., operating areas), at the site boundary, and at specified distances from the site. Although USDOE-SR has reduced the number of air monitoring stations since 1993, the current on-site and off-site environmental air surveillance stations are placed in order to detect large, unexpected releases and to monitor routinely for tritium and radioactive particulates (WSRC 1993; SRNS 2009, 2011a). The site boundary stations are approximately located in every 45-degree sector around the site with additional stations located in the direction of major population centers. Stations are also located in population centers 25 and 100 miles from the site. Each station has a glass fiber filter paper for airborne particulates, a charcoal canister for sampling iodine and other gamma-emitting radionuclides, silica gel for sampling tritiated water vapor, a rainwater collection system used to analyze for tritium in rainwater, and a rain ion resin column for sampling gamma-

emitting radionuclides, gross alpha and beta measurements, total strontium, and relevant actinides[11] (Table 6).

GDNR-EPD had nine air stations in 1993 and eleven in 2002; however, due to budget constraints, GDNR-EPD has only maintained four stations (#11, #20, #35, and #49 in Figure 8) since April 2009. Each station has a glass fiber filter paper, a charcoal canister, and a rainwater collection system for analyzing tritium in rainwater. Until 2004, GDNR-EPD also used silica gel for sampling tritiated water vapor (Table 6).

SCDHEC-ESOP began their air surveillance program in 1997 with four air surveillance stations. As of 2010, eight stations were being maintained (five within two miles of the site boundary, two within 25 miles of the site, and one at the center of the site). Each station has glass fiber filters used to collect total airborne particulates, a rainwater collection system for analyzing tritium in rainwater, and silica gel for sampling tritiated water vapor (Table 6).

Table 6. GDNR-EPD, SCDHEC-ESOP, and USDOE-SR offsite radiological air and rainwater monitoring measurements reported during 1993–2010

Data Source	Number and Location of Off-site Air Monitors	Type of Samples Collected	Reported Radiological Parameters	Time Period of Monitoring	Reference
GDNR-EPD	1993: 9 2010: 4	Glass fiber particulate filters	Alpha radiation	1993–2008, 2010	Blackman 2003; GDNR 2004, 2005, 2009, 2012
			Beta radiation	1993–2008, 2010	
			Cesium-137	1993–2010	
			Iodine-129	1997–1998, 2000, 2004–2008	
			Lead-210	2004–2008	
			Plutonium-238	1994–2004	
			Plutonium-239	1994–2004	
			Strontium-89	1995–2004	
			Strontium-90	1994–2004	
		Activated charcoal cartridge	Iodine-131	1993–2010	
			Xenon-133	1997, 1999	
		Silica gel distillate	Tritium (hydrogen-3)	1996–2004	
		Rainwater collection pans used to obtain rainwater samples for analyses	Gross alpha	1993—2008	
			Gross beta	1993—2008	
			Cesium-137	1993—2004	
			Plutonium-238	1994—2004	
			Plutonium-239	1994—2004	
			Strontium-89	1994—2004	
			Strontium-90	1994—2004	
			Tritium (hydrogen-3)	1993—2010	
SCDHEC-	1997: 4	Glass fiber	Americium-243	2001	SCDHEC 1999a,

[11] The term "actinidess" refers to 15 elements with atomic numbers 89 through 103: $_{89}$Ac (Actinium), $_{90}$Th (Thorium), $_{91}$Pa(Protactinium), $_{92}$U (Uranium), $_{93}$Np (Neptunium), $_{94}$Pu (Plutonium), $_{95}$Am (Americium), $_{96}$Cm (Curium), $_{97}$Bk (Berkelium), $_{98}$Cf (Californium), $_{99}$Es (Einsteinium), $_{100}$Fm (Fermium), $_{101}$Md (Mendelevium), $_{102}$No (Nobelium), $_{103}$Lr (Lawrencium).

Table 6. GDNR-EPD, SCDHEC-ESOP, and USDOE-SR offsite radiological air and rainwater monitoring measurements reported during 1993–2010

Data Source	Number and Location of Off-site Air Monitors	Type of Samples Collected	Reported Radiological Parameters	Time Period of Monitoring	Reference
ESOP	▪ 3 on or within 2 miles of SRS perimeter ▪ 1 within 25 miles of site 2010: 8 ▪ 5 on or within 2 miles of SRS perimeter ▪ 2 within 25 miles of site ▪ 1 at center of site	particulate filters	Cesium-134	1998	2004a, 2005a, 2005b, 2006a, 2006b, 2007a, 2008a, 2009b, 2010a, 2011a
			Cesium-137	1998	
			Cobalt-60	1998	
			Gross alpha	1998–2010	
			Gross beta	1998–2010	
			Iodine-129	1999	
			Plutonium-238	1998–2001, 2006	
			Plutonium-239	1998, 2006	
			Plutonium-239/240	1999–2001	
			Strontium, total	1998	
			Strontium-89/90	1999–2000, 2006	
			Uranium-234	1999–2001	
			Uranium-235	1999–2001	
			Uranium-238	1999–2001	
		Silica gel distillates	Tritium (hydrogen-3)	1997–2010	
		Rainwater collection pans used to obtain rainwater samples for analyses	Tritium (hydrogen-3)	1997—2010	
USDOE-SR	1993: 30 ▪ 14 perimeter ▪ 12 within 25 miles of site ▪ 4 within 100 miles of site ▪ 3 stations for rainwater ion-exchange collection[a] 2010: 15 • 11 onsite or along site perimeter, 3 within 25 miles of site, 1 within 100 miles of site ▪ 7 stations for rainwater ion-exchange collection[a]	Glass fiber particulate filters	Americium-241	1999–2010	SRNS 2009, 2010, 2011a; USDOE 2005c; WSRC 1994a,1994b,1995, 1996b, 1997, 1998a, 1998b, 1999, 2000, 2002b, 2003, 2004, 2005, 2006, 2007, 2008
			Cesium-137	1994–2010	
			Cobalt-60	1993, 1996–2010	
			Curium-244	1999–2010	
			Gross alpha	1993–1996, 1998–2010	
			Gross beta	1993–1996, 1998–2010	
			Manganese-54	1993	
			Plutonium-238	1993–1998, 2000–2010	
			Plutonium-239[b]	1993–1996, 1998–2010	
			Strontium-89/90[c]	1993–2010	
			Uranium-234	1999–2010	
			Uranium-235	1999–2010	
			Uranium-238	1999–2010	
			Zinc-65	2010	
		Activated charcoal canisters	Cesium-137	1993–1996, 1998–2010	
			Cobalt-60	1996, 1998–2010	
			Iodine-129	2004–2010	
			Neptunium-237	1995	
			Niobium-95	1996	
		Silica gel distillate	Tritium (hydrogen-3)	1993–2010	
		Rainwater collection pans	Americium-241	1999—2010	
			Cesium-137	1993, 1995—2010	

Table 6. GDNR-EPD, SCDHEC-ESOP, and USDOE-SR offsite radiological air and rainwater monitoring measurements reported during 1993–2010

Data Source	Number and Location of Off-site Air Monitors	Type of Samples Collected	Reported Radiological Parameters	Time Period of Monitoring	Reference
		used at all stations to obtain rainwater samples for analyses[a] Ion-exchange resin column samples collected at limited locations[a].	Cobalt-60	1996–2010	
			Curium-244	1999–2010	
			Gross alpha	1993–2010	
			Gross beta	1993–2010	
			Plutonium-238	1993–2010	
			Plutonium-239	1993–2010	
			Strontium-89/90	1993–2010	
			Tritium (hydrogen-3)	1993–2010	
			Uranium-234	1999–2010	
			Uranium-235	1999–2010	
			Uranium-238	1999–2010	

Notes:
GDNR-EPD: Georgia Department of Natural Resource's Environmental Protection Division
SCDHEC-ESOP: South Carolina Department of Health and Environmental Control's Environmental Surveillance and Oversight Program
USDOE-SR: U.S. Department of Energy-Savannah River
[a]USDOE-SR collects rainwater for analysis of tritium. Ion exchange resin columns are used to analyze for all other listed radionuclides in rain. In 2010 ion-exchange resin columns were located at D-Area, Darkhorse, Green Pond, Patterson Mill, Highway 301, Savannah, GA, and Burial Ground North (on-site)
[b]USDOE-SR summed the values for unidentified alpha-emitting radionuclides in airborne releases with the values reported for plutonium-239 (WSRC 1998a).
[c]USDOE-SR summed the values for unidentified beta-emitting radionuclides in airborne releases with the values reported for strontium-89/90 (WSRC 1998a).

These agencies use glass fiber particulate filters to collect total suspended particulates (TSP) in air and then screen the particulates to determine the gross alpha and beta-emitting activities. SCDHEC-ESOP has screened these filters *weekly* for these parameters. In 1993 USDOE-SR sampled and analyzed the particulate filters *weekly* for gross alpha and gross beta activities, as well as, gamma emitting radionuclides. By 2010, USDOE-SR sampled and analyzed particulate filters *every 2 weeks* (26 samples per year) for gross alpha, gross beta, and gamma emitting radionuclides. Once a year they would analyze composites for other radionuclides, such as strontium-89/90, the uranium isotopes, plutonium-238, plutonium-239, americium-241, and curium-244, In 1993 GDNR-EPD sampled and analyzed their particulate filters for gross alpha and beta activities *every 2 weeks*, but by 2010, GDNR-EPD analyzed them *monthly*[12] (GDNR 2012; SCDHEC 2011a; SRNS 2011a).

In addition, USDOE-SR and GDNR-EPD use charcoal cartridges to measure for certain radionuclides. Specifically, GDNR-EPD monitored for iodine-131 *monthly* through 2010; although, monitoring results were not reported for August to November 2008 or for January to July 2009 (GDNR 2009a, 2012). USDOE-SR uses charcoal cartridges to monitor for

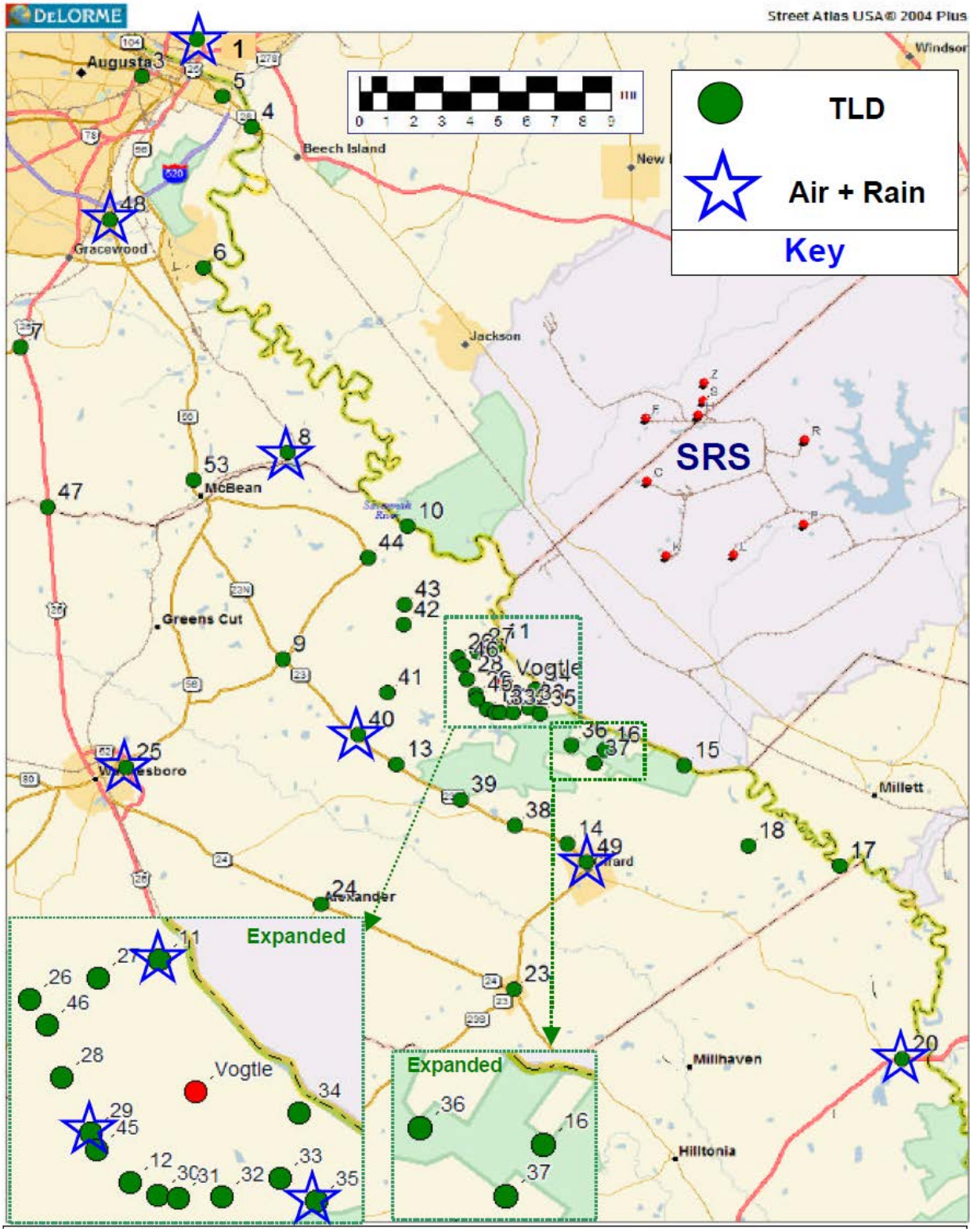
[12] GDNR-EPD did not report alpha and gross beta in 2009, and reporting in 2010 began in June.

radionuclides listed in Table 6. Beginning in 1999, USDOE-SR started analyzing charcoal cartridge samples from one biweekly collection period to be representative for the year at each location (i.e., for 2010, these were analyzed in March (SRNS 2011a)). Continuous monitoring and sample collections were performed but the samples were only analyzed if any abnormal airborne effluent release was observed onsite.

All three agencies have also used silica gel for sampling tritium in water vapor. In 2000, SCDHEC-ESOP analyzed the silica gel distillate every two weeks; however, by 2010, SCDHEC-ESOP analyzed the distillate monthly (SCDHEC 2000, 2011a). At the beginning of 1993, USDOE-SR performed their analyses of the silica gel distillate weekly but in September 1993 switched to every two weeks (WSRC 1994a; SRNS 2011a). GDNR-EPD used silica gel to monitor tritium in water vapor every two weeks until 2004, when the agency discontinued using this sampling (GDNR 2005).

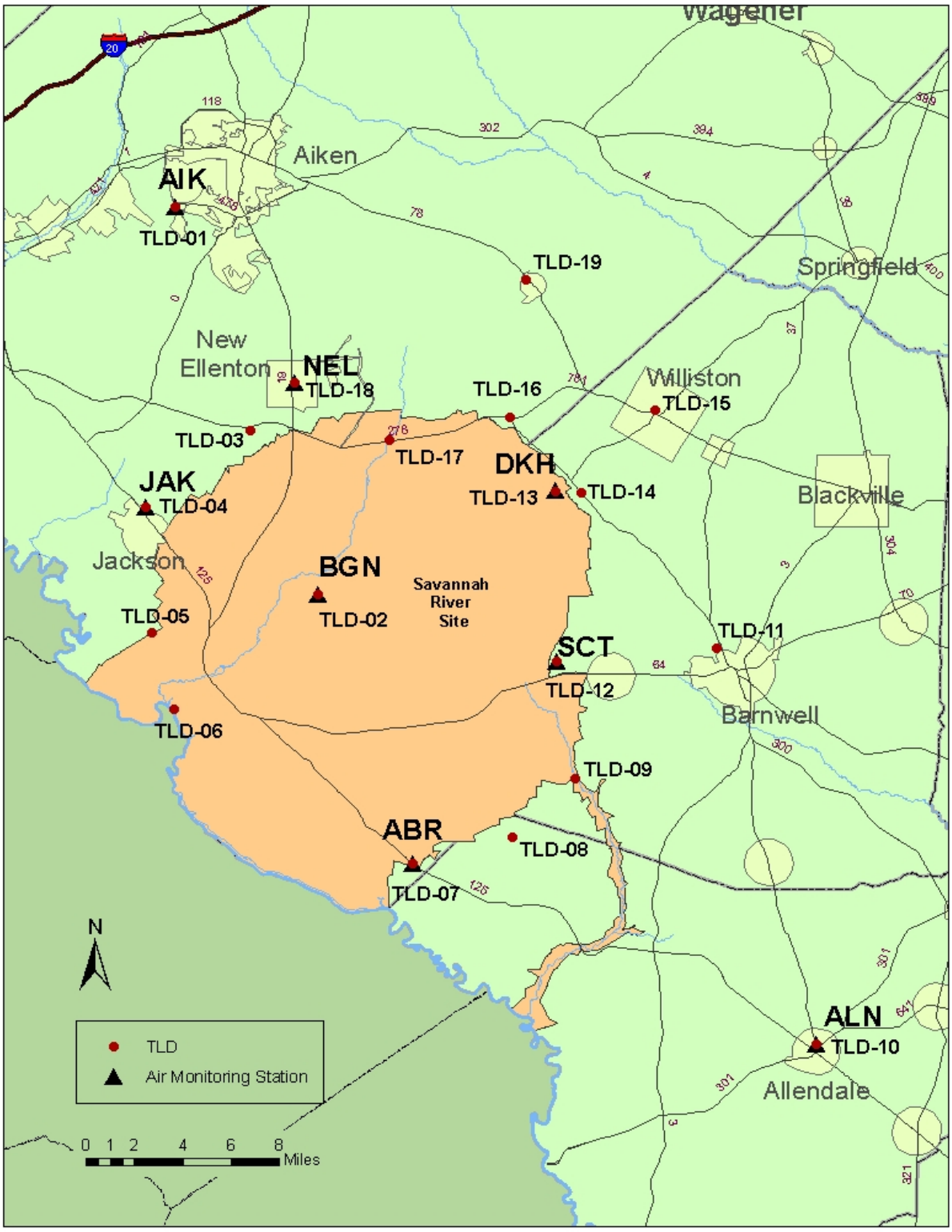
All three agencies monitor radionuclide concentrations in rainwater at their own sampling stations. The rainwater is collected to determine the wet deposition of airborne tritium. When precipitation is present, SCDHEC-ESOP analyzes rain samples monthly. USDOE-SR and GDNR-EPD also analyze the samples approximately monthly. USDOE-SR also runs rainwater through ion-exchange units at limited locations to analyze for other radionuclides.

Figure 8. Georgia Department of Natural Resources/Environmental Protection Division's Radiological Air, TLD, Soil, and Rain Monitoring Locations near SRS in 2002 (Note: By 2010, only #11, #20, #35, and #49 used for air and rainwater sampling; no soil)



Source: GDNR 2004

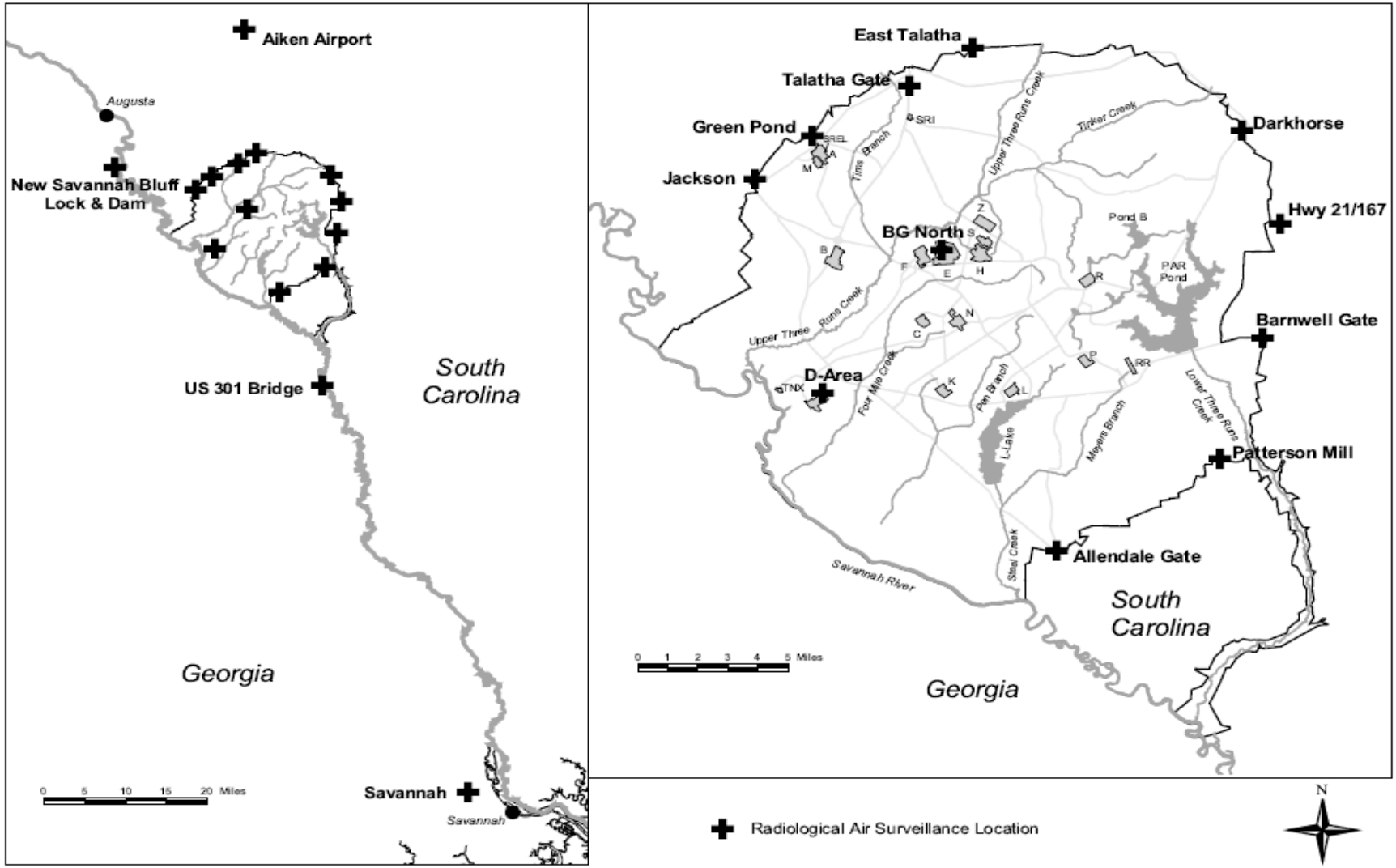
988 **Figure 9. South Carolina Department of Health and Environmental Control/Environmental Surveillance and Oversight Program's Radiological Air, TLD, and Rain Monitoring Stations in 2010**



990

Source: SCDHEC 2011c

992 **Figure 10. United States Department of Energy-Savannah River's Radiological Atmospheric Monitoring Locations in 2010**



994 Source: SRNS 2011a
Note: SRS collects rainwater samples and monitors air contaminant concentrations at these monitoring locations

Evaluation of radioactive contaminants in off-site air

ATSDR reviewed all air monitoring results obtained from USDOE-SR, SCDHEC-ESOP, and GDNR-EPD. Initially, ATSDR considered any radioactive contaminant detected in air at the site boundary or off the site as a potential contaminant of concern and evaluated the maximum concentrations at all monitoring locations. These maximum concentrations represent the highest concentration of each radionuclide detected between 1993 and 2010 during any sampling event (e.g., weekly, quarterly) by GDNR-EPD, SCDHEC-ESOP, and USDOE-SR. As seen in Table 7, there is not a predominant location where maximum concentrations of all radionuclides were reported in any one year. Therefore, ATSDR reviewed the maximum airborne concentrations reported for each location for each year.

Table 7. Maximum radionuclide concentrations detected during any sampling event in air off-site of Savannah River Site from 1993 to 2010

Substance	Year	Maximum Concentration Detected in pCi/m3 (in Bq/m3)	Monitoring Station	Location in Relation to SRS	Data Source
Americium-241	2003	4.73E-05 (1.75E-06)	Green Pond	Site perimeter	USDOE-SR
Americium-243	2001	2.53E-05 (9.87E-07)	Snelling, SC (SCT)	At or near SRS boundary	SCDHEC
Cesium-134	1998	3.54E+00 (1.31E-01)	Williston, SC (WIL)	At or near SRS boundary	SCDHEC
Cesium-137	1998	2.77E+00 (1.03E-01)	Williston, SC (WIL)	At or near SRS boundary	SCDHEC
Cobalt-60	1998	3.48E+00 (1.29E-01)	Snelling, SC (SCT)	At or near SRS boundary	SCDHEC
Curium-244	2003	3.63E-05 (1.34E-06)	Aiken Airport	Within 25-mile radius	USDOE-SR
Iodine-129	2007	1.24E-03 (4.59E-05)	Allendale Gate	Site perimeter	USDOE-SR
Iodine-131	1993	1.00E-03 (3.70E-05)	11- Hancock Landing Road at Savannah River	In GA, north of GPC's VEGP	GDNR
Lead-210	2006	2.00E-02 (7.41E-04)	35- GPC's VEGP Simulator Building	In GA, south of GPC's VEGP	GDNR
Manganese-54	1993	1.11E-02 (4.11E-04)	Barnwell Gate	Site perimeter	USDOE-SR
Neptunium-237	1995	3.20E-02 (1.19E-03)	Talatha Gate	Site perimeter	USDOE-SR
Plutonium-238	2008	7.35E-05 (2.72E-06)	Patterson Mill Road	Site perimeter	USDOE-SR
Plutonium-239/240	2008	4.62E-05 (1.71E-06)	Patterson Mill Road	Site perimeter	USDOE-SR
Strontium-89/90	1999	3.73E-02 (1.38E-03)	West Jackson	Site perimeter	USDOE-SR
Tritium (hydrogen-3)	2004	1.45E+03 (5.37E+01)	Jackson, SC (JAK)	Perimeter (within 2 miles)	SCDHEC
Uranium-234	2001	1.05E-04 (3.89E-06)	Allendale Gate	Site perimeter	USDOE-SR
Uranium-235	2002	3.99E-05 (1.48E-06)	Aiken Airport	Within 25-mile radius	USDOE-SR
Uranium-238	2005	1.11E-04 (4.11E-06)	Talatha Gate	Site perimeter	USDOE-SR
Xenon-133	1997	3.60E-02 (1.35E-03)	25- GPC's Maintenance Office	In Waynesboro, GA (within 25-mile radius)	GDNR

Table 7. Maximum radionuclide concentrations detected during any sampling event in air off-site of Savannah River Site from 1993 to 2010

Substance	Year	Maximum Concentration Detected in pCi/m3 (in Bq/m3)	Monitoring Station	Location in Relation to SRS	Data Source

Notes:
GPC's VEGP: Georgia Power Company's Vogtle Electric Generating Plant
GDNR: Georgia Department of Natural Resource
SCDHEC: South Carolina Department of Health and Environmental Control
USDOE-SR: U.S. Department of Energy-Savannah River
pCi/m^3=picocuries per cubic meter; Bq/m^3 = becquerels per cubic meter

Only USDOE-SR supplied results for *americium-241* and *curium-244* for the years 1999 through 2010. ATSDR will use this information to evaluate potential maximum exposures at the reported locations for these years.

Only SCDHEC-ESOP supplied results for *americium-243 (Am-243)*, which was measurable on particulate filters at all five sampling locations in 2001. The maximum result (2.53E-11 $\mu Ci/m^3$) was detected at the Snelling, SC location (near Barnwell Gate). The results could have been misidentified since other isotopes emit radiation with similar energies (i.e., uranium 232). However, potential dose estimates would be similar. ATSDR will use these results.

Only SCDHEC-ESOP supplied results for *cesium-134 (Cs-134)*, which was reported in 1998 for six locations. Only one location had a result above the minimum detectable activity which was not significant. Therefore, ATSDR will *not* use these results for Cs-134.

Only GDNR-EPD supplied results for *lead-210* (2004 through 2008). Lead-210 is a decay product of naturally-occurring radon-222. All results are very similar and appear to represent natural background. ATSDR will *not* use these results to evaluate releases from SRS.

Manganese-54 was reported to ATSDR in the electronic data received from USDOE-SR for 1993 and in the *Savannah River Site Environmental Report for 1993*. Three detectable concentrations were reported at or near the site boundary. USDOE-SR investigated these results in 1993. (Cobalt-60 was also detected on the filters but could not be explained by any site releases.) The exact cause for these results is unknown (WSRC 1994a). Manganese-54 has a 312.7 day half-life and was reported only in 1993. ATSDR will use this information for 1993.

One result for *neptunium-237* (from a charcoal sample) was reported to ATSDR in the electronic data received from USDOE-SR. There was no indication that this result was not reliable; however, it was not reported in the 1995 annual report or in the 1995 NESHAP report. All reviewed source release data for 1995 did not indicate neptunium-237 was released from the site that year. USDOE-SR reviewed the 1993 through 1998 Annual Radiological Air (NESHAP) reports, their annual environmental reports, and the laboratory practices for the same period and found nothing to substantiate this result. A review of the NESHAP reports indicates that in other years neptunium-237 releases were estimated from minor unmonitored diffuse and fugitive sources with no point source emissions identified; however, it was not detected at the boundary or off the site (Gail Whitney, USDOE-SR, personal communication, June 11, 2012). ATSDR

determined that if this was a legitimate sample result, it would not have resulted in a maximum dose to an off-site individual in excess of ATSDR's comparison value. ATSDR will *not* use this result in further evaluations of airborne concentrations.

Only GDNR-EPD reported low level concentrations of *xenon-133* in 1997 and 1999. Xenon-133 is an inert gas with a 5.27 day half-life. Any detectable xenon-133 would have recently been created or released and is most likely not from SRS. Both sampling stations were in Georgia near Plant Vogtle. Therefore, these results will *not* be used to evaluate for SRS's releases.

For screening purposes, maximum concentrations reported for each sampling location for each year from 1993 through 2010 were used to determine if a hypothetical maximally exposed individual could receive in excess of 10 mrem per year from inhalation of airborne contaminants. The dose calculations were performed for six age groups but adult doses were consistently the highest. Maximum concentrations for all analyzed radionuclides from the perimeter, 25-mile radius, and Savannah monitoring locations were used. Although tritium concentrations were reported each year for each location, reporting of other radionuclide concentrations varied with more results reported in recent years. However, the majority of the inhalation doses are attributed to tritium. Other radionuclides contributed very little to the potential offsite doses. Calculated doses using USDOE-SR reported concentrations were less than 5 mrem/year (0.05 mSv/year).

The most elevated off-site tritium concentration was reported by SCDHEC-ESOP in 2004 for their Jackson air monitoring station. Using this maximum concentration (1.45E+03 pCi/m^3), the calculated inhalation dose for a hypothetical adult individual at this location is 11 mrem/year (0.11 mSv/year). However, the maximum USDOE-SR air sampling result at the Jackson perimeter location for 2004 was 38 pCi/m^3 resulting in a potential dose of less than 1 mrem/year. Neither of these hypothetical doses are at a level that would result in adverse health effects.

Table 8 shows the ranges of maximum and mean tritium concentrations reported by USDOE-SR. USDOE-SR's 1994 and 2000 annual environmental reports indicate that changes in sampling techniques in 1994 produced artificially high airborne tritium concentrations and an abrupt change in silica gel type during 2000 created high variability in the airborne tritium results for that year. A correction factor was applied starting in 2000; however, because of uncertainty in the analytical results, 1994 and 2000 results are reported separately in Table 8.

Table 8. USDOE-SR air sampling locations and tritium concentrations, 1993 through 2010

Location	Range of tritium concentrations in pCi/m^3 with year reported (not including 1994 and 2000)	Maximum result from 1994 or 2000 in pCi/m^3 (year of maximum)
Allendale Gate Perimeter	Maximum: 16.4 (2006) - 72.7 (2008) Mean: 2.79 (2007) – 12.2 (2001)	152 (2000)
Barnwell Gate Perimeter	Maximum: 16.1 (2007) – 233 (1993) Mean: 4.93 (2007) – 25.8 (1993)	233 (1994)
D-Area Perimeter	Maximum: 19.6 (2010) – 161 (1993) Mean: 7.95 (2010) – 60.3 (1993)	235 (1994)
Darkhorse @ Williston Gate Perimeter	Maximum: 17.9 (2007) – 273 (2008) Mean: 6.3 (2009) – 30.4 (1993)	635 (2000)
East Talatha Perimeter	Maximum: 16.9 (2009) – 175 (1993) Mean: 5.36 (2009) – 29.4 (1993)	300 (1994)
Green Pond Perimeter	Maximum: 12.1 (2007) – 136 (1993) Mean: 4.78 (2007) – 31.6 (1993)	225 (1994)
Highway 21/167 Perimeter	Maximum: 16.6 (2007) – 135 (1993) Mean: 5.43 (2007) – 27.4 (1993)	427 (2000)
Jackson Perimeter	Maximum: 19.9 (2006) – 186 (1993) Mean: 6.88 (2009) – 35.5 (1993)	137 (1994)
Patterson Mill Road Perimeter	Maximum: 13.3 (2010) – 78.7 (2004) Mean: 3.82 (2007) – 15.3 (2001)	225 (2000)
Talatha Gate Perimeter	Maximum: 21.8 (2009) – 164 (1993) Mean: 7.92 (2010) – 36.3 (1993)	489 (1994)
Aiken Airport (25-mile radius)	Maximum: 11.4 (2006) – 74.2 (1999) Mean: 3.32 (2006) – 12.6 (2001)	179 (2000)
Augusta Lock & Dam (25-mile radius)	Maximums: 10.2 (2009) – 160 (2008) Means: 2.56 (2010) – 14.1 (2001, 2008)	372 (2000)
Highway 301 (25-mile radius)	Maximums: 11.8 (2007,2010) – 47.6 (2008) Mean: 2.54 (2007) – 10.6 (2001)	82.6 (2000)
Savannah, Georgia (100-mile radius)	Maximum: 9.73 (2007) – 69.7 (2008) Mean: 2.51 (2007) – 10.5 (1993)	127 (2000)

Sources: SRS Annual Environmental Reports
USDOE-SR: United States Department of Energy-Savannah River; pCi/m^3 = picocurie per cubic meter

Evaluation of radioactive contaminants in off-site rainwater

As part of the air surveillance programs, GDNR-EPD, SCDHEC-ESOP and USDOE-SR independently monitor radionuclide concentrations in rainwater at their own sampling locations depicted in Figure 6, Figure 7, and Figure 8, respectively. These agencies use their monitoring results to measure the wet deposition of airborne radioactive materials potentially released from SRS. USDOE-SR runs some of the rainwater through an ion exchange column to determine the amount of certain radionuclides deposited per square meter of surface soil and uses this information to estimate plant uptake, etc. However, for this PHA, ATSDR is interested in the concentration of the radionuclides (particularly tritium oxide) in rainwater. Radioactive material intake by humans can be due to consuming rainwater collected in cisterns or from migration to wells. Therefore, to screen the rainwater results, ATSDR compared the maximum concentrations reported for each year to USEPA's Safe Drinking Water Standard in Table 9 below.

Table 9. Maximum tritium concentrations in rainwater detected off-site of SRS (1993 through 2010)

Substance[a]	Year	Maximum Concentration Detected (pCi/L)	Monitoring Station	USEPA MCL Values (pCi/L)	Data Source
Gross alpha	1996	4	Augusta Youth Development Center (#48)	15	GDNR-EPD
Gross beta	1998	33	US 301 GA/SC Welcome Center (#20)	50	GDNR-EPD
Tritium (hydrogen-3)	1993	22300	D-Area (site perimeter)	20000	USDOE-SR
	1994	7590	Talatha Gate (site perimeter)		USDOE-SR
	1995	6120	D-Area (site perimeter)		USDOE-SR
	1996	4080	D-Area (site perimeter)		USDOE-SR
	1997	3050	D-Area (site perimeter)		USDOE-SR
	1998	6070	West Jackson (site perimeter)		USDOE-SR
	1999	8030	Barnwell Gate (site perimeter)		USDOE-SR
	2000	8510	Green Pond (site perimeter)		USDOE-SR
	2001	2360	D-Area (site perimeter)		USDOE-SR
	2002	9850	D-Area (site perimeter)		USDOE-SR
	2003	6350	D-Area (site perimeter)		USDOE-SR
	2004	1910	Green Pond (site perimeter)		USDOE-SR
	2005	1530	East Talatha (site perimeter)		USDOE-SR
	2006	2570	Jackson (site perimeter)		USDOE-SR
	2007	886	D-Area (site perimeter)		USDOE-SR
	2008	9920	Augusta Lock & Dam (25 miles radius)		USDOE-SR
	2009	7760	Green Pond (site perimeter)		USDOE-SR
	2010	1680	East Talatha (site perimeter)		USDOE-SR

[a] GDNR-EPD analyzed rainwater samples from Georgia locations for cesium-137 (1993-2004), plutonium-238 (1994-2004), plutonium-239 (1994-2004), strontium-89 (1994-2004), and strontium-90 (1994-2004). All results were below the level of detection.
MCL = Maximum Contaminant Level (USEPA's Safe Drinking Water Standard); pCi/L = picocuries per liter
SRS: Savannah River Site
USDOE-SR: United States Department of Energy-Savannah River
USEPA: United States Environmental Protection Agency
GDNR-EPD: Georgia Department of Natural Resources' Environmental Protection Division

Although SCDHEC-ESOP and GDNR-EPD tritium results were included in this screening, USDOE-SR maximum tritium results exceeded those from the other agencies for all years 1993 through 2010 and are the only tritium results in Table 9. USDOE-SR results also exceed all EPA's RADNET precipitation sampling results for Barnwell, South Carolina (see Appendix C for both RadNet precipitation and SCDHEC/GDNR maximum tritium results).

The only *maximum* tritium result that exceeds USEPA's Safe Drinking Water Standard (USEPA's maximum contaminant level [MCL]) was reported by USDOE-SR for the D-Area perimeter location in 1993. However, 24 rain samples were collected from that location and analyzed in 1993, with an *average* concentration of 3,030 pCi/L which is less than USEPA's MCL and a minimum concentration that was below the minimum detectable activity for tritium. Also, the D-Area air monitoring station is considered a perimeter location, but it is actually located in a restricted area on the onsite side of the non-operating D-Area facilities away from the Savannah River. The reported gross alpha and gross beta rainwater results do not exceed USEPA's MCLs. Since the average concentration of tritium is less than USEPA's MCL and the

monitoring location is not accessible to the general public, no further public health evaluation will be done for potential offsite exposures from rainwater. However, tritium monitoring efforts should be continued as long as tritium is actively being processed at the site.

ATSDR reviewed the results of USDOE-SR's ion exchange sampling results for other radionuclides found in rainwater. Table 10 below summarizes the *maximum* results. These results are not in rainwater concentration but are reported as the radioactivity potentially deposited. ATSDR looked at the relationship of these results to the location of maximum concentrations in surface soil samples in the next section.

Table 10. Summary of radionuclide concentrations detected in USDOE-SR's rain ion exchange column samples from 1993 through 2010

Contaminant	Maximum concentration in pCi/m^2	Year	Off-site location	Distance from site
Americium-241	0.21	2008	Highway 301 at state line	25 mile radius
Cesium-137	75.70	2007	Patterson Mill Road	Site perimeter
Cobalt-60	41.10	2004	D-Area	Site perimeter
Curium-244	0.041	2010	Patterson Mill Road	Site perimeter
Gross alpha	43.0	2001	D-Area	Site perimeter
Gross beta	562.0	2003	D-Area	Site perimeter
Plutonium-238	0.40	2008	D-Area	Site perimeter
Plutonium-239	0.35	1997	Augusta Lock & Dam 614	25 mile radius
Strontium-89/90	12.2	1995	Olar, SC	25 mile radius
Uranium-234	2.69	2005	D-Area	Site perimeter
Uranium-235	0.13	1999	Highway 301 at state line	25 mile radius
Uranium238	2.52	2005	D-Area	Site perimeter

USDOE-SR = United States Department of Energy-Savannah River
pCi/m^2 = picocuries per meter squared

In this table, it should be noted that although the gross alpha and beta results for the D-Area are elevated, the concentrations reported for gross alpha and beta in rainwater by GDNR-EPD on the other side of the Savannah River do not exceed USEPA's MCLs (refer to Table 9). It is also interesting to note that 2003 (when USDOE-SR reported the highest gross beta results) was the year that the heaviest rainfall between 1993 and 2010 was recorded (see Table 2) with an average monthly rainfall that year of 5.1 inches and the maximum monthly rainfall of 11 inches in June.

Off-site monitoring of radioactive materials in surface soils and direct radiation levels

This section provides an overview of the extent to which SRS air emissions from 1993 through 2010 might be affecting off-site surface soil contamination levels. Included in this section are 1) a discussion of the USDOE-SR, SCDHEC-ESOP, and GDNR-EPD sampling programs and a summary of the off-site soil sampling data available for ATSDR's review, 2) identification of radioactive contaminants found above screening levels, and 3) a discussion of the screening results and site specific information.

During the time period for this PHA, USDOE-SR, GDNR-EPD, and SCDHEC-ESOP independently conducted off-site soil sampling to examine concentration levels of radioactive

materials around SRS. Soil sampling data were available from USDOE-SR and SCDHEC-ESOP for 1993 to 2010, and data were available from GDNR-EPD from 1993 to 2008. The soil monitoring programs enable these agencies 1) to examine long-term trends of radioactive material deposited into the atmosphere from routine and non-routine SRS atmospheric releases and from other sources via fallout, and 2) to obtain information on the radionuclide levels in the environment around SRS. As mentioned previously, there is great variation in the radionuclide concentrations detected in different soil sampling locations as a result of different soil types and rainfall patterns (SRNS 2011a; WSRC 1998a). Soil can also become contaminated through other mechanisms, such as irrigation, soil additives, fallout from weapons testing and other global nuclear incidents.

Table 11 presents an overall summary of each agency's off-site radiological soil monitoring program from 1993 through 2010. It includes the number of off-site soil sampling locations, a description of each agency's monitoring program, and the time period that each radionuclide was measured. As shown in the table, GDNR-EPD's off-site surface soil sampling program remained relatively unchanged over time. USDOE-SR and SCDHEC-ESOP, on the other hand, have increased both the number of off-site soil stations and the radiological parameters measured. The most recent sampling locations for GDNR-EPD can be located in Figure 8 (soil sampling locations are the same as TLD locations), SCDHEC-ESOP's nonrandom off-site soil sampling locations for 2010 are identified in Figure 9, and USDOE-SR's off-site stations are detailed in Figure 10. In 2004, SCDHEC-ESOP changed their surface soil sampling program to include more random coverage of samples taken within 50 miles of SRS (referred to as perimeter samples) and background samples collected greater than 50 miles from the site. (See SCDHEC's annual reports from 2004 to 2010 for locations of random off-site soil sampling locations.) Frequency of soil sampling across the agencies varied during the time period for this PHA. In 2008, GDNR-EPD sampled annually (July 2008); in 2010, USDOE-SR sampled monthly, and SCDHEC-ESOP sampled approximately monthly at various locations (GDNR 2009b; SCDHEC 2009a, 2011a; SRNS 2011a).

Table 11. GDNR-EPD, SCDHEC-ESOP, and USDOE-SR off-site radiological soil sampling measurements reported during 1993–2010

Data Source	Number of Off-site Soil Sampling Locations	Sampling Description	Monitored Radiological Parameters	Time Period of Monitoring	Reference
GDNR-EPD	1993: 10 2008[a]: 12	Samples are collected in a 500-milliliter container from the top 2 inches of undisturbed soil	Americium-241	2003–2004	GDNR 2000, 2004, 2005, 2009b
			Cesium-137	1993–2008	
			Cobalt-60	2004, 2006	
			Gross alpha	1996–1998	
			Gross beta	1996–1998	
			Plutonium-238	1994–2004	
			Plutonium-239	1994–2004	
			Potassium-40	1993—2008	
			Radium-226	1993–2008	
			Radium-228	1993–2008	
			Strontium-89	1997–2004	
			Strontium-90	1994–2004	
SCDHEC-ESOP[b]	1993: 6 ▪ 2 background locations in a 100-mile radius ▪ 4 quadrant locations (northeast, northwest, southeast, and southwest) 2010: 46 ▪ 12 random sites within 50-mile radius ▪ 13 random background sites outside 50-mile radius ▪ 12 non-random samples from perimeter and background locations ▪ 9 samples from riverbanks along publicly accessible Savannah River boat landings	Samples are collected from the surface to a 6-inch depth; uses nonrandom and random sampling locations (random sampling used to determine whether elevated radionuclide levels are associated with SRS releases)	Actinium-228	1998–1999, 2003–2010	SCDHEC 1999a, 2004a, 2005a, 2005b, 2006b, 2007a, 2008a, 2009a, 2009b
			Americium-241	1998–1999, 2003–2010	
			Antimony-125	1998–1999, 2003–2010	
			Barium-133	1998–1999	
			Beryllium-7	1998–1999, 2003–2010	
			Cerium-144	1998–1999, 2003–2010	
			Cesium-134	1998–1999, 2003–2010	
			Cesium-137	1993-1999, 2003–2010	
			Cobalt-57	1998–1999	
			Cobalt-58	1998–1999, 2003–2010	
			Cobalt-60	1998–1999, 2003–2010	
			Europium-152	1998–1999, 2003–2010	
			Europium-154	1998–1999, 2003–2010	
			Europium-155	1998–1999, 2003–2010	
			Gross alpha	2005–2010	
			Gross beta	2005–2010	
			Iodine-131	2003–2010	
			Lead-212	1998–1999, 2003–2010	
			Lead-214	1998–1999, 2003–2010	
			Manganese-54	1998–1999, 2003–2010	
			Plutonium-238	2000–2001	
			Plutonium-239/240	2000-2002	
			Potassium-40	1999, 2003–2010	
			Radium-226	2003–2010	
			Ruthenium-103	1998–1999, 2003–2010	
			Sodium-22	1998–1999, 2003–2010	
			Strontium-89	2002	
			Strontium-90	2002	
			Technetium-99	2003	
			Thorium-234	2003–2007	
			Thorium/uranium-234	1998–1999	
			Uranium/thorium-238	2008	
			Uranium-234	2004–2005	
			Uranium-235	2004–2005	
			Uranium-238	2004–2005	

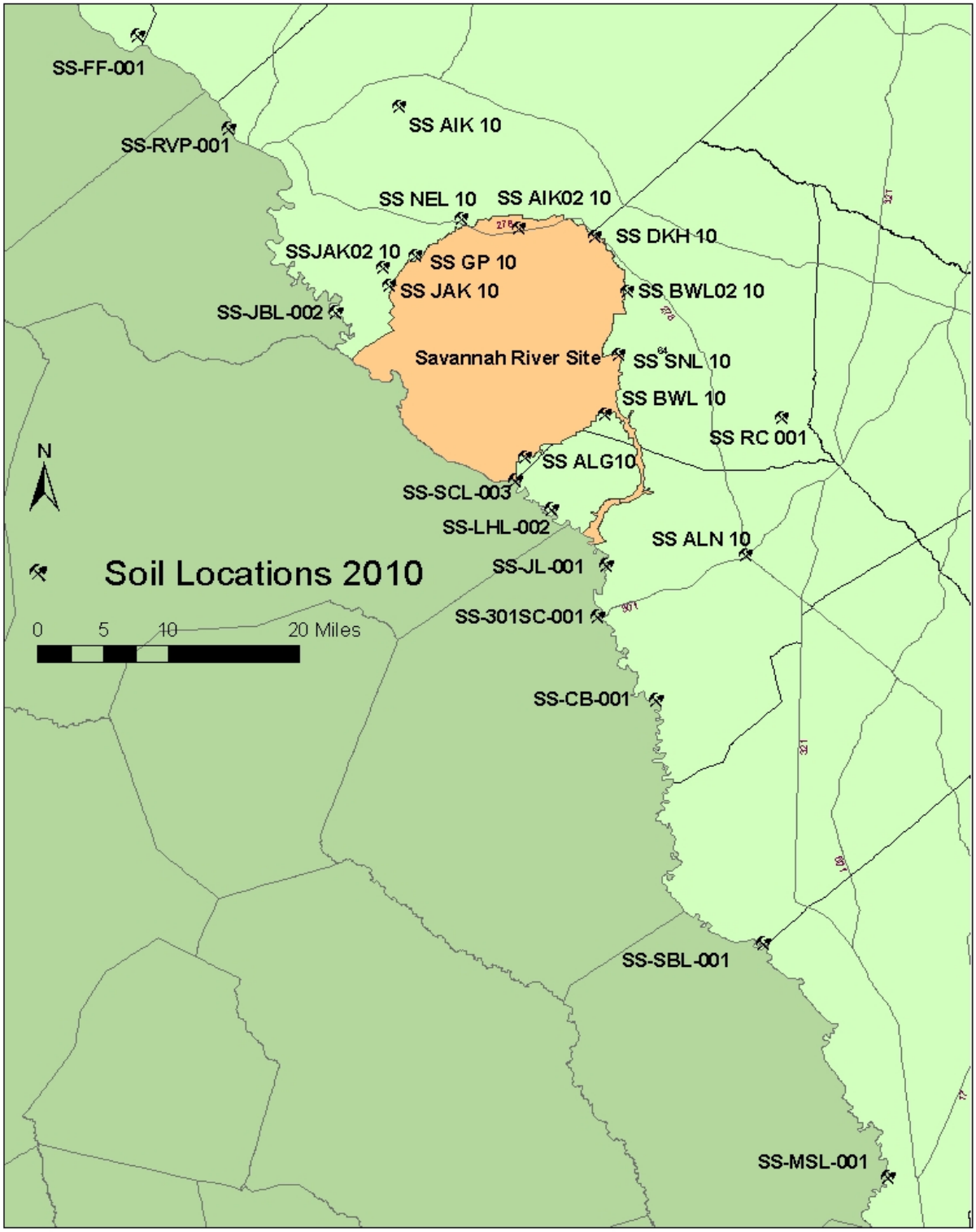
Table 11. GDNR-EPD, SCDHEC-ESOP, and USDOE-SR off-site radiological soil sampling measurements reported during 1993–2010

Data Source	Number of Off-site Soil Sampling Locations	Sampling Description	Monitored Radiological Parameters	Time Period of Monitoring	Reference
			Ytterium-88	1998–1999, 2003–2010	
			Zinc-65	1998–1999, 2003–2010	
			Zirconium-95	1998–1999, 2003–2010	
USDOE-SR	1993: 6 ▪ 4 around SRS perimeter ▪ 2 100 miles from SRS 2010: 16 ▪ 12 around perimeter ▪ 3 within 25-mile radius ▪ 1 within 100 miles of SRS	Devices such as hand augers are used to collect samples from a depth of 3 inches	Americium-241	2002–2010	SRNS 2009, 2010, 2011a; USDOE 2005c; WSRC 1994a, 1998a, 2002b, 2003, 2004, 2005, 2006, 2007, 2008
			Cesium-137	1993–2010	
			Cobalt-60	1996–2010	
			Curium-244	2002–2010	
			Neptunium-237	2009–2010	
			Plutonium-238	1993–1994, 1996–2010	
			Plutonium-239	1993–1994, 1996–2010	
			Strontium-89/90	1993–2010	
			Uranium-234	2002–2010	
			Uranium-235	1993, 1999, 2002–2010	
			Uranium-238	2002–2010	

Notes:
GDNR-EPD = Georgia Department of Natural Resources' Environmental Protection Division
SCDHEC-ESOP = South Carolina Department of Health and Environmental Control's Environmental Surveillance and Oversight Program
USDOE-SR = United States Department of Energy-Savannah River
SRNS = Savannah River Nuclear Solutions, LLC
WSRC = Westinghouse Savannah River Company
[a]GDNR-EPD did not perform site-related soil sampling after 2008.
[b]SCDHEC monitored many radionuclides only in 1998–1999 and then again in 2003 and thereafter, when the agency conducted gamma scans of surface soils for gamma-producing radionuclides (SCDHEC 2004).

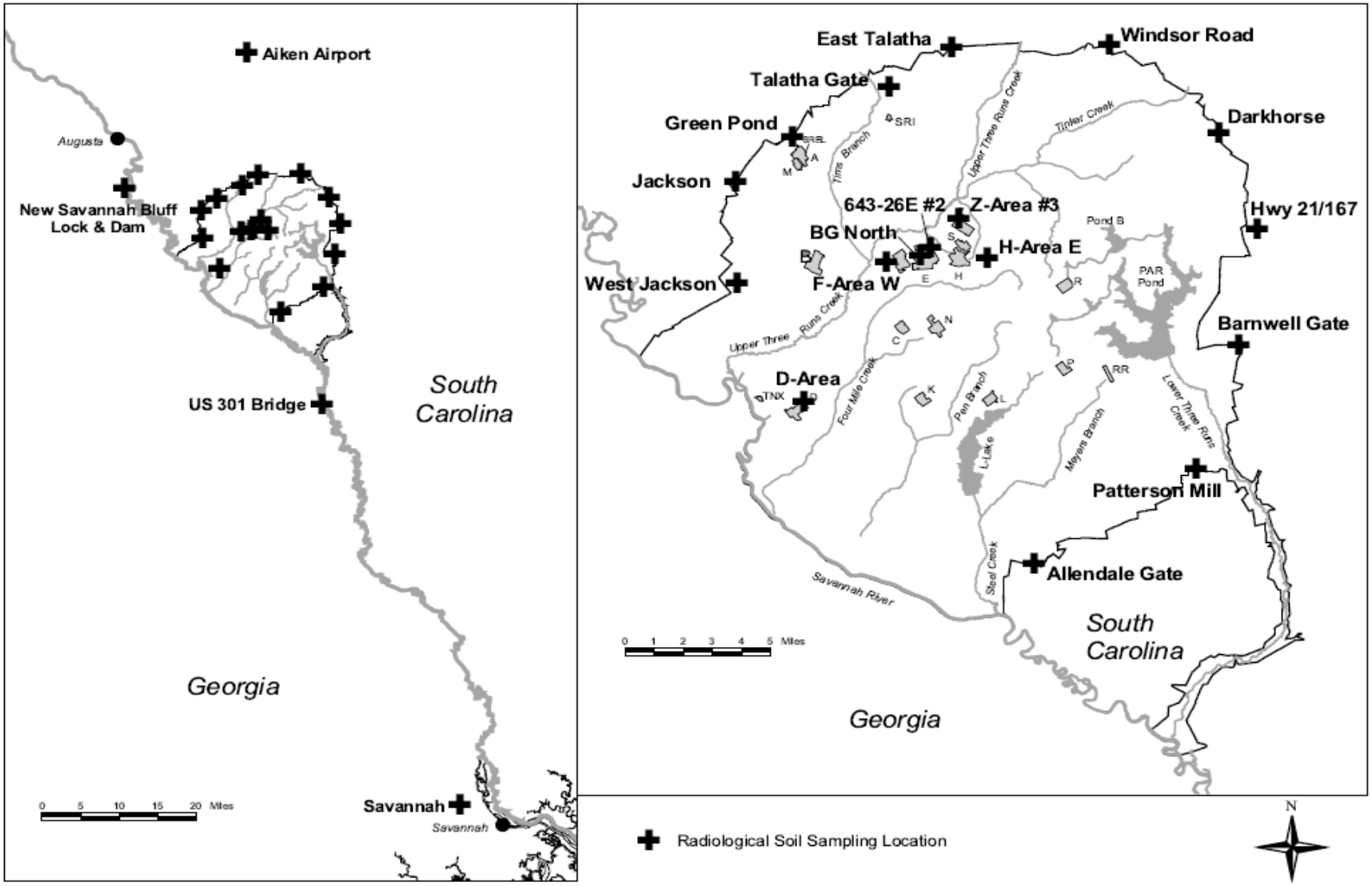
1150

Figure 11. Nonrandom South Carolina Department of Health and Environmental Control/ Environmental Surveillance and Oversight Program's Off-site Radiological Soil Sampling Locations in 2010



Source: SCDHEC 2011a

1156 **Figure 12. United States Department of Energy-Savannah River's Off-site Radiological Soil Sampling Locations in 2010**



1158 Source: SRNS 2011a

Evaluation of radioactive contaminants in off-site soil

As mentioned previously, radioactive materials released into the air from on-site processes can eventually be deposited in off-site surface soil which can increase potential exposures by inhalation and ingestion of particulates and can increase external exposures to ambient radiation levels. To determine if any of the radionuclides detected in off-site soils need further evaluation, ATSDR compared the *maximum* radionuclide concentrations detected to screening levels. The maximum concentrations evaluated here are not annual averages: these maximum concentrations represent the highest concentration of each radionuclide detected between 1993 and 2010 during any sampling event (e.g., weekly, quarterly) by GDNR-EPD, SCDHEC-ESOP, and USDOE-SR. Thus, this is a very conservative approach as concentrations averaged over a year would likely be much lower than the maximum concentration detected during a single sampling event.

Table 12 shows the maximum concentrations reported for each radionuclide from 1993 to 2010, and indicates the corresponding detection year, monitoring station, location in relation to SRS (e.g., site perimeter, 25-mile radius), and the agency that provided the data.

Table 12. Maximum radionuclide concentrations detected during any off-site soil sampling event from 1993 to 2010

Radionuclide	Year	Maximum Concentration in pCi/g (Bq/kg)	Monitoring Station	Location in Relation to SRS	Data Source
Americium-241	2007	0.76 (28.1)	SSE46	Less than 50 miles from SRS (Cordova)	SCDHEC-ESOP
Cerium-144	2003	0.26 (9.6)	AKN-251	25-mile radius (Aiken)	SCDHEC-ESOP
Cesium-134	1999	0.01(0.4)	BWL-003	Site perimeter (Patterson Mill Road and Lower Three Runs Creek)	SCDHEC-ESOP
Cesium-137	2007	16.68 (617.8)	SSALD-001	Site perimeter (Savannah River Swamp below Steel Creek)	SCDHEC-ESOP
Cobalt-60	2004	0.03 (1.1)	Highway 301 @ State Line	25-mile radius	USDOE-SR
Curium-244	2005	0.18 (6.7)	Aiken Airport	25-mile radius	USDOE-SR
Europium-155	2005	0.97 (35.9)	E13	Less than 50 miles from SRS (Norway east)	SCDHEC-ESOP
Neptunium-237	2010	0.0113 (0.42)	Augusta Lock & Dam 614	25-mile radius`	USDOE-SR
Plutonium-238	2005	0.29 (10.7)	Aiken Airport	25-mile radius	USDOE-SR
Plutonium-239	2005	0.16 (5.9)	Aiken Airport	25-mile radius	USDOE-SR
Plutonium-240	2001	5.90 (218.5)	BWL-002	Site perimeter (north of Snelling/Barnwell)	SCDHEC-ESOP
Potassium-40	2000	26.00 (963.0)	10	GA 80 end at camp	GDNR-EPD
Radium-226	2008	47.80 (1770.4)	SSAIK-0804	Less than 50 miles from SRS (between Aiken and Williston)	SCDHEC-ESOP
Radium-228	2003	5.00 (185.2)	27	Hancock Landing Road (11 miles from SRS,1.5 miles from Vogtle)	GDNR-EPD
Strontium-90	1994	0.90 (33.3)	27	Hancock Landing Road (11 miles from SRS, 1.5 miles from Vogtle)	GDNR-EPD
Technetium-99	2003	5.16 (191.1)	AKN-004	Site perimeter (north of site)	SCDHEC-ESOP
Uranium-234	2004	2.12 (78.5)	Highway 301 @ State Line	25-mile radius	USDOE-SR
Uranium-235	2004	0.12 (4.4)	Highway 301 @ State Line	25-mile radius	USDOE-SR

Table 12. Maximum radionuclide concentrations detected during any off-site soil sampling event from 1993 to 2010

Radionuclide	Year	Maximum Concentration in pCi/g (Bq/kg)	Monitoring Station	Location in Relation to SRS	Data Source
Uranium-238	2004	2.06 (76.3)	Highway 301 @ State Line	25-mile radius	USDOE-SR
Zinc-65	2006	0.12 (4.4)	SSAIK-004	Site perimeter (north of site)	SCDHEC-ESOP
Zirconium-95	1999	0.14 (5.2)	AKN-004	Site perimeter (north of site)	SCDHEC-ESOP

Notes:
pCi/g = picocuries per gram
Bq/kg = becquerel per kilogram (1 Bq = 27 pCi)
GDNR-EPD: Georgia Department of Natural Resource's Environmental Protection Division
SCDHEC-ESOP: South Carolina Department of Health and Environmental Control's Environmental Surveillance and Oversight Program
USDOE-SR: United States Department of Energy-Savannah River

ATSDR did not find a correlation between the maximum rainfall concentrations described in Table 9 and the maximum surface soil concentrations reported in Table 12 above.

ATSDR screened radionuclide contaminant concentrations in surface soil using values from NCRP's Report No. 129, Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies (NCRP 1999) (more information is presented in the text box). The recommendations in NCRP's report are based on limiting the maximum exposure rate to an individual to 0.25 mSv/yr (25 mrem/yr) above natural background. This is a conservative method of screening for soil contaminants since ATSDR's health-based comparison value for chronic exposure to ionizing radiation is 1 mSv/yr (100 mrem/yr) above natural background. ATSDR made individual calculations for six[13] separate land-use scenarios, distinguishing between land use with different dose pathways, evaluating the most exposed population group, and considering a range of particular critical parameters. The six groups included:

NCRP Report No. 129 contains radiation guidelines and soil screening limits developed as tools for cleaning up radionuclide contamination in surface soil. NCRP derived the radiation guidelines and soil screening limits by first reviewing the current models for estimating dose, then using the estimation in eight different land-use scenarios to calculate the highest annual dose from external exposure, or the dose from inhalation or ingestion that would be delivered by the radionuclide and its daughter products.

ATSDR uses the NCRP's radiation guidelines and soil screening limits as a conservative method of relating an effective dose limit for an exposed population to a corresponding soil contamination level. In other words, ATSDR selects conservative NCRP values to overestimate possible doses and to protect public health. This approach results in annual doses and screening limits that are realistic but still conservative. If radionuclide concentrations fall below the suggested limits, no further action is required. If the soil concentration exceeds the limit, then ATSDR conducts a more detailed review. Source: ATSDR 2005a

[13] ATSDR did not use two of the eight land-use scenarios in NCRP's Report No. 129 for the SRS off-site soil radiological evaluations: sparsely vegetated pasture (PS) and sparsely vegetated rural (RS).

- Agriculture (AG). Category deals primarily with food production, and considers there are no dwellings on contamination. Therefore, ATSDR assumed only adults were exposed via inhalation and external radiation, whereas children and infants were exposed via ingestion of food only.

- Heavily vegetated pasture (PV). Group primarily for milk and meat production with no dwellings on contamination. Thus, only adults were assumed to be exposed via inhalation and external radiation, whereas children and infants were exposed via ingestion of food only.

- Heavily vegetated rural (RV). Category represents an area with open fields and forest. Some ingestion of contaminated food occurs via gardens, wild game, fruits, and mushrooms. Dwellings could be present on contaminated sites. Most exposed population would be children and infants living on the property who were ingesting milk from backyard cows or other food products grown on site.

- Suburban (SU). Group includes residential properties with minor food production such as vegetable gardens. The most exposed population would be children living on the property, playing outdoors, and ingesting home-grown vegetables with possibly some soil.

- No food suburban (SN). Category refers to mainly parks, schools, recreational sites, and residential lawns. The most exposed population would be children playing outdoors who were possibly inhaling and ingesting soil.

- Construction, commercial, industrial (CC). Group includes soil disturbance from activities. No dwellings are on these properties, and no exposures are expected for children or infants. Exposure to adults could occur, mainly from external radiation and potential inhalation and ingestion of suspended soil. Exposures would be short term.

Except for some naturally-occurring decay products at low concentrations (i.e., actinium-228, lead-212, lead-214, and thorium-234), Table 13 contains the most conservative values (i.e., the lowest screening limits) for the NCRP land-use scenarios for each maximum radionuclide concentration in off-site soil. Table 14 presents all six of the land-use scenario screening values for the radionuclides that exceeded the most conservative screening level (indicated by an "*" in Table 13). These screening levels are not used to calculate population exposures or estimate health effects. Scenarios are hypothetical and help identify potential contaminants of concern and locations of interest for further investigation.

Table 13. Screening of maximum radionuclide concentrations detected in off-site surface soil using limits from NCRP's Report No. 129

Radionuclide	Land-use Scenario		NCRP 129 Concentration in pCi/g (in Bq/kg)	SRS Maximum Soil Concentration in pCi/g (in Bq/kg)
Americium-241	CC		12.69 (470)	0.76 (28.1)
Cerium-144	RV		67.5 (2,500)	0.26 (9.6)
Cesium-134	RV		1.97 (73)	0.01 (0.4)
Cesium-137*[a]	RV		4.05 (150)	16.68 (617.8)
Cobalt-60	RV		0.86 (32)	0.03 (1.1)
Curium-244	CC		20.25 (750)	0.18 (6.7)
Europium-155	RV,SU,SN		67.5 (2,500)	0.97(35.9)
Neptunium-237	AG		2.09 (96)	0.0113 (0.42)
Plutonium-238	AG, CC		12.96 (480)	0.29 (10.7)
Plutonium-239	CC		12.69 (470)	0.16 (5.9)
Plutonium-240	CC		12.69 (470)	5.90 (218.5)
Potassium-40*[a, b]	RV, SU,SN		17.82 (660)	26.00 (963.0)
Radium-226*[a, c]	RV		0.11 (4.1)	47.80 (1770.4)
Radium-228*[a, d]	AG		0.07 (2.7)	5.00 (185.2)
Strontium-90*[a, e]	PV		0.43 (16)	0.90 (33.3)
Technetium-99*[a]	RV		0.59 (22)	5.16 (191.1)
Uranium-234	RV		25.92 (960)	2.12 (78.5)
Uranium-235	RV		7.56 (280)	0.12 (4.4)
Uranium-238	RV		21.87 (810)	2.06 (76.3)
Zinc-65	PV		1.32 (49)	0.12 (4.4)
Zirconium-95	RV,SU,SN		8.37 (310)	0.14 (5.2)

Notes:
pCi/g = picocuries per gram of soil; Bq/kg = becquerels per kilogram of soil (1 Bq = 27 pCi)
AG–agriculture; SU–suburban; PV–heavily vegetated pasture; SN–no food suburban; RV–heavily vegetated rural; CC–construction, commercial, industrial

[a] Radionuclides with * indicate that the maximum concentration exceeds the most conservative scenario. The land use for the locations where these samples were collected were reviewed and compared to the other scenarios in Table 13. *For those radionuclides that are part of natural background (i.e., potassium-40, radium-226 and radium-228), the NCRP values are those concentrations above the background found in nature. SRS maximum soil concentrations include background and will need a site-specific review.*

[b] Potassium-40 is naturally occurring (average background level is about 400 Bq/kq [10.8 pCi/g]) and the result reported here is probably the result of fertilizer on agricultural lands; however, it appears to exceed the screening value. NCRP Report No. 129 (NCRP 1999) states that the amount of potassium in the body is under tight homeostatic control; thus, only the dose from external exposure was considered for these K-40 screening limits.

[c] *Background radium-226 for the SRS area appears to be ~1 pCi/g (~37 Bq/kg).*

[d] *Background radium-228 for the SRS area appears to be 2 pCi/g (~74 Bq/kg).*

[e] Strontium-89/90 is assumed to be strontium-90 because it is of more health concern than strontium-89. The highest value reported at a non-background location was for strontium-90 (this value is reported here).

Table 14. Surface soil screening limits from NCRP's Report No. 129 for six land-use scenarios for radionuclides detected in off-site surface soil above the most conservative land-use screening limit

Radionuclide	Maximum[a] Soil Concentration in Bq/kg (in pCi/g)	NCRP Report No. 129 Land-use Scenario Screening Values in Bq/kg (Converted to pCi/g)											
		Agriculture		Heavily Vegetated Pasture		Heavily Vegetated Rural		Suburban		No Food Suburban		Construction, Commercial, Industrial	
		NCRP Limit	Above Limit?	NCRP Limit	Above Limit?	NCRP Limit	Above Limit?	NCRP Limit	Above Limit?	NCRP Limit	Above Limit?	NCRP Limit	Above Limit?
Cesium-137	617.8 (16.68)	250 (6.75)	Yes	250 (6.75)	Yes	150 (4.05)	Yes	200 (5.40)	Yes	210 (5.67)	Yes	450 (12.15)	Yes
Potassium-40[b]	963.0 (26.00)[c]	1,200 (32.4)	No	1,500 (40.5)	No	660 (17.82)	Yes	660 (17.82)	Yes	660 (17.82)	Yes	1,500 (40.5)	No
Radium-226	1770.4 (47.80)[c]	9.1 (0.25)	Yes	17 (0.46)	Yes	4.1 (0.11)	Yes	5.4 (0.15)	Yes	6.1 (0.16)	Yes	19 (0.51)	Yes
Radium-228	185.2 (5.00)[c]	2.7 (0.07)	Yes	9.6 (0.26)	Yes	3.2 (0.09)	Yes	7.9 (0.21)	Yes	60 (1.62)	Yes	140 (3.78)	Yes
Strontium-90	33.3 (0.90)	26 (0.70)	Yes	16 (0.43)	Yes	17 (0.46)	Yes	84 (2.27)	No	9,300 (251.1)	No	31,000 (837)	No
Technetium-99	191.1 (5.16)	24 (0.65)	Yes	42 (1.13)	Yes	22 (0.59)	Yes	81 (2.19)	Yes	420,000 (11,340)	No	1,300,000 (35,100)	No

Notes:
Bq/kg = becquerel per kilogram; pCi/g = picocurie per gram
[a] It was not possible to use an annual average concentrations since none of these radionuclides were detected (or analyzed for) in more than one sample at the same location in the same year.
[b] NCRP Report No. 129 (NCRP 1999) states that the amount of potassium in the body is under tight homeostatic control; thus, only the dose from external exposure was considered for these K-40 screening limits.
[c] These radionuclides are naturally occurring and their maximum concentrations include background concentrations. The NCRP Report No. 129 values are for concentrations above background. This will require a site-specific review.

ATSDR reviewed these concentration results further and considered the locations where they were collected, the frequency of sampling, the possibility of the public being exposed to these levels, and the source of these radionuclides. Below is a discussion for each of the six radionuclides in the table above.

Cesium-137 (Cs-137) in soil:

USDOE-SR, SCDHEC-ESOP, and GDNR-EPD have monitored for Cs-137 in surface soils in areas around SRS since 1993. The maximum Cs-137 concentration reported to ATSDR is 16.68 pCi/g in a river bank sample at Little Hell's Landing. This sample was collected and analyzed by SCDHEC-ESOP in 2007. Four months later they collected another sample at this location that contained 0.0675 pCi/g Cs-137. In 2008 SCDHEC-ESOP also collected two samples that exceed the NCRP screening values (7.952 pCi/g and 5.686 pCi/g) that were taken from the Steel Creek delta and Savannah River swamp. All of these concentrations have likely been caused by a past surface water release (ATSDR 2007) and not from air releases from the site. All other concentrations have been less than the NCRP screening value for Cs-137. Cs-137 air releases do not appear to have caused soil contamination off-site at levels of health concern.

Since no one lives or farms on the Steel Creek delta and the contamination of the Savannah River swamp is well documented, monitored routinely, and discussed in ATSDR's first public health assessment for SRS, it will not be further evaluated here.

Potassium-40 (K-40) in soil:

The NCRP Report No. 129 states that the amount of potassium in the human body is under tight homeostatic control; thus, only the dose from external exposure was considered for the K-40 screening limits (NCRP 1999). Both GDNR-EPD (1993 through 2008) and SCDHEC-ESOP (1999, 2005 through 2007) reported K-40 concentrations in soil. K-40 is naturally-occurring, but concentrations in the soil can vary significantly due to soil additives (i.e., fertilizer for agricultural purposes). SCDHEC-ESOP reported three concentrations that exceed the screening level at "background" locations greater than 50 miles from the site. GDNR-EPD reported three concentrations that slightly exceed the screening level, all located near the Savannah River from Augusta to the Plant Vogtle site. The *maximum* concentrations are 18 pCi/g near Augusta in 2004 (2004 annual *average* concentration is less than screening level), 26 pCi/g at the end of Georgia highway 80 in 2000 (only one result for 2000), and 20.3 pCi/g near Plant Vogtle in 2002 (only one result for 2002). For all three locations, the concentrations *averaged* over the period of time from 1993 through 2008 were less than the screening level. Also, the external radiation levels measured by thermoluminescent dosimeters at these locations were not above natural background for these years. (Refer to the next section for a discussion of thermoluminescent dosimeters and the reported results.) The K-40 soil concentrations are not related to air releases from SRS. These concentrations appear to be naturally-occurring and at levels that would not cause adverse health effects.

Radium-226 (Ra-226) in soil:

Radium-226 is a naturally occurring radioactive material. SCDHEC-ESOP (2003 through 2007) and GDNR-EPD (1993 through 2008) reported results for radium-226 in soil. The maximum result is 47.8 pCi/g detected in a soil sample collected in 2008 by SCDHEC-ESOP between Aiken and Windsor. Other sample results from nearby locations and other samples collected that same year were well below this concentration in the range of background levels. ATSDR did not find an explanation for this elevated concentration. The next highest concentration for that year was 4.69 pCi/g, which is similar to concentrations found in other samples collected in the area.

The site specific background concentrations for radium-226 in soil samples range from less than 1 pCi/g to approximately 7 pCi/g. Other than the one 2008 sample with the maximum concentration, the radium-226 in soil concentrations appears to be naturally-occurring and not related to air releases from SRS.

Although the Ra-226 concentrations may exceed the NCRP screening levels, except for one sample, they do not exceed USEPA's Soil Cleanup Criteria in 40CFRPart192 (Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites) of 5 pCi/g for Ra-226, Ra-228, or a combination in surface soil and 15 pCi/g for subsurface soil. These standards have been accepted by USEPA as protective of human health and the environment for CERCLA sites. Also, 5.0 pCi/g is the limit allowed by EPA for backfill materials following cleanup.

Radium-228 (Ra-228) in soil:

Radium-228 is a naturally occurring radioactive material. Only GDNR-EPD reported results for radium-228 (from 1993 through 2008). The maximum result was 5.0 pCi/g detected in an annual sample (2003) collected near a transmission line on County Road 98 near the river north of Plant Vogtle. Other annual sample results from this location range from 0.4 pCi/g to 2.7 pCi/g which appear to be normal background levels for this area and not related to air releases from SRS.

Although these concentrations exceed the NCRP screening levels, they do not exceed USEPA's Soil Cleanup Criteria in 40CFRPart192 (Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites) of 5 pCi/g for Ra-226, Ra-228, or a combination in surface soil and 15 pCi/g for subsurface soil. These standards have been accepted by USEPA as protective of human health and the environment for CERCLA sites. Also, 5.0 pCi/g is the limit allowed by EPA for backfill materials following cleanup.

Strontium-90 (Sr-90) in soil:

GDNR-EPD analyzed soil samples for strontium-90 from 1994 through 2008. They detected only one sample with a strontium-90 concentration above the laboratory's usual "minimum detectable activity" of 0.5 pCi/g. This was the maximum result reported (0.9 pCi/g), was collected at the transmission line off county road 98 near the river north of Plant Vogtle, and was the only sample collected from this location for 1994. This concentration does not exceed the screening level for construction, commercial or industrial land uses. Also, strontium-90 has not been detected at this location since that time. SCDHEC analyzed their soil samples for strontium-90 only in 2002 with no detections above the "minimum detectable activity" (less than 0.3 pCi/g). USDOE-SR reported results as strontium-89/90 from 1993 through 2010. All results were less than their "minimum detectable activity" of less than 0.4 pCi/g. Based on these sampling results, it appears that the average strontium-90 or strontium-89/90 concentrations do not exceed the screening levels and are at levels that would not be of health concern.

Technetium-99 (Tc-99) in soil:

Only SCDHEC-ESOP reported soil concentrations of technetium-99. SCDHEC-ESOP reported only one result, and that result exceeds the screening level. This sample was collected at Green

Pond Road just outside SRS. Although this one concentration exceeds the screening level for agricultural land, heavily vegetated pasture and rural land, and suburban properties, only one sample is inadequate to make any public health determination. Tc-99 is a beta-emitter with a long half-life. USDOE assumes that any beta emitters not identified in the analyses are screened as strontium-90, which is more conservative when estimating potential exposures; however, USDOE-SR did not detect this level of beta-emitters at this location.

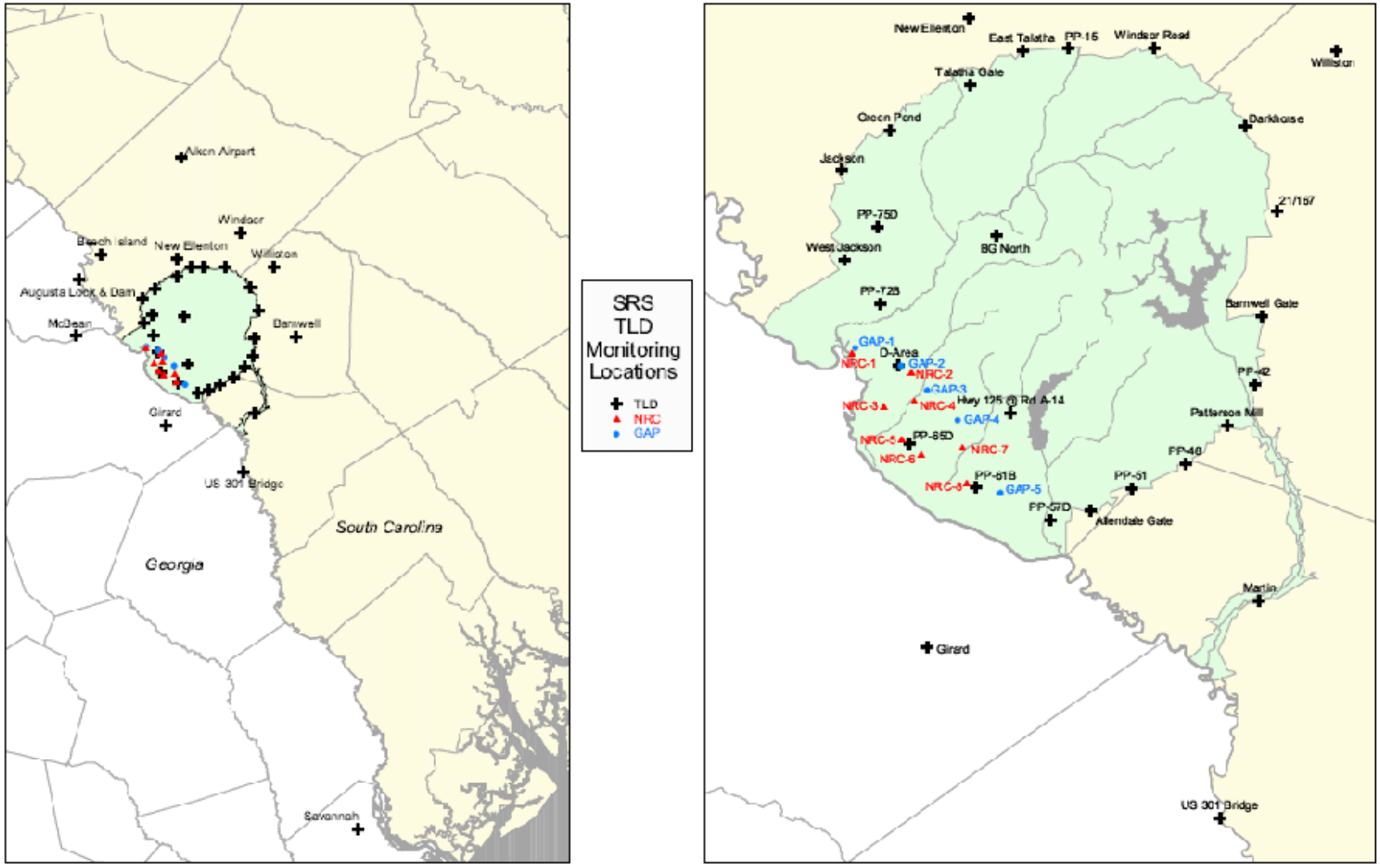
After further review of the above radionuclides and their concentrations, locations, and source, ATSDR concluded that the reported levels of radioactive materials in soil are not as a result of airborne releases from SRS or at a level of health concern and do not need further evaluation.

Evaluation of direct radiation levels based on thermoluminescent dosimeter results

Thermoluminescent dosimeters,[14] or TLDs, placed in off-site locations measure ambient beta and/or gamma radiation potentially associated with radionuclide releases from SRS. These devices are deemed reliable for determining external doses to the off-site population from radioactive materials (WSRC 1998a). There is an extensive network of dosimeters around SRS, including monitors maintained by GDNR-EPD (see Figure 8), SCDHEC-ESOP (see Figure 9), and USDOE-SR (see Figure 13). Table 15 presents information about the number and location of TLDs maintained by each agency, the types of radioactivity measured, and the time periods that TLDs have been used. All three agencies have used these dosimeters to monitor ambient gamma radiation, while GDNR-EPD and SCDHEC-ESOP also have used them to measure ambient beta radiation. The agencies collect the TLDs on a quarterly basis for analysis and replace them with new devices (WSRC 1994a). As evident in the table, SCDHEC-ESOP used the same number of TLDs in 1993 and 2010; however, subtle variations in TLD numbers occurred throughout the entire time period of the PHA. On the other hand, GDNR-EPD used 54 locations for TLDs in 2003 but discontinued its site-related TLD monitoring in April 2009. Although USDOE-SR reduced its number of offsite TLDs by 5.5-fold during the 1993–2010 time period as a result of periodic evaluations of radiological environmental surveillance program needs, they continue to maintain TLDs in population centers within 9 miles of the site border and perform limited monitoring at its air stations located 25 and 100 miles from SRS (SRNS 2011a).

[14] A thermoluminescent dosimeter, or TLD, measures ionizing radiation exposure by measuring the amount of visible light emitted from a crystal in the detector when the crystal is exposed to radiation and then heated. The amount of light emitted is dependent upon the amount of radiation exposure. Only certain materials exhibit thermoluminescence in response to ionizing radiation (i.e., calcium fluoride and lithium fluoride).

Figure 13. United States Department of Energy-Savannah River's Thermoluminescent Dosimeter Monitoring Locations in 2010



Source: SRNS 2011a

Table 15. GDNR-EPD, SCDHEC-ESOP, and USDOE-SR offsite monitoring of direct ambient gamma radiation with thermoluminescent dosimeters (TLDs)

Data Source	Number and Location of Offsite TLDs	Radiological Parameters Measured	Time Period of Monitoring	Reference
GDNR-EPD	1993: 49 with 3 background locations 2009[a]: 47 offsite around SRS, VEGP, and background locations in Georgia	Ambient beta Ambient gamma	1993–2009	Blackman 2003; GDNR 2000, 2004, 2012
SCDHEC-ESOP	1997: 19 in site perimeter locations 2010: 19 ▪ 13 on or near site perimeter ▪ 5 within 25 miles of site ▪ 1 control (kept in office)	Ambient beta Ambient gamma	1997,[b] 1999–2010	SCDHEC 1999a, 2004a, 2005a, 2005b, 2006b, 2007a, 2008a, 2009b, 2010a, 2011c
USDOE-SR	1993: 298 ▪ 39 air surveillance stations ▪ 18 in vicinity of VEGP (co-located with Nuclear Regulatory Commission and Georgia Power Company locations) ▪ 179 at site perimeter ▪ 62 at population centers 2010: 54 ▪ 18 air surveillance stations ▪ 18 in vicinity of VEGP (co-located with Nuclear Regulatory Commission and Georgia Power Company locations) ▪ 9 at site perimeter ▪ 9 at population centers	Ambient gamma	1993–2010	SRNS 2009, 2010, 2011a; WSRC 1994a, 1995, 1996a, 1997, 1998a, 1999a, 2000, 2001, 2002b, 2003, 2004, 2005, 2006, 2007, 2008

Notes:
GDNR-EPD: Georgia Department of Natural Resource's Environmental Protection Division
SCDHEC-ESOP: South Carolina Department of Health and Environmental Control's Environmental Protection Division
USDOE-SR: U.S. Department of Energy-Savannah River
[a]GDNR-EPD discontinued its site-related TLD monitoring in April 2009.
[b]SCDHEC-ESOP did not report TLD data in 1998 due to equipment difficulty (SCDHEC 1999a).

TLDs measure external exposure from gamma and/or beta radiation, which comes from background and man-made radiation sources. Background radiation can come from terrestrial (naturally-occurring radioactive materials in the earth's crust) or cosmic (solar particles and cosmic rays) sources. The entire worldwide population is continually exposed to background radiation sources, but the radiation dose received by an individual from background sources varies depending on that person's activities and place of residence. Natural background radiation sources and levels vary by geographic region. In the United States, and particularly in the southeast where SRS is located, background radiation levels are generally lower than in other parts of the country. Moreover, coastal areas, such as where SRS is situated, have lower land elevations: this corresponds with lower background radiation levels than mountainous regions of the country.

Because SRS is divided by the coastal ridge line, the TLD locations to the south—toward the Atlantic Coast—typically have lower background levels than the locations to the north of the site. For instance, the TLD results for the USDOE-SR's monitoring locations in Savannah, Georgia are slightly lower than the TLD results obtained from its monitors in Augusta, Georgia. Also, levels recorded by USDOE-SR's TLD monitors located in population centers and close to the Savannah River appear to be slightly higher than levels recorded by its TLD monitors that are in some of the rural areas away from the river. Population centers can have other sources that increase the radiation exposure levels such as coal-burning power plants and construction materials used for roads and buildings (NCRP 2009).

Table 16. Range of direct radiation levels measured by thermoluminescent dosimeters (TLDs) off site of SRS from 1993 to 2010 (without background subtracted)

Data Source	Range of Direct Annual Radiation Levels Without Background Subtracted (millirem/year)		TLD Location	TLD Location in Relation to SRS	Year of Minimum/ Maximum Reported Level
GDNR-EPD[a]	Minimum	32	102	I-20 and GA 44, Greensboro, SC	1994
	Maximum	122	101	I-20 and GA 162, Conyers, GA	1995
SCDHEC-ESOP[b]	Minimum	45	Allendale Barricade	At or near SRS boundary	2001
	Maximum	130	US 278 near Upper Three Runs Creek	At or near SRS boundary	2004
USDOE-SR	Minimum	37	NRC 2 and NRC 8	Georgia Power Company's Vogtle Electric Generating Plant Vicinity	1993
	Maximum	136.7	West Columbia, Lexington County, SC	Population center about 77 miles northeast of SRS	1993

Notes:
GDNR-EPD: Georgia Department of Natural Resource's Environmental Protection Division
NRC: Nuclear Regulatory Commission
SCDHEC-ESOP: South Carolina Department of Health and Environmental Control's Environmental Surveillance and Oversight Program
USDOE-SR: U.S. Department of Energy-Savannah River
[a] GDNR-EPD monitored TLDs from 1993 until April 2009.
[b]SCDHEC-ESOP did not report TLD data in 1998 due to equipment difficulty (SCDHEC 1999a).

Based on a review of information presented in NCRP Report No. 160[15] (NCRP 2009), ATSDR estimated that background exposures (not including radon and radon daughter products) in the SRS area could be in the range of 50 to 90 mrem/yr (0.5 to 0.9 mSv/yr). Although this range appears appropriate for Georgia, close examination of the TLD data collected off site from 1993

[15] ATSDR used information in Chapter 3, Summary, and Sections 3.2, 3.3, and 3.4 (with Table 3.1 and Figures 3.3, 3.4, and 3.9) from NCRP Report 160 (NCRP 2009) to estimate the background range for the SRS area.

through 2010 by USDOE-SR and SCDHEC-ESOP indicates that the natural background for South Carolina may be a little higher than this estimated range. ATSDR determined that the slight elevation in natural background for South Carolina was not caused by SRS (i.e., not site-related) due to the consistency of the results for each TLD monitoring location and the fact that many of the sites with the highest results were at far distances from the site as illustrated in Table 16. The most elevated TLD result from USDOE-SR is for West Columbia, South Carolina approximately 90 miles from the site. From 2007 until August 2008, SCDHEC-ESOP tried using Beaufort, South Carolina as a background location because of the distance from the site, but the TLD results were very similar to and sometimes higher than the TLDs results from locations closer to the site. The TLD results closer to the site were also very consistent. Table 16 also illustrates that the highest results were found at far distances in Georgia, as GDNR-EPD's most elevated TLD level was from a monitoring station in Conyers, Georgia, which is 180 miles northwest of SRS.

From the evaluation of these results and the locations, ATSDR believes that the radiation levels reported close to the site are consistent with normal background and in some cases elevated background due to construction materials. ATSDR also noted the difference between urban and rural areas with more elevated radiation levels in urban areas. Based on a review of the soil sample results along with the TLD results, GDNR-EPD determined that naturally occurring radionuclides from the uranium, thorium, and potassium decay chains account for over 99% of the direct radiation dose recorded on the TLDs. Also, GDNR-EPD determined that the ambient radiation levels near Plant Vogtle and SRS are lower than in the urban locations in Georgia (GDNR 2004).

Since ambient radiation levels do not appear to be related to SRS and appear to be natural background levels or caused by naturally occurring radionuclides in construction materials, no further evaluation will be performed.

Non-radioactive Contaminants in Off-site Air

SRS has many emission sources of non-radioactive contaminants (both *criteria pollutants* and *toxic air pollutants*). These emission sources are either permitted or exempted by SCDHEC. The permitted sources may be further limited by SCDHEC on the basis of state and federal regulations (WSRC 2002b). *Criteria pollutants* are regulated by SCDHEC's Standard No.2, "Ambient Air Quality Standards" while *toxic air pollutants* are regulated by SCDHEC's Standard No. 8, "Toxic Air Pollutants." Compliance with these standards is determined through the use of air dispersion modeling (WSRC 2002b, SCDHEC 2001a).

Evaluating residents' off-site exposures to SRS air emissions of non-radioactive contaminants is detailed in the following sections. The first section discusses the major routine SRS operations that can result in air releases of non-radioactive contaminants to off-site areas. The second section discusses SRS's air dispersion modeling data for *criteria* and *toxic* air pollutant releases. The third section evaluates how SRS meets the requirements for *criteria pollutants*. The fourth section evaluates how SRS meets the requirements for *toxic air pollutants*.

On-site Emission Sources for Non-radioactive Contaminants

Although not every emission unit can be listed in this PHA, some of the main emission sources of these pollutants are discussed below.

Several combustion sources operated at SRS during the time frame considered in this PHA (1993-2010) would have emitted both Standard No. 2 *criteria pollutants* and Standard No. 8 *toxic air pollutants*. These sources would include the coal fired boilers in the A-, D-, and H-Areas; the package steam boilers in the K-Area as well as other diesel operated equipment; and the Consolidated Incineration Facility (WSRC 2002b, 2007; SCDHEC 2005c).

One of the more interesting sources of air pollutants at the Savannah River Site are the soil vapor extraction units (SVEUs) and air strippers used to remediate contaminated soil and groundwater at the site. These units emit Standard *No. 8 toxic air pollutants* as well as volatile organic compounds (VOC) which are precursors of the criteria pollutant ozone (WSRC 2002b, 2007; SCDHEC 2005c, USEPA 2004). SVEUs typically emit the most pollutants during the initial stages of operation, and then the amount of pollutants emitted will decline until a limit is reached (Switzer et al. 2004, Jordan et al. 1995).

The primary way SRS monitors air emissions of the *criteria and toxic air pollutants* is the annual emissions inventory. The operational parameters (*e.g*. the hours of operation, process throughput, and emission factors) of different emission units are used to calculate the annual amount of pollutants emitted. The calculated amounts of pollutants actually emitted can then be compared to the limits specified in their Title V permits (operating permits for major stationary sources; refer to the previous section in this PHA entitled Current Regulatory Requirements Pertinent to Air Releases at SRS) (WSRC 2007).

Air Dispersion Modeling Data for SRS Criteria and Toxic Air Pollutants

SRS conducts air dispersion modeling to estimate the level of both Standard No. 2 criteria pollutants and Standard No. 8 toxic pollutants in ground-level ambient air. While SRS does not provide the results of this air dispersion modeling in their annual reports, ATSDR was able to obtain several documents that summarize SRS's air modeling completed between 1993 and 2010. The types of documents are summarized below.

Air Dispersion Modeling Summary Sheets. ATSDR received Air Dispersion Modeling Summary Sheets from SCDHEC's Bureau of Air Quality. The majority of these documents are for construction permits. SCDHEC regulations require that any person who plans to construct, alter, or add to a source of air contaminants must first obtain a construction permit, unless the requirements for an exemption are met. Among other things, the construction permit application must include air dispersion modeling or other information demonstrating that emissions from the facility, including those in the application, will not interfere with the attainment or maintenance of any ambient air quality standard. The modeling results in the construction permit applications are used to update the previous Air Dispersion Modeling Summary Sheets already on file. Similarly, updated air dispersion modeling is required for Title V permit renewals if the previous modeling is no longer accurate (SCDHEC 2011a). The modeling completed for both construction permits and Title V permits is based on the maximum permitted emissions and must use approved methods. SCDHEC's Air Quality Modeling Guidelines also allow companies to use simple screening techniques as well as more refined USEPA screening models to show compliance with Standard No. 8. Level II analysis is a simple screening technique based on the stack height, the distance to the property line, and the maximum emission rate of a pollutant in pounds per day. If the results of the Level II analysis show compliance with the state rule, no further analysis is required (SCDHEC 2001a). Typically, even if the more refined USEPA screening models are used to show compliance with the state air quality rules, a company will use simple but very conservative assumptions. If compliance with the state rules is demonstrated by modeling using conservative assumptions, no further analysis is needed even though more refined modeling could demonstrate that the estimated concentration of a pollutant would be even less (Personal Communication, J.Glass, SCDHEC). Most of the Air Dispersion Modeling Summary Sheets for SRS involve the use of USEPA models rather than Level II analysis.

The modeling and analysis completed as a part of the permitting process is reviewed by personnel in SCDHEC's Bureau of Air Quality who summarize the results in Air Dispersion Modeling Summary Sheets. It has been the experience of SCDHEC personnel that the levels of pollutants predicted by modeling are higher than the levels that would be measured by actual monitoring (Personal Communication, J.Glass, SCDHEC). The summary sheets for SRS obtained by ATSDR cover the years 1996 to 2011.

Environmental Impact Statements (EISs). EISs are required by the National Environmental Policy Act which requires consideration of environmental factors during the planning process for all federal activities that could significantly affect the quality of the environment (WSRC1998a). EIS may also evaluate the cumulative impact of the

potential emissions of all foreseeable activities, not just the specific activity being considered in the environmental impact statement. Many of the documents obtained by ATSDR (both EIS and Air Dispersion Modeling Summary Sheets) update the modeling based on the maximum permitted emission limits in 1998 which is considered the baseline year (USNRC 2005, USDOE 2001). ATSDR was able to obtain EISs completed in 1994, 1995, 1999, 2000, 2001, 2002 and 2005 (USDOE 1994, 1995, 1999, 2000c, 2001, 2002; USNRC 2005; WSRC 1999b).

Atmospheric Technologies Group Documents. Air dispersion modeling for the air permits was completed by SRNL's Atmospheric Technologies Group (ATG). ATG also completed some additional air dispersion modeling during the timeframe of this PHA (1993—2010). Typically, this modeling was done at the request of another department at SRS. ATG has completed modeling based not only on the maximum potential permitted emission limits, but also on the actual emissions. The actual emissions from different processes are recorded in SRS's Air Emissions Inventory (AEI) database (Hunter 2005). The ATG has also on two occasions modeled the annual average concentrations for Standard No. 8 toxic air pollutants (Stewart 1997, Hunter 2005). The Air Dispersion Modeling Summary Sheets contain only the maximum 24-hour average concentrations for these pollutants.

In addition to the documents described above, ATSDR also included the results of air dispersion modeling for criteria pollutants recorded in CDC's Dose Reconstruction Project as a part of this PHA. The modeling recorded in CDC's Dose Reconstruction Project was based on the maximum permitted emission limits in 1990. Although 1990 is slightly before the time frame considered in this PHA, the results are included due to the lack of other available information that documents the modeling SRS completed between 1993 and 1996. The modeled results for Standard No. 8 pollutants recorded in CDC's Dose Reconstruction Project were not included in this PHA because the modeled averaging times are unknown. Consequently, it is not known if the modeled concentrations represent short or long term concentrations and should be compared to acute or chronic comparison values.

How SRS Complies with SCDHEC Standard No.2 for Non-radioactive Criteria Pollutants and ATSDR's Evaluation

As mentioned previously, SRS conducts air dispersion modeling to estimate the level of criteria pollutants in the ground-level ambient air. SCDHEC's Standard No. 2, "Ambient Air Quality Standards," specifies allowable concentrations of each of the criteria pollutants and the intervals at which the pollutants must be measured. In lieu of measuring the concentration of criteria pollutants, SCDHEC allows sources to show compliance with Standard No. 2 through air dispersion modeling. SRS conducts air dispersion modeling to estimate the concentrations of criteria pollutants emitted from each onsite source. SCDHEC determines whether SRS is in compliance with Standard No. 2 by comparing the modeled concentrations of each criteria pollutant to the allowable concentrations in the standard (SRNS 2011a).

Many of the documents ATSDR obtained state the results of the criteria pollutant modeling SRS completed between 1993 and 2010, providing an overall picture of estimated criteria pollutant concentrations in ambient air at the SRS site boundary during the time period covered in this

PHA (SCDHEC 1994, 1996, 1997a—1997h, 1998a—1998n, 1999b, 2000, 2001c, 2001d, 2002a, 2002b, 2003, 2004b, 2006d, 2006e, 2010c, 2011d; WSRC 1999b). These air modeling data are quite useful for evaluating offsite exposures to SRS releases, because the modeled pollutant concentrations are comparable to air quality standards, which are levels determined to be safe for the public. Accordingly, in Table 17, ATSDR compares the maximum estimated modeled concentration for each criteria pollutant (over different averaging times) to national and state ambient air quality standards (USEPA's National Ambient Air Quality Standards and SCDHEC's Standard No.2, respectively). (Refer to previous section entitled Current Regulatory Requirements Pertinent to Air Releases at SRS for details on USEPA requirements.)

Table 17. Maximum modeled concentrations of criteria pollutants at the SRS boundary Compared to National Ambient Air Quality Standards (NAAQS) and South Carolina's Standard No. 2

Pollutant	Averaging Time	Maximum Modeled Concentration ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	South Carolina Standard No. 2 ($\mu g/m^3$)	Reference for Maximum Modeled Concentration
Sulfur dioxide	3 hours	2319.06	1300	1300	CDC 2001
Sulfur dioxide[a]	24 hours	1039.10	365	365	CDC 2001
Sulfur dioxide	Annual	78.31	80	80	SCDHEC 1996
PM_{10}	24 hours	145.5	150	150	USNRC 2005
PM_{10}[b]	Annual	31.42	50	50	SCDHEC 1998h
$PM_{2.5}$	24 hours	33	35	35	SCDHEC 2011d
$PM_{2.5}$	Annual	13.6	15	15	USNRC 2005
Carbon monoxide	1 hour	15117	40000	40000	SCDHEC 1998h
Carbon monoxide	8 hours	7472	10000	10000	SCDHEC 1998i
Ozone	1 hour	220	235	NA	USDOE 2001[c]
Nitrogen dioxide	Annual	125.41	100	100	CDC 2001
Lead[d]	For any rolling 3-month average	0.112	0.15	0.15	Kabela 2011

Notes: $\mu g/m^3$ = microgram per cubic meter
[a] The 24-hour and annual NAAQS for sulfur dioxide were revoked in 2010.
[b] The annual NAAQS for PM_{10} was revoked in 2006.
[c] The USDOE 2001 reference is the only document reviewed by ATSDR that contains the results of modeling for ozone.
[d] The NAAQS for lead was 1.5 $\mu g/m^3$ for a calendar quarter until 2008 when it was changed to 0.15 $\mu g/m^3$ for any rolling 3-month average. South Carolina's Standard No. 2 was changed in 2009 to 0.15 $\mu g/m^3$ for a rolling 3-month average.

Maximum modeled concentrations for two pollutants—sulfur dioxide (3- and 24-hour) and nitrogen dioxide (annual)—exceeded their respective ambient air quality standards (see Table 17). The maximum modeled 3- and 24-hour averages for sulfur dioxide were 2319.06 $\mu g/m^3$ and 1039.10 $\mu g/m^3$, respectively. The maximum modeled annual concentration for nitrogen dioxide was 125.14 $\mu g/m^3$. These modeled concentrations were recorded in the CDC's Dose

Reconstruction (CDC 2001), which stated that this modeling incorporated many conservative assumptions and was based upon the maximum permitted limits in 1990. It is important to note that the modeled pollutant concentrations identified in all other source documents for sulfur dioxide and nitrogen dioxide did not exceed the national and state standards for these pollutants. However, because the modeled concentrations of nitrogen dioxide and sulfur dioxide initially exceeded the ambient air quality standards, they are discussed further below.

Sulfur Dioxide

As mentioned previously, Savannah River Site's 1990 modeling referenced in CDC's Dose Reconstruction showed concentrations that possibly exceeded the 3- and 24-hour sulfur dioxide NAAQS. The areas where these exceedances could occur were near the D-area Powerhouse and the A-area. SRS believes one of the primary reasons that the initial modeling showed concentrations that could exceed the nitrogen dioxide and sulfur dioxide NAAQS is that a low stack temperature was used for modeling the D-area Boilers (Gail Whitney, USDOE-SR, personal communication, 2012). Stack temperature is an important modeling parameter and using a low stack temperature could result in an overestimation of the concentrations near the source (USEPA 2005). SCDHEC issued the D-area Powerhouse air permit in August of 1994. The cover letter to this permit stated that it was SCDHEC's conclusion that the D-area Powerhouse could comply with South Carolina Air Quality Control Regulations as long as it was properly run and maintained (SCDHEC 1994).

CDC's Dose Reconstruction also discussed some of the ambient air sampling for criteria pollutants that took place at SRS. While this sampling all took place prior to the time period considered in this PHA (1993-2010), it can provide perspective on the modeling results. In 1977, a program was initiated at SRS that used air sampling equipment in mobile trailers to measure sulfur dioxide which was frequently detected in the D-Area. CDC's Dose Reconstruction reported that the maximum sulfur dioxide level detected by these samplers was 500 $\mu g/m^3$, and the average level for all these stations was 11 $\mu g/m^3$. These values are considerably below the modeled concentrations of 2319.06 $\mu g/m^3$ for the 3-hour standard and 1039.10 $\mu g/m^3$ for the 24-hour standard. By 1985, the SRS monitored air quality at five or six stations. The stations continuously measured particulate matter, ozone, nitrogen dioxide, and sulfur dioxide (CDC 2001). The last full year any of these stations were in operation was 1990. Table 18 summarizes the results of that year's sampling.

Table 18. Maximum 1990 sampled concentrations of criteria pollutants at onsite SRS stations compared to National Ambient Air Quality Standards (NAAQS) and South Carolina's Standard No. 2

Pollutant	Averaging Time	Maximum Sampled Concentration ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	South Carolina Standard No. 2 ($\mu g/m^3$)
Sulfur dioxide	3 hours	130	1300	1300
Sulfur dioxide	24 hours	89	365	365
Sulfur dioxide	Annual	32	80	80
PM_{10}	24 hours	90.6	150	150
PM_{10}	Annual	39.9	50	50
Ozone	1 hour	220	240	240
Nitrogen dioxide	Annual	11	100	100

Notes: $\mu g/m^3$ = microgram per cubic meter
The values reported in SRS's annual environmental reports used to show compliance with annual nitrogen dioxide and sulfur dioxide standards were quarterly averages.
The annual PM_{10} value given is the quarterly geometric mean.
The 24-hour and annual NAAQS for sulfur dioxide were revoked in 2010.
The annual NAAQS for PM_{10} was revoked in 2006.
Source: WSRC 1991

Although SRS did not conduct sampling for criteria pollutants onsite from1993 through 2010, SCDHEC monitored for criteria pollutants in Aiken and Barnwell County during this time period (see General Air Quality section). Sulfur dioxide monitoring took place in Aiken County from 1993 to 1999; and in Barnwell County from 1993 until 2007. The results of this monitoring can be found on USEPA's AirData online repository (USEPA 2012e) as well as on SCDHEC's online Data Monitoring Summaries (SCDHEC 2010b). ATSDR reviewed these data summaries and found the highest value for sulfur dioxide was a 1-hour average of 260 $\mu g/m^3$ in 1999 in Barnwell County (SCDHEC 2012). This value is above the sulfur dioxide 1-hour NAAQS (200 $\mu g/m^3$) that was established in 2010, but it includes releases of sulfur dioxide from other sources in Barnwell County. Furthermore, compliance with this 1-hour standard is determined by calculating a 3 year average[16]. USEPA's Air Data online repository gives the averages for the 1-hour sulfur dioxide measurements in Aiken and Barnwell Counties. The maximum average for the 1-hour sulfur dioxide concentration between 1993 and 2007 was 150 $\mu g/m^3$ (USEPA 2012e).

Nitrogen Dioxide

In addition to the modeled concentrations exceeding the 3- and 24- hour sulfur dioxide standards, initial modeling also showed the annual nitrogen dioxide standard of 100 $\mu g/m^3$ was exceeded by 25.41 $\mu g/m^3$. Later modeling by SRS that corrected for the low stack temperature of the D-area boiler showed compliance with the annual nitrogen dioxide standard. Table 18 also shows that the highest nitrogen dioxide level measured onsite in 1990 was 11 $\mu g/m^3$. According to

[16] The daily 1-hour concentrations of sulfur dioxide for one year are evaluated and the 99th percentile (concentration for which 99% of the results are equal to or below) is calculated. If 3-year average of the annual 99th percentile is below 260 $\mu g/m^3$, compliance with 1-hour sulfur dioxide standard has been demonstrated (USEPA 2011d).

USEPA's AirData online repository and SCDHEC online Monitoring Data Summaries, nitrogen dioxide sampling took place in Aiken County between 1993 and 2008; and in Barnwell County between 1993 and 2007 (USEPA 2012e, SCDHEC 2012). No concentrations exceeding the annual nitrogen dioxide standard were documented. The highest level recorded in these databases in Barnwell and Aiken Counties between 1993 and 2008 was a 1-hour average of 120 $\mu g/m^3$. This level is slightly above the annual NAAQS for nitrogen dioxide; however, it is a 1-hour average and is most appropriately compared to the recently established 1-hour nitrogen dioxide NAAQS of 190 $\mu g/m^3$. The highest 1-hour average is below this level. Therefore, it is unlikely that emissions from SRS exceeded the nitrogen dioxide NAAQS.

How SRS Complies with SCDHEC Standard No.8 for Non-radioactive Toxic Air Pollutants and ATSDR's Evaluation

SCDHEC's Standard No. 8 establishes maximum allowable air concentrations for most of the 257 toxic air pollutants listed in the standard. Compliance with this standard is determined by using air dispersion modeling and the maximum permitted emission limits to estimate concentrations of the 257 pollutants at or beyond the plant property line averaged over a 24-hour period (SCDHEC 2001a, 2001b).

ATSDR was able to obtain several documents that summarize the modeling SRS completed to show compliance with SCDHEC's Standard No. 8. Since different processes and potential emissions took place at SRS between 1993 and 2010, the modeled 24-hour concentrations of some of the Standard No. 8 pollutants varied between 1993 and 2010. Most of the documents obtained by ATSDR updated modeling based upon the maximum potential emission limits in 1998, which was considered a baseline year (USNRC 2005; USDOE 2001).

ATSDR's methodology for evaluating contaminants of concern is discussed in Appendix B. Also, for certain chemicals, the USEPA has established the following reference concentrations (RfCs) which are below the levels at which adverse health effects have been observed:

- Acute Reference Concentrations: An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure for 24 hours or less to a human population (including sensitive subgroups) that is likely to be without an appreciable risk of adverse health effects during a lifetime. Generally used to evaluate non-cancer health effects.

- Chronic Reference Concentrations: An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure for up to a lifetime to a human population (including sensitive subgroups) that is likely to be without an appreciable risk of adverse health effects during a lifetime. Generally used to evaluate non-cancer health effects.

Similarly, ATSDR has established environmental media evaluation guides (EMEGs) for certain chemicals. EMEGs represent concentrations of substances in water, soil, and air to which humans may be exposed during a specified period of time without experiencing adverse health effects:

- Acute exposures are defined as those of 14 days or less
- Intermediate exposures are those lasting 15 days to 1 year
- Chronic exposures are those lasting longer than 1 year.

For certain chemicals, ATSDR has established cancer risk evaluation guides (CREGs). CREGs are media-specific comparison values used to identify concentrations of cancer-causing substances that are unlikely to increase cancer rates in an exposed population (ATSDR 2005a).

The maximum allowable concentrations for Standard No. 8 pollutants are typically derived from occupational exposure limits. SCDHEC took the level workers could be exposed to in an 8-hour day and divided that level by an uncertainty factor (Workgroup on South Carolina Air Toxics Regulation 2000). The maximum allowable concentrations in Standard No. 8 are not typically lower than the chronic RfCs established by USEPA for the same pollutants and are not necessarily as low as ATSDR's EMEGs. Nevertheless, they typically are below the lowest-observed-adverse-effect level (LOAEL) or the no-observed-adverse-effect level (NOAEL) that was used to derive USEPA's RfC or ATSDR's EMEG.

Because compliance with the rule is determined by using the maximum permitted emission limit to calculate the 24-hour average concentration at the site boundary, the results are most appropriately compared to short term exposure guidelines such as ATSDR acute EMEGs. Annual averages are more appropriate for assessing potential non-cancer health effects from chronic exposure (Guinnup 1992; Personal Communication. J.Glass, SCDHEC). Moreover, the actual emissions of a pollutant are often considerably less than the maximum permitted levels. Nonetheless, for screening purposes, the maximum modeled concentration for each pollutant was compared to the maximum allowable concentration in the state rule, USEPA's RfCs, and ATSDR's EMEGs. For most of the modeled pollutants, the estimated maximum concentrations were below the lowest comparison values for non-cancer health effects. Four pollutants (hexavalent chromium, hydrochloric acid, manganese, and nickel) had 24-hour average modeled concentrations greater than a chronic EMEG or RfC. However, when SCDHEC guidelines are used to convert these 24-hour average concentrations to an annual average concentrations, the results were below their respective chronic comparison values. Standard No.8 pollutants with 24-hour average concentrations greater than short term comparison values are shown in the next section.

Airborne mercury was one of the pollutants below the comparison values; however, there has been concern about the amount of mercury in the local environment, especially in Savannah River fish. SRS conducted a pilot program for the monitoring, collection, and analyses of mercury in rainwater from 2005 through 2011. The purpose of this program was to evaluate the collection, analytical methods, and data in order to decide on incorporating this information into the routine environmental surveillance program. SRNL also sponsored a collecting and monitoring station that was part of the National Mercury Deposition Network of the National Atmospheric Deposition Network which provides information on the trends and geographic distribution of mercury (MDN 2012). Further information on the monitoring of mercury in rainwater at SRS is discussed in Appendix D to this report.

Non-Cancer Health Effects from SCDHEC Standard No. 8 Toxic Air Pollutants

Table 19 shows the estimated concentrations of Standard No. 8 pollutants that exceed short term comparison values for non-cancer health effects.

Table 19. Maximum site boundary modeled concentrations of Standard No. 8 pollutants above comparison values for non-cancer health effects.

Pollutant	Maximum Modeled 24-Hour Average Concentration (µg/m^3)	Comparison Value (µg/m^3)	Reference for Comparison Value	Reference for Maximum Modeled Value
Benzene	124.9	29	ATSDR Acute EMEG	SCDHEC 1997b
Cadmium	0.0614	0.03	ATSDR Acute EMEG	SCDHEC 1998g.
Sulfuric Acid	59.27	10.00	South Carolina Standard No. 8	Stewart 1997
Tetrachloroethylene	2889.14	1400	ATSDR Acute EMEG	SCDHEC 2004b
Trichloroethylene	1054.1	21* 190*	USEPA Modeled LOAEL	SCDHEC 2004b

Notes:
µg/m^3 = micrograms per cubic meter

*Recently, the USEPA developed a new RfC for trichloroethylene. As part of this process, USEPA first modeled two levels (21 and 190 µg/m^3) from studies of animals exposed to drinking water containing trichloroethylene that are thought to potentially cause adverse effect levels in humans. Please see the "Public Health Implications" section Of this document for further information.

Because the modeled concentrations are above the screening levels for non-cancer health effects, these chemicals are discussed further in the health implications section of this PHA. However, the modeled results in Table 19 were based on the maximum permitted limits; consequently, the estimated concentrations shown would be an overestimation if SRS never operated at its full permitted capacity. Other conservative assumptions were also often used in the modeling. To better understand the modeling assumptions and how the results of the modeling varied between 1993 and 2010 for the chemicals in Table 19, additional detail is provided below.

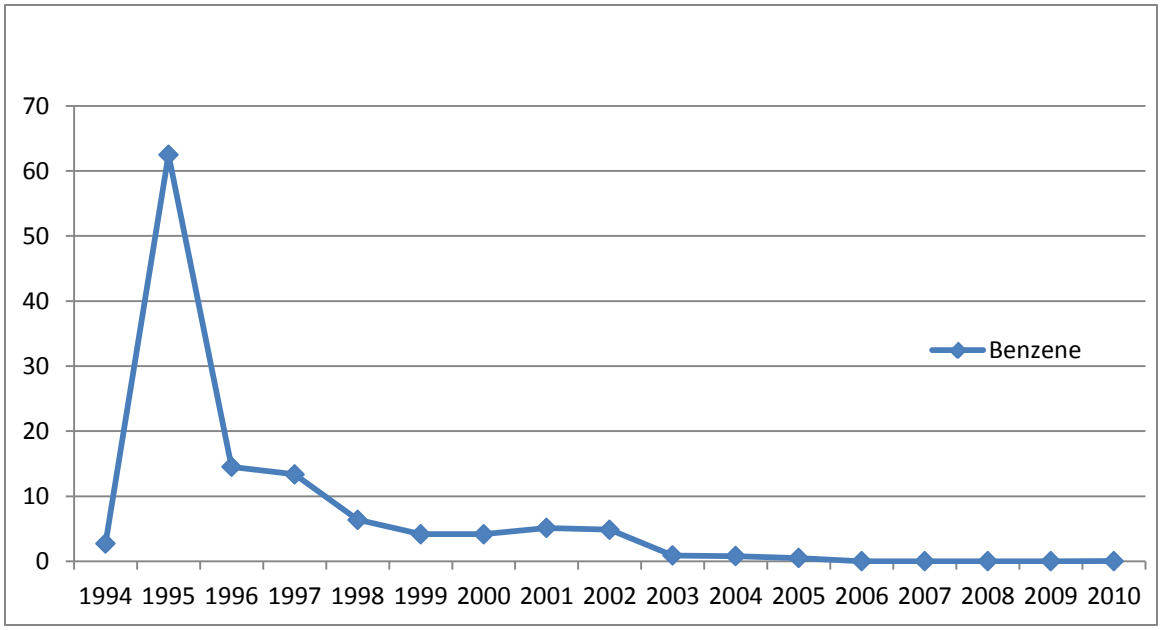
Benzene

The highest modeled value for benzene was 124.9 µg/m^3 which is above ATSDR's acute EMEG (29 µg/m^3), intermediate EMEG (20 µg/m^3), and chronic EMEG (10 µg/m^3). It is also above the USEPA's chronic RfC of 30 µg/m^3. However, 124.9 µg/m^3 was calculated using only Level II analysis and not more refined modeling (SCDHEC 1997b). The Level II analysis was completed as a part of a 1997 construction permit and does not seem to be representative of the estimated concentration for benzene during most of the timeframe considered in this PHA (1993-2010). The 1997 construction permit was for the Benzene Retention and Release Demonstration, a project which was completed by April 10, 1998 (SCDHEC 1998e). The concentration 124.9 µg/m^3 was calculated by adding the impact of the emissions from the Benzene Retention and Release Demonstration to the previous concentration calculated for the site (SCDHEC 1997b). The 24-hour average concentration for benzene typically given in the Air Dispersion Summary

Sheets between 1998 and 2010 is 4.6 µg/m^3 (SCDHEC1998f, 2000, 2001c, 2002a, 2002b, 2003, 2004b, 2006d, 2006e, 2010c). This estimated concentration is based on the 1998 baseline year and is lower than ATSDR's EMEGs and USEPA's chronic RfC for benzene (USNRC 2005, SCDHEC 1998f, USDOE 2001). Modeling, completed by SRNL's ATG in 1997 and based upon the maximum permitted emissions in 1994, estimated the 24-hour concentration of benzene at the site boundary to be 27.74 µg/m^3 (Stewart 1997). The 1997 paper by ATG also demonstrated the difference between modeling based on the maximum permitted emissions, which is recorded in the Air Dispersion Modeling Summary Sheets, and modeling based on the actual emissions. Modeling based on the maximum permitted emissions in 1994 estimated the annual average concentration of benzene to be 3.19 µg/m^3 while the estimated annual concentration based on the actual emissions was 0.602 µg/m^3 (Stewart 1997). The most recent estimate for the concentration of benzene at the property line averaged over a 24-hour period is 0.55 µg/m^3 (SCDHEC 2011d).

SRS's annual environmental reports contain estimates of the actual amounts of Standard No. 8 pollutants emitted in tons per year for the years 1994 to 2010. These estimates provide additional insight into the results of the modeling. It is worth noting that the estimates of the actual amount of benzene emitted from 1995 through 2010 show a downward trend (see Figure 14). The benzene emissions peaked in 1995 at 62.5 tons and have been less than a half a ton per year since 2006 (WSRC 1995, 1996a, 1996b, 1997, 1998b, 1999—2001, 2002b, 2003—2008; SRNS 2009, 2010, 2011a). This downward trend in benzene emissions is consistent with the fact that earlier modeling reports estimated the benzene level at the site boundary to be higher than the current estimate (0.55 µg/m^3). However, Figure 14 does not show an increase between 1997 and 1998, the time when the Benzene Retention and Release Demonstration took place. Therefore, it seems unlikely that the concentration of benzene at the site boundary ever reached 124.9 µg/m^3. A better estimate of the maximum 24-hour average benzene concentration at the site boundary between 1993 and 2010 is the one recorded in Stewart's 1997 paper of 27.74 µg/m^3, although this concentration is likely still an overestimate of the actual concentration because it was based on the maximum permitted emissions. However, potential health effects from exposure to benzene are discussed in the Public Health Implications section of this report.

Figure 14. Benzene Emitted (tons per year) at Savannah River Site between 1994 and 2010



Cadmium

The highest estimated 24-hour concentration of cadmium is above ATSDR's chronic EMEG (0.01 µg/m^3) and acute EMEG (0.03 µg/m^3). However, this estimate is based on the Level II analysis rather than the more refined USEPA models. Other cadmium modeling results reviewed by ATSDR estimate the concentration to be less than 0.01 µg/m^3 (SCDHEC 2000, 2001c, 2002a, 2002b, 2003, 2004b, 2006d, 2006e, 2010c, 2011d; Stewart 1997; CDC 2001). However, cadmium is discussed in the Public Health Implications section of this report.

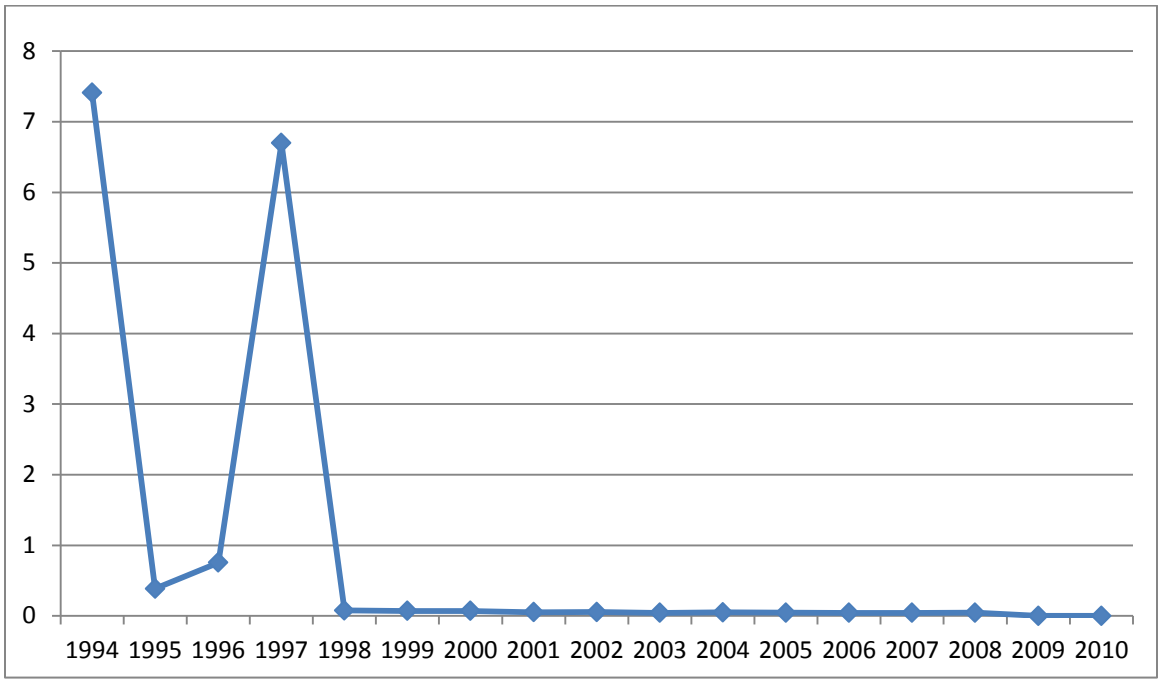
Sulfuric Acid

After reviewing the modeling reports, ATSDR found only one instance where the 24-hour average concentration of a chemical was above the level given in the state rule. The modeled level of sulfuric acid was 59.27 µg/m^3. However, the annual average concentration was estimated to be 3.46 µg/m^3 (Stewart 1997). Additionally, the Air Dispersion Modeling Summary Sheets provided by SCDHEC from 2000 forward show the estimated 24-hour average concentration of sulfuric acid at the site boundary to be 0.12 µg/m^3 or less (SCDHEC 2000, 2001c, 2002a, 2002b, 2003, 2004b, 2011d), a level well below the level established by Standard No. 8 (10 µg/m^3). The 24-hour average concentration 59.27 µg/m^3 and annual average concentration 3.46 µg/m^3 were based on the maximum permitted limits in 1994. Therefore, it is possible that the differences in the modeling results are due largely to the different processes that took place at SRS between 1993 and 2010.

The estimated amount of sulfuric acid emitted in tons per year reported in SRS's environmental reports for the years 1994 to 2010 are shown in Figure 15 (WSRC 1995, 1996a, 1996b, 1997, 1998b, 1999—2001, 2002b, 2003—2008; SRNS 2009, 2010, 2011a). These estimates provide

additional insight into the results of the modeling. As can be seen from Figure 15, the estimated emissions of sulfuric acid were around seven tons per year in 1994 and 1997. The third highest level was around 0.8 tons per year in 1996. ATSDR was not able to obtain the permit limits for all sulfuric acid emission units, but it seems reasonable that the only years SRS may have come close to the maximum permitted sulfuric acid emissions would have been 1994 and 1997. Sulfuric acid is discussed further in the Public Health Implications section of this report.

Figure 15. Reported Savannah River Site Emissions of Sulfuric Acid in Tons Per Year



Tetrachloroethylene (PCE)

Between 1993 and 2010, most PCE emissions at SRS were emitted from the soil vapor extraction units (SVEU) and air strippers used to remediate groundwater and soil contaminated with PCE and other chemicals. A review of the Air Dispersion Modeling Summary Sheets indicates that two of the biggest emitters of PCE during this time frame were the Western Sector Dynamic Underground Stripper (Western Sector DUS) and the SRS Groundwater Closure Project Soil Vapor Extraction Units (SGCP SVEU) (SCDHEC 1999b, 2002b, 2004b).

The highest modeled 24-hour average concentration of PCE was 2889.14 µg/m^3. This concentration is below the level established in Standard No. 8. However, it is above ATSDR's acute EMEG of 1400 µg/m^3 and USEPA's recently published chronic RfC of 40 µg/m^3. A review of the source documents obtained by ATSDR shows that the modeled concentration for PCE was not always estimated to be this high. Modeling based on the maximum permitted emissions in 1994 estimated the maximum 24-hour average concentration of PCE to be 8.70 µg/m^3 and the annual average concentration to be 0.79 µg/m^3 (Stewart 1997). The estimated 24-hour concentration in 1998, the baseline year, was 99.0 µg/m^3 (Hunter 2004a). The estimated

levels of PCE at the site boundary as recorded in the Air Dispersion Modeling Summary Sheets continued to increase after 1998 as SRS continued to add more SVEU and air strippers. The biggest modeled increases occurred when emissions from the Western DUS and SGCP SVEU were added in 2002 and 2004 (SCDHEC 2002b, 2004b). The maximum concentration of 2889.14 µg/m^3 recorded in the Air Dispersion Modeling Summary Sheets between 2004 and 2010 reflects the cumulative impact of all the SVEU and air strippers on site, and apparently also reflects the conservative assumption that all of these units would impact the same point along the site boundary, which is unlikely.

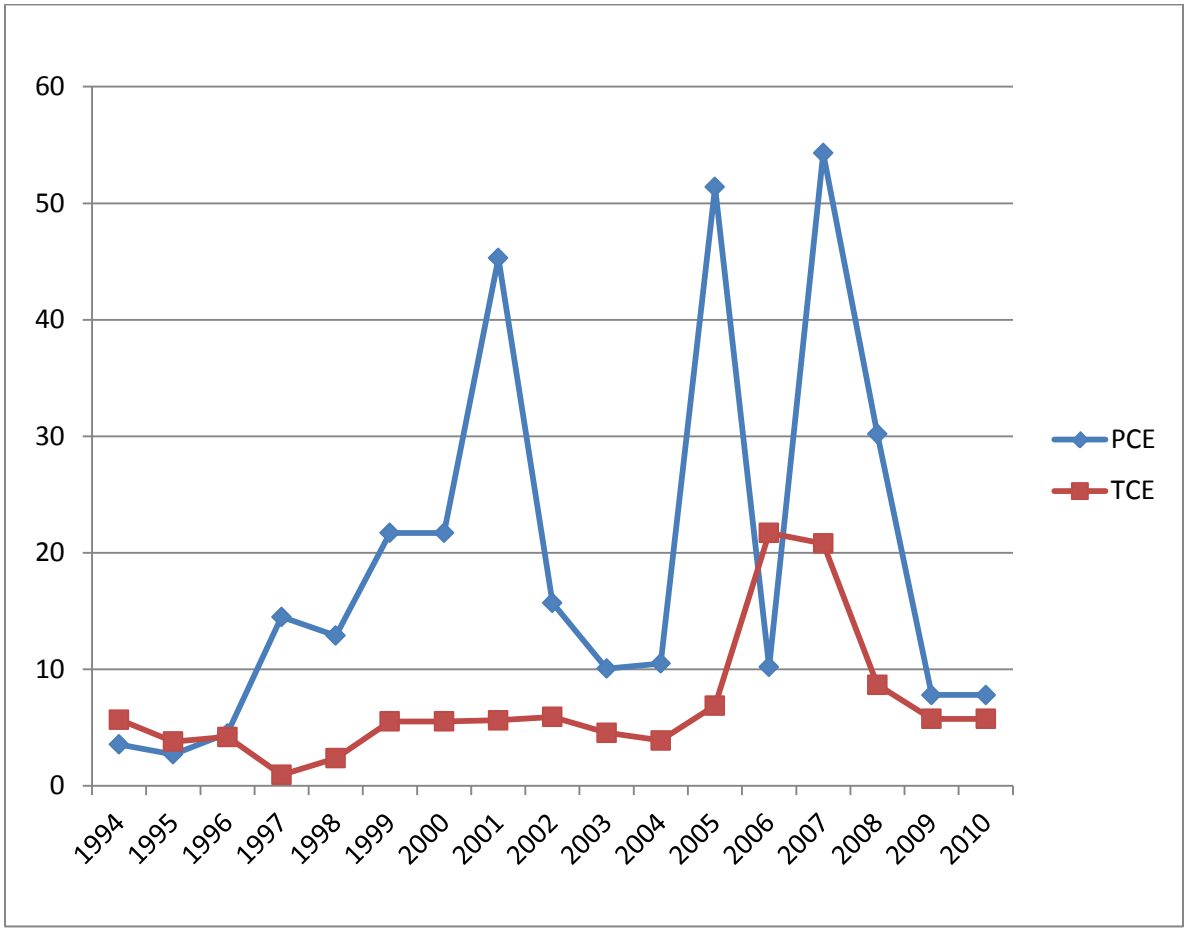
The modeling for the SGCP SVEU, which was completed in 2004, also included several other conservative assumptions. It assumed the emissions from up to 10 units were coming from the worst possible location only 600 feet from the site boundary and estimated the concentration of PCE from the SGCP SVEU to be 1400 µg/m^3 (SCDHEC 2004b; J. Glass, SCDHEC, personal communication, May 25, 2012; Hunter 2004a). Later, the ATG modeled the potential impact of the SGCP SVEU based on the actual worst location and estimated the concentration of PCE at the site boundary from SGCP SVEU to be 780 µg/m^3 (Hunter 2004b). This revised modeling also assumed the lowest stack height and the maximum permitted emission limits.

The SGCP SVEU's modeling used an emission rate of 34.2 pounds of PCE per hour or 150 tons per year (SCDHEC 2004b; Hunter 2004a). ATSDR is unaware of any modeling completed by SRS based on the actual emissions after 2003, but two sources of information on the actual emissions between 2004 and 2010 exist.

1. *SRS Annual Environmental Reports.* The annual reports contain the estimated amounts of Standard No. 8 pollutants emitted in tons per year. Figure 16 shows the tons per year data for PCE and trichloroethylene (discussed in the next section).
2. *Detailed Emission Inventory Reports.* The tons per year data in the annual reports do not break down the emissions by unit, but the detailed reports from SCDHEC's Emissions Inventory Section do. ATSDR reviewed Detailed Emission Inventory Reports for 2005, 2008, and 2010 (the only years between 2004 and 2010 that SRS was required to submit emission inventory reports to the state) (L. Barnes, SCDHEC, personal communication, June 20, 2012).

As shown in Figure 16, the maximum amount of PCE emitted in one year between 2004 and 2010 was 54.3 tons in 2007 (WSRC 2005—2008; SRNS 2009, 2010, 2011a). The Detailed Emission Inventory Reports state that the maximum amount coming from any one of the SGCP SVEU was 1.88 tons per year and the most emitted from all of the SGCP SVEU was 2.83 tons per year (SCDHEC 2005c, 2008b, 2010d). These values are considerably below the modeled parameter of 150 tons per year.

Figure 16. Reported Savannah River Site emissions of tetrachloroethylene (PCE) and trichloroethylene (TCE) in tons per year



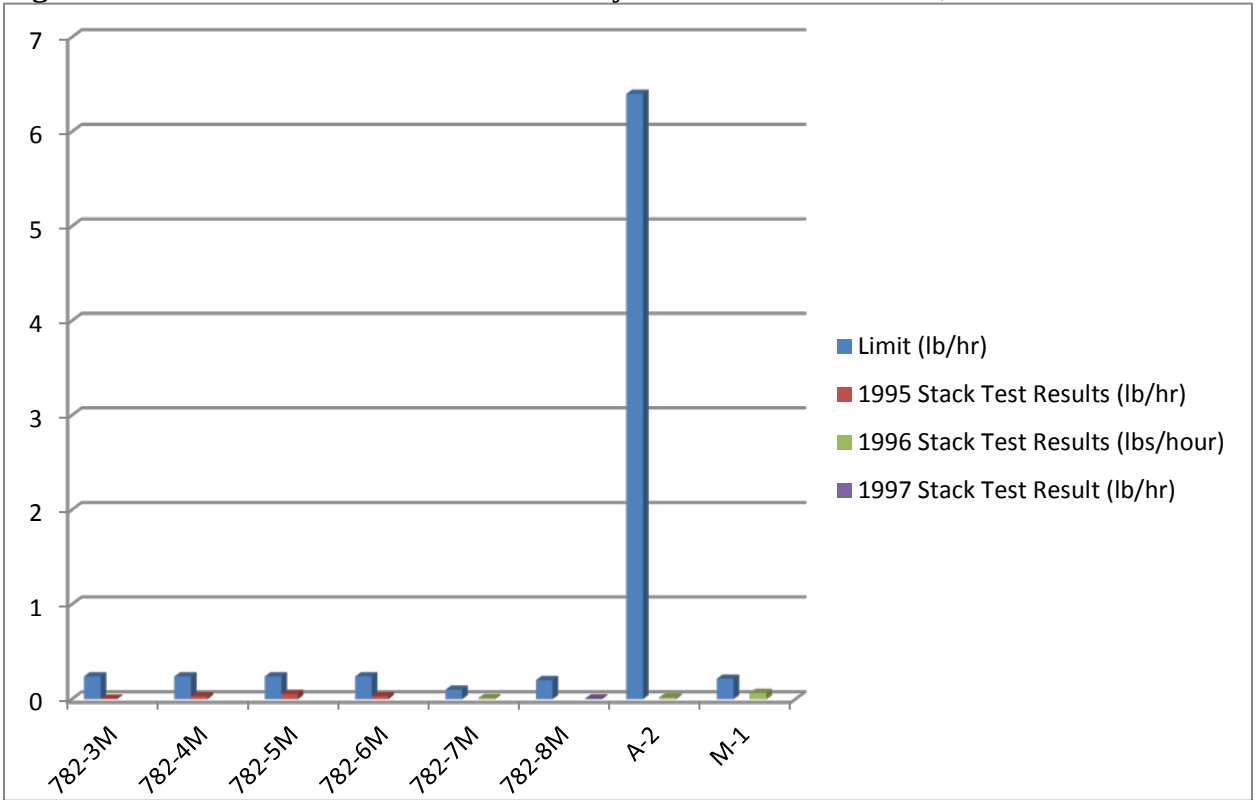
Trichloroethylene (TCE)

The highest modeled site boundary concentration for TCE was 1054.1 µg/m^3, which is above USEPA's recently published RfC of 2 µg/m^3. It is even above the LOAEL of 21 µg/m^3 that the USEPA used to derive the RfC. Like PCE, the emissions of TCE from SRS between 1993 and 2010 came primarily from the SVEU and air strippers used to remediate contaminated ground water and soil. However, this maximum modeled concentration has the same uncertainties as the highest modeled concentration of PCE discussed earlier. Modeling based on the maximum permitted emissions in 1994 estimated the 24-hour average concentration of TCE at the site boundary to be 6.22 µg/m^3 and the annual average concentration to be 0.57 µg/m^3 (Stewart 1997). The modeling based on the maximum potential emissions in 1998 was 23.0 µg/m^3 and the estimated concentration recorded in the Air Dispersion Modeling Summary Sheets continued to increase as more SVEU and air strippers were added to the site. By 2000, the estimated concentration of TCE at the site boundary was 51.8 µg/m^3 (Hunter 2004a, 2004b; SCDHEC 2000). Like PCE, the modeled concentration of TCE recorded in the Air Dispersion Modeling Summary Sheets increased in 2004 as a result of the SGCP SVEU modeling (SCDHEC 2004b)

Considering what is known about the actual TCE emissions between 1993 and 2010 is again helpful. Figure 16 shows that the actual TCE emissions increased after 2004 but decreased since 2006. Another piece of information that suggests using the maximum permitted emissions limits for modeling purposes overestimates the actual concentration of TCE is the stack tests results from 1995 through 1997. During this time, SCDHEC required some of the soil vapor extraction units and air strippers at SRS to be stack tested to show compliance with their permitted limits. The results are available in SRS's annual environmental reports and are summarized in

Figure 17, which compares the stack test results to the permitted limits for six soil vapor extraction units and two air strippers. As can be seen from this figure, the actual emissions were typically well below the permitted limits. Thus, the modeled value for the 1998 baseline year of 23 µg/m^3 likely overestimates the actual TCE concentration at the property line. Additional modeling based on the actual emissions between 2001 and 2003 found the highest annual average concentration of TCE at any point along the site boundary to be 0.063 µg/m^3 (Hunter 2005).

Figure 17. Savannah River Site Trichloroethylene Stack Test Results, 1995-1997.



Notes: Units 782-3M, 782-4M, 782-5M, 782-6M, 782-8M are soil vapor extraction units. Units A-2 and M-1 are air strippers. The different units were given different permitted emission rates.
lb/hr= pound per hour.

The estimated level of TCE from the SGCP SVEU was originally 340 µg/m^3 and the Air Dispersion Modeling Summary Sheets reflect this concentration. However, this concentration was based on emissions from all 10 units coming from the worst location only 600 feet from the boundary (Hunter 2004a; SCDHEC 2004b, 2003; J. Glass, SCDHEC, personal communication,

May 25, 2012). The later modeling based on the actual worst case location of the SVEU estimated the concentration to be 190 µg/m^3. A comparison of TCE emission rates used in 2004 for the SGCP SVEU construction permit modeling and the actual emissions is also possible. The modeling for the SGCP SVEU assumed an emission rate of 8.22 pounds per hour of TCE or 36 tons per year (Hunter 2004a; SCDHEC 2004b). Yet, Figure 16 shows the greatest amount of TCE emitted for the entire site between 2004 and 2010 was 21.7 tons per year (WSRC 2008). The Detailed Emission Inventory Reports from SCDHEC show the maximum amount from any one of the SGCP SVEU was 0.0939 tons per year and the most emitted from all SGCP SVEU was approximately 0.25 tons per year (SCDHEC 2005c, 2008b, 2010d).

Cancer Health Effects from SCDHEC Standard No. 8 Toxic Air Pollutants

The SRS modeling included results for carcinogens such as benzene, tetrachloroethylene, trichloroethylene, arsenic, and beryllium. For these and certain other chemicals, ATSDR has established cancer risk guides (CREGs). CREGs are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons during their lifetime (70 years). ATSDR's CREGs are calculated from USEPA's unit risk values for inhalation exposures (ATSDR 2005a). If the concentration of a pollutant exceeds a CREG, ATSDR conducts further evaluation to estimate the likelihood of increased cancer risk.

The modeling completed to show compliance with South Carolina's Standard No. 8 used the maximum permitted emission limits to estimate the 24-hour concentrations of pollutants at the site boundary. This methodology would not give an accurate estimation of the potential cancer risks. Lifetime cancer risks for inhalation exposures are best estimated using annual average concentrations of chemicals in ambient air (Guinnup 1992). ATSDR was able to obtain only two references with modeled annual concentrations (Stewart 1997; Hunter 2005). The most recent reference estimated the annual average concentrations of Standard No. 8 pollutants at the site boundary based upon the actual emissions between 2001 and 2003 (Hunter 2005). None of the pollutants modeled in this reference were above their respective CREGs. However, the earlier reference which was based on SRS's 1994 emissions estimated the maximum concentration of some pollutants at the site boundary to be above their CREGs. Table 20 lists those pollutants and states the maximum modeled concentration (annual average) and the relevant CREGs.

Table 20. Maximum modeled concentration of Standard No 8 pollutants above cancer risk guides (CREGs)

Pollutant	Maximum Modeled Concentration (µg/m^3)	CREG (µg/m^3)
Arsenic	3.68E-03	2 E-04
Benzene	3.19	0.1
Benzidine*	1.75E-04	1 E-05
Bis (Chloromethyl) ether*	1.75E-04	2 E-05
Chloroform	0.06	0.04
Tetrachloroethylene	0.79	0.2
Trichloroethylene	0.57	0.24

Notes: The averaging time for the maximum modeled concentrations in this table is annual. Modeled concentrations are based on the maximum permitted emission limits in 1994.
* According to SRS's annual reports, benzidine and bis(chloromethyl)ether were never actually emitted between 1994 and 2010.

µg/m^3 is micrograms per cubic meter; CREG = Cancer Risk Evaluation Guideline
Source: Stewart 1997

The estimated amounts of Standard No. 8 pollutants emitted in tons per year contained in SRS's annual reports provide additional insight into the modeling results contained in Table 20. ATSDR reviewed the tons per year data in the annual reports and found that benzidine and bis (chloromethyl) ether were never actually emitted between 1994 and 2010 which is also stated in the report based on the 1994 emissions (Stewart 1997). Therefore, benzidine and bis (chloromethyl) ether were not considered any further.

Public Health Implications

Non-Cancer Health Effects Evaluation

Benzene

Benzene is commonly found in the environment. Benzene levels in the air can be elevated by emissions from burning coal and oil, benzene waste and storage operations, motor vehicle exhaust, and evaporation from gasoline service stations. Natural sources of benzene, which include gas emissions from volcanoes and forest fires, also contribute to the presence of benzene in the environment (ATSDR 2007b).

ATSDR derived its acute and intermediate EMEGs for benzene from two different studies. In both studies benzene was found to affect the lymphocytes in mice, and both studies had a lowest-observed-adverse-effect-level (LOAEL) of 32,000 µg/m^3. From these LOAELs, human equivalent concentrations (HECs) of 8,200 µg/m^3 (for the acute EMEG) and 5,800 µg/m^3 (for the intermediate EMEG) were derived (ATSDR 2007b). The highest modeled 24-hour average concentration of benzene (124.9 µg/m^3) is below the $LOAEL_{HEC}$ derived from these studies. Moreover, the estimates of the benzene concentration at the site boundary based on more refined USEPA models did not estimate the 24-hour average concentration to be as high as 124 µg/m^3. As discussed previously, a more likely estimate of the maximum concentration of benzene individuals could have been exposed to between 1993 and 2010 was 27.74 µg/m^3.

The USEPA based its chronic RfC on a study of workers exposed to benzene with the LOAEL of 24,000 µg/m^3. The USEPA adjusted this LOAEL to account for differences between worker exposure and exposures to the general public and calculated a benchmark concentration of 8,200 µg/m^3. This benchmark concentration was further adjusted to derive the RfC (USEPA 2003). ATSDR's chronic EMEG for benzene was based on a more recent occupational studies and an adjusted benchmark concentration of 100 µg/m^3 (ATSDR 2007b; Lan et al. 2004a, 2004b). A concentration of 124 µg/m^3 is slightly above this level suggesting there could be an increased risk of the health effect observed in the study used to derive the chronic EMEG (a decrease in white blood cells and platelets). However, 124.9 µg/m^3 was an estimate of the highest 24-hour average concentration at the site boundary using Level II analysis for a project that lasted only a little over a year. The occupational studies used to derive the chronic EMEG involved workers exposed to benzene for an average of 6.1 $\pm$ 2.9 years and used 1-month average concentration of benzene (rather than 24-hour averages) to characterize the workers exposures (ATSDR 2007b; Lan et al. 2004a, 2004b). It is also worth noting that a 1997 study did not observe any abnormal

hematological values for workers exposed to an average 8-hour benzene concentration of 1800 μg/m^3 (Collins et al. 1997, ATSDR 2007b). Therefore, non-cancer health effects are not expected from off-site exposures to benzene at SRS.

Cadmium

Cadmium is an element that occurs naturally in the earth's crust. It has many uses in industry and consumer products, and is found in batteries, pigments, metal coatings, plastics, and some metal alloys (ATSDR 2008a).

The highest modeled 24-hour average concentration of cadmium of 0.0641 μg/m^3 is greater than ATSDR's chronic and acute EMEGs (0.03 and 0.01 μg/m^3, respectively). The acute EMEG was derived from a study with a LOAEL of 88 μg/m^3 (ATSDR 2008a). Rats exposed to this concentration of cadmium experienced some respiratory effects, but this level is orders of magnitude above the highest modeled 24-hour average concentration. In deriving the chronic EMEG for cadmium, ATSDR reviewed several studies and concluded that exposure to a cadmium concentration of 0.1 μg/m^3 could affect the kidneys. Moreover, as discussed earlier, the highest modeled 24-hour average concentration was calculated using Level II analysis; and the majority of the modeling results available indicate that the maximum 24-hour average concentration was less than 0.01 μg/m^3. Consequently, adverse health effects from cadmium are not expected.

Sulfuric Acid

Sulfuric acid is a clear, colorless, corrosive oily liquid. The odor threshold of sulfuric acid in air is estimated to be 1000 μg/m^3. Sulfuric acid is found in the air as small droplets or attached to small particles. It dissolves in air moisture and can remain suspended for varying periods of time. It can irritate the nose and throat and cause difficulties breathing if inhaled. Breathing small droplets of sulfuric acid in the air may make it more difficult to breathe. This effect is more likely to occur during exercise or among asthmatics. Common household exposures to sulfuric acid can occur from mixing certain toilet bowl cleaners with water, or from cutting onions. Factors that affect how an individual will respond to sulfuric acid exposure include aerosol size, relative humidity, condition of the individual (e.g., asthmatic), amount of ammonia present in the mouth, breathing rate and depth of breathing (ATSDR 1998).

The USEPA has not developed any reference concentrations for sulfuric acid and has not listed it as one of the 187 federal hazardous air pollutants. Similarly, ATSDR has not developed an EMEG or CREG for sulfuric acid. However, occupational exposure limits for sulfuric acid have been developed. Both the National Institute of Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have established a time-weighted average (TWA) of 1000 μg/m^3 for sulfuric acid[17]. Thus, the modeled 24-hr average concentration of 59.27 μg/m^3 is below the level to which workers may be exposed.

[17] For NIOSH recommended exposure limits, "TWA" indicates a time-weighted average concentration for up to a 10-hour workday during a 40-hour workweek. TWA concentrations for OSHA permissible exposure limits must not be exceeded during any 8-hour work shift of a 40-hour workweek (NIOSH 2007).

Several occupational studies that considered the potential health effects from chronic exposure to sulfuric acid are also available. A slight increase in bronchitis was observed in 460 battery factory workers exposed to sulfuric acid aerosols at an average concentration of 1400 $\mu g/m^3$ for up to 40 years (ATSDR 1998, Williams 1970). No effects on lung function tests were observed. A different study found no effects on lung functions tests for workers exposed to an average concentration of 100 $\mu g/m^3$. The workers in this study were exposed for an average of 12.2 years (Gamble et al. 1984). Based on these studies and the fact that the maximum 24-hour average concentration of sulfuric acid from 2000 forward is 0.12 $\mu g/m^3$, chronic adverse health effects from sulfuric acid exposure are not expected.

Several acute-duration human exposure studies have examined the respiratory effects of sulfuric acid exposure. Because these studies involved exposure times less than 24 hours, it is worthwhile to consider what the maximum 1-hour average may have been. SCDHEC's Air Quality Modeling Guidelines state the 1-hour average concentration is 2.5 higher than the 24-hour average concentration. If this guidance is used to convert the averaging times, the 1-hour average could have been as high as 148.2 $\mu g/m^3$ if SRS had operated at its maximum permitted capacity.

These acute-duration human studies include both asthmatic and non-asthmatic subjects, but asthmatics are considered more sensitive to the effects of sulfuric acid. The clearance of particles from the lungs after sulfuric acid exposure has only been studied in normal individuals. Decreased clearance was observed in subjects exposed to sulfuric acid aerosols with a nasal mask for 1 hour at 980 $\mu g/m^3$ for test particles 7.6 micrometers in diameter and at 108 $\mu g/m^3$ for test particles 4.2 micrometers in diameter (Leikauf 1981, 1984). Similarly, a 1989 study also reported slower clearance in 10 male volunteers exposed to 100 $\mu g/m^3$ of sulfuric acid for 1 or 2 hours (Spektor et al. 1989). In both studies, this effect was temporary. There are several other studies that did not report acute adverse health effects in non-asthmatics exposed to concentrations equal or greater than 100 $\mu g/m^3$, and some studies did not report any adverse health effects in non-asthmatics exposed to sulfuric acid concentration of 1000 $\mu g/m^3$ or greater (ATSDR 1998, Avol et al. 1988, Bowes et al. 1995, Chancy et al. 1980, Frampton et al. 1992, Horvath et al. 1987, Kulle et al. 1982, Gamble et al. 1984). Therefore, it is unlikely that exposure to sulfuric acid would have resulted in acute effects in non-asthmatics even if SRS operated at its maximum permitted capacity and the 1-hour average concentration was as high as 148.2 $\mu g/m^3$.

The lowest concentration that resulted in changes in lung function tests in studies of asthmatic subjects was 70 $\mu g/m^3$ (ATSDR 1998, Hanley et al. 1992). Adolescent asthmatics in this study were exposed to sulfuric acid for 40-45 minutes with intermittent exercise and experienced transitory decreases in FVC (a measure of the amount of air that can be forcefully exhaled rapidly after maximal inspiration) and FEV_1 (the amount of air that can be forcefully exhaled in 1 second). Respiratory effects have also been reported in asthmatics exposed to 100 $\mu g/m^3$ for 50 minutes with exercise (ATSDR 1998, Koenig et al. 1985). Although asthmatics are considered more sensitive to changes in lung function following exposure to sulfuric acid, not all studies have reported changes in lung function tests in asthmatics exposed to sulfuric acid aerosols. For example, changes in lung function tests were not observed in asthmatics exposed to 100 $\mu g/m^3$ for 1 hour with intermittent exercise. Lung function was affected in 1 of 15 exposed subjects leading the study authors to conclude there may be a subgroup of asthmatics that are more sensitive to sulfuric acid exposure (ATSDR 1998, Anderson et al. 1992). In fact, one study found no adverse respiratory effects in asthmatics exposed to 410 $\mu g/m^3$ of sulfuric acid for 1 hour with

alternating 10-minute periods of exercise (Linn et al. 1986). Taken together, the studies suggests that temporary acute health effects from past SRS emissions of sulfuric acid could only have occurred if the facility operated at its maximum permitted capacity and highly susceptible individuals were exposed to the sulfuric acid at the site boundary. However, it appears from the 1997 paper by Stewart that the susceptible individual would have to have been at the point of maximum impact along the boundary. Additionally, as shown in Figure 15, the only years SRS may have been close to the maximum permitted sulfuric acid emissions were 1994 and 1997.

Tetrachloroethylene

Historically, tetrachloroethylene has been used as a metal degreaser, dry cleaning solvent, and even a general anesthetic. It is also known as perchloroethylene or PCE (ATSDR 1997a). Ambient air concentrations as high as 220 $\mu g/m^3$ for samples collected over a 24-hour period have been detected in the United States (USEPA 1985). The highest modeled concentration of PCE at SRS (a 24-hour average concentration of 2889 $\mu g/m^3$) is above this level as well as above the screening levels set by ATSDR and the USEPA.

ATSDR reviewed several studies in deriving both the acute and chronic EMEGs for tetrachloroethylene and based its acute EMEG on a study in which human volunteers were exposed to tetrachloroethylene for 4 hours a day for 4 days. The NOAEL for this study was 68,000 $\mu g/m^3$ (ATSDR 1997a); however, this study involved only a 4-hour exposure time. It is therefore worthwhile to consider what the 1-hour average concentration may have been. If SCDHEC guidelines are used to convert the 24-hour average concentration to a 1-hour average for the SRS modeled value, the 1-hour average may have been as high as 7223 $\mu g/m^3$. This concentration is well below the NOAEL observed in the study used to derive the acute EMEG.

The neurological effects of PCE have also been observed in several chronic exposure studies. Compared to 30 unexposed women, significantly prolonged reaction times were reported in 60 women occupationally exposed to tetrachloroethylene at a median concentration of 102,000 $\mu g/m^3$ for an average of ten years (ATSDR 1997a, Ferroni et al. 1992). Dry cleaning workers exposed to a time weighted average concentration of 81,000 $\mu g/m^3$ or 370,000 $\mu g/m^3$ had significantly impaired perceptual function, attention, and intellectual function compared to a control population when evaluated by a battery of psychological tests and questionnaires (Seeber 1989, ATSDR 1997a). Another study of 22 Belgian dry cleaners exposed to a time-weighted average concentration of 140,000 $\mu g/m^3$ over an average of 6 years found no significant alterations in neurological symptoms or psychomotor performances compared to 33 unexposed controls. However, subjective neurological symptoms, particularly memory loss and difficulty in falling asleep, were more prevalent in the exposed group (Lauwerys et al. 1983, ATSDR 1997a). Similarly, workers exposed to a geometric mean tetrachloroethylene concentration of 140,000 $\mu g/m^3$ for 1 to 120 months also reported an increase in subjective symptoms including dizziness and forgetfulness relative to controls (Cai et al. 1991, ATSDR 1997a). In a study of 65 dry cleaners exposed to tetrachloroethylene for at least a year, behavioral tests that measured short-term memory for visual designs showed deficits in the high-exposure group (280,000 $\mu g/m^3$) compared to the low-exposure group (76,000 $\mu g/m^3$) (Echerverria et al. 1995, ATSDR 1997a). Loss of color vision is one of the potential effects of tetrachloroethylene exposure reported in the literature at relatively low concentrations, but the reports on this effect are conflicting. No effect on blue-yellow color vision was noted in 30 men or 34 women occupationally exposed to

tetrachloroethylene at average concentrations of 104,000 µg/m^3 or 73,000 µg/m^3, respectively (Nakatsuka et al. 1992, ATSDR 1997a). However, loss of color vision in the blue-yellow range was observed in dry cleaners exposed to an average concentration of 50,000 µg/m^3 for an average of 106 months (ATSDR 1997a, Cavalleri et al. 1994). But the exposure concentrations in this study were measured in a single day, and it is unclear how well this measurement represents the workers long term exposure. Moreover, the mechanism of color vision loss and the contribution of peak exposure to this effect are not known. Nevertheless, since many of the occupational studies involve workers exposed to tetrachloroethylene for more than a year, it is helpful to consider what the annual average concentration of tetrachloroethylene may have been. If the SCDHEC guidance is used to convert the maximum 24-hour average concentration into an annual average, the resulting PCE concentration is 361.14 µg/m^3, which is at least an order of magnitude below the concentration at which workers experienced health effects. Furthermore, since the highest modeled tetrachloroethylene concentration was based on very conservative assumptions as discussed previously, it seems unlikely that the 24-hour average concentration of tetrachloroethylene at SRS would have been as high as 2,889.14 µg/m^3.

Since no air dispersion modeling estimating tetrachloroethylene concentrations at the SRS boundary based upon the actual SRS emissions exist after 2004, ATSDR considered the results of USEPA's 2005 National-Scale Air Toxics Assessment (2005 NATA). The 2005 NATA is a tool used to prioritize and characterize public health risk from air toxics including both cancer and non-cancer. USEPA used emission inventories and modeling to characterize these risks for all counties in the United States (USEPA 2011a, 2011b). USEPA strongly cautions that these estimates should not be used to compare risks between neighborhoods or to pinpoint the risk from specific sources in a census tract (USEPA 2011a, 2011b). Nevertheless, it is helpful to consider the estimated concentration of tetrachloroethylene in the three SRS counties. The estimated concentrations of tetrachlorethylene in Aiken, Allendale, and Barnwell counties are 0.081 µg/m^3, 0.034 µg/m^3, and 0.037 µg/m^3, respectively (USEPA 2011c). The 2005 NATA also estimated the South Carolina statewide concentration of tetrachloroethylene to be 0.086 µg/m^3. These estimated concentrations are below levels of health concern and suggest there is not an increased risk of health effects from tetrachloroethylene simply from living in Aiken, Allendale and Barnwell Counties.

Trichloroethylene

Trichloroethylene has also been historically used as a metal degreaser, but has also been used in several consumer products (ATSDR 1997b). It is also known as TCE. A review of the sampling results of 115 monitors that collected TCE data in 1998 found the concentration of TCE in the ambient air ranged between 0.01 µg/m^3 and 3.9 µg/m^3 (Wu and Schaum 2000). However, levels as high as 6.4 µg/m^3 have been detected in the United States and as high as 36 µg/m^3 have been detected in Finland. Indoor air can also be a significant source of exposure to TCE. A survey of indoor air found levels as high as 27 µg/m^3 in a North Carolina office building (ATSDR, 1997b). The highest modeled level of TCE (1054.1 µg/m^3) is well above these levels as well as above USEPA's recently derived LOAELs of 21 µg/m^3 and 190 µg/m^3. However, USEPA's recently derived LOAELs are also modeled values.

USEPA identified one rat and one mouse study as the basis of the Reference Concentration (RfC) for noncancerous effects (USEPA 2011e, 2012g). The exposure route in both studies was

via ingestion of TCE in drinking water. The most sensitive adverse effects involved the immune system and the developing fetus (Johnson et al. 2003, Keil et al. 2009). In both studies, USEPA used physiologically based pharmacokinetic (PBPK) modeling to convert the oral TCE dose in animals to a human equivalent concentration (HEC) in air (USEPA 2001).

To summarize the results, USEPA predicts that:

- a small risk of fetal heart malformations exists for pregnant women exposed to TCE at 21 $\mu g/m^3$, and
- a small risk of decreased thymus weight exists for humans exposed to TCE at 190 $\mu g/m^3$.

To derive the RfC of 2 $\mu g/m^3$, USEPA used an uncertainty factor of 10 for interspecies extrapolation of fetal heart malformations in rats and an uncertainty factor of 100 for decreased thymus weight in mice (10 fold for interspecies extrapolation and 10 fold for LOAEL).

A recently released epidemiologic study concluded that maternal residence in areas where soil vapor intrusion of TCE or PCE into indoor air was associated with cardiac defects (Forand et al. 2012). Although the study did not evaluate a dose-response relationship, it suggests that cardiac effects are the appropriate toxicological endpoint in humans and supports the use of the animal studies for the RfD/RfC.

There is great uncertainty in drawing conclusions about the potential health impacts from trichloroethylene for residents near the Savannah River Site. One of the uncertainties is that since no suitable inhalation studies are available, the RfC is based on animal studies where exposure occurred through drinking water. PBPK modeling was used to convert an oral dose (in mg/kg/day) in animals to a human equivalent concentration in air (in $\mu g/m^3$), and bench mark dose modeling was used to estimate the air concentration that equates to a 1% response rate for the fetal cardiac effects. The exposure level associated with a 1% response rate is a model prediction and is below the level that has been evaluated in any experimental study or exposed human population. Additionally, although the highest modeled 24-hour average concentration is well above the concentrations at which USEPA predicts there could be possible health effects, this concentration was calculated using several conservative assumptions including the assumption that SRS was running at its maximum permitted capacity. Clearly, modeling based on SRS's actual emissions between 2004 and 2010 would be beneficial.

Since the USEPA based the potential health effect of decreased thymus weight on a chronic study, it is also worth considering what the annual average concentration of trichloroethylene may have been. If SCDHEC guidance is used to convert the highest modeled 24-hour average concentration to an annual concentration, the result is only 131.8 $\mu g/m^3$; and if the most recently modeled 24-hour average concentration (548.42 $\mu g/m^3$) is converted to an annual average, the result is only 68.6 $\mu g/m^3$. These annual concentrations are below the 190 $\mu g/m^3$ level at which USEPA predicts that a small risk of decreased thymus weight exists. However, it is still above the level at which the USEPA predicts there is a small increased risk of fetal cardiac malformations as discussed earlier.

In order to gain a broader perspective of trichloroethylene exposures, it is again helpful to consider the county-wide 2005 NATA estimates. The estimated trichloroethylene concentrations

for Aiken, Allendale, and Barnwell counties are 0.042 µg/m^3, 0.022 µg/m^3, and 0.026 µg/m^3, respectively (USEPA 2011c). The South Carolina state-wide trichloroethylene concentration was estimated to be 0.047 µg/m^3. Like tetrachloroethylene, there does not seem to be an increased health risk from trichloroethylene exposure from merely living in Aiken, Allendale, or Barnwell County.

Cancer Health Effects Evaluation

Cancer risk estimates calculated for exposures occurring during adulthood and childhood are combined and expressed as the risk of an individual developing cancer over his or her lifetime. It should be noted that an increased cancer risk is not a specific estimate of expected cancers. Rather, it is an estimate of the increase in the probability that a person may develop cancer sometime during his or her lifetime following exposure to a particular chemical. The recommendations of many scientists, including ATSDR and USEPA, has been that an increased lifetime cancer risk of one in one million (1×10^{-6}) or less is generally considered an insignificant increase in cancer risk. Cancer risk less than 1 in 10,000 (or 1×10^{-4}) is not typically considered a health concern. In a 1990 study, the USEPA estimated the lifetime risk of cancer from outdoor air pollutants in urban areas varied between 1×10^{-5} and 1×10^{-3} (USEPA 1990). More recently, the USEPA has estimated the national average cancer risk as a result of breathing air toxics from outdoor sources to be 50 in a million (5×10^{-5}) (USEPA 2011b).
Increases in cancer risk can be estimated by multiplying the maximum concentrations of carcinogenic pollutants by the USEPA's inhalation unit risk for each pollutant and summing the results (Guinnup 1992). Using this approach, Table 21 gives an estimate of the increased cancer risk by using the maximum annual concentrations listed in Table 20. The increase in cancer risk is estimated to be 4.44×10^{-5} for residents that would be exposed to the maximum annual concentrations of carcinogenic pollutants in 1994 for 70 years. This estimate indicates no apparent increase in cancer risk and is consistent with USEPA's most recent estimate of the national average in 2005 (USEPA 2011b).

Table 21. Calculation of increased cancer risk based on Savannah River Site's maximum potential Emissions in 1994

Pollutant	Maximum Modeled Concentration (µg/m^3)	Inhalation Unit Risk (µg/m^3)$^{-1}$	Increased Risk
Arsenic	3.68E-03	4.3E-03	1.58 E-05
Benzene	3.19	7.8E-06	2.49 E-05
Chloroform	0.06	2.3 E-05	1.38 E-06
Trichloroethylene	0.57	4.1 E-06	2.34 E-06
Total			4.44 E-05

Notes: The averaging time for the maximum modeled concentrations in this table is annual. Modeled concentrations are based on the maximum permitted emission limits in 1994.
µg/m^3 is micrograms per cubic meter.

Source: Stewart 1997

There are, however, important limitations to the estimates given in Table 21. The concentrations used were based upon the maximum permitted limits in 1994.

Air Dispersion Modeling Summary Sheets suggest that the potential arsenic and benzene emissions are currently less than the potential emissions of these pollutants in 1994. The calculations for the results in this table assumed a 70-year exposure to the concentrations given. However, a later reference showed no Standard No. 8 pollutants above the CREG (Hunter 2005).

As discussed previously, the Air Dispersion Modeling Summary Sheets indicate the potential emissions of tetrachloroethylene and trichloroethylene have increased since 1994. Similarly, the Air Dispersion Modeling Summary Sheets indicate the levels of chloroform could potentially have increased since 1994. The maximum 24-hour concentration of chloroform based on the 1994 emissions was 1.11 $\mu g/m^3$, but the maximum level in the Air Dispersion Modeling Summary Sheets is 89.812 $\mu g/m^3$ (Stewart 1997, SCDHEC 2006d).

The most current results of modeling completed by SRS, as a part of their Title V renewal, shows 24-hour averages above the CREGs for PCE, TCE, and chloroform as well as other chemicals. If SCDHEC guidelines are used to convert the 24-hour concentrations of PCE, TCE, and chloroform to annual averages, the resulting levels would show potential cancer risks greater than 1×10^{-4} for these three chemicals. Although the levels for PCE and TCE listed in the Air Dispersion Modeling Summary Sheets are based on very conservative assumptions as discussed previously, no sampling or modeling results after 2003 exist to establish the actual levels of PCE and TCE at the site boundary.

However, the USEPA's 2005 National-scale Air Toxics Assessment (2005 NATA) estimates the cancer risk for Aiken, Allendale, and Barnwell counties: 4.8×10^{-5}, 3.5×10^{-5}, and 3.7×10^{-5}, respectively (USEPA 2011h). The 2005 NATA also estimated the state-wide cancer risk as 4.2×10^{-5}. Overall, these results suggest there are no apparent increased cancer risks from living in Aiken, Allendale, or Barnwell Counties, but the 2005 NATA estimates should not be used to estimate the risk for specific individuals or at specific locations (i.e., "hotspots") (USEPA 2011f, 2011g).

Child Health Considerations

ATSDR recognizes that infants and children can be more sensitive to environmental exposure than adults in communities faced with contamination of their water, soil, air, or food. Children are not small adults; a child's exposure can differ from an adult's in many ways. Developing fetuses, infants, and children have unique vulnerabilities. This sensitivity is a result of (1) children's higher probability of exposure to certain media because they crawl on the floor, put things in their mouths, play closer to the ground, and spend more time outdoors; (2) children's shorter height, which means that they can breathe dust, soil, and vapors close to the ground; and (3) children's generally smaller stature, which means childhood exposure will result in higher doses of chemical exposure per body weight (i.e., a child drinks more liquid, eats more food, and breathes more air per unit of body weight than an adult). Also, young children have less ability to avoid hazards because they lack knowledge and depend on adults for decisions. As part of ATSDR's Child Health Initiative, ATSDR is committed to evaluating the special interests of children at sites such as SRS.

Conclusions

This PHA addresses the potential for off-site human exposure to radioactive and chemical airborne contaminants released from sources at the Savannah River Site. The evaluation emphasized the period of time following the CDC Dose Reconstruction Project (from 1993 through 2010).

Based on information reviewed by ATSDR, emissions of *radioactive materials* and *criteria pollutants* (carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide) from SRS were at levels unlikely to cause adverse health effects for the general population.

Due to limited information, ATSDR cannot make a public health conclusion for non-cancer health effects from *trichloroethylene* emissions from the Savannah River Site between 1997 and 2010.

Due to limited information, ATSDR cannot make a public health conclusion for potential cancer health effects from *toxic air pollutants* (257 air pollutants listed in South Carolina Standard No.8 regulation) released from the Savannah River Site.

Due to limited information, ATSDR cannot make a public health conclusion for potential adverse health effects in highly sensitive asthmatics from Savannah River Site emissions of *sulfuric acid* in 1994.

Recommendations

USDOE-SR should conduct air modeling for *trichloroethylene* based on actual emissions between 1997 and 2010. The modeling should include both short and long term averaging times.

USDOE-SR should conduct air dispersion modeling for all carcinogenic South Carolina Standard No. 8 pollutants based on the actual emissions between 2004 and 2010.

USDOE-SR should consider ambient air sampling at the site boundary for South Carolina Standard No. 8 air pollutants to better understand the relationship between the modeled and actual concentrations of these pollutants.

USDOE-SR should continue to monitor for airborne radioactive materials and model releases of criteria pollutants as long as release sources continue to be present at the Savannah River Site.

Public Health Action Plan

The public health action plan for SRS contains a description of actions taken at the site and those to be taken at the site following completion of this public health assessment. The purpose of the public health action plan is to ensure that this document not only identifies potential and ongoing public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to harmful substances in the environment. The following public health actions at SRS are completed, ongoing, or planned:

Completed Actions

SRS has been monitoring releases of airborne radioactive materials from the plants and facilities at the site since they went in to operation in the early 1950s.

SRS has modeled offsite concentrations from chemical releases at the site in accordance with required SCDHEC permitting requirements.

SRS has replaced their coal-fired steam plants and powerhouses with biomass plants, eliminating the release of many of the hazardous environmental contaminants caused by burning coal.

Ongoing Actions

Although some of the original sources of airborne radioactive materials are no longer operating, SRS continues to monitor, estimate, and report routine and non-routine releases from the reactor buildings; separation, waste management, and tritium facilities, diffuse and fugitive sources; and the Savannah River National Laboratory. SRS uses models to estimate potential exposures to off-site populations from airborne radioactive releases and maintains air monitoring stations throughout the site, at the site boundary, and at specified distances from the site.

The States of South Carolina and Georgia also maintain offsite air monitoring stations in order to detect offsite concentrations of airborne radioactive materials. During the period covered by this public health assessment (1993 through 2010), South Carolina has increased the number of offsite air monitoring stations, and Georgia has significantly decreased the number of air monitoring stations,

New applications for chemical releases are modeled based on current permitted releases and potential new releases.

Planned Actions

ATSDR will release this document as a public comment draft to receive comments from stakeholders. A press release will be issued announcing the release and where copies of the document are available for review. Copies of this public health assessment will be provided to interested stakeholders and to state and federal governments.

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APPENDICES

Appendix A. ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Ambient
Surrounding (for example, ambient air).

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An

"exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

EPA
United States Environmental Protection Agency.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public health surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Public meeting
A public forum with community members for communication about a site.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see public health surveillance]

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tritium

A common name for radioactive hydrogen

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)
National Center for Environmental Health (CDC) (http://www.cdc.gov/nceh/dls/report/glossary.htm)
National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

Appendix B. ATSDR's Methodology for Evaluating Contaminants of Concern

ATSDR scientists select contaminants for further evaluation by comparing the maximum environmental contaminant concentrations or potential radiation doses against health-based comparison values (CVs). The CVs are developed by ATSDR from available scientific literature related to exposure and health effects. CVs reflect an estimated contaminant concentration or radiation dose that is *not likely* to cause adverse health effects, assuming a standard daily contact rate (e.g., an amount of water or soil consumed or an amount of air breathed) and representative body weight. ATSDR's CVs represent contaminant concentrations that are many times lower than levels at which no adverse health effects were observed in studies on experimental animals or in human epidemiologic studies and are considered protective of public health in essentially all exposure scenarios. Thus, chemical concentrations or radiation doses below ATSDR's CVs are not considered for further evaluation. For radioactive materials, the comparison value is based on a potential radiation dose from one or more radioactive substances via multiple pathways.

ATSDR comparison values are used as screening values in the preliminary identification of site-specific "contaminants of concern." The latter term should not be misinterpreted as an indication of "hazard." As ATSDR uses the phrase, a "contaminant of concern" is a chemical or radioactive substance detected at the site in question and selected by the health assessor for further evaluation of potential health effects. Generally, a chemical or a radioactive material is selected as a "contaminant of concern" because its maximum concentration in air, water, or soil at the site or the resulting potential radiation dose exceeds one of ATSDR's comparison values.

Nevertheless, it must be emphasized that comparison values are not thresholds of toxicity. Although concentrations at or below the relevant comparison values could reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects. The principal purpose behind conservative, health-based standards and guidelines is to enable health professionals to recognize and resolve potential public health hazards before they become actual public health consequences. Thus comparison values are designed to be preventive-rather than predictive-of adverse health effects. The probability that such effects will actually occur does not depend on environmental concentrations alone, but on a unique combination of site-specific conditions and individual lifestyle and genetic factors that affect the route, magnitude, and duration of actual exposure.

If the chemical or radioactive material is selected as a "contaminant of concern", then ATSDR further analyzes the site-specific exposure variables (such as exposure locations and duration and frequency of exposures) and the scenario similarity to the toxicologic research for the contaminant and the epidemiologic studies. This analysis is discussed in the Public Health Implications section of the main report.

Listed and described below are the various comparison values that ATSDR uses to select chemicals or radioactive substances for further evaluation, as well as other non-ATSDR values that are sometimes used to put environmental concentrations into perspective.

CREG	=	Cancer Risk Evaluation Guides
MRL	=	Minimal Risk Level
EMEG	=	Environmental Media Evaluation Guides
RMEG	=	Reference Dose Media Evaluation Guide
RfD	=	Reference Dose
RfC	=	Reference Dose Concentration
RBC	=	Risk-Based Concentration
MCL	=	Maximum Contaminant Level

Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations expected to cause no more than one excess cancer in a million persons exposed over a lifetime. CREGs are calculated from EPA's cancer slope factors, or cancer potency factors, using default values for exposure rates. That said, however, neither CREGs nor cancer slope factors can be used to make realistic predictions of cancer risk. The true risk is always unknown and could be as low as zero.

Minimal Risk Levels (MRLs) are estimates of daily human exposure to a chemical (doses expressed in mg/kg/day) or radioactive material (doses expressed as mrem/yr, or mSv/yr) that are unlikely to be associated with any appreciable risk of deleterious non-cancer effects over a specified duration of exposure. MRLs are calculated using data from human and animal studies and are reported for acute (first to 14 days), intermediate (15 through 364 days), and chronic (365 or more days) exposures. MRLs for specific chemicals are published in ATSDR toxicological profiles.

Environmental Media Evaluation Guides (EMEGs) are concentrations that are calculated from ATSDR minimal risk levels by factoring in default body weights and ingestion rates. They factor in body weight and ingestion rates for acute exposures (Acute EMEGs — those occurring for 14 days or less), for intermediate exposures (Intermediate EMEGs — those occurring for more than 14 days and less than 1 year), and for chronic exposures (Chronic EMEGs — those occurring for 365 days or greater).

Reference Dose Media Evaluation Guide (RMEG) is the concentration of a contaminant in air, water or soil that corresponds to EPA's RfD for that contaminant when default values for body weight and intake rates are taken into account.

Reference Dose (RfD) is an estimate of the daily exposure to a contaminant unlikely to cause noncarcinogenic adverse health effects. Like ATSDR's MRL, EPA's RfD is a dose expressed in mg/kg/day.

Reference Concentrations (RfC) is a concentration of a substance in air that EPA considers unlikely to cause noncancer adverse health effects over a lifetime of chronic exposure.

Risk-Based Concentrations (RBC) are media-specific concentrations derived by Region III of the Environmental Protection Agency from RfDs, RfCs, or EPAs cancer slope factors. They represent concentrations of a contaminant in tap water, ambient air, fish, or soil (industrial or residential) that are considered unlikely to cause adverse health effects over a lifetime of chronic exposure. RBCs are based either on cancer or non-cancer effects.

Maximum Contaminant Levels (MCLs) represent contaminant concentrations in drinking water that EPA deems protective of public health (considering the availability and economics of water treatment technology) over a lifetime (70 years) at an exposure rate of 2 liters of water per day.

Appendix C. USEPA's RadNet Sampling Results for Barnwell, South Carolina and GDNR/SCDHEC Maximum Tritium Concentrations in Rainwater

Table C-1. RadNet (ERAMS) air filter sampling results for Barnwell, South Carolina in pCi/m^3

Date	Beryllium-7	Cesium-137	Plutonium-238	Plutonium-239	Uranium-234	Uranium-235	Urnium-238
30-Jun-93	NR	NR	2.1E-07	5.7E-07	1.68E-05	1.06E-06	2.04E-05
31-Dec-93	NR	NR	3.9E-08	1.1E-07	5.18E-06	2.94E-07	5.06E-06
30-Jun-94	NR	NR	9.0E-08	4.6E-07	1.15 E-05	5.6E-07	1.06E-05
31-Dec-94	NR	NR	2.5E-08	2.77E-07	8.6E-06	3.0E-07	8.38E-06
30-Jun-95	NR	NR	4.0E-08	1.19E-07	8.75E-06	4.5E-07	1.09E-05
31-Dec-95	NR	NR	2.7E-07	1.95E-07	9.8E-06	8.3E-07	1.13E-05
31-Dec-96	NR	NR	4.0E-07	1.8E-07	1.29E-05	1.21E-06	1.06E-05
31-Dec-97	NR	NR	1.15E-07	1.38E-07	1.31E-05	1.29E-06	1.12E-05
31-Dec-98	NR	NR	3.6E-07	2.4E-07	1.04E-05	8.7E-07	1.19E-05
31-Dec-99	NR	NR	1.1E-07	1.6E-07	9.47E-06	4.5E-07	9.12E-06
31-Dec-00	NR	NR	4.9E-07	1.0E-07	9.01E-06	3.3E-07	7.02E-06
31-Dec-01	NR	NR	2.1E-07	1.05E-07	1.10E-05	8.1E-07	1.02E-05
31-Dec-02	NR	NR	1.7E-07	2.8E-07	1.44E-05	1.02E-06	1.19E-05
31-Dec-03	NR	NR	5.0E-08	1.3E-08	3.8E-06	2.8E-07	3.48E-06
31-Dec-04	NR	NR	3.5E-07	0	8.0E-06	3.9E-07	8.3E-06
31-Dec-05	NR	NR	2.9E-07	2.9E-07	7.6E-06	3.5E-07	6.09E-06
31-Dec-06	NR	NR	8.2E-07	4.1E-07	2.11E-05	1.57E-06	2.15E-05
31-Dec-07	NR	NR	0	1.2E-07	7.7E-06	4.0E-07	7.9E-06
31-Dec-08	NR	NR	5.7E-07	1.9E-07	1.36E-05	2.0E-06	1.14E-05
31-Dec-09	4.3E-03	5.0E-06	5.4E-08	9.7E-08	8.3E-06	1.2E-06	5.73E-06

Table C-2. RadNet (ERAMS) precipitation sampling results for Barnwell, South Carolina in pCi/L

Date	Hydrogen-3	Date	Hydrogen-3	Date	Hydrogen-3	Date	Hydrogen-3
15-Jan-93	300	15-Oct-95	444	15-Jul-98	282	15-Jan-01	113*
15-Feb-93	500	15-Nov-95	176	15-Aug-98	328	15-Feb-01	246
15-Mar-93	200	15-Dec-95	116	15-Sep-98	32*	15-Mar-01	123*
15-Apr-93	600	15-Jan-96	142	15-Oct-98	15*	15-Apr-01	-----
15-May-93	300	15-Feb-96	-30*	15-Nov-98	500	15-May-01	-26*
15-Jun-93	100	15-Mar-96	62*	15-Dec-98	40*	15-Jun-01	-----
15-Jul-93	300	15-Apr-96	55*	15-Jan-99	175	15-Jul-01	80*
15-Aug-93	100	15-May-96	116*	15-Feb-99	307	15-Aug-01	353
15-Sep-93	200	15-Jun-96	209	15-Mar-99	-----	15-Sep-01	80*
15-Oct-93	300	15-Jul-96	105*	15-Apr-99	257	15-Oct-01	-----
15-Nov-93	400	15-Aug-96	23*	15-May-99	79*	15-Nov-01	56*
15-Dec-93	1200	15-Sep-96	193	15-Jun-99	195	15-Dec-01	-----
15-Jan-94	1300	15-Oct-96	57*	15-Jul-99	70*	15-Jan-02	328
15-Feb-94	500	15-Nov-96	18*	15-Aug-99	57*	15-Feb-02	345
15-Mar-94	800	15-Dec-96	45*	15-Sep-99	23*	15-Mar-02	24*
15-Apr-94	600	15-Jan-97	-----	15-Oct-99	10*	15-Apr-02	13*
15-May-94	800	15-Feb-97	-----	15-Nov-99	193	15-May-02	93*
15-Jun-94	200	15-Mar-97	88*	15-Dec-99	144	15-Jun-02	75*
15-Jul-94	300	15-Apr-97	12*	15-Jan-00	-5*	15-Jul-02	225
15-Aug-94	200	15-May-97	148*	15-Feb-00	-----	15-Aug-02	-----
15-Sep-94	400	15-Jun-97	93*	15-Mar-00	-----	15-Sep-02	-----
15-Oct-94	200	15-Jul-97	109*	15-Apr-00	97*	15-Oct-02	292
15-Nov-94	300	15-Aug-97	293	15-May-00	-----	15-Nov-02	-----
15-Dec-94	500	15-Sep-97	70*	15-Jun-00	95*	15-Dec-02	-----
15-Jan-95	100	15-Oct-97	133*	15-Jul-00	66*	15-Jan-03	-----
15-Feb-95	400	15-Nov-97	991	15-Aug-00	249	15-Feb-03	-----
15-Mar-95	100	15-Dec-97	-----	15-Sep-00	75*	15-Mar-03	-----

15-Apr-95	100	15-Jan-98	335	15-Oct-00	-36*	15-Apr-03	-----
15-May-95	100	15-Feb-98	284	15-Nov-00	-----	15-May-03	-----
15-Jun-95	100	15-Mar-98	26*	15-Dec-00	-----	15-Jun-03	-----
15-Jul-95	500	15-Apr-98	-----			15-Jul-03	88*
15-Aug-95	-60*	15-May-98	-----	NOTE: Although reported values given, * indicates values are less than the reported minimum detectable concentration (MDC)			
15-Sep-95	-40*	15-Jun-98	-----				

3532

Table C-3. Maximum tritium concentrations in rainwater detected off-site by GDNR-EPD
(NOTE: ATSDR Comparison Value for tritium in drinking water is 20,000 pCi/L)

Year	Location	Maximum monthly concentrations in pCi/L	Date (month)	Number of stations
1993	Handcock Landing at Savannah River	7,000	January	8
1994	GPC Maintenance Office, Waynesboro, GA	3,000	May	10
1995	GPC Vogtle Electric Generating Plant Simulator Building	3,700	September	10
1996	CO 59 at Delaigle Trailer Park	1,300	October	10
1997	Handcock Landing at Savannah River	1,100	September	9
1998	GPC Vogtle Electric Generating Plant Simulator Building	1,300	December	10
1999	GPC Vogtle Electric Generating Plant Simulator Building	900	April	9
2000	Handcock Landing at Savannah River	1,000	December	8
2001	Handcock Landing at Savannah River	700	December	9
2002	Handcock Landing at Savannah River	700	December	10
2003	Handcock Landing at Savannah River	2,000	February	10
2004	GA 80 and GA 56C	1,000	August	10
2005	Handcock Landing at Savannah River	600	October	6
2006	GPC Vogtle Electric Generating Plant Simulator Building; Handcock Landing	300	February, July October	6
2007	GA 23, 1 mile north of Girard, GA	300	October	4
2008	Handcock Landing at Savannah River	300	December	4
2009	Handcock Landing at Savannah River	1,395	October	4
2010	Handcock Landing at Savannah River	360	January	4

GDNR-EPD = Georgia Department of Natural Resources' Environmental Protection Division
pCi/L = picocuries per liter

Table C4. Maximum tritium concentrations in rainwater detected off-site by SCDHEC-ESOP

Year	Location	Maximum monthly concentration in pCi/L	Date	Number of stations
1997	Jackson, SC	1,663		4
1998	Allendale Barricade	3,364	December	6
1999	Williston, SC	3,216	February	6
2000	Snelling, SC	664	June	6
2001	New Ellenton, SC	1,097	March	7
2002	Snelling, SC	2,009	October	7
2003	New Ellenton, SC	507	September	7
2004	New Ellenton, SC	551	March	7
2005	New Ellenton, SC	794	April	7
2006	Jackson, SC	439	February	7
2007	Snelling, SC	471	May	7
2008	Allendale	606	September	7
2009	Williston, SC	865	October	7
2010	New Ellenton, SC	692	November	7

SCDHEC-ESOP = South Carolina Department of Health and Environmental Control's Environmental Surveillance and Oversight Program
pCi/L = picocuries per liter

Appendix D. SRS Pilot Program for Monitoring Mercury in Rainwater

Mercury occurs naturally as a mineral and is distributed throughout the environment by both natural and man-made processes. The natural global bio-geochemical cycling of mercury is characterized by degassing of the element from soils and surface waters, followed by atmospheric transport, deposition of mercury back to land and surface water, and sorption of the compound to soil or sediment particulates. Mercury deposited on land and open water is in part re-volatilized back into the atmosphere. This emission, deposition, and re-volatilization create difficulties in tracing the movement of mercury to its sources. Atmospheric deposition of elemental mercury from both natural and man-made sources has been identified as an indirect source of mercury to surface waters. Concentrations of mercury in rainwater and fresh snow are generally less than 0.2 microgram per liter (µg/L) (ATSDR 1999; USEPA 1984; WHO 1991).

SRS conducted a pilot program for the monitoring, collecting, and analyzing mercury in rainwater from 2005 through 2011. The purpose of this program was to evaluate the collection, analytical methods, and data in order to decide whether or not to incorporate this type of surveillance into the routine environmental surveillance program. Since the data were collected for evaluation purposes, the data were never published. Nevertheless, ATSDR received a copy of the sample results from this pilot program (Gail Whitney, USDOE, personal communication, May 16, 2012). Most of the samples (798 out of 845) were below the practical quantitation limit of 0.02 µg/L. The largest concentration detected was 0.1363 µg/L in a sample from Savannah, Georgia. These levels are well below ATSDR's chronic EMEGs for methylmercury in drinking water (3 µg/L for a child and 10 µg/L for an adult).

During the time frame of this PHA, SRNL sponsored a collecting and monitoring station that was part of the National Mercury Deposition Network of the National Atmospheric Deposition Network. The National Mercury Deposition Network provides information on the trends and geographic distribution of mercury. All sampling stations in the network are equipped with the same type of precipitation collectors and gauges, and the samples are sent to the same laboratory for analysis (SRNS 2010, MDN 2012). This laboratory reviews field and laboratory data for completeness and accuracy; and flags samples that were compromised or contaminated. All data and information are delivered to the National Air Deposition Program Office where they are again reviewed, and then the data are made available on the program's website (http://nadp.sws.uiuc.edu/mdn/). From this website, ATSDR was able to obtain the sample results of SRS's monitoring station from the years 2001 to 2010 and compare these results to the results from other network stations in South Carolina operating during the same time period. Table D-1 summarizes this information. The results indicate that mercury levels in rainwater from samples collected at Savannah River site are similar to those collected from other monitoring sites in South Carolina. The South Carolina data are also similar to data published in a study of the mercury in rainwater in Florida. The range of mercury in rainwater samples in the Florida study was 0.014-0.130 µg/L (ATSDR 1999, Dvonch et al. 1995).

Table D-1. Mercury in Rainwater Results from South Carolina National Mercury Deposition Network Sampling Stations

Location	Range of Mercury in Rainwater (µg/L)	Years
Savannah River Site Barnwell County, SC	0.00131-0.0873	2001-2010
Congaree Swamp Richland County, SC	0.00036-0.1255	2001-2010
Cape Romain National Wildlife Refuge Charleston County, SC	0.00064-0.06455	2004-2010
Alibi Hunt Club Dorchester County, SC	0.00133-0.03586	2005-2008

Source: National Mercury Depositon Website, http://nadp.sws.uiuc.edu/sites/sitemap.asp?net=mdn&state=sc
Notes:
The Savannah River Site, Congaree Swamp, and Cape Romain National Wildlife Refuge monitoring stations are all still in operation; however, this report does not consider data later than 2010.
The Congaree Swamp monitoring station started in 1996, but data presented is only from 2001-2010 for more relevant comparison to the Savannah River Site data.
Although the National Mercury Deposition website provides sample results for invalidated samples, only validated sample results were used in this comparison.

µg/L= micrograms per liter

References:

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3596

Appendix E. Community Health Concerns for the Savannah River Site

#	Summarized Concern/Issue	ATSDR's Response
Environmental Releases and Contamination		
1	The U.S. Department of Energy denies that SRS airborne radioactivity, outside the site boundary, exceeds background levels. Specifically, SRS denies off-site airborne contamination exceeds background levels that remain from worldwide fallout from atmospheric nuclear weapons testing during the 1950s and 1960s.	In this PHA, ATSDR presents and evaluates maximum concentrations of radioisotopes detected above background levels in air off site of SRS from 1993 through 2010, regardless of the origin of the releases (e.g., as a result of SRS operations, worldwide fallout). Please refer to ATSDR's Radioactive Contaminants in Off-site Air section of this PHA for more information.
2	Concerned about the cleanup of contaminated areas at the site, including concentration of contaminants themselves (e.g., tritium) and air.	Potential exposures that occur on site at remediated areas are not evaluated by ATSDR in this PHA because public access to onsite remediation areas is generally restricted. Concentrations of airborne contaminants potentially released off site as a result of on-site cleanup activities would be captured in this PHA.
3	Concerned about radioactive releases and follow ups to reports on tritium releases. Continuous leaks and accidental releases from SRS were being carried downstream and downwind, contributing to contamination and these releases were being covered up. Contamination possibly from the leaching of buried SRS waste (especially hazardous and radioactive liquid waste) and SRS releases (particularly long-lived radioactive releases). A participant stated that SRS had told the public that all contaminants from an SRS radioactive cloud released 2 years ago had dissipated, but that everyone knows that many types of radioactive particles have a long life. Questioned whether SRS was being honest with the community about the danger. We know tritium is out there because it has been released a time or two. We need to know when they have said it was just a small amount, don't worry about it, we've got it under control—was that true?	SRS has had an on-site surveillance program in place since 1951 to monitor site releases to the environment (CDC 2001; SRNS 2009; WSRC 1994). Since SRS operations began in 1952, the site has maintained a comprehensive inventory of radioactive atmospheric releases from on-site sources (WSRC 1993, 1998). On-site radiological monitoring occurs at facilities' points of discharge (stacks or vents) at varying time periods depending on the facility. Monitoring also occurs at various locations throughout the site (e.g., operating areas) and at the site boundary. SRS management uses these monitoring results for compliance purposes with various federal and state regulations and emissions standards (WSRC 1993; SRNS 2009). On-site emissions are summarized in the On-site Emission Sources for Radioactive Contaminants section of this PHA. . USDOE-SR conducts off-site monitoring to assess compliance with federal and state atmospheric radiological release regulations and requirements. In addition, during the timeframe covered by this PHA, GDNR-EPD and SCDHEC-ESOP both had monitoring networks in off-site areas to independently estimate concentrations of radionuclides released into ambient air as a result of SRS's routine and accidental events (WSRC 1998). ATSDR carefully examined the data from these three different sources to ensure they were of sufficient quality, and determined that the data were adequate for making public health decisions. Concentrations of contaminants released via on-site leaks and accidental releases that traveled downwind would be captured in the off-site ambient air samples collected by DOE, SCDHEC-ESOP, and GDNR-EPD and evaluated in this PHA. Releases and leaks that distributed contamination downstream of SRS would have been included in the environmental data reviewed in ATSDR's PHA that evaluated off-site groundwater and surface water (ATSDR 2007) and biota (ATSDR 2012).

#	Summarized Concern/Issue	ATSDR's Response
4	Can groundwater go to airborne contamination?	Under certain circumstances, some contaminants present in groundwater can volatilize (i.e., evaporate) into air. However, ATSDR evaluated groundwater in a previous PHA (ATSDR 2007), and determined that no site-related groundwater plumes had migrated beyond the SRS boundary. However, SRS operates soil vapor extraction units and air-strippers onsite. These units remove contaminants from groundwater and soil, and these contaminants are then released into the air. SRS must obtain air permits from SCDHEC in order to operate these units. The permitting process includes air dispersion modeling of the contaminants released with estimates of the maximum concentrations and potential maximum exposures to an individual at the site boundary. The results of this modeling are discussed in this PHA.
5	What kind of risk factors are there from fugitive emissions from soil contamination with regards to the closure of the F-, H-, and M-Area seepage basins?	Fugitive emissions from soil contamination associated with the seepage basin closure are monitored at the boundary by the perimeter monitors. For instance, the air station at Green Pond is fairly close to the M-Area. USDOE-SR and SCDHEC-ESOP also have on-site air monitoring stations at Burial Ground North that are close to The F- and H-Areas. Refer to Figures 9 and 10 in this document.
6	Was the airborne release of radioactive particles considered at the Consolidated Incineration Facility (CIF), and what was the level of radioactive particle removal at the CIF?	An off-gas removal system was used at the CIF to remove radioactive particles. Monitoring of emissions from the CIF occurred continuously. The CIF system was designed to remove 99.99 percent of radioactive emissions.
7	Are there air monitors on tops of the High Level Waste (HLW) container tanks?	Yes, there are monitors in place and all air is monitored before release.
8	Concerned about contamination of the whole ecosystem—air, water, soil, plants, and animals.	ATSDR has been evaluating all of these media through its public health assessment process. This PHA evaluates radioactive contaminants detected in off-site air, rainwater, and soil. Previous PHAs can be obtained for off-site water (i.e., groundwater and surface water; see ATSDR 2007) and biota (i.e., plants and animals; see ATSDR 2012).
9	In 1987, there was a release of tritium. What measures were taken to address the contamination?	On July 31, 1987, approximately 172,000 curies of tritium were released from the H-Area tritium facilities as a result of a line break during a maintenance operation. At the time of the incident the wind direction was toward the east but shifted to the north-northeast. The calculated dose to a maximally exposed individual at the site boundary was 0.02 mrem (0.0002 mSv). Air samples were collected along the path of the plume, vegetation samples were collected on-site, along the plant perimeter, and along a 15- and 25 mile radius in the path of the plume. Milk samples were also collected from local dairies. For more details refer to the USDOE Savannah River Plant Environmental Report for 1987 (Doc. DPSPU-88-30-1, Vol. 1). Tritium gas and tritium oxide that mix readily with non-radioactive hydrogen and water are not conducive to large-scale clean-up efforts. For this incident, thunderstorms broke up the plum and diluted the concentration as it move to the north-northeast.

#	Summarized Concern/Issue	ATSDR's Response
10	Concerned about the potential for accidents during transportation of hazardous materials through their communities.	All USDOE facilities, including the Savannah River Site, are required to follow proper packaging and transportation guidelines set forth in DOE Order 460.1C: Packaging and Transportation Safety (USDOE 2010a). SRS follows these guidelines for off-site shipments as well as on-site transfers of radioactive and other hazardous materials. These policies conform to the packaging and transportation guidelines established by the U.S. Department of Transportation (USDOT) for hazardous materials and by the U.S. Nuclear Regulatory Commission (USNRC) for radioactive materials (USDOE 2010a). ATSDR acknowledges that radioactive and other hazardous materials might be released if any serious accidents occurred during transport. However, ATSDR believes that the numerous safeguards set forth in the USDOT and USNRC guidelines, which are followed by USDOE, minimize the occurrence of hazards from transporting these materials off the site. In 2010, USDOE initiated a National Transportation Stakeholders Forum (NTSF) to serve as a means through which USDOE can communicate with states and tribes about its shipments of radioactive and nonradioactive hazardous materials. Through the NTSF, USDOE seeks feedback from transportation stakeholders on their key issues and concerns (USDOE 2010b).
11	Questioned the validity of SRS reports that state that air, soil, and groundwater are safe.	In addition to USDOE-SR's collection of off-site air, soil, and water monitoring data, GDNR-EPD and SCDHEC-ESOP both have monitoring networks in off-site areas to independently estimate concentrations of radionuclides released into ambient air, soil, and groundwater. ATSDR has evaluated monitoring data from all three sources. The findings associated with off-site air and soils are included in this PHA. ATSDR evaluated groundwater monitoring data collected by USDOE-SR, GDNR-EPD, and SCDHEC-ESOP in a separate PHA (ATSDR 2007).
12	One participant expressed concern about people eating fruits and vegetables from their gardens, which may have contaminated soil or contamination from the air.	In a previously prepared PHA, ATSDR evaluated potential off-site exposures to SRS-related contaminants in fruits, vegetables, meat, and fish. ATSDR presents its evaluation and findings in its SRS Biota PHA (ATSDR 2012). Also, the modeled data presented in this PHA includes exposure by ingestion of food products potentially contaminated by air releases.

#	Summarized Concern/Issue	ATSDR's Response
13	Radioactive gas is being dispersed into the air from SRS. Using computer modeling and air samples collected at various points around the perimeter of the site, we detected a variety of toxic air pollutants outside the boundaries. The atmospheric emissions from SRS include tritium and many other pollutants. Our principal conclusion based on the findings of this report is that recent and ongoing operations at SRS are having and may continue to have negative impacts on the health of residents in the central Savannah River area unless sweeping changes are made. Our investigation centered on the atmospheric emissions from smokestacks at SRS and how they affect nearby towns and rural communities. We know that the consequences of contamination have had an impact on people in all directions for hundreds of square miles around SRS. The airborne emission of dangerous radionuclides has had and will continue to have a negative impact on the health of people living in the Central Savannah River Area, especially children and the unborn who are particularly vulnerable to radiation. Additional exposure to the region must be reduced and eliminated.	It is true that SRS has released several different radioactive and non-radioactive contaminants to the atmosphere as a result of routine and non-routine operations. The majority of radionuclide releases to air from SRS came from five reactors (C, K, L, P, and R), the reprocessing area (F-Area and H-Area), and the tritium production area (CDC 2001). USDOE-SR monitors SRS emissions and uses these monitoring results for compliance purposes with various federal and state regulations and emissions standards (WSRC 1993; SRNS 2009). Moreover, off-site radioactive releases are monitored not only by USDOE-SR, but also independently by SCDHEC-ESOP and GDNR-EPD. To evaluate potential exposures, ATSDR evaluated more than 65,000 off-site air monitoring data collected by USDOE-SR, SCDHEC-ESOP, and GDNR-EPD from 1993 through 2010 and reviewed SRS state permits and enforcement history. For more information on ATSDR's evaluation, refer to the Evaluation of Environmental Contamination and Potential Exposure Pathways section of this PHA.

#	Summarized Concern/Issue	ATSDR's Response
14	In 2003, evidence was found of radioactive releases into the environment which may have contaminated nearby residential areas. Cs-137 was found in soil samples downwind from SRS as high as 174 picocuries/kg and downstream from SRS in vegetation as high as 1254 pCi/kg. The latter contamination was six times the EPA drinking water maximum of 200 pCi/kg.	Based on ATSDR's evaluation of over 7,000 soil monitoring data records collected by USDOE-SR, GDNR-EPD, and SCDHEC-ESOP from 1993 to 2010, the maximum concentration of cesium-137 in off-site soil was 16.68 picocuries per gram (pCi/g), which exceeded the NCRP Report No. 129 Land-use Scenario Screening Values used by ATSDR to evaluate this exposure pathway. However, this sample was collected on the river bank at Little Hell's Landing and four months later another sample was collected at this location with the result of 0.0675 pCi/g Cs-137. One sample from the Steel Creek delta and one sample from the Savannah River swamp also exceeded the ATSDR screening level. All of these concentrations were likely caused by a well-known past surface water release from the site. No one lives on or farms this area. All other soil sample results reviewed by ATSDR were below the screening level. (See the Evaluation of Radioactive Contaminants in Off-site Surface Soils section of this PHA). In this community concern, a contaminant concentration detected in vegetation is being compared to a drinking water standard: this is entirely inappropriate for public health screening. Instead, a cesium-137 concentration in vegetation needs to be compared to a screening level for cesium-137 in that same type of vegetation, and so forth. Please refer to the SRS PHA on biota (ATSDR 2012). Cesium-137 concentrations detected in water were evaluated by ATSDR in its PHA titled "Evaluation of Off-Site Groundwater and Surface Water Contamination at the Savannah River Site (USDOE)" (ATSDR 2007). Please refer to that PHA for an appropriate public health evaluation that compares contaminant concentrations detected in groundwater and surface water to water comparison values.
Air Quality and Pollution		

15	People living near SRS are concerned about quality of air.
	
	The quality of the air is not good.
	
	Concerned about whether the air quality is being monitored.
	
	Participants reported that they had been warned not to open car windows when driving through SRS because the air quality is poor.
	
	Air quality throughout the region has decreased and the impacts of SRS on that trend should be discussed.
		As mentioned in the General air quality section of this PHA, for over 20 years USEPA and state environmental agencies have evaluated general air quality in South Carolina based on ambient air concentration measurements of six common air pollutants (i.e., criteria pollutants) as well as radioactive materials. The criteria pollutants include the following:
		
		• Carbon monoxide
		• Lead
		• Nitrogen dioxide
		• Ozone
		• Two forms of particulate matter
		  o Particulate matter with aerodynamic particle size of 2.5 microns or less ($PM_{2.5}$)
		  o Particulate matter with aerodynamic particle size of 10 microns or less (PM_{10})
		• Sulfur dioxide
		
		Various sources contribute to airborne levels of the criteria pollutants. USEPA has established a health-

#	Summarized Concern/Issue	ATSDR's Response
	We don't know that, there is no danger from the radiation and the chemicals in the air, but you wonder how much of this "stuff" is in the air we breathe because we are right here in the backyard of SRS.	based National Ambient Air Quality Standard (NAAQS) for each criteria pollutant. In the event that air quality measurements do not meet the NAAQS, USEPA requires states to develop and implement plans to lower levels so the pollutant measurements are in attainment with the health-based standards. ATSDR reviewed the general air quality for the counties that SRS lies within: Aiken, Allendale, and Barnwell Counties in South Carolina. During the time period of interest for this PHA (i.e., 1993–2010), SCDHEC operated air network monitoring stations in two of these three counties: Barnwell County (1998– 2007) and Aiken County (1993–2010). SCDHEC collected measurements in Aiken County for all criteria pollutants except carbon monoxide, and in Barnwell County for all except lead, carbon monoxide, and $PM_{2.5}$. According to USEPA, these counties in South Carolina have been in attainment for all of the criteria pollutants monitored in these counties during 1993–2010, with the exception of periodic exceedances of 8-hour averages of ozone (both counties were in attainment for 1-hour averages of ozone) (USEPA 2012). In addition, although on-site monitoring of non-radiological parameters for ambient air quality does not occur, SRNL has conducted air dispersion modeling to assess compliance with applicable federal and state regulations and standards since 2001. Modeling of SRS sources of toxic air pollutants (257 chemical air pollutants listed in SCDHEC Standard 8) and criteria pollutants has reportedly indicated that emissions are in compliance with these regulations and standards (SRNS 2011). In addition, USDOE-SR, GDNR, and SCDHEC closely monitor radioactive emissions. Based on ATSDR's evaluation of more than 65,000 air monitoring records collected from 1993 through 2010, ATSDR believes that off-site air is not being adversely impacted by SRS operations.
16	Tree leaves have "sticky stuff" on them. The evergreen trees are "different" looking—the tops are not green. Vegetation dying from air pollution due to SRS activities. Is it because of something in the air?	ATSDR believes that the effects reported here on leaves are most likely the result of several possible natural processes rather than from anything potentially in the air. A few examples follow: First, scale insects are common pests that can be present on the leaves of many evergreen and deciduous trees (i.e., trees that lose their leaves). These pests make a sticky substance called honeydew, which can stick to leaves and other surfaces (e.g., cars, decks) (Wawrzynski and Ascerno 2010). Second, there are many types of trees that, during Spring through Summer, naturally release a sticky sap that can be clear to dark amber in color. Many things can affect how plants and other vegetation grow and their overall appearance. Poor growth of trees and other types of vegetation can be caused by several factors, such as adverse climate conditions (e.g., no rainfall, extremely hot temperatures), not enough soil moisture or aeration, lack of necessary nutrients, and land disturbances caused by construction (Evans 2001). Based on ATSDR's evaluation of off-site air, ATSDR believes that the changes in trees and other types of vegetation are due to other causes rather than air pollutants.

#	Summarized Concern/Issue	ATSDR's Response
17	Concerned about damage to the ozone layer from SRS airborne releases.	Certain industrial processes, consumer products, and natural sources worldwide emit halogen source gases into the atmosphere. These halogen source gases contain bromine and chlorine atoms that can harm the ozone layer (NOAA 2002). While it is true that some substances released into the air can contribute to damage of the ozone layer, ATSDR is not able to quantify any damage to the ozone layer that could be caused by SRS airborne releases specifically. Laws have been put in place to protect the ozone layer from these types of harmful emissions. Specifically, ozone protection of the stratosphere is addressed in Title VI of the 1990 Clean Air Act Amendments (CAAA). Under this law, USEPA is required to establish regulations for phasing out the production and use of ozone-depleting substances (ODSs). Many sections within Title VI of the 1990 CAAA are applicable to the SRS site, as well as regulations recently established by USEPA in 40 CFR 82. The site's 1994 "Savannah River Site Refrigerant Management Plan" outlines guidance for SRS and USDOE to apply to phasing out chlorofluorocarbons (CFCs), organic compounds containing carbon, chlorine, and fluorine. CFCs are used as refrigerants and in equipment. For large sources of ODS emissions, SRS has decreased its CFC refrigerant usage more than 99 percent since 1993. SRS is also phasing out its Halon use to work towards its goal of eliminating use of Class I ODSs "to the extent economically practicable" (SRNS 2009).
Potential Health Effects and Health Concerns		
18	She acknowledged that SRS annual releases are low, but cumulative effects from air, water, and other sources increase the potential for adverse health effects.	ATSDR agrees that doses from all exposure pathways contribute to the overall exposure a person experiences. ATSDR considered the contribution from other potential exposures in its evaluation in this PHA. Specifically, for evaluating the air exposure pathway, ATSDR used the comparison value of 10 mrem per year (0.10 mSv per year) since it is only one pathway of potential exposure. (ATSDR's comparison value for total radiation exposure per year above background is 100 mrem per year (1 mSv per year)). Similarly, for evaluating exposures to off-site surface soil, ATSDR based its evaluation on limiting the maximum exposure rate to an individual to 0.25 mSv/yr (25 mrem/yr) (i.e., one-fourth of 100 mrem). In previously prepared PHAs, ATSDR evaluated exposures to water (ATSDR 2007) and biota (ATSDR 2012) for areas off site of SRS.
19	Concerned about the effect of ongoing plutonium missions at SRS on the youth. Specifically, 1) What kind of environment are they growing up in? 2) How might it be harming them? 3) How is it affecting the older populations, and others who may be vulnerable? A chronological assessment that studies the toxic air releases and problems that could arise from exposure is needed.	This PHA is an assessment that addresses SRS off-site air releases, possible exposures, and potential health effects. In this document, ATSDR evaluated off-site monitoring data collected by USDOE-SR, GDNR-EPD, and SCDHEC-ESOP from 1993 through 2010. In this review, ATSDR closely examined more than 65,000 air monitoring data records, which included concentrations of plutonium-238 and plutonium-239/240. Based on this evaluation, the maximum off-site concentrations of plutonium-238 and plutonium-239/240 in air were 7.35E-11 and 4.62E-11 microcuries per cubic meter (μCi/m3), respectively. Exposure to these levels of plutonium-238 and plutonium-239/240 would not be associated with adverse health effects, including exposure experienced by sensitive individuals (e.g., elderly, infants).

#	Summarized Concern/Issue	ATSDR's Response
20	General health concerns, including respiratory problems caused or made worse by air pollution (especially asthma). Questioned whether airborne contaminants from SRS caused respiratory problems and lung disease. Desire information on the effects of radiation from the air they breathe.	As mentioned in the General Air Quality section and the response to public comment #15, for over 20 years USEPA and state environmental agencies have evaluated general air quality in South Carolina based on ambient air concentration measurements of six common (i.e., criteria) air pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, two forms of particulate matter, and sulfur dioxide. ATSDR reviewed the general air quality data that are available for two of the counties that SRS lies within: Aiken and Barnwell Counties in South Carolina. According to USEPA (2012), with the exception of periodically exceeding the 8-hour averages for ozone (not 1-hour averages of ozone), these counties in South Carolina have been in attainment for the criteria pollutants monitored in these counties during 1993–2010. See USEPA (2012) and the response to comment #15 for more information. Moreover, SRNL's air dispersion modeling of SRS sources of toxic air pollutants and criteria pollutants has reportedly indicated that emissions are in compliance with these federal and state regulations and standards (SRNS 2011). In addition, USDOE-SR, GDNR-EPD, and SCDHEC-ESOP closely monitor radioactive emissions. This PHA evaluated these off-site monitoring data, and based on ATSDR's evaluation of more than 65,000 air monitoring records collected from 1993 through 2010, ATSDR believes that off-site air is not being adversely impacted by SRS operations and breathing this air is not expected to result in adverse health effects for people living off site of SRS.
21	One participant noted that it is a fact that radiation causes cancer and SRS is the source of radioactive leaks in the area.	Data suggest that rates for all cancers in the SRS area are not elevated. Specifically, according to "Cancer in South Carolina, USA, 1996–2005: South Carolina Central Cancer Registry Ten Year Report" (Hurley et al. 2009), the age-adjusted incident rates for all cancers combined for males and females of all races in Aiken, Allendale, and Barnwell Counties from 1996–2005 are lower than the state incident rates and are very similar to the national incidence rates reported by the U.S. Cancer Statistics Working Group for each year from 1999–2006 and for 2002–2006 combined (USCS 2010).
22	Concerned about effects of soil contamination on kids playing, animals, and gardeners.	These activities were considered when evaluating soil concentrations for various use scenarios. Please refer to the Evaluation of Radioactive Contaminants in Off-site Soil section of this report.
23	Concerned about skin diseases from exposure to SRS contaminants. Worried about physical deformities from exposure to SRS contaminants.	The types and levels of contaminants detected off-site at SRS would not be related to these illnesses or adverse health effects.
24	Concerned about skin cancer caused by SRS airborne radioactive particles settling on the skin.	Data indicate that skin cancer rates are not elevated in the SRS area. According to "Cancer in South Carolina, USA, 1996–2005: South Carolina Central Cancer Registry Ten Year Report" (Hurley et al. 2009) the age-adjusted incident rates for melanoma of the skin for males and females of all races in Aiken and Barnwell Counties (the number of cases was too small to calculate a reliable rate for Allendale County) from 1996–2005 are lower than the state incident rates and are lower than the national incidence rates reported by the U.S. Cancer Statistics Working Group for each year from 1999–2006 and for 2002–2006 combined (USCS 2010).

#	Summarized Concern/Issue	ATSDR's Response
25	Is there any research that will show if babies are affected by radiation from the SRS? Concerned about possible health effects including birth defects caused by radiation.	According to the Nuclear Energy Institute (NEI), people who live close to a nuclear power plant such as SRS are only exposed to a tiny amount of radiation from the facility. Specifically, an average person receives less than 1 percent of his or her total radiation exposure from nuclear power plants (NEI 2010). The U.S. Nuclear Regulatory Commission (NRC) concurs with the NEI's finding, as it reports that a person living within 50 miles of a nuclear power plant such as SRS would receive an average radiation dose of about 0.01 mrem/year, or 0.003 percent of the amount an average person living in the United States receives every year from natural background radiation sources (i.e., 300 mrem/year). In fact, even if someone remained at the border of a nuclear power plant facility for an entire year, the additional radiation exposure would still be less than 1 percent of natural background (USNRC 2010). Moreover, gamma and/or beta radiation levels as measured by thermoluminescent dosimeters (TLDs) indicate that the levels measured off site near SRS were in line with normal background. Therefore, based on a review of the NEI and NRC information and site-related TLD data, ATSDR does not believe that infants or unborn fetuses would be adversely affected by living near the SRS facility.

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