CHAPTER 1

EXECUTIVE SUMMARY

The Centers for Disease Control and Prevention (CDC) is studying the potential human health risks to people exposed to chemicals and radioactive releases to the offsite environment from the Savannah River Site (SRS). The SRS is a U. S. Department of Energy (DOE) complex occupying about 300 square miles along the Savannah River in South Carolina, on the Georgia border. The SRS has produced plutonium, tritium, and other materials for the national defense and some civilian purposes. The study is evaluating past releases leading to human exposure and dose, and is called a "Dose Reconstruction." Figure 1-1 shows important steps in the dose reconstruction process. The term dose is used regularly throughout this report and refers to the committed effective dose, which refers to the organ and tissue weighted dose to a person received from an intake of radioactive material during the 50-year period following the intake. Beyond this, risks associated with these dose values are calculated to put the exposures to contaminants in perspective to other risks, such as the risk from smoking or the risk associated with natural background radiation.

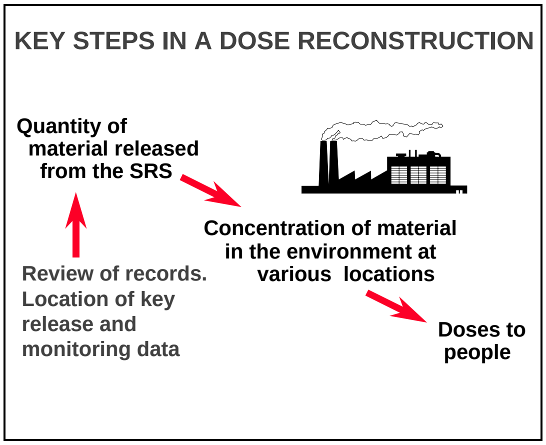

Figure 1-1. The key steps in a dose reconstruction, which evaluates the effects of past releases to the environment on offsite residents.

The CDC contracted with *Radiological Assessments Corporation* (*RAC*)[1] to conduct Phase II of this health risk study. Phase I was a search of SRS and other areas to find and copy documents and other records of potential value to the dose reconstruction project. Phase I was finished in June 1995, and an electronic document database was the primary product. Phase II began in October 1995 to estimate the releases of radionuclides and chemicals from the SRS to the environment during past operations from 1951 through 1992. Future phases of the dose reconstruction will include assessing the movement of the contaminants into the environment, estimating radiation doses and chemical exposures, and evaluating health risks to those living offsite.

The project Study Area is shown in Figure 1-2. It includes all communities within a distance of 50-miles from the SRS boundary, Columbia, South Carolina, and communities along the Savannah River south of the SRS. The CDC, the SRS citizens' Health Effects Subcommittee, and others helped *RAC* set up the Study Area, and find population, food crop, and similar information for this Study Area. The initial scope of this part of the project was cut back early in Phase II because of Federally mandated funding limitations, but with the help of South Carolina State University, *RAC* and CDC have collected a great deal of useful information, stored as a set of

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[1] *Radiological Assessments Corporation* changed its name to *Risk Assessment Corporation* (*RAC*) in 1998.

computerized maps that will be available to those people who are interested. These types of data will be useful during later phases of the project.

This report and its computer files are part of the results of the Phase II study, along with a collection of about 5500 documents, declassified for this project and available to the public. The documents are the result of *RAC*'s systematic review of *all* records at the SRS. *RAC* opened and examined documents from about 50,000 boxes, and recorded their findings in a computer database. CDC received the document database, which will also be available to the public.

The Phase II work has been open to the public, and has offered opportunities for people to become involved. *RAC* has conducted hundreds of interviews and dozens of public meetings and visits to the site to learn about the SRS and potential sources of data.

SRS Dose Reconstruction Phase II Study Area

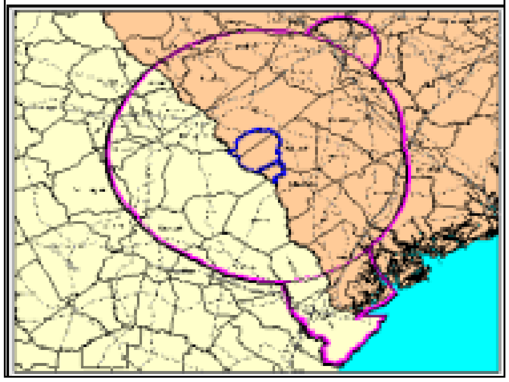


Figure 1-2. The project Study Area surrounding the SRS.

The study results are available as a report and as computer files with hypertext links to references, and to Excel® files containing the data sets summarized via graphics within the chapters. The document files are in Word2000® format, and the associated Excel files are in Excel2000® format. Eleven appendices to the report present procedures and supporting data. In addition, several of these appendices contain information specifically to support future stages of the dose reconstruction. Appendix D summarizes the meetings, fact sheets, newsletters, and other means used to communicate interim results to members of the public. Appendix F describes the large set of map-based data (Geographic Information System data) and demographic data collected by *RAC* and South Carolina State University during the course of the study. The GIS data were provided to CDC as part of the report, on CD ROM disks.

This report presents our results in this order: 1) radionuclide releases, 2) environmental monitoring data, 3) chemical releases and environmental monitoring, and 4) appendices and computer files. This current report summarizes the site history that was described in detail in the Phase I, Task 3 report, and includes diagrams of process areas onsite. *RAC* compiled and reviewed declassified production information for the five production reactors and the two reprocessing canyons, and estimated tritium production from the records (Figure 1-3). The release estimates presented here may be used to estimate doses to people living near the facility during its production history (1954-1992). The CDC will decide later whether such a dose reconstruction is needed. The scientific community and the

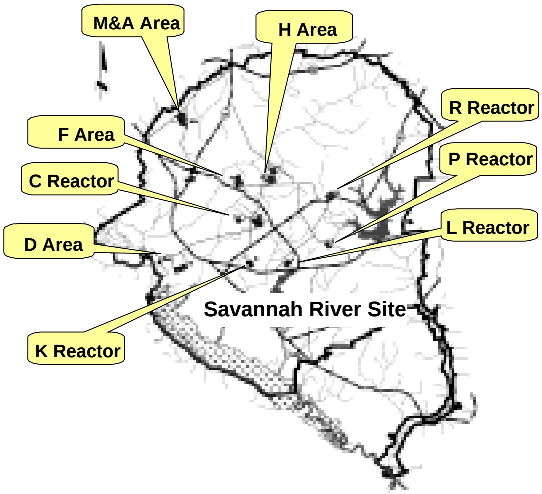


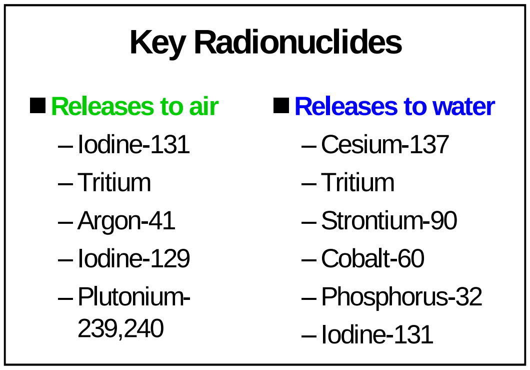
Figure 1-3. Diagram of the Savannah River Site showing the main facilities.

public have had the opportunity to review the report and have provided comments, which have been addressed and incorporated into this Final Phase II Report.

SELECTING MATERIALS OF CONCERN

Because there are numerous materials potentially released from a facility like the SRS to the environment, screening calculations helped to make objective decisions about the focus of the source term work. Through the screening methods, *RAC* identified certain chemicals (see Chapter 16) and radionuclides (see Chapter 3) through a phased approach. This approach did not eliminate any materials from consideration but rather focused first on those that are most important for public health. For screening radionuclides, we used the National Council on Radiation Protection and Measurements (NCRP) screening methods that have been revised and updated over the years and used extensively in other projects. This method involves a phased approach to screening and does not eliminate any radionuclides from consideration; rather, it focuses first on those radionuclides that are most important for public health (Table 1-1). For radionuclides, the screening process also evaluated how important each radionuclide was with respect to the exposure pathway (air or water), and produced a list of key radionuclides for which detailed source term, or release, estimates were developed

Table 1-1. Radionuclides identified in our screening process as the important contributors to dose



Key Radionuclides

■ Releases to air	■ Releases to water
– Iodine-131	– Cesium-137
– Tritium	– Tritium
– Argon-41	– Strontium-90
– Iodine-129	– Cobalt-60
– Plutonium-239,240	– Phosphorus-32
	– Iodine-131

For chemicals, *RAC* reviewed their use in site processes and their potential for release from the SRS in the screening process. This evaluation of their hazards and magnitude of the quantities of the chemicals onsite led to the selection of key chemicals for further evaluation (Table 1-2). Chemicals that were detected in the environment around the SRS were added to the list of chemicals subjected to the ranking, shown here.

Table 1-2. Chemicals identified as potentially important from an initial screening of SRS chemicals

arsenic	benzene
cadmium	chromium
coal	coal ash
hydrogen sulfide	hydrazine
gasoline	diesel fuels
lead	manganese
mercury	nickel
nitric acid	nitrogen dioxide
sulfur dioxide	tetrachloroethylene
trichloroethylene	trichloroethane
uranium	zinc

RELEASES OF RADIONUCLIDES FROM THE SRS

Sources of Radionuclide Contamination

When evaluating the effects of radionuclides released from a DOE weapons facility, it is important to be aware of the radionuclides present in the environment that were released from other sources. Figure 1-4 shows that one of the main sources of radioactivity in the environment was fallout from the nuclear weapons testing program in the 1950s and 1960s. *RAC* evaluated these sources, including fallout from nuclear weapons tests in the 1950's and 1960's, to help place SRS releases in the appropriate context of these sources and of background levels.

Particular emphasis was given to examining a March 1955 incident during which atmospheric and ground surface contamination appeared at the SRS, apparently caused by the rainout of radionuclides from a Nevada nuclear weapon test. This case provides a detailed example of the methods used to identify SRS-released vs. offsite contamination, and also provides a reevaluation of an incident that still concerns some individuals who lived near the site at that time.

Some radionuclides would be expected to come almost exclusively from SRS releases. These include: ^{85}Kr, ^{41}Ar, ^{32}P, ^{35}S, ^{60}Co, ^{129}I, ^{99}Tc, and ^{51}Cr. In addition, ^{238}Pu is mainly released to the environment from facilities that produce or process nuclear materials (such as the SRS), although weapons or satellite launch accident fallout have contributed lesser amounts. Radionuclides in weapons fallout, including ^{241}Am, ^{137}Cs, ^{3}H, ^{131}I, ^{90}Sr, ^{239,240}Pu, ^{65}Zn, and ^{95}Zr/Nb were also released in significant quantities from the SRS. A careful examination of quantities and trends is necessary before an informed judgment can be made about radionuclides arising from multiple sources.

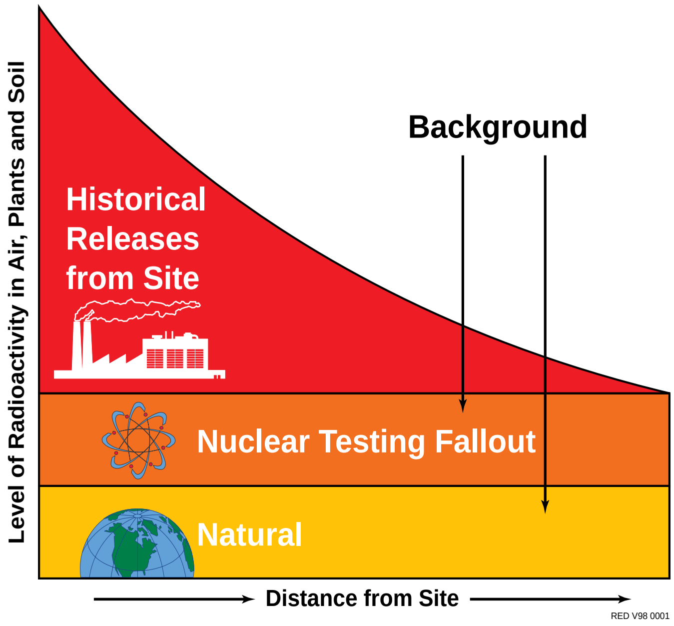


Figure 1-4. Other sources of radionuclide contamination.

Releases of Radionuclides to Air

Releases of Tritium To Air

Tritium (^{3}H or T) was one of the principle nuclear materials produced at the SRS to multiply the firepower of plutonium in nuclear weapons. It is the heaviest and only radioactive isotope of hydrogen, with a physical half-life of 12.5 years. Tritium processing operations began at the SRS facility in October 1955 in the F-Area (Building 232-F). In July 1957, the process was moved to the H-Area (Building 232-H) and operations doubled by 1958. The key processes that lead to tritium releases at the SRS were:

- Reactor operations (C, K, L, P, and R Reactors)
- Recovery of transuranic elements in the separations facilities (H-Area and F-Area)
- Recovery of tritium in the Tritium Facilities (H-Area)
- Laboratory research area
- Heavy water rework facility.

The releases of tritium from the SRS are generally very well documented in published reports. Records of releases have been kept since the beginning of operations. In general, there is quite good agreement between the different release values reported in the different sources. Because in most cases the summary values were within 10% of the published values, it is likely that most "unchecked" monthly values are also valid. The key processes that have lead to atmospheric tritium releases are reactor operations, recovery of transuranic elements in the separations facilities (F-Area and H-Area), recovery of tritium in the tritium processing facilities, laboratory research area, and heavy water rework facility. The majority of the tritium releases came from the reactors and the tritium facilities through routine operations. In addition, there were about 3000 release incidents involving tritium releases. Figures 1-5 and 1-6 show the annual tritium releases to air from the reactors and from the tritium facilities in the F-Area and H-Area. Table 1-3 lists our annual median release estimates for tritium to air from SRS sources. Our tritium release estimates to air are described fully in Chapter 4.1.

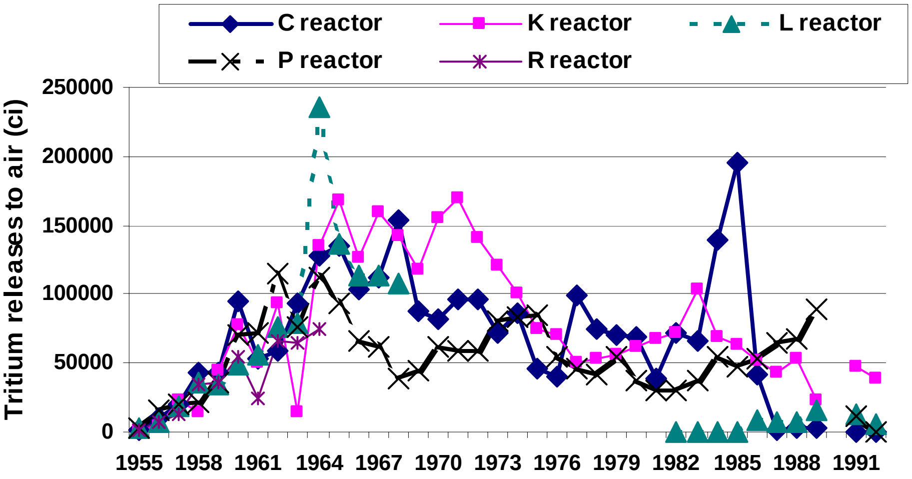


Figure 1-5. Annual releases of tritium to air from the 5 production reactors for all years of operation. The L Reactor released over 235,000 curies in 1964, the highest annual total of any of the reactors onsite. The L reactor was shut down after 1968 and restarted in 1982. The R reactor operated only through 1964. The C Reactor, which operated from 1954 through 1987, had high releases in 1984 (150,000 Ci) and 1985 (200,000 Ci) due to leaks in the reactor vessel. (See Figure 1-6 for comparison with releases from the tritium facilities in the H-Area and F-Area).

Table 1-3. *RAC* Median Release Estimates of Tritium to Air (Ci)

Year	C reactor	K reactor	L reactor	P reactor	R reactor	232F	232H	234H	238H	244H
1955	1044	1694	2745	3075	783	17860	10997			
1956	10037	4967	6936	15250	6652	436662	19990			
1957	19441	22820	19279	20595	13235	665665	665231	498102		
1958	43007	14856	35629	22182	34442	868285	1349157	249945		
1959	43007	44515	34820	35916	35557		596399	280047		
1960	94200	77443	48303	70632	54417		426420	250241		
1961	53209	49609	55558	72497	23855		451435	217586		
1962	59214	93494	75957	114893	66786		376473	390601		
1963	93788	14686	78591	76067	64331		430499	338132		
1964	127339	134994	235424	111557	75240		345264	652547		
1965	135144	168067	136136	93526			182393	144144		
1966	103764	125843	112807	66754			147635	165242		
1967	112399	158956	113617	61267			193225	130930		
1968	153151	141998	107220	38165			226760	202871		
1969	87297	118276		45246			147072	118236	2045	
1970	81939	155790		61386			136798	122507	1902	521
1971	96018	169705		58719			194523	204444	6226	82
1972	95785	141291		58825			299624	252260	3429	
1973	71512	120422		80632			198546	124097	4192	
1974	86137	101168		83914			131235	508598	3512	642
1975	45432	74662		84904			65262	256696	3320	367
1976	39682	69934		55206			56640	70283	3255	71
1977	98776	50295		46661			86916	106696	6770	1097
1978	74871	52709		41156			120247	63154	8339	373
1979	70380	56609		54794			76262	84139	7898	
1980	69334	61904		37548			71414	68933	5284	1450
1981	39430	67809		30042			92438	144738	3762	
1982	71607	71443	149	30611			122771	143252	3839	507
1983	66259	104078	491	36692			172842	253529	4646	1286
1984	139132	68511	127	54677			140483	388456	4739	1271
1985	195877	63303	683	47664			136764	231312	3889	
1986	41565	51817	7943	53252			127007	132209	3191	
1987	2040	43456	7009	64289			283003	183954	2332	
1988	2656	52496	6711	67757			95080	167944	3902	
1989	2329	22687	15713	89685			60436	122182	2984	
1990							48573	131522	4145	
1991	553	46805	12261	10872			49837	86557	3722	
1992	368	38427	6017	307			68742	62223		

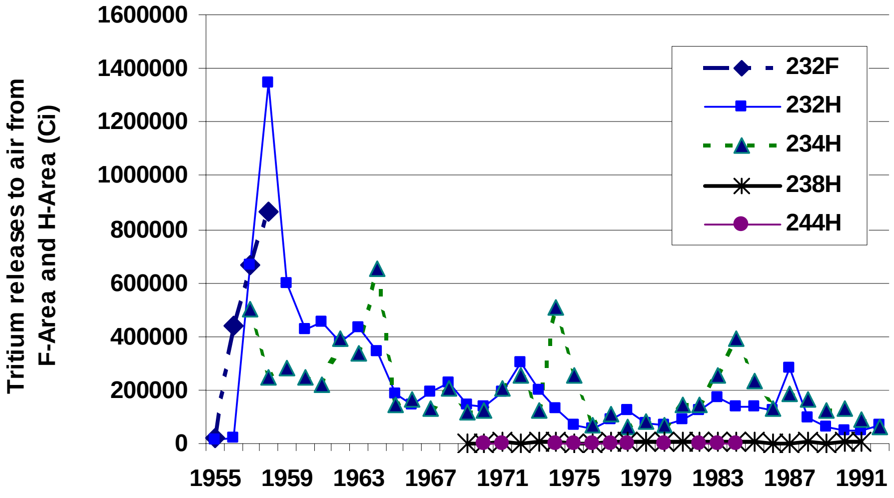


Figure 1-6. Annual releases of tritium to air from the tritium facilities in the F-Area and H-Area for all years of operation. The original tritium extraction facility in 232-F operated from 1954 through 1958. It was replaced by the H-Area tritium facilities (232-H and 234-H) that have operated continuously since 1957. The largest releases of tritium occurred from the H-Area facilities from 1957 through 1959, with over 1.3 million curies released from 232H in 1957. (See Figure 1-5 for comparison with tritium releases to air from the 5 reactors).

Releases Of Radioiodines and Beta-Gamma-Emitting Particles to Air

Radioactive iodine and other beta-gamma-emitting materials are produced during fission of uranium and plutonium in reactor fuels. Because most of the releases of radioiodines and beta-gamma-emitting particles occurred when the fuel was processed (usually many days after removal from the reactor), the radionuclides of greatest interest are those produced in large quantities and that have half-lives that exceed 1 day. Reprocessing facilities were the largest sources of airborne radioiodine releases. From the point of view of human health, the most important discharges are those of elemental iodine (I_2), which are most important for human thyroid. Releases of organic iodides (like CH_3I), which are relatively unimportant for food chain pathways, contribute to exposure by inhalation. Releases of ^{131}I were highest in the 1950s, and our estimates for that time for elemental ^{131}I are about four times those that were reported by the SRS. This is due mainly to a correction for deposition in the sampling line. Only elemental iodine was measured at that time; however, organic iodides accounted for 70-90% of the ^{131}I release from the separations areas. Thus, the organic iodide releases are roughly 4 times higher than the elemental iodine releases. This leads to a big addition in the early years because no contribution to the total from the release of organic iodides was previously considered. After 1961 when total iodine was being measured there are smaller differences between previous reports and the revised estimates. Figures 1-7 and 1-8 show the annual releases from the SRS of elemental and organic forms of ^{131}I, respectively. See Chapter 4.2 for full details on iodine release estimates.

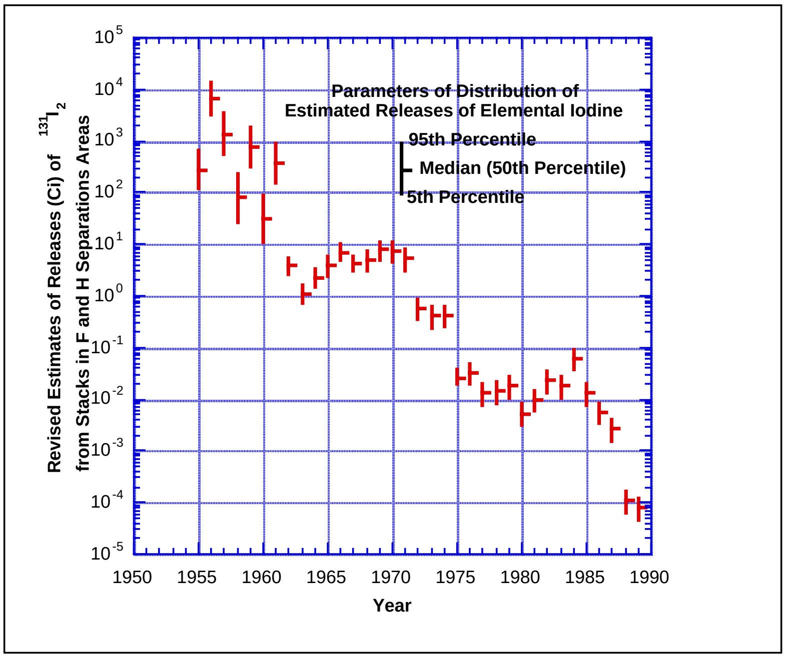


Figure 1-7. *RAC* releases estimates of ^{131}I in elemental form (I_2) from stacks in the F and H separations areas. For each year, the length of the vertical line shows the range (5th to 95th percentiles) of the distribution of release estimates and the median estimate is indicated by the horizontal bar.

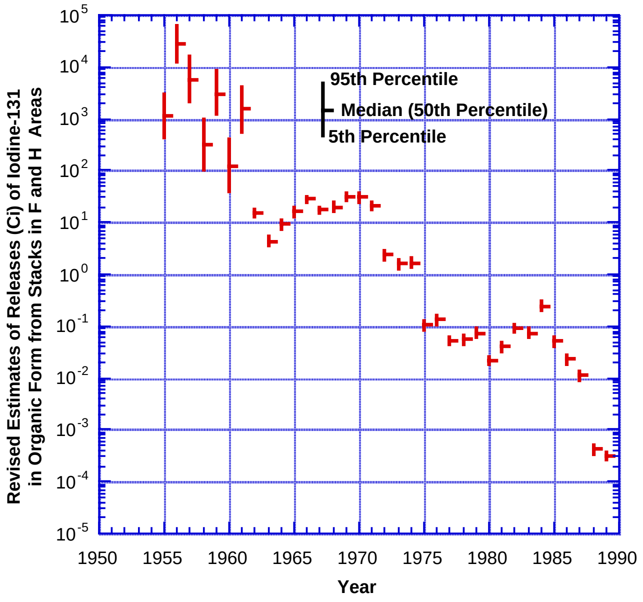


Figure 1-8. *RAC* estimates of releases of ^{131}I as organic iodides from stacks in the F and H separations areas. For each year, the length of the vertical line shows the range (5th to 95th percentiles) of the distribution of release estimates and the median estimate is indicated by the horizontal bar.

Releases of Activation Products to Air

While most of the radioactivity produced by a reactor involves the products of fission, some isotopes are produced as activation products, when neutrons interact with materials in the reactor. The quantities of activation products are smaller but are created outside the fuel area of the reactor so that they are closer to the outside environment. Several SRS locations had the potential to release activation products. The largest releases occurred during the 1960s, and consisted primarily of ^{41}Ar from the production reactors. Figure 1-9 presents annual data for ^{41}Ar releases. For additional details on the production and release of activation products, see Chapter 4.3.

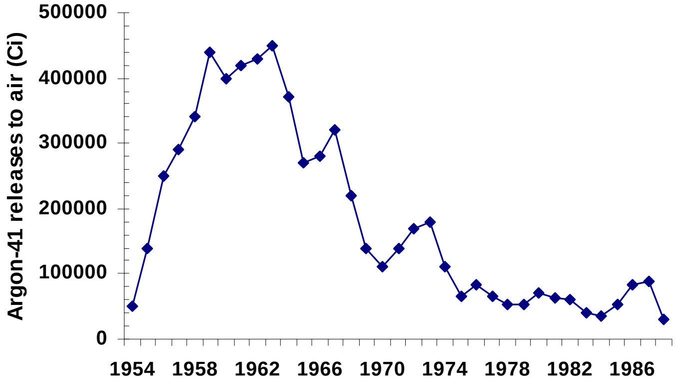


Figure 1-9. Annual releases of ^{41}Ar to air from reactors at the SRS.

Releases Of Alpha-Emitting Radionuclides to Air

The alpha-emitters, primarily plutonium and uranium at the SRS, were released from the fuel fabrication facilities in the M-Area, the reactors, and the reprocessing facilities in the H-Area and F-Area. Releases from the separations facilities were monitored since December 14, 1954, shortly after startup. Continuous sampling was accomplished by passing a portion of stack effluent through a filter designed to trap particulates. The filter was changed weekly and analyzed for specific isotopes. Measured releases from the M-Area and reactor facilities (R reactor, P reactor, K reactor, L reactor, and C reactor) were quite small. The data indicate that the majority of plutonium emissions from both F-Area and H-Area stacks occurred during 1955 and 1969. The data also indicate that the majority of uranium emissions from H-Area stacks occurred during 1955, 1968, and 1969, and that the majority of uranium emissions from F-Area stacks occurred during 1955, 1956, and throughout the 1960s. Evaluation of potential impacts resulting from alpha-emitting radionuclide releases should be focused on these years because the relative magnitude of total emissions during other years (including all years since 1970) appears to be quite small. Figure 1-10 shows our annual release estimates for plutonium from the main F-Area and H-Area stacks. See Chapter 4.4 for details on release of alpha-emitting radionuclides to air from the SRS.

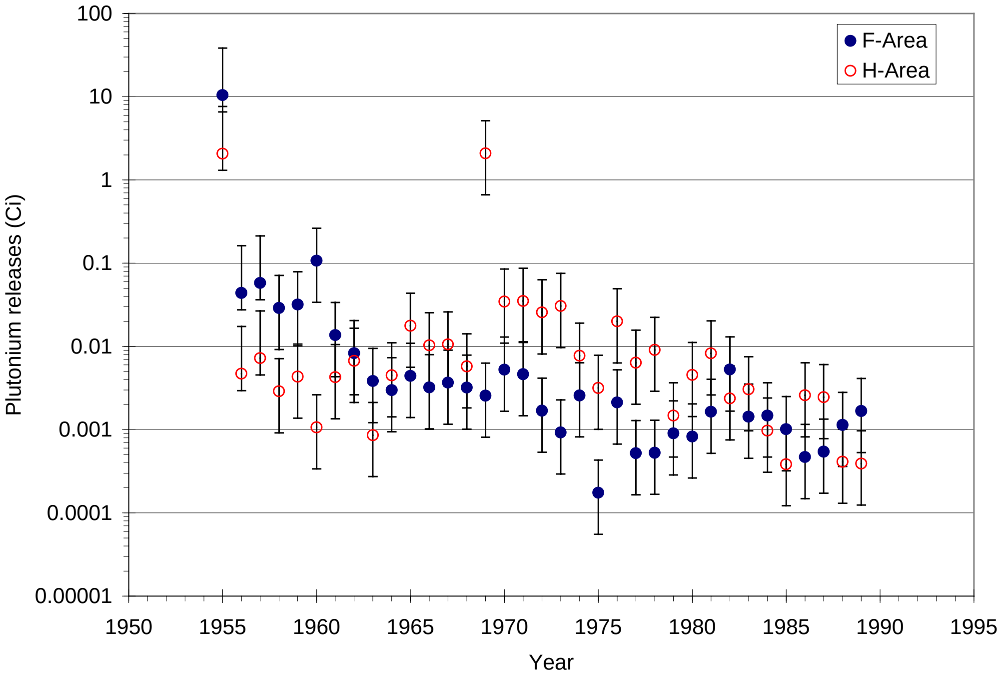


Figure 1-10. Annual median plutonium (including ^{238}Pu and ^{239,240}Pu) release estimates for F-Area and H-Area. The upper and lower error bars represent the 95th and 5th percentile values, respectively.

Releases Of Radionuclides to Surface Water

The controlled fission process within the reactors produced enormous amounts of heat. Heavy water (water made from the hydrogen isotope deuterium) was circulated in a closed system through heat exchangers to cool and moderate the reactors. Incoming Savannah River water was stored in holding basins at each reactor, passed through the heat exchangers, then was discharged to Site streams. In 1958, Par Pond, a 2,700-acre lake, began providing cooling water for the P and R Reactors. The water was pumped back to the pond, allowing more river water to be pumped to the L, K, and C Reactors. In 1985, L Lake was formed by damming Steel Creek, to provide cooling water for the L Reactor. Before Par Pond and L Lake were created, water was discharged directly to Lower Three Runs Creek (from P and R Reactors), to Steel Creek (from L Reactor), to Pen Branch (from K Reactor), or to Four Mile Creek (from C Reactor).

The Disassembly Basins were the primary sources of radionuclide releases to surface water from the reactors. Spent fuel and irradiated target elements were removed from the reactor and stored in these large water-filled basins adjacent to the reactor building. The water in the basins cooled the components and provided shielding. Contamination from these elements gradually moved into the basin water. From startup to the mid-1960s, visual clarity was maintained in the basins by continuously purging them with fresh, filtered river water. These purges released radioactivity dissolved or suspended in the basin water to the SRS streams.

Complex chemical and physical processes in the F- and H-Canyon Buildings separated uranium, plutonium, and fission products. Fission products were placed in underground high-level waste tanks nearby. Cooling water for portions of the F-Area separations process line was pumped from deep wells and discharged to Four Mile Creek. At times, this water contained some radioactivity because of cooling coil leaks. The F-Area liquid effluent included process cooling water, sanitary wastewater treatment effluents, and spill runoff; H-Area effluent was similar.

The SRS had a fairly broad effluent monitoring program for releases of key radionuclides from the main facilities onsite to the streams and seepage basins. Tritium and ^{137}Cs were the main radionuclides of concern for releases to surface streams and the Savannah River. We developed detailed source terms for those radionuclides (see Chapter 5 for details). Other radionuclides of importance include ^{90}Sr, ^{131}I, ^{60}Co, ^{32}P, and uranium releases from the M-Area to Tim's Branch Creek. Surface water releases of radionuclides were highest in the early to mid-1960s and decreased into the 1980s. Figure 1-11 shows annual release estimates of tritium to surface water.

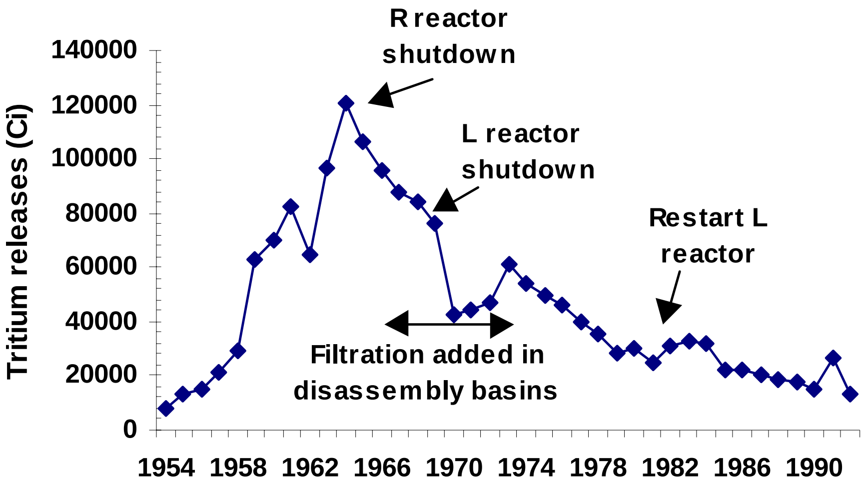


Figure 1-11. *RAC*'s annnual tritium release estimates to surface water. Some important events that affected releases of radioactivity to surface water at the SRS are shown. The highest releases of tritium to surface water occurred in the mid-1960s.

Figure 1-12 shows our annual release estimates of ^{137}Cs to surface water with uncertainty estimates. There is overall general agreement between our reconstructed release estimates to the Site and the annual total reported by SRS.

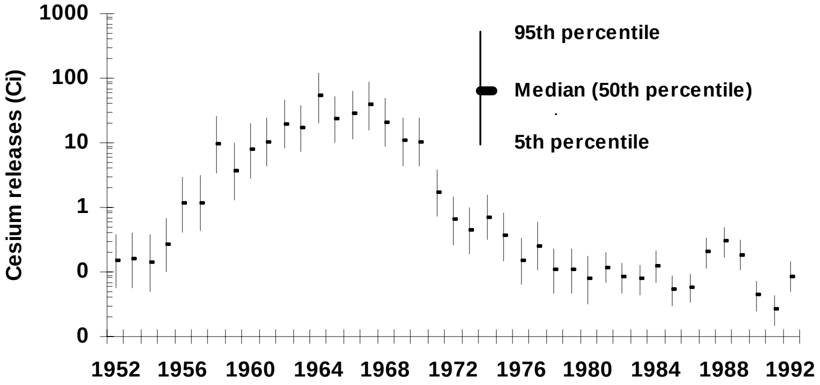


Figure 1-12. *RAC* estimates of ^{137}Cs releases to surface water from the SRS with uncertainty estimates, shown on a logrithmic scale. Each year is represented by a vertical line that represents the 95th (top) and 5th (bottom) percentiles of the distribution of releases with the median or 50th percentile shown as the filled shape in the center.

Environmental Monitoring For Radionuclides

Environmental monitoring data are valuable resources for dose reconstruction because they provide direct information about the concentrations of radionuclides in air, water, vegetation, and foods at particular places and times. These data may be used to independently check the source term estimates or environmental transport model calculations, for example. In some cases, the data may also be useful for direct exposure assessment. The current report describes the history, scope, and results of the environmental monitoring programs for:

- Air and rainwater
- Vegetation and agricultural products
- Milk
- Wild game
- Sediments and soil
- Savannah River water, community water supplies, and water treatment plants
- Fish.

Air and rainwater have been sampled at various locations on or in the vicinity of the SRS since background measurements began in 1951. Air represents a major pathway for transport of SRS releases and exposure of offsite individuals. The key contaminants detected in air and rainwater during the period of interest (1951-1992) are radioiodine and tritium. Their concentration decreases with distance from the SRS. Air monitoring and other environmental data may be used to validate airborne source terms and dispersion models.

The report describes the extent and analytical results of the radiological monitoring program for water supplies of 14 communities surrounding the SRS, for one upstream and two downstream drinking water treatment plants supplied by the Savannah River, and for offsite locations from the Savannah River. For dose reconstruction, the potential impacts of SRS operations on both the surrounding community water supplies and the downstream water treatment plants are of greatest concern because the safety of drinking water is of great interest to the public. Figure 1-13 shows tritium concentrations in water from the treatment plants near the SRS. The Savannah River monitoring data can be used evaluate the impact of SRS releases of radionuclides on the downstream drinking water supplies, and will be useful to evaluate other exposure pathways, such as the ingestion of fish and the recreational use of the river.

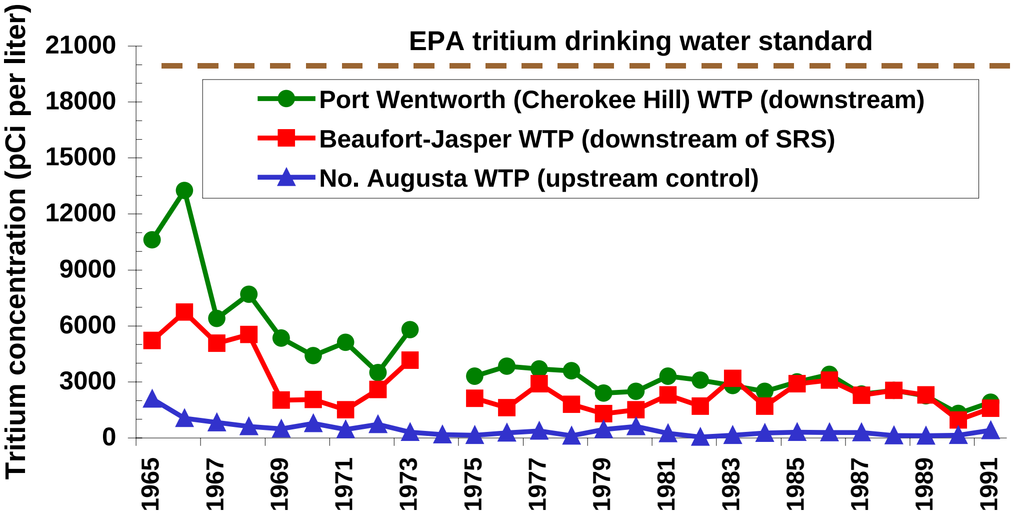


Figure 1-13. Tritium concentrations in water from the water treatment plants.

RELEASES OF CHEMICALS FROM THE SRS

While radionuclides released from the SRS are important in evaluating potential risks to individuals living offsite, it is also necessary to understand that the SRS used, produced, and released large quantities of chemicals. The extent of releases of these chemicals must also be considered when evaluating the potential risk to offsite residents. Source term, or release, estimates were determined using inventory or usage estimates, knowledge of processes, information currently required by regulatory agencies, and monitoring data. There is sparse or no monitoring data for chemicals used at the SRS, especially before 1980. A limited amount is available from ambient air monitoring, water quality monitoring, and special studies. For some chemicals, extrapolating back in time from the 1980s monitoring data was the best way to estimate a source term, assuming that the amounts and types of materials used and the processes did not change greatly over the years.

RAC used emissions estimates from the air emissions inventory to estimate chemical releases to air. Large amounts of sulfur dioxide, nitrogen dioxide, and particulates (ash) were released from seven coal-fired power plants. We estimated releases of mercury, lead, manganese, nickel, nitric acid, chromium, cadmium, and hydrogen sulfide to air, as well. We found enough information to calculate the uncertainty associated with the release estimates for the chemicals listed in Table 1-4.

Table 1-4. Release Estimates and Uncertainty Ranges for Chemicals Released to the Air

Chemical	Median average annual release (ton y^{-1})	5th–95th percentile values on the median (ton y^{-1})
Coal ash	4200	2300–7100
Mercury	0.3	0.18–0.51
Nitrogen dioxide	6050	4320–8480
Sulfur dioxide	11000	8470–14400

Uncertainty calculations were not made for the chemicals listed in Table 1-5 because there was a lack of information; however, a range of releases was estimated.

Table 1-5. Release Estimate Ranges for Some Chemicals Released to the Air

Chemical	Range of release estimates (ton y^{-1})
Benzene	1.8–18
Lead	0.05–0.12
Manganese	0.07–1.9
Nickel	0.11–0.42
Nitric acid	30–150

Table 1-6 shows that thousands of tons of chlorinated solvents were released from the M Area. The table displays our median release estimates of solvents to air and to Tim's Branch Creek from the M-Area. Almost all of the chlorinated solvents evaporated during use or after being discharged to surface water. Until 1979, waste solvent was released to the M-Area settling basin or to a stream called the Tim's Branch, where most evaporated. Table 1-6 summarizes the release estimates for trichloroethylene, tetrachloroethylene, and trichloroethane. Chapter 17 has details on releases of chemicals to air.

Table 1-6. Trichloroethylene, Tetrachloroethylene, and Trichloroethane Releases to Tim's Branch from the M-Area

Solvent	Source	Time period	Median
Trichloroethylene	M-Area use	1952–1970	1700 ton (average of 90 ton/y over 19 y)
	M-Area air strippers	1985–1990	70 ton (average of 12 ton/y over 6 y)
Tetrachloroethylene	M-Area use	1962–1975	4055 ton (average of 289 ton/y over 14 y)
	M-Area air strippers	1985–1992	30 ton (average of 3.8 ton/y over 8 y)
Trichloroethane	M-Area use	1979–1988	2200 ton (average of 220 ton/y over 10 y)

For releases of chemicals to surface water, we described the sources and potential releases of arsenic, cadmium, chromium, coal and coal ash, gasoline, hydrogen sulfide, lead, manganese, mercury, nickel, nitrates, uranium, and zinc to water. Mercury was used for several purposes at the SRS, and in the early years was often discarded after use. In summary, historical releases of chemicals to the Savannah River are difficult to determine and quantify. Release estimates are summarized in Table 1-7. In addition, an undetermined amount of chromium used to treat high level waste tank cooling coil water was released.

Table 1-7. Summary of the Estimated Releases of Chemicals to Surface Water

Release estimate (maximum or estimated range)	Released to
1 kg y^{-1} of cadmium	To Tim's branch
900 kg y^{-1} of hydrogen sulfide	To Beaver Dam Creek
8–50 kg y^{-1} of lead	To Tim's Branch
15–623 kg y^{-1} of lead	To the Separations Area Seepage Basins
16–70 kg y^{-1} of mercury	To the Separations Area Seepage Basins
0.1–8 kg y^{-1} of mercury	Entering Four Mile Creek in Groundwater
116–2000 kg y^{-1} of nickel	To Tim's Branch
0–1383 tons y^{-1} of nitrate	To the Separations Area Seepage Basins
Up to 108 tons y^{-1} of nitrate	To Four Mile Creek in Groundwater
27–200 tons y^{-1} of nitrate	To Tim's Branch

Although large amounts of some chemicals were released to seepage basins and SRS streams, the impacts to surface water extending beyond the Site boundary do not appear to be measurable. The available environmental monitoring information does not support an appreciable source term from the SRS for nonradiological contaminants for all identified chemicals and heavy metals of concern measured in surface water, groundwater, and ambient air.

CONCLUSIONS

The review of some 50,000 boxes of records associated with the SRS has produced a large set of data pertinent to the reconstruction and validation of radionuclide and chemical source terms for the Site's operational history. We conclude that, for the key radionuclides, the available data are adequate to develop estimates of dose to individuals living offsite during past SRS operations. For the key chemicals, information prior to the 1980s is very sparse. However, we have reconstructed approximate ranges of key chemical releases for SRS operations, and it may be feasible to develop conservative, bounding risk estimates for these chemicals to members of the public living offsite.