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H-Area Seismology Summary and General Overview-Rev 1

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SUMMARY

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 19808

Prepared for the U. S. Department of Energy under contract no. DE-AC09-89SR18035

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I-Area Seismology Summary and General Overview

. C. Lee

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List of Figures

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The purpose of this document is to summarize the technical discussion contained in the H-Area Seismology Report (Lee 1994) and provide a perspective of the evolution of seismic design basis at SRS. Many sections of this summary were extracted from the report Update of H-Area Seismic Design Basis and readers should refer to that report for a more detailed technical basis of results and for technical references. Although this document applies, in a general sense, to H-Area, all site-specific data were derived from geotechnical investigations conducted at the ITP site.

ıtroduction

For engineering design of earthquake-resistant structures, seismic response spectra are most commonly derived from recorded seismic data. Response spectra serve the engineering function of characterizing ground motion as a function of frequency. These motions then provide the input parameters used in the analysis of structural response or for geotechnical evaluation. Response spectra are described in terms of oscillator damping, amplitude, and frequency and are defined as the maximum earthquake response of a suite of damped single degree-of-freedom oscillators. The response spectra are related to earthquake source parameters, travel path, and site conditions. Savannah River Site (SRS) response spectra have evolved from the use of a particular record of earthquake response to spectra that may represent the response of more than one earthquake, with each earthquake controlling narrow frequency bands. Controlling design basis earthquakes represent, in general, a suite of earthquake magnitude and distance pairs that provide the maximum oscillator response in discrete frequency bands. The basis for controlling earthquakes is derived from detailed geologic and seismologic investigations conducted in accordance with 10CFR100 (Appendix A) and taking into consideration proposed changes as described in Draft 10CFR 100 (Appendix B). The above approach is typically labeled the "deterministic" approach. The primary disadvantage of this approach is that the selection of controlling earthquakes does not explicitly incorporate the rate of seismicity or the uncertainty in earthquake source parameters and ground motion.

An important alternative to the deterministic approach is the probabilistic hazard assessment (PHA). The PHA incorporates the source zone definition and ground motion prediction assessments required for the

deterministic approach, but adds the estimated rates of occurrence of earthquakes, and explicitly incorporates the uncertainties in all parameters. This approach allows one to predict the probability of exceeding a particular ground motion value at a point in space over a specified period of time. This approach is essential for hazard mitigation of spatially distributed facilities having different risk factors. The current DOE criteria are probabilistic based (e.g., DOE-STD-1024-92)

For SRS, design spectral shapes are employed for earthquakes of different magnitudes and travel paths. The following three principal spectra have been developed for the SRS using deterministic methodologies:

- Housner (1968)
- Blume (URS/Blume, 1982)
- Geomatrix (1991)

Each of these studies portray an evolution of understanding of the seismic process.

The Housner spectra was the response of a single record, the Taft record, from the 1952 Tehachippi earthquake. In the Blume study (URS/Blume 1982), a free-field spectrum was developed corresponding to each of three events: random local (<25 km), Bowman, South Carolina, and Charleston, South Carolina. Although different methodologies were used to develop response, the Geomatrix study (Geomatrix 1991) used the same three sources except that the 1886 Charleston earthquake was increased in size and moved closer to the site. In both Geomatrix and Blume investigations, the Bowman earthquake did not control motions at any frequency; consequently, two controlling events were modeled, the random local and distant Charleston.

The Housner and Blume spectra were based on western U.S. strong motion data. This is because recorded strong motion data are unavailable in the eastern U.S. for earthquake magnitudes and distances necessary for design. Since the Blume study was conducted, research has shown that seismic path and site properties are very different between the eastern U.S. (EUS) and western U.S.(WUS). Consequently, Geomatrix used analytical approaches that correct WUS spectra for EUS conditions, and they directly estimated spectra by using Coastal Plain conditions to model the source and path. Thus, the Geomatrix spectral shape has specific site dependencies.

The H-Area Tank Farm engineering analysis requires specification of design basis motion for determination of liquefaction susceptibility and structural integrity. To perform the engineering evaluation at H-Area, the only state-of-the-art site-specific spectra available, the Replacement Tritium Facility (RTF) spectra [developed from the Geomatrix (1991) K-Reactor investigation], was used as a basis. The RTF spectra are the DOE supported spectra for SRS. The local event spectrum was scaled to 0.19g following DOE STD-1024-92 with the 0.19g associated with a mean probability of exceedance of $2x10^{-4}$/year. The distant earthquake spectrum was not scaled because it did not control the high frequencies. For the H-Area analysis, the RTF spectra was identified as the evaluation basis earthquake (EBE) spectra. The adequacy of the distant event EBE spectrum is reviewed in a parallel investigation with the engineering and geotechnical analysis of H-Area. Following guidance from the Tank Seismic Expert Panel (TSEP) H-Area 50th and 84th percentile rock and soil spectra were developed to judge the adequacy of the distant earthquake.

Criteria

Earthquake design basis criteria for H-Area is provided in DOE STD-1020 and STD-1024. DOE STD-1020 develops the facility-specific hazard categories and specifies that a median spectral shape be anchored to the assigned peak ground acceleration (PGA) where the PGAs will be exceeded at a mean annual probability. Specific direction for EUS DOE facilities that have Electric Power Research Institute (EPRI) and Lawrence Livermore National Laboratory (LLNL) hazard curves are contained in STD-1024, and that standard provides criteria for the SRS that constrain the mean soil PGA at 0.19g for the probability of exceedance of $2x10^{-4}$. This is based on the geometric mean of EPRI and old LLNL median hazard soil curves scaled to represent the mean hazard. The SRS local event spectrum controls high frequency and its median shape is scaled to the STD-1024 design PGA at $2x10^{-4}$. The distant event spectrum was treated similarly to RTF, where it was determined to be adequately conservative and was applied unscaled.

Criteria for scaling lower frequency components of the design basis spectra to probability-derived values are contained in DOE-STD-1024-92 (Appendix B). STD-1024 recommends a procedure to scale deterministically derived median spectral shapes to the maximum spectral velocity having the appropriate annual probability of exceedance. However, STD-1024 does not provide correction factors for the averaged EPRI and LLNL spectral velocities, which exhibit significant differences (see discussion below).

The RTF spectra were applied to H-Area in the interim (EBE earthquake spectra). Following guidance provided by TSEP, as an alternative to developing a scaling factor for the maximum spectral velocity, adequacy of the distant EBE is assessed on the basis of comparison to H-Area specific median and 84th percentile deterministic ground motions.

Deterministic Estimates of Ground Motion at the Savannah River Site

Investigations of historical seismicity, together with detailed seismic monitoring and geologic studies, have resulted in three hypothetical earthquakes, two of which control the seismic hazard at SRS. One of these two earthquakes is a local event comparable in magnitude and intensity to the Union County earthquake of 1913 but occurring within a distance of about 25 km of the site. The other is an earthquake representing a potential repeat of the 1886 Charleston earthquake (similar magnitude and location) (Figure 1).

Sporadic and apparently random low-level seismicity is prevalent in the Coastal Plain and Piedmont geologic provinces (excepting clusters of seismicity in Bowman and Middleton Place). Regulatory guidance (10CFR100, App. A) prescribes a design basis local event to occur at a random location within a specified radius of the site. Recent geologic investigations, conducted to determine and limit the age of deformation of known basement faults at SRS, indicate ages no more recent than Eocene. Consequently, deterministic analyses have assumed source properties for a random local event, with on-site faults considered not capable.

The key seismological investigations conducted for the evaluation of SRS facilities that completed deterministic estimates of ground motion were the Blume and Geomatrix studies.

lume, 1982

The recommended site acceleration and spectra in the Blume analysis were based on conservative assumptions on the occurrence of specific earthquakes. Two hypothetical earthquakes consistent in size with earthquakes that have occurred in similar geologic environments were found to control SRS spectra and peak ground motion: a hypothesized site intensity VII (MMI) local earthquake of epicentral intensity VII, causing an estimated site PGA of 0.10g, and a hypothetical intensity X (1886 Charleston-type), occurring at a distance of 145 km causing an estimated site PGA of <0.1g. For added conservatism, the site PGA was doubled to 0.2g and corresponded to a site intensity of about VIII. Local and distant earthquake response spectral shapes were derived from statistical analyses of primarily WUS data (Figure 2) and scaled to the 0.2g PGA.

Although the Blume study represents the state of knowledge in the early 1980s, the design spectra shape are now known to be biased. This bias toward low frequency is a result of using WUS recorded data. Estimated motions at the site did not account for any soils or rock data. Furthermore, the two-fold increase in spectral acceleration is not required by current standards.

Geomatrix, 1991

In a manner similar to Blume, the Geomatrix (1991) investigation performed a deterministic analysis following the acceptance criteria defined by USNRC Standard Review Plan, Section 2.5.2. The resulting spectra, to be used for evaluations of K Reactor, were for a distant and local source. The Charleston source (Mw 7.5) employed a Random Vibration Theory (RVT) model and site-specific data. The local source (Mw 5) used WUS deep soil, strong motion data corrected for EUS soil and rock conditions. The 5% damped spectra for the two hypothetical earthquakes are illustrated in Figure 3. The local spectrum is scaled to 0.19g and the distant event is unscaled. The Blume envelope is shown for comparison.

According to the Geomatrix report, the "spectra... represent median or average levels of ground motion" (Geomatrix, 1991). Our current review suggests that the source assumptions used in that calculation are more than median predicted motions for a repeat of the 1886 Charleston earthquake.

Figure 3 shows that spectral peaks estimated from WUS data (Blume spectrum) are shifted to lower frequencies relative to the predicted EUS data. Although the Geomatrix spectra do not employ an arbitrary scaling factor for conservatism, other added conservatisms (described below) were applied in the distant source definition.

H-Area Spectra

To support initial engineering evaluations for the H-Area Tank Farm, an interim spectra was specified. The EBE spectra consists of Geomatrix median local spectral shape scaled to 0.19g per DOE-STD-1024 and Geomatrix unscaled "median" Charleston spectrum (Salomone 1994). This spectra was used based on the input parameters being greater than a median and the local earthquake being scaled to the DOE recommended PGA with an annual probability of exceedance of 2×10^{-4}.

rametric Studies for Distant Earthquake

As part of the current program and to respond to reviewer comments, limited parametric studies were conducted to understand the basis for the distant EBE. These studies looked at parameters that impact facility design response such as the following:

- earthquake source parameters such as source distance, magnitude focal depth, stress drop, and moment
- bedrock and crustal path properties
- soil properties that vary facility-to-facility in strength, layering, shear-wave velocity, and thickness

The following conclusions have been drawn regarding the application of the EBE spectra to H-Area:

- Source distance has a major impact on predicted response, and the 110 km distance used for the Charleston source is over-conservative and inappropriate for quantification of ground motion for a repeat of the 1886 Charleston earthquake. The epicentral distance to the 1886 Charleston earthquake is 145 km.
- The selection of focal depth is important for the point-source calculation, and Geomatrix used the value producing the largest response.
- Predicted motions are sensitive to stress drop, and the 150 bar stress-drop used for K Reactor is on the upper end of the range considered median for an EUS earthquake. (Measured values of stress-drop range from 20 to about 600 bars for EUS earthquakes.)
- Crustal structure and Q models were region specific. However, the Q model used in the analysis is the only published model representing data recorded in the southeastern Coastal Plain.
- SRS facility sites have different seismic response because of differences and uncertainties in the average soil velocity, depth to bedrock, and strain-related material strengths.

Su...ary of the Distant Event EBE Spectra for H-Area

The EBE distant earthquake spectrum, applied at H-Area, used conservative source parameters (greater than median) and a source distance and PGA scaling that are more conservative than the median. Taking into account the differences in the shallow soil properties of H and K Areas suggests that the EBE distant event spectra provides greater margin than median when applied at H-Area.

Comparison of the Distant EBE to H-Area 50th and 84th Percentile Spectra

Adequacy of the distant EBE spectrum was evaluated based on comparison to estimates of the 50th and 84th percentile rock motion using updated earthquake source parameters and H-Area site-specific properties. The approach taken in the development of H-Area distant EBE spectrum was to develop a median based rock prediction for a repeat of the 1886 Charleston earthquake. While the source size is considered maximum, best estimate or median values are used for stress-drop, path, and site properties. The 84th percentile rock spectrum was developed to account for variability and uncertainty in modeling, source, and path. Free-surface soil spectra are estimated from convolving the median and 84th rock spectra through the site-specific soil.

The Charleston earthquake median source and path properties used a Mw 7.5 earthquake with a stress-drop of 100 bars at a distance of 120 km. The 84th percentile spectrum used a spectral scaling factor that accounts for variability associated with source, path, and modeling. Preliminary median and 84th percentile RVT rock spectra for H-Area are shown in Figure 4. Rock spectra for K Reactor were not available from the Geomatrix (1991) work; consequently, an approximation to that spectra was derived (Figure 4).

WSRC derived surface spectra from the median and 84th percentile rock spectra by using H-Area soil properties (Figure 5). Comparison of the H-Area distant EBE rock spectrum (Figure 4) and the H-Area 50th and 84th response spectra indicates that the EBE spectrum falls between the 50th and 84th deterministic spectra.

The prior version of this report used alternative source parameters for the distant earthquake. A Mw 7.5 at 145 km, having a stress drop of 150 bars was assumed to represent median source parameters for a repeat of the 1886 Charleston earthquake. There is less than about 10% difference in predicted motions between these "assumed" median source definitions.

F and LLNL Hazard Spectra

During the 1980s, two probabilistic seismic hazard analyses were performed for SRS. LLNL performed a study using the input and methods developed through support of the USNRC. The other analysis was performed using the input and methodology developed by EPRI. These studies were evaluated in detail by DOE and are discussed in DOE-STD-1024. These studies provide uniform hazard spectra (UHS), which differ greatly from deterministic spectra in that uncertainties in seismicity and ground motion parameters are explicitly incorporated into the analysis. UHS provide a probability of exceedance at each spectral frequency; normally for a given UHS, each spectral value will have the same probability of exceedance.

In general, earthquakes with differing magnitudes and distances control different spectral frequencies and thus different portions of the UHS. Guidance on defining these controlling earthquakes can be found in DOE-STD-1024, the draft NRC RG-1015, and the National Research Council (1988). The average earthquake magnitude and distance that controls motion at a particular frequency is defined as M-bar and D-bar. The deterministic approach assumes that the largest hypothetical events will occur and the approach is to estimate the distribution of the response spectra. Depending on how the UHS was developed, M-bar and D-bar may bear some association to the deterministically derived controlling earthquake magnitudes and distances.

WSRC compared the LLNL and EPRI rock and soil uniform hazard spectra to the EBE and the H-Area 50th and 84th spectra. The UHS have been decomposed by event magnitudes to illustrate relative contribution to hazard by earthquake magnitude (Figure 6). Although it is in general difficult to make comparisons between probabilistic and deterministic spectra, the decomposition allows an indirect comparison of the UHS to a deterministically derived spectra (Figures 7 and 8).

The EPRI and LLNL UHS for SRS can be summarized as follows:

- The absolute value of the mean hazard differ dramatically between EPRI and LLNL, suggesting that the values should be used only after a detailed understanding of the differences in the models.
- The EPRI soil model is generic and does not account for SRS site effects.

- The Mw 7.5 Charleston-type earthquake is not a major contributor to hazard.
- Average event magnitudes and distances (M-bar, D-bar) do not match deterministic event magnitudes and distances.
- Deterministic median rock spectra derived using M-bar and D-bar values are below the EBE rock spectra.

Based on the EPRI and LLNL M-bar and D-bar values, the seismic source zones used to derive the UHS are inconsistent with the fundamental deterministic assumptions for source distance and magnitude used in the Blume and Geomatrix studies. This situation is apparent from the M-bar and D-bar results, where the average earthquake magnitudes exceeded those of the local earthquake and show that the Mw 7.5 Charleston earthquake is not a significant seismic hazard contributor (Lee 1994).

Outstanding Issues for Site Spectra

The H-Area investigations have pointed to a number of significant data needs, calculations, and other issues that deserve continued attention and eventual resolution but were beyond this scope of the H-Area/ITP Program. These issues are as follows:

- *Deep soil velocity profile*. Models use one deep measurement at SRS and is not H-Area site-specific.
- *Soil velocity variability*. Models use only mean values; sufficient data are available to explore variability effects on ground motion predictions.
- *Triassic Basin response*. One-dimensional model used for basin; sufficient data are available to construct a more appropriate 3-D model.
- *Charleston earthquake finite source*. Model uses point source; development of a finite source will eliminate issues associated with point source models.
- *SRS UHS*. Improvements can be made to the LLNL and EPRI hazard studies by incorporating up-to-date data in the source zone and soil models and by reviewing in detail the quantitative uncertainty in parameters.
- *Coastal Plain Q Model*. The Q model differs significantly from other EUS models and should be validated.

- *Controlling earthquake magnitude and distance.* The deterministic magnitude and distance for the EBE local and distant earthquakes are inconsistent with the probabilistic (LLNL an EPRI) average controlling magnitude and distance.

- *Local Earthquake Spectrum.* The local event spectrum should be modeled using H-Area site properties as a check on the corrected empirically derived shape.

Conclusion

A review of the technical basis for the H-Area EBE spectra was conducted together with an overview of the history of recent spectra development at SRS. The EBE spectra for H-Area consist of: (1) a 0.19g scaled "local" 5% damped response spectrum and (2) an unscaled spectrum for the "distant" earthquake. The unscaled distant spectrum was based on work completed by Geomatrix (1991) for K-Reactor. Based on H-Area data, application of the EBE "distant" earthquake spectrum at H-Area provides motions that are more conservative than median. This judgment is based on assessments of deterministic "distant" event spectra using H-Area specific properties for the 50th and 84th percentile expected motions (Figure 4). These spectra indicate that the EBE "distant" spectrum is in excess of the 50th percentile and less than the 84th percentile of deterministic ground motions.

EPRI and LLNL rock and soil UHS were also reviewed for applicability to H-Area. It was determined that the applicability of the LLNL rock and soil UHS were limited until improvements are made in the LLNL seismicity model. The EPRI soil model was also not suitable for a site-specific comparison, however, the rock UHS are useful to compare to deterministic ground motion predictions. The 84th deterministic rock spectra is "close" to the EPRI $1x10^{-4}$ rock UHS in the 1–2.5 Hz range (Figure 7). The contribution to risk of the H-Area EBE rock and 84th percentile distant response spectra will be evaluated in the probabilistic analysis to be completed in a later phase of this investigation.

The EBE spectra together with the 84th percentile deterministic spectrum meet the acceptance criteria as defined by DOE-STD-1024 with the TSEP recommendations for the distant event spectrum. These criteria are considered temporary until specific guidance on the LLNL UHS are developed by the DOE. The TSEP recommendations for applying a deterministic 84th percentile spectrum in lieu of the unscaled distant EBE spectrum effectively compensate for the problematic LLNL UHS but are not consistent criteria for future investigations and facility ground motion prescription.

Additional direction is required from facilities for the performance and hazard goals. The acceptance criteria of DOE-STD-1024 anchors the local median spectral shape to the pseudo-mean of the LLNL and EPRI hazard curves at the 2×10^{-4} annual probability of exceedance. This hazard level falls between that required for PC3 and PC4 facility levels described in DOE-STD-1020 (i.e., corresponding hazard levels of 5×10^{-4} & 1×10^{-4} respectively). This investigation uses a hazard annual probability of exceedance of 2×10^{-4}, corresponding to the highest hazard category of DOE-STD-1024. The distant 84th percentile spectrum is not scaled to any probability derived spectral acceleration, but is near the EPRI 1 x 10-4 UHS at 1-2.5 Hz range. Until the performance/hazard guidelines are issued, engineering evaluation of foundations should use the scaled local and 84th percentile deterministic spectra in their evaluation. Evaluations of structures should use an envelope of the scaled local and 84th percentile deterministic spectra.

Acknowledgments

Many calculations reported within were conducted by Carl Constantino and Ernest Hymsfield of the City College of New York, Walter Silva of Pacific Engineering, El Cerrito, California, and Jeff Mulliken of WSRC. Critical reviews of the document were provided by members of the WSRC Site Characterization Task Team, Jeff Kimball of DOE, Robin McGuire of Risk Engineering, Inc, and Kenneth Campbell of EQE International.

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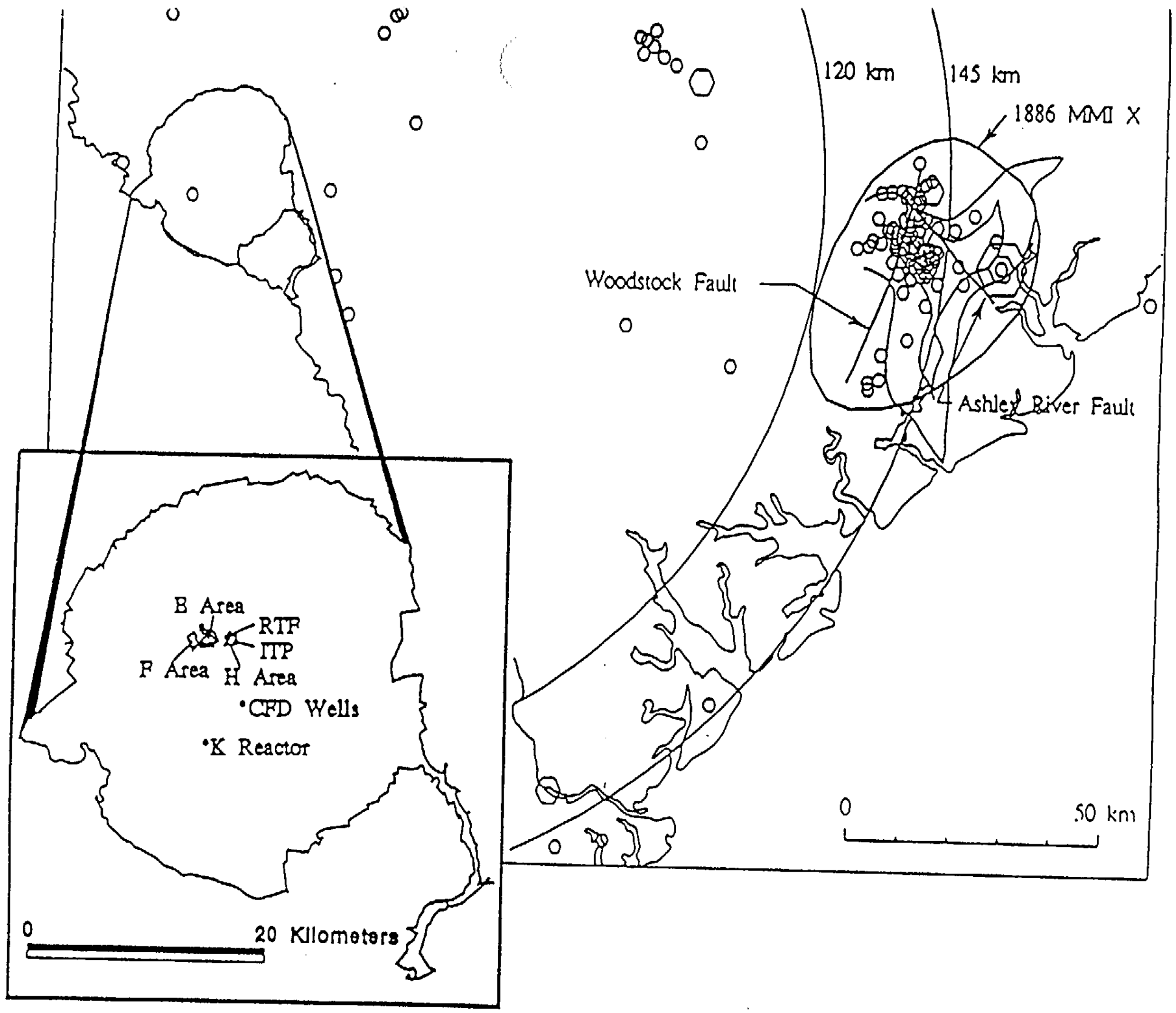

Figure 1. Savannah River Site relationship to Charleston 1886 modified Mercalli Intensity X isoseismal, historic and instrumental seismicity, and inferred active faults in the Charleston area; also shown are site center radii of 120 and 145 km (dark, irregular lines are the isoseismals for the Charleston earthquake taken from Dutton (1890).

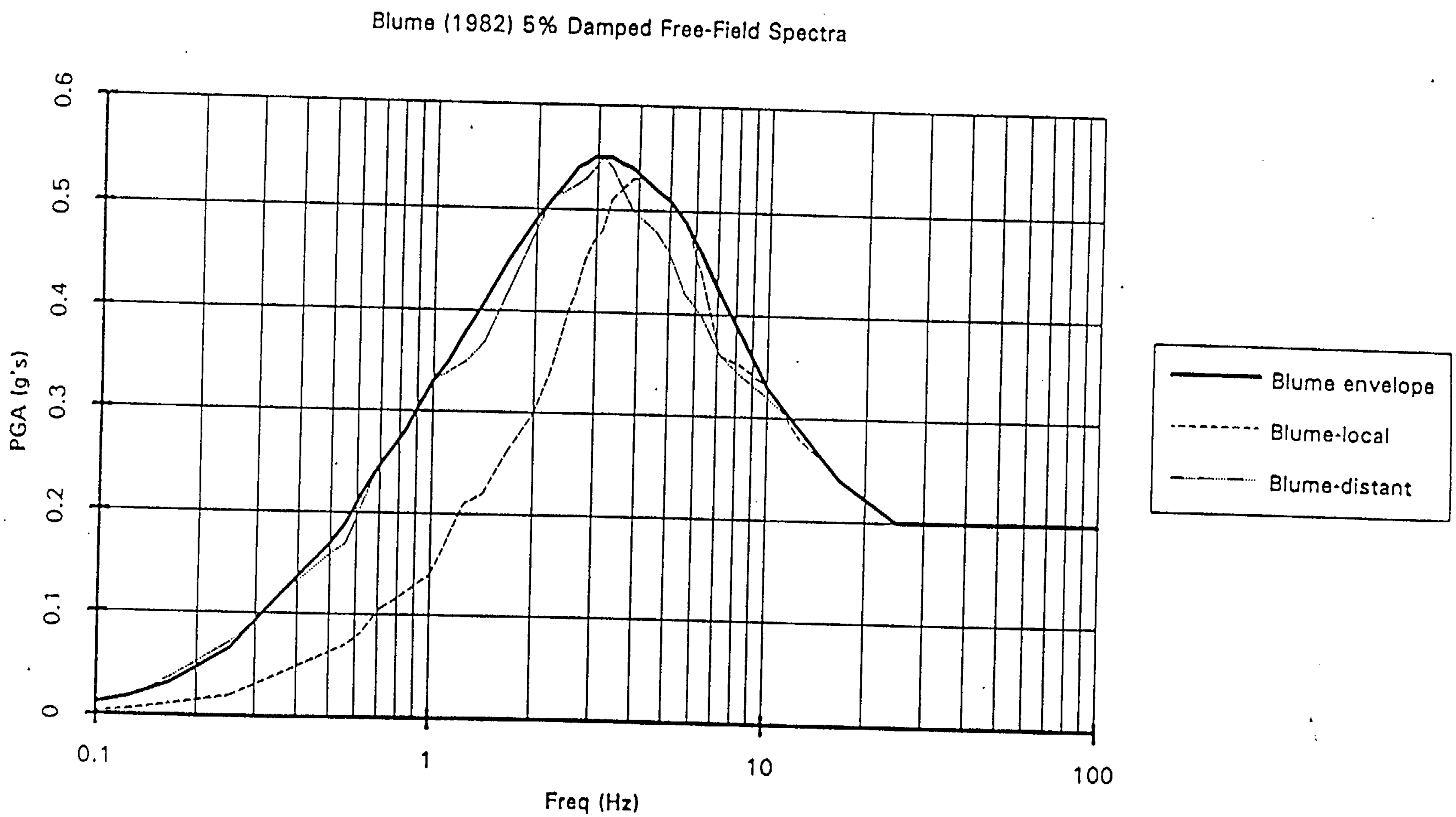

Figure 2. URS/Blume (1982) recommended 5% damped mean response spectra for local and distant earthquakes. Motions predicted for soil.

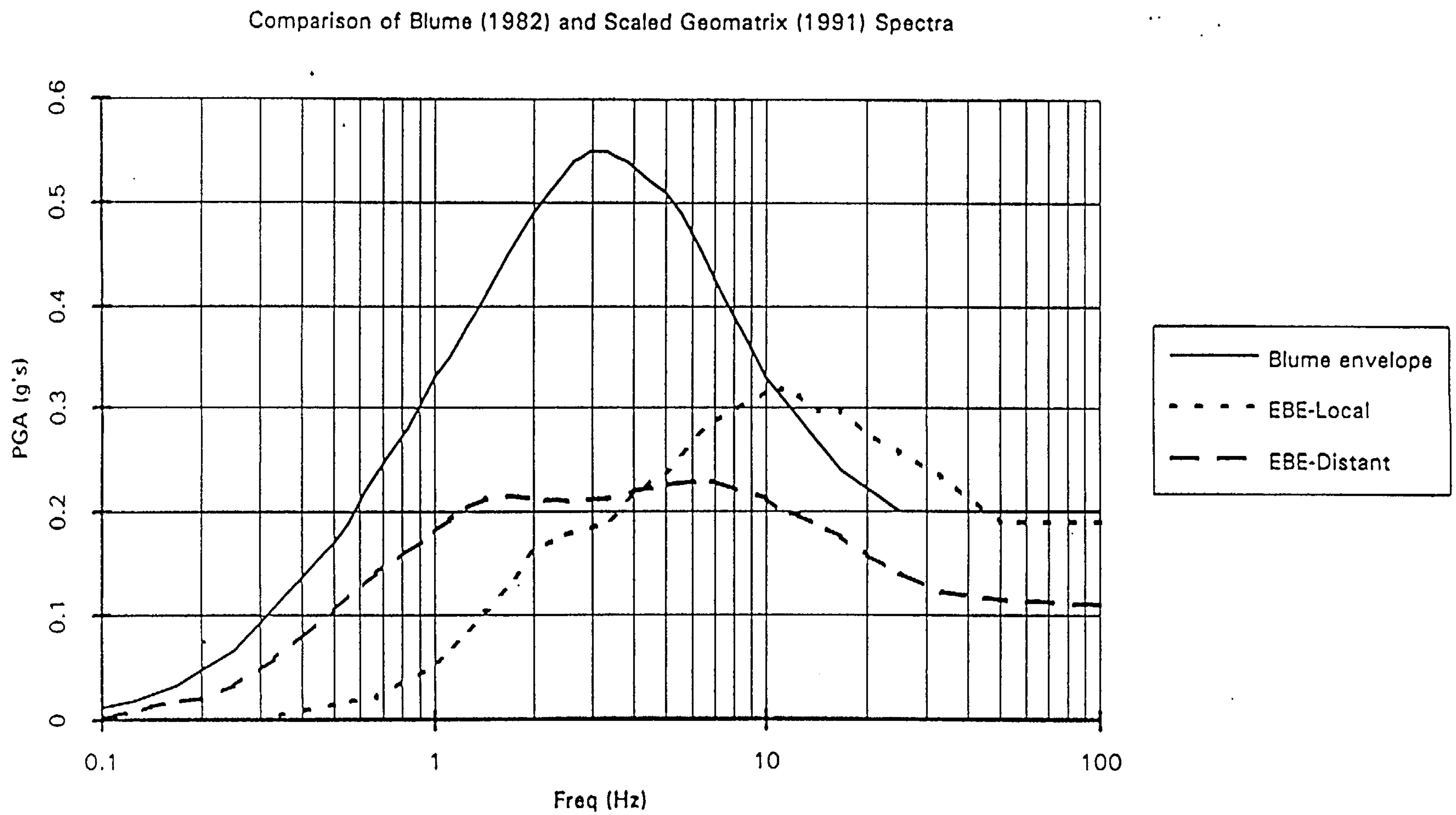

Figure 3. Geomatrix (1991) 5% damped mean response spectra for the local (scaled to 0.19g) and distant (unscaled) earthquakes used for RTF and H-Area (EBE); Blume (1982) envelope shown for reference. All motions predicted for soil.

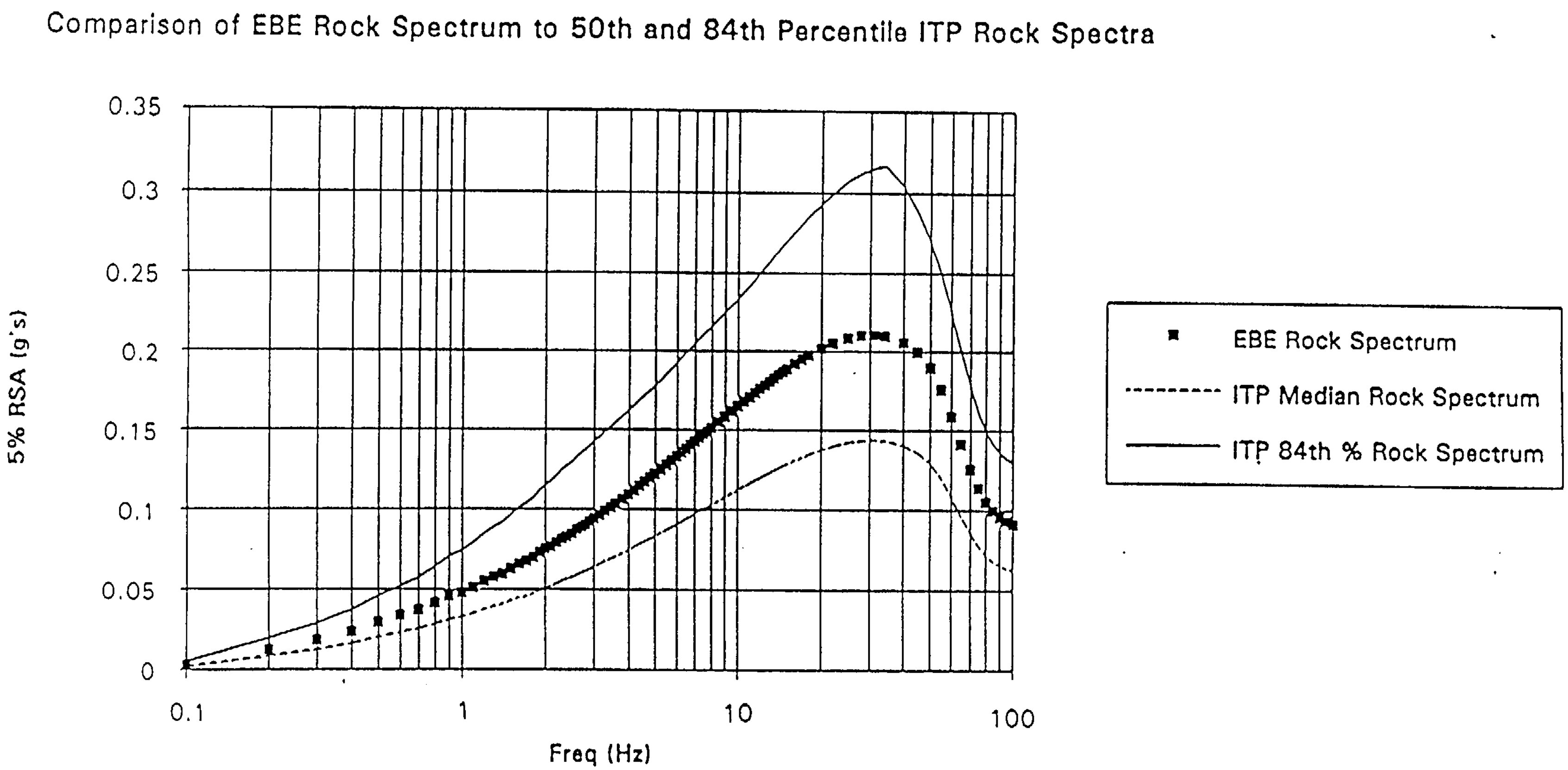

Figure 4. Median and 84th percentile rock spectra for Mw 7.5, 100 bar stress-drop and 120-km distance; also shown are spectra for Mw 7.5, 150 bar and 120-km distance (EBE rock spectrum).

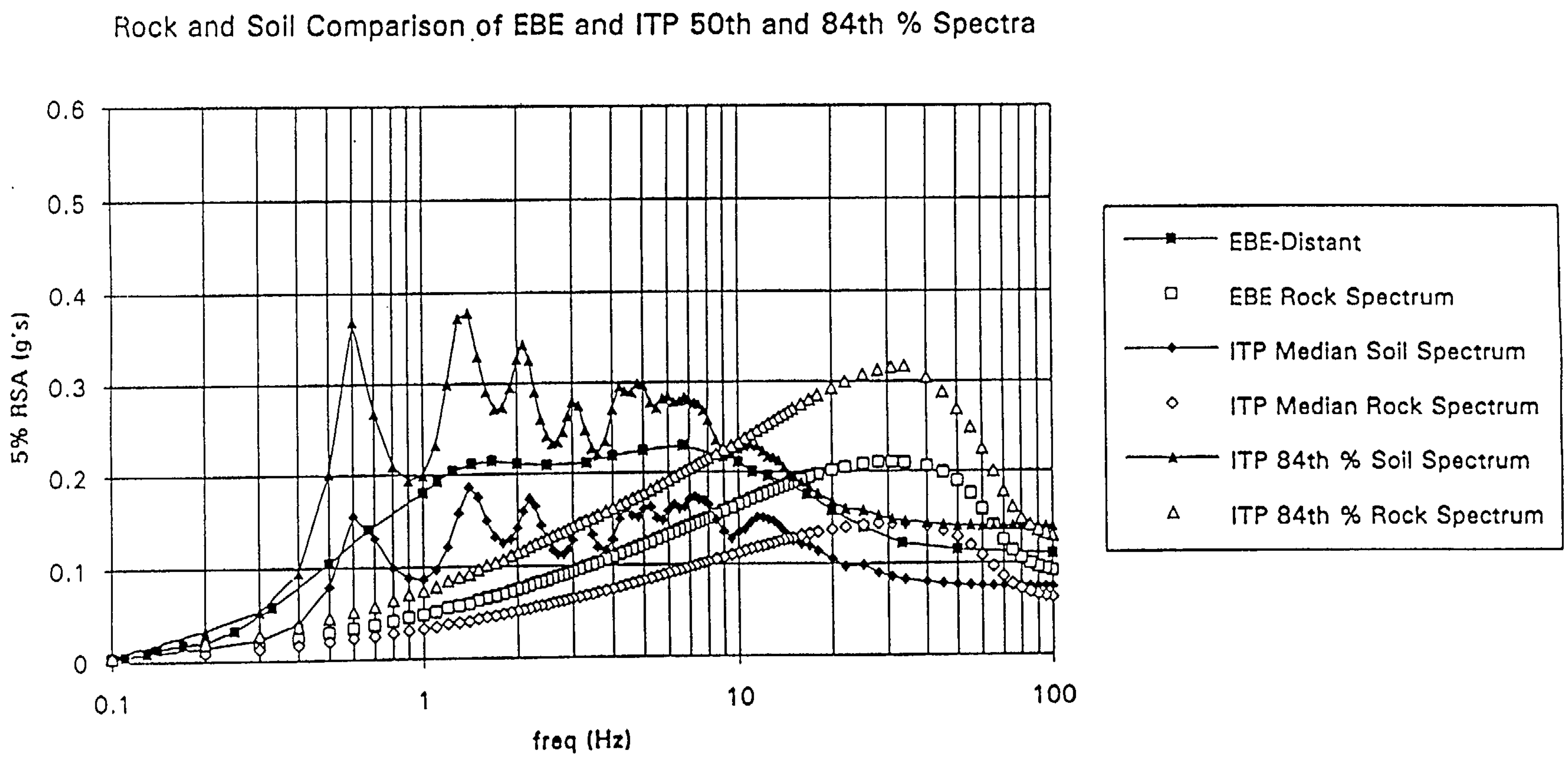

Figure 5. EBE and surface spectra derived from median and 84th percentile rock spectra.

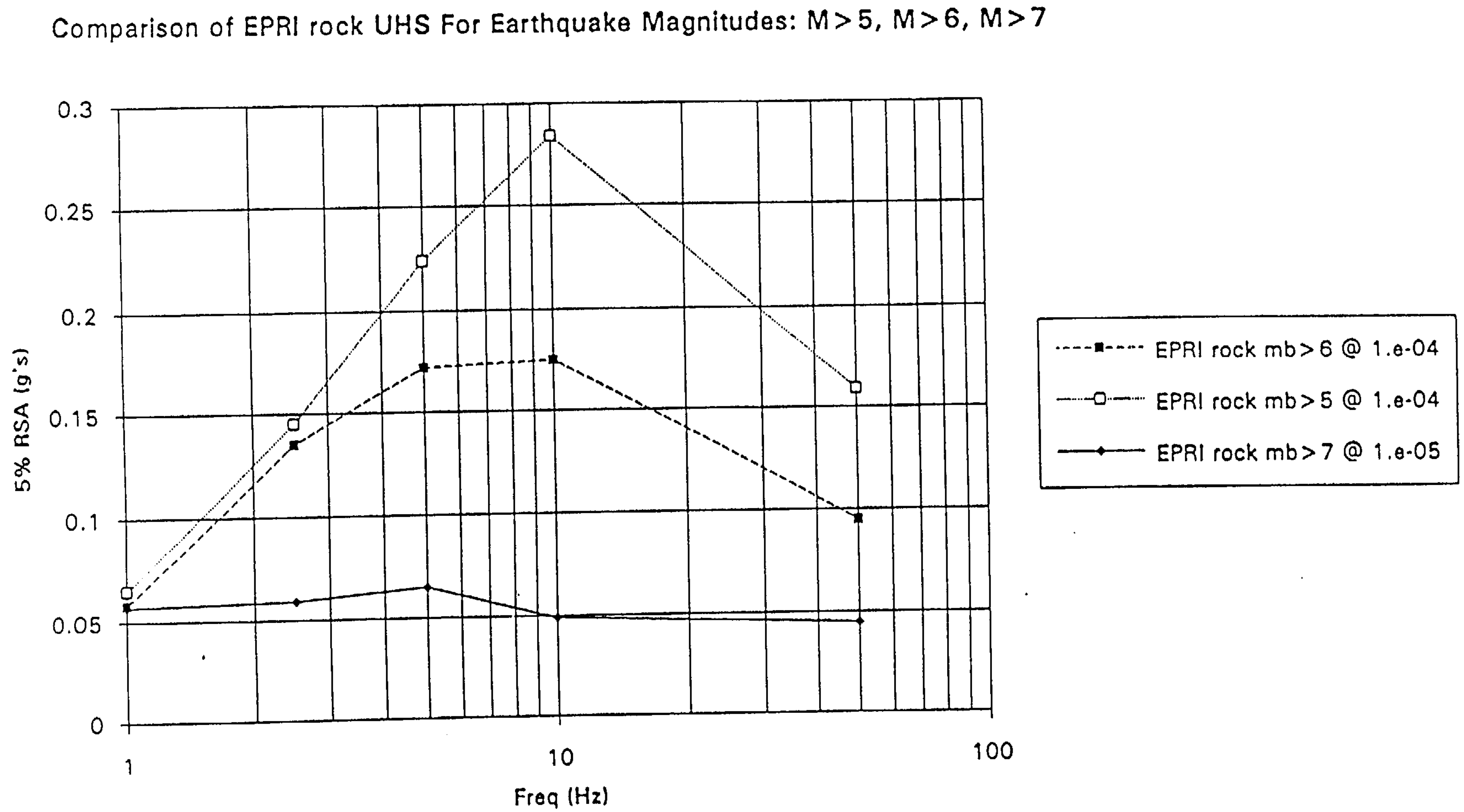

Figure 6. EPRI mean rock UHS at 1×10^{-4} annual probability of exceedance, for magnitudes $m_b > 5, 6$. UHS at 1×10^{-5} annual probability of exceedance for $m_b > 7$.

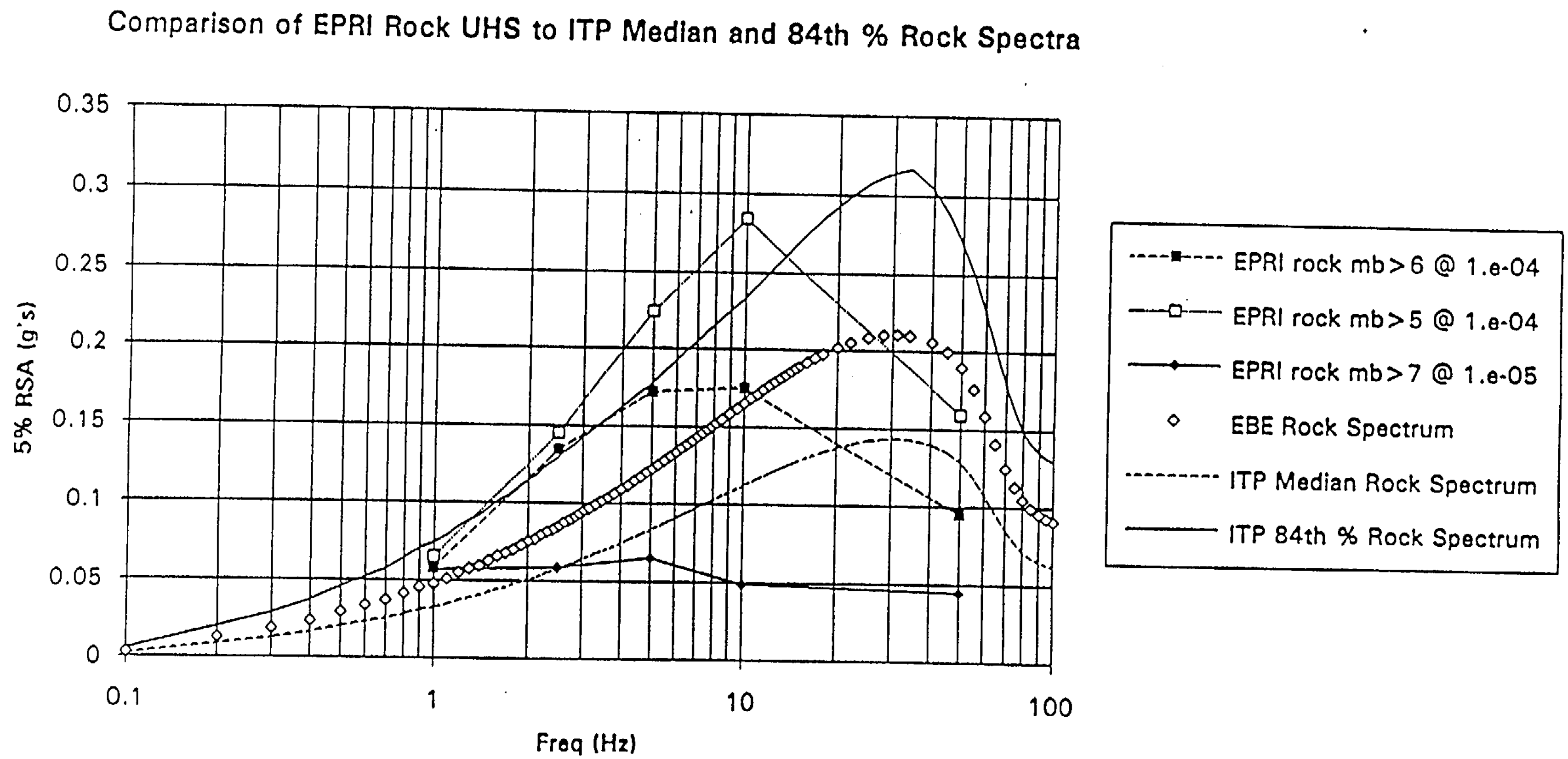

Figure 7. Comparison of EPRI mean rock UHS @ $1x10^{-4}$ to ITP median and 84th percentile deterministic rock spectra. UHS at 1 x 10^{-5} annual probability of exceedance for $m_b > 7$.

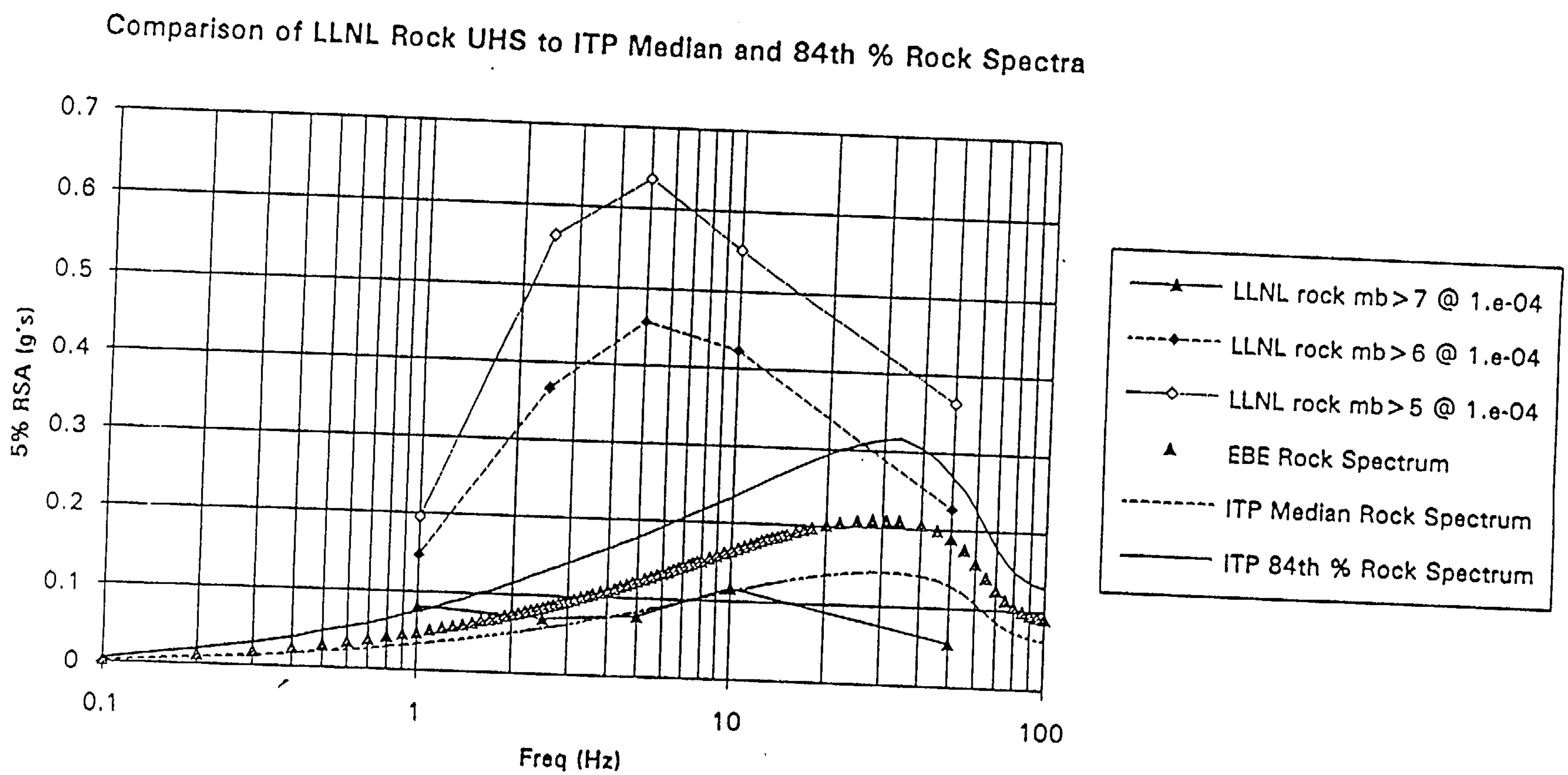

Figure 8. Comparison of LLNL mean rock UHS @ $1x10^{-4}$ to ITP median and 84th percentile deterministic rock spectra.

WSRC–TR–97–0173

Savannah River Site Environmental Report for 1996

Summary

Environmental Monitoring Section
Environmental Protection Department

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Cover—*Nelumbo lutea*, the water lotus, is a coastal plain wetlands plant found in South Carolina and other Southeastern states. A member of one of the oldest groups of flowering plants on earth, the water lotus produces hard, durable seeds that remain dormant until their outer coats are worn away and that provide excellent food for waterfowl. The seed pods often are used in ornamental displays, such as dried floral arrangements. The plants have been thriving along the shores of the Savannah River Site's PAR Pond (where the cover photograph was made) since at least the mid-1960s. Savannah River Ecology Laboratory personnel in 1987 transplanted 25 of the plants to the site's L-Lake, where they since have spread to cover approximately 20 acres along the shoreline. The photograph was taken by Al Mamatey of Westinghouse Savannah River Company's Environmental Monitoring Section. The cover was designed by Eleanor Justice of the company's Multimedia/Network Publishing group.

WSRC–TR–97–0173

Savannah River Site Environmental Report for 1996

Summary

Editor

Margaret W. Arnett

Prepared for the U.S. Department of Energy
Under Contract No. DE–AC09–89SR18035
Westinghouse Savannah River Company
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Introduction

The Savannah River Site (SRS) publishes an environmental report each year to provide environmental monitoring and surveillance results to the U.S. Department of Energy (DOE), the public, Congress, state and federal regulators, universities, local governments, the news media, environmental and civic groups. The *Savannah River Site Environmental Report for 1996* (WSRC-TR-97-0171) contains detailed information on site operations, environmental monitoring and surveillance programs, environmental compliance activities, and special projects for the calendar year 1996. The purpose of this document is to give a brief overview of the site and its activities, to summarize the report and the impact of 1996 SRS operations on the environment and the public, and to provide a brief explanation of radiation and dose.

The data used to compile the annual environmental report and this summary can be found in *Savannah River Site Environmental Data for 1996* (WSRC-TR-97-0077).

This summary was critiqued by students in South Carolina's Aiken County GATEWAY (Gifted and Talented Education with Artistic Youth) Program. GATEWAY is a creative writing program for gifted middle school writers who have demonstrated creativity, a love of writing, and the desire to develop their writing potential. Students participating in the review were Michelle Brown, Kristina Burgess, Michael Guilherme, Ryan Hanlin, Ashley Isminger, Cathryn Lyons, Fleckney Miller, Molly Nelson, April Sakiewich, Noel Sakiewich, and Jenny Thomas. The editor is most grateful to the students for their review and for their contributions to the summary.

Copies of these documents can be obtained from

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List of Acronyms Used in This Pamphlet

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

CIF – Consolidated Incineration Facility

DOE – U.S. Department of Energy

DWPF – Defense Waste Processing Facility

EPA – U.S. Environmental Protection Agency

GDNR – Georgia Department of Natural Resources

NPDES – National Pollutant Discharge and Elimination System

RCRA – Resource Conservation and Recovery Act

SCDHEC – South Carolina Department of Health and Environmental Control

SRARP – Savannah River Archaeological Research Program

SREL – Savannah River Ecology Laboratory

SRFS – Savannah River Forest Station

SRS – Savannah River Site

SRTC – Savannah River Technology Center

VOC – volatile organic compound

WSRC – Westinghouse Savannah River Company

Scientific Notation

Scientific notation is used to express very large or very small numbers. For example, the number 1 billion could be written as 1,000,000,000 or by using scientific notation written as 1E+09. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from the number. If the value given is 2E+03, the decimal point should be moved three places to the right of its present location. The number would then read 2,000. If the value given is 2E–05, the decimal point should be moved five places to the left of its present location. The result would be 0.00002.

The Savannah River Site

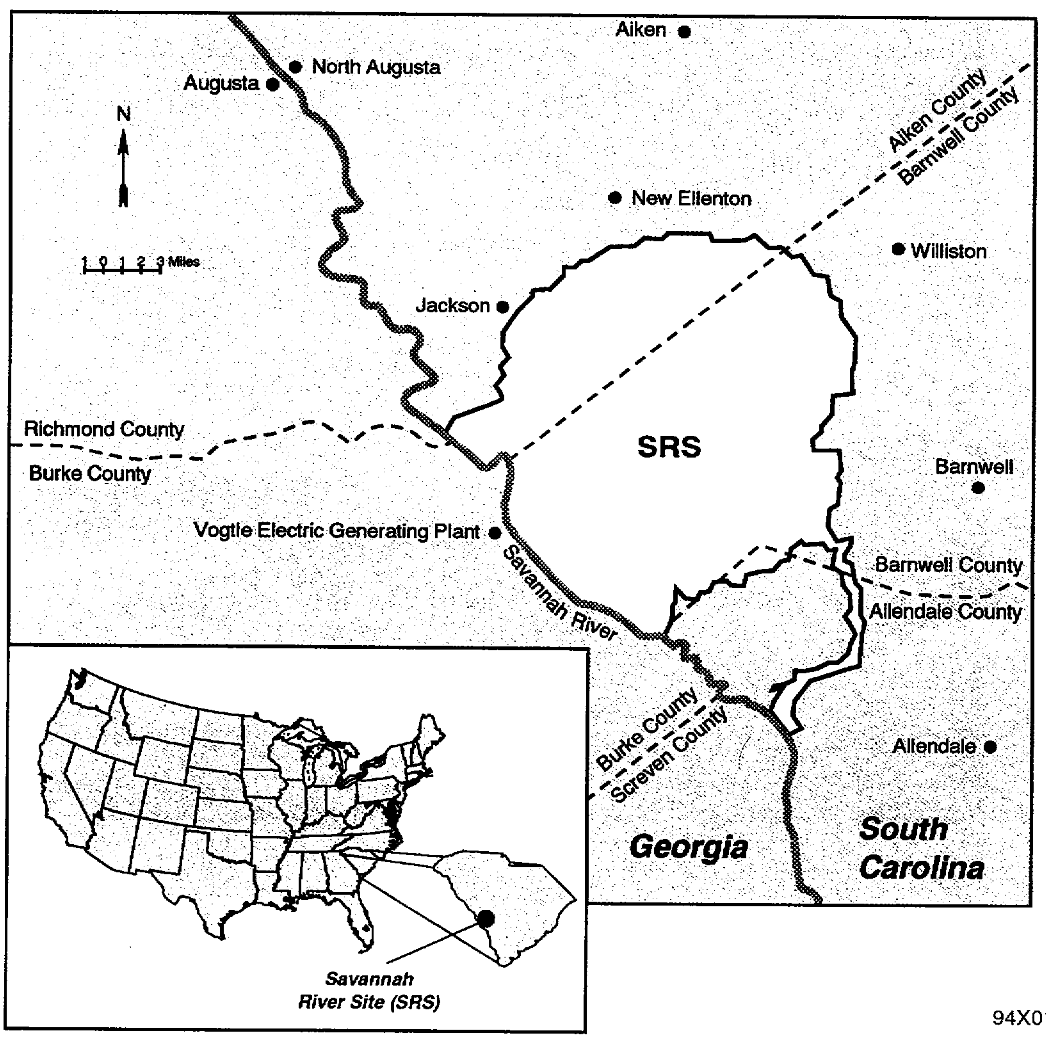
SRS is a government-owned, contractor-operated facility in the DOE complex. It was constructed during the early 1950s to produce basic materials used in the fabrication of nuclear weapons.

The 310-square-mile site is located in South Carolina, principally in Aiken and Barnwell counties; the Savannah River flows along its southwestern border for approximately 17 miles. The site is about 12 miles south of Aiken, South Carolina, and about 25 miles southeast of Augusta, Georgia.

Approximately 40 percent of the site's environs is forested. Major plant communities at SRS include cypress-gum and lowland hardwood swamps, sandhills, and old agricultural fields, as well as aquatic and semiaquatic areas. These habitats range from very sandy, dry hilltops to continually flooded swamps.

SRS is populated with more than 50 species of mammals. More than 100 species of reptiles and amphibians and more than 200 species of birds also inhabit the site.

Various industrial, manufacturing, medical, and farming operations are conducted in the area around SRS. Major industrial and manufacturing facilities include textile mills, polystyrene foam and paper products plants, chemical processing facilities, and a commercial nuclear power plant. Farming is diversified and includes crops such as cotton, soybeans, corn, and small grains.



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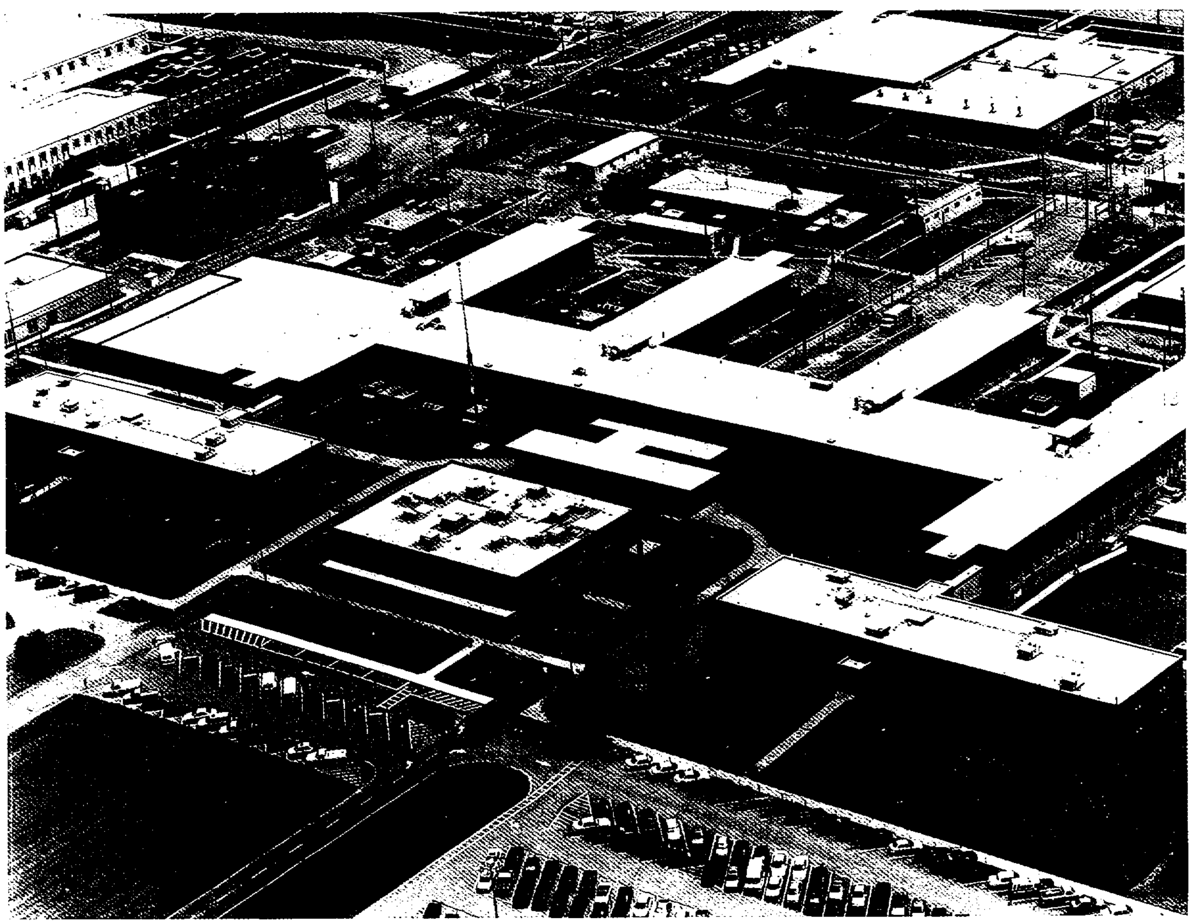
Production of nuclear materials at the site continued for more than 40 years. However, when the Cold War ended, DOE responded to changing world conditions and national policies by refocusing its missions. The site's priorities shifted toward managing nuclear materials to achieve nonproliferation objectives (curbing an excessive, rapid spread of nuclear weapons); managing waste; restoring the environment; transferring applied environmental technology to government and non-government entities; and forming economic and industrial alliances.

E.I. du Pont de Nemours and Company operated the site until March 31, 1989. On April 1, 1989, Westinghouse Savannah River Company (WSRC) became the prime operating contractor. Beginning October 1, 1996, the site began operating under a new contract with an integrated team. This team is composed of WSRC (leader); Bechtel Savannah River, Inc.; Babcock & Wilcox Savannah River Company; and British Nuclear Fuels Savannah River Corporation. (Parent companies of the new additions are Bechtel National, Inc., Babcock & Wilcox Government Group, and British Nuclear Fuels, Inc.)



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The administration area (A-Area) of SRS contains organizations that provide direct support for site operations. DOE's Savannah River Operations Office and WSRC's administrative offices are located here. Other facilities in A-Area include Savannah River Technology Center and Savannah River Ecology Laboratory.

New Mission

The ending of the Cold War brought changes to SRS. Older missions of producing basic materials used in the fabrication of nuclear weapons were replaced by new missions. Current missions include contributing to the national defense (which includes the reduction of nuclear danger), protecting and improving environmental quality, and enhancing technological and economic development. Information about SRS's mission and vision as well as "fact sheets" about site activities and facilities can be found on SRS's Home Page on the Internet (http://www.SRS.GOV).

How Does SRS Contribute to the National Defense?

One site project involves tritium processing. Tritium is a form of hydrogen gas that is a vital component of nuclear weapons. Because of radioactive decay, tritium in the weapons stockpile must be replenished continually. To accomplish this, it currently is being recycled from existing weapons reservoirs; however, a new source of tritium eventually must be developed. The newest SRS tritium recycling facility is the Replacement Tritium Facility, which started up in 1994 and replaced the older tritium processing facilities. The Replacement Tritium Facility is safer, more cost effective, and more protective of the environment.[16]

The site also receives select spent nuclear fuel rods from certain other nations (under very special conditions). These are rods that have been withdrawn from a nuclear reactor following irradiation. Collecting these rods at SRS keeps them out of the wrong hands and ensures that they are disposed of or contained properly.

How Does SRS Improve the Environment?

There are many ways to improve the environment. One way is to clean up waste sites by removing hazardous substances or by stabilizing, containing, or treating substances so that they do not affect human health or the environment. More about this process (environmental restoration) can be found on page 16.

Another way to improve the environment is to eliminate or better contain radioactive substances. With the processes used at the Defense Waste Processing Facility (DWPF) and the Consolidated Incineration Facility (CIF), SRS will do this. DWPF and the CIF are discussed on page 18. Also, low-level radioactive waste, such as that which in the past would have been buried in trenches, is now stored in vaults. Storage in the vaults is safer than burial.

As described in the next section, SRS also improves the environment by developing technology in the environmental arena and transferring it into the commercial world.

One of the objectives of the environmental monitoring program at the site (discussed on page 8) is to identify any environmental quality problem and to evaluate the need for corrective action.

How Does SRS Enhance Technological and Economic Development?

Scientists and engineers at SRS have developed and used technology to solve many problems at the site. The transfer of this technology moves existing government-developed technologies into the commercial world, helping businesses sharpen their competitive edge and providing American taxpayers a second return on their investment. Through government/industry partnerships and alliances for the development of new technologies, the site also benefits from industry expertise in finding the best available solutions to the site's environmental restoration and waste management challenges. Other partnerships are created with educational institutions, local communities, and federal and state agencies. Cooperative Research and Development Agreements result in the joint research and development of new technologies that benefit all partners. The use of site technologies, capabilities, and facilities is important in creating new jobs in the local region. SRS long has played a vital role in the economy of its surrounding region. As site employment declines in the post-Cold War era, other employment opportunities must be added to preserve the area's economic vitality.

Radiation

Because radiation is so important a part of the environmental issues associated with SRS, a brief discussion of its nature, sources, and levels will be useful. In the following paragraphs, an explanation will be given to provide a better understanding of radiation. In later sections, how the environment is monitored and how the potential effect of radiation on human health is determined will be discussed. A chart on estimated risk is presented on page 14.

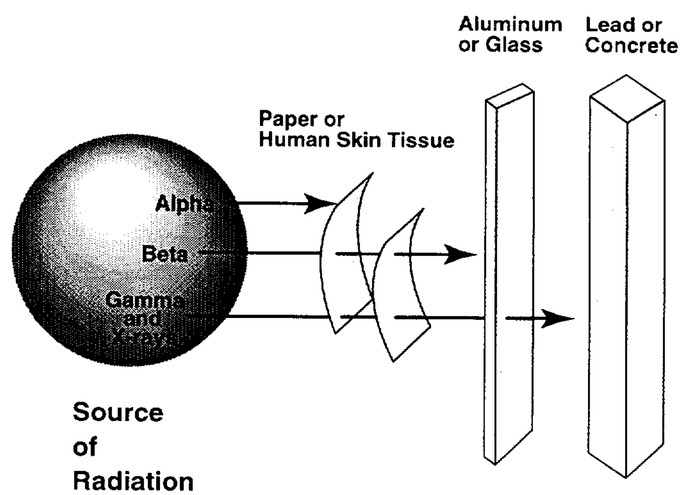
All matter is made up of atoms. Radioactive material contains unstable atoms that attempt to become stable by breaking apart (decaying). When an atom decays, energy is released as particles or waves. These particles (alpha or beta) or rays (gamma) are called radiation. One type of radiation—ionizing radiation—has enough energy to separate electrons from atoms. Ionizing radiation can change the chemical composition of atoms that it strikes, causing them to become electrically charged, or "ionized." In the discussion that follows, the term radiation is used to describe ionizing radiation.

Radiation has the potential to cause changes in matter (such as damage in cells of the human body). The danger varies greatly, depending upon the nature of the radiation, its intensity, and duration. Radiation can damage the cells in human bodies by affecting the DNA (deoxyribonucleic acid), the genetic blueprint of life. Although the body has several effective repair mechanisms, severely damaged cells cannot always repair themselves. Thus, overexposure to radiation can cause illness, such as cancer, or even death.

Some radiation is manmade, but most radiation occurs naturally. Whether radiation is natural or manmade, the effect on the human body is the same.

Because there are different types of radiation, different materials may be used to shield (or protect) people who are exposed to radiation. The following examples illustrate some differences between several types of radiation:

- An alpha particle can be stopped by a piece of paper or the skin.
- A beta particle can be stopped by aluminum foil, glass, or an inch of wood.
- A gamma ray, which acts like an x-ray, requires lead or concrete to stop it.



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Sources of Natural Radiation

The major source of radiation in the world is and has always been nature. Another name for this natural radiation is background radiation. Radiation occurs naturally in our food, our water, and our air. The sun is a natural source of radiation. Even human bodies contain natural levels of radiation.

One type of background radiation is radon gas (and its decay products), produced by the decay of uranium in the earth. It currently accounts for 55 percent of the average annual radiation dose to Americans.[5]

Sources of Manmade Radiation

Radiation that results from manufacture of consumer products, generation of electricity, and production of nuclear materials is called "manmade." Many consumer products, such as smoke detectors, cigarettes, fertilizers, and color televisions, are potential sources of low levels of radiation.

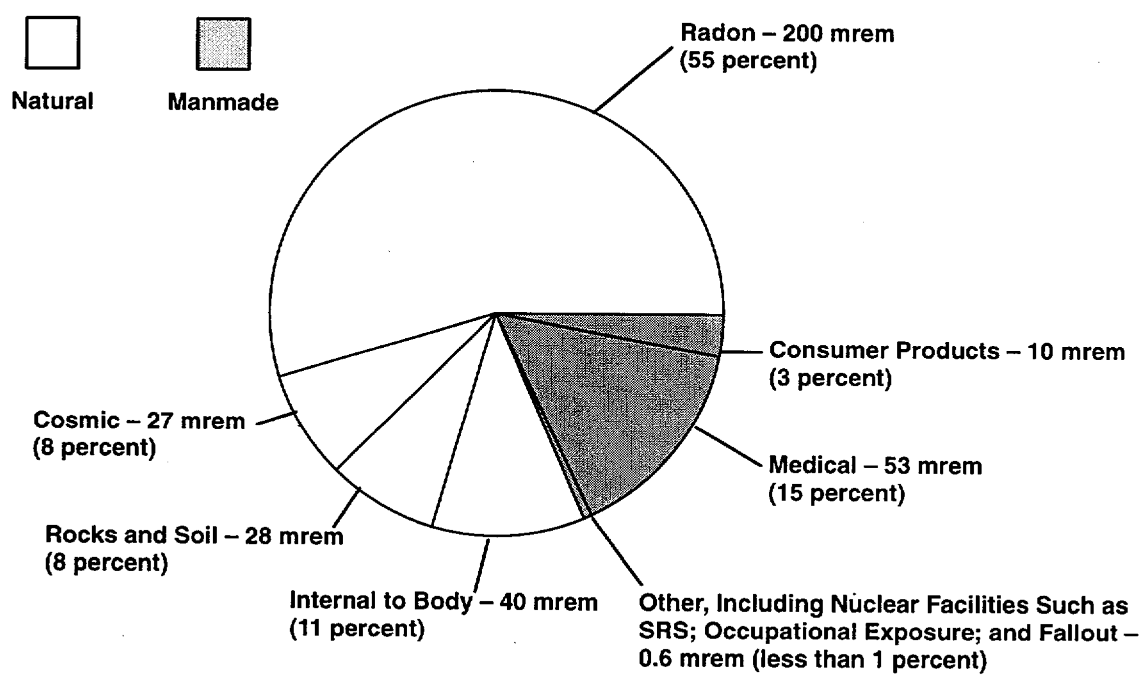
Manmade radiation also is used to take x-rays and to treat cancer and a variety of other diseases. X-rays and nuclear medicine account for 15 percent of the average radiation exposure.

The nuclear industry works to produce power, create nuclear fuel sources, and create weapons-grade materials. Currently, the nuclear industry accounts for less than 1 percent of the radiation received by a typical American.

SRS as a Source of Radiation

Materials released to the environment during SRS operations are referred to as contaminants. These contaminants can contain radioactive elements. Releases of radioactive materials are limited to very small fractions of the amount handled, in accord with regulatory limits, and SRS makes every effort to reduce the amount released well below these limits.

One of the goals of the environmental program at SRS is to look for, identify, and quantify the contaminants (both radiological and nonradiological) resulting from site activities. The primary concern is for the safety of site employees and of the public in surrounding communities. Radiation exists at SRS in alpha particles, beta particles, and gamma rays emitted from substances such as tritium, plutonium, and cesium. While radiation exists at SRS, the important matter is how much exposure occurs to humans. As the information in these and following sections depict, the exposure is a tiny fraction of that received by the typical American.



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Contributions to the U.S. Average Individual Dose
(See page 12 for an explanation of "mrem.")

The major contributor to the annual average individual dose in the United States, including residents in the area around SRS, is naturally occurring radiation (about 300 mrem)5. During 1996, SRS operations potentially contributed a maximum individual dose of 0.19 mrem, which is less than 0.1 percent of the 360-mrem total annual average dose (natural plus manmade sources of radiation).

Environmental Monitoring Program

SRS looks for, identifies, and quantifies its released contaminants through an extensive environmental monitoring program. This program's main parts are called effluent monitoring and environmental surveillance. In the program, samples of air, water, and other media are collected and analyzed to determine the presence of contaminants from site operations. Results are used to show effects on natural resources and human health and also to show compliance with regulations.

Much of the onsite monitoring is done by the Environmental Protection Department's Environmental Monitoring Section and by the Savannah River Technology Center (SRTC). Groups outside of SRS also monitor the site. These include the South Carolina Department of Health and Environmental Control (SCDHEC) and the Georgia Department of Natural Resources (GDNR).

Effluent Monitoring

Effluent monitoring is the collection of samples at the point where materials are released from the facilities and their subsequent analysis. Two types of effluent monitoring are done at SRS. Radiological effluent monitoring looks for radioactive elements that are released from the facilities. (More than 4,400 radiological effluent samples were collected and analyzed during 1996.) Nonradiological effluent monitoring looks for nonradioactive materials that are released from the facility.

Environmental Surveillance

Environmental surveillance covers more than 31,000 square miles and extends up to 100 miles from the site. With results of this surveillance, scientists attempt to measure contaminants that may have spread into the environment. Like effluent monitoring, environmental surveillance can be both radiological and nonradiological.

A composite sampler collects water from one of the SRS effluent outfalls for laboratory analysis. The physical properties and concentrations of chemicals in SRS effluents must meet specific requirements before being released to the environment.

Photograph by Al Mamatey

Radiological Releases in 1996

Contaminants released from the site can travel through the environment, potentially causing exposure to the offsite public. Routes that contaminants may follow through the environment are called pathways. Airborne release pathways include (1) inhalation and (2) the consumption of locally produced foods and milk; liquid release pathways include the consumption of (1) fish, (2) shellfish from downriver where the Savannah River is met by Atlantic Ocean tides, and (3) Savannah River water. Monitoring groundwater migration from seepage basins (contaminated areas on site) is important in determining liquid releases.

SRS radiological releases vary each year because site facilities operate at different levels during different years. Releases include any radionuclide that has moved off site.

All releases in 1996 were well below all applicable regulatory levels. Tritium is the primary radioactive material processed at SRS and was the major contributor to 1996 air and liquid releases. It accounted for more than 90 percent of the total radioactivity released. This percentage was a decrease from that in 1995 because of increased operations in the site's separations areas and unparalleled drastic reductions in tritium releases.

1996 Releases

(Radioactivity is expressed in a unit of measure known as a curie (Ci); more about measurement of radioactivity can be found on page 12).

- SRS released 55,600 Ci of tritium into the air—primarily from separations and reactor areas. This is down 43 percent from 1995, when 96,700 Ci of tritium were released.
- Liquid releases of tritium decreased from 9,900 Ci in 1995 to 7,560 Ci in 1996.
- The total quantity of tritium migrating from the seepage basins and the Solid Waste Disposal Facility was about 6,610 Ci, compared to 8,560 Ci in 1995. (The Solid Waste Disposal Facility is an area that contains buried unwanted radioactive material.) The remainder of 1996 tritium releases (949 Ci) came from process (reactor, separations, heavy water rework, etc.) areas.

Radiological Surveillance

Routine surveillance is performed on the atmosphere (air and rainwater), surface water (seepage basins, site streams, and the Savannah River), drinking water, food products (terrestrial and aquatic), wildlife, soil, sediment, vegetation, and groundwater. Monitoring of gamma radiation in the environment is conducted on site, at the site boundary, and in surrounding communities.

In 1996, more than 10,000 radiological analyses were performed on approximately 5,000 radiological environmental surveillance samples, not including groundwater. Results generally were consistent with those of recent years. Groundwater is discussed on page 11.

Nonradiological Effluent Monitoring and Environmental Surveillance

The nonradiological effluent monitoring program at SRS, like the radiological effluent program, includes both airborne emissions and liquid discharges. It is designed to monitor and/or collect and analyze samples from all stacks (air) and outfalls (liquid) that have the potential to release contaminants. The nonradiological program is used to demonstrate compliance with U.S. Environmental Protection Agency (EPA) and SCDHEC regulations, including the National Pollutant Discharge and Elimination System (NPDES), and to identify potential environmental problems.

The focus of nonradiological environmental surveillance at SRS is on surface water (site stream water and Savannah River water), drinking water, sediment, fish, and groundwater. Approximately 8,600 nonradiological analyses for specific chemicals and metals were performed on about 1,800 samples, not including groundwater. Groundwater is discussed on page 11.

1996 Results

Airborne Releases

- Because the compilation and calculation process for operations for all site air emission sources begins each year in January and requires up to 6 months to complete, a comprehensive report of 1996 emissions is not included in the *Savannah River Site Environmental Report for 1996* but will be included in the *Savannah River Site Environmental Report for 1997.* Therefore, no 1996 results are summarized here. However, in 1996, data were compiled and emissions calculated for 1995 operations. All 1995 calculated emissions were within applicable SCDHEC standards and permit limitations.

Liquid Releases

- SRS maintained its NPDES compliance rating of more then 99 percent, as only 14 of the 5,737 analyses performed exceeded NPDES permit limits.

Surface Water

- Comparison of 1996 data with published historical data for site surface water monitoring did not indicate any abnormal deviations from past monitoring data. Analysis for pesticides, herbicides, and volatile organic compounds yielded positive results for a pesticide at one location. All other analyses were below detection limits. Coliform analysis results exceeded recommended standards 20 times (17 in site streams and 3 in the river). The exceedances decreased in number from 1995 (when site streams analysis results exceeded guides 36 times and river analysis results exceeded guides 13 times).

Drinking Water

- All SRS drinking water systems complied with SCDHEC bacteriological, lead and copper, chemical, synthetic organic, and volatile organic water quality standards.

Sediment

- No pesticides or herbicides were found to be above the practical quantitation limits in sediment samples. All sample results were below the detection limits of the EPA analytical procedures used. All inorganic contaminants results were within normal fluctuations.

Fish

- SRS analyzed 193 fish from site streams and ponds and the Savannah River. Mercury concentrations in onsite fish ranged from below the reporting limit (0.33 µg Hg/g) to 1.70 µg Hg/g. Mercury concentrations in offsite fish ranged from below the reporting limit to 1.67 µg Hg/g.

Groundwater

Groundwater often is the most practical source of new water supply because of its general good quality and availability near the source of need. However, groundwater is vulnerable to contamination and, once contaminated, is extremely difficult to remediate (clean up). Thus, many communities, including those around SRS, are concerned about maintaining the quality of their groundwater aquifers.

Groundwater beneath an estimated 5 to 10 percent of SRS has been contaminated by industrial solvents, tritium, metals, or other constituents used or generated by site operations.

In 1996, SRS monitored the groundwater at 101 locations from about 1,600 wells. The well numbers are estimates because not all wells are monitored regularly. Groundwater in certain areas at SRS contains one or more of the previously noted constituents at or above drinking water standards. (SRS compares its groundwater against drinking water standards set by the federal Safe Drinking Water Act.) Approximately 49,000 radiological analyses were performed on groundwater samples during the year. Nonradiological analyses of groundwater samples numbered about 328,000.

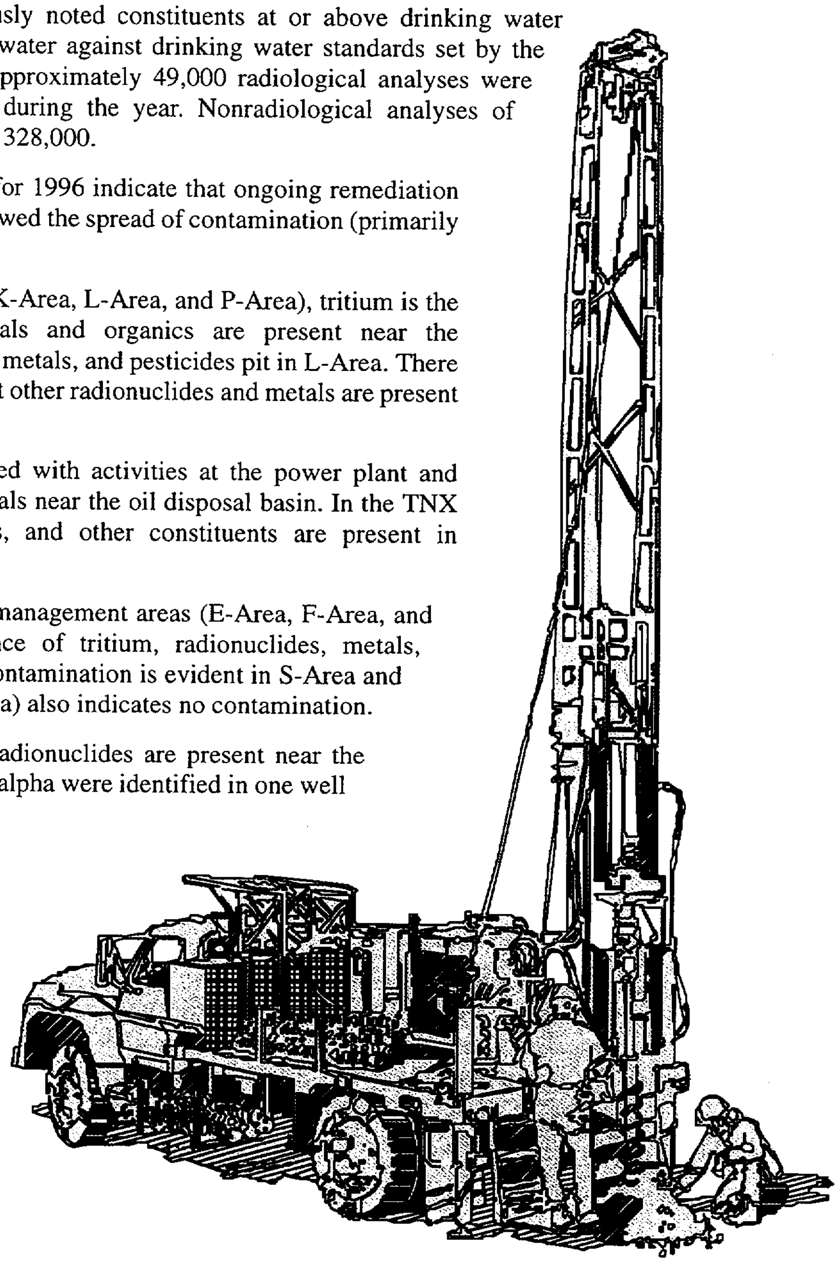
SRS groundwater monitoring results for 1996 indicate that ongoing remediation efforts at A-Area and M-Area have slowed the spread of contamination (primarily organics and metals) in those areas.

In most of the reactor areas (C-Area, K-Area, L-Area, and P-Area), tritium is the most widespread contaminant. Metals and organics are present near the burning/rubble pits and the chemicals, metals, and pesticides pit in L-Area. There is no evidence of tritium in R-Area, but other radionuclides and metals are present in the groundwater.

D-Area shows contaminants associated with activities at the power plant and related facilities and organics and metals near the oil disposal basin. In the TNX area, organics, metals, radionuclides, and other constituents are present in groundwater near disposal sites.

In the general separations and waste management areas (E-Area, F-Area, and H-Area), results indicate the presence of tritium, radionuclides, metals, organics, and other constituents. No contamination is evident in S-Area and Z-Area. The central shops area (N-Area) also indicates no contamination.

Organics, metals, tritium, and other radionuclides are present near the sanitary landfill, and tritium and gross alpha were identified in one well each in B-Area.



Radiation and Dose

Radiation cannot be seen, smelled, tasted, felt, or heard. But, with modern technology, very small amounts of radionuclides in the environment can be detected. What is actually being measured is the rate of radioactive decay, or radioactivity, of a given element. This radioactivity is expressed in a unit of measure known as a curie (Ci). A curie is a measure of radioactivity, not a quantity of material. More specifically, one curie equals 37 billion atom disintegrations per second. One gram of a radioactive substance may contain the same amount of radioactivity as several tons of another radioactive substance. For example, one gram of tritium equals about 10,000 Ci, while one gram of uranium equals about 0.000000333 Ci.

Radiation dose (the amount of energy in the form of radiation actually deposited in a given mass) is measured in units called rem.[8] As the rem number goes up, so does the possibility of harm (or risk). When measuring small amounts of radiation dose, millirems (mrem) are used. A millirem is 1/1000 of a rem. The easiest way to understand the significance of the measurements is to compare them with existing measurements that people do understand. The chart on page 15 allows a comparison of radiation doses.

Calculation of Dose

As discussed earlier, very small amounts of radionuclides in environmental samples can be detected. However, many of the radionuclides released from SRS have such low concentrations when dispersed into the environment that they cannot be detected (measured) using typical/routine sampling and laboratory methods. Also, it can be impossible to tell if a radionuclide in the environment comes from SRS or from another source, such as fallout from nuclear weapons testing. These factors make it difficult to measure directly the public's exposure to some of the radioactive materials released from the site. Therefore, mathematical models must be used to estimate the concentrations of radionuclides present in the environment as a result of the measured releases to air and water.

Beginning with the measurements from monitoring of all air and liquid discharges from SRS and factoring in many other conditions (for example, wind direction, river flow rates, and, in some cases, actual measurements from environmental samples), concentrations in the environment are predicted. These concentrations are used to compute estimated doses from site releases.

Maximally Exposed Individual

Since the habits of individuals vary from day to day, SRS defines a "maximally exposed individual." This is a hypothetical person; no such person can exist.

The maximally exposed individual for air pathways would live at the site boundary 365 days a year and would consume large amounts of meat, vegetables, and milk produced at the site boundary.

The maximally exposed individual for liquid pathways would live downriver from SRS 365 days a year, drink 2 liters of untreated water directly from the Savannah River each day, eat a large amount of fish from the river, and spend the majority of time on or near the river.

To demonstrate compliance with federal regulations, SRS conservatively combines the maximally exposed individual airborne pathway and liquid pathway dose estimates, even though the two doses are calculated for hypothetical individuals residing at different geographic locations. The SRS maximum potential all-pathway doses to the maximally exposed individual are depicted in the graph on page 13.

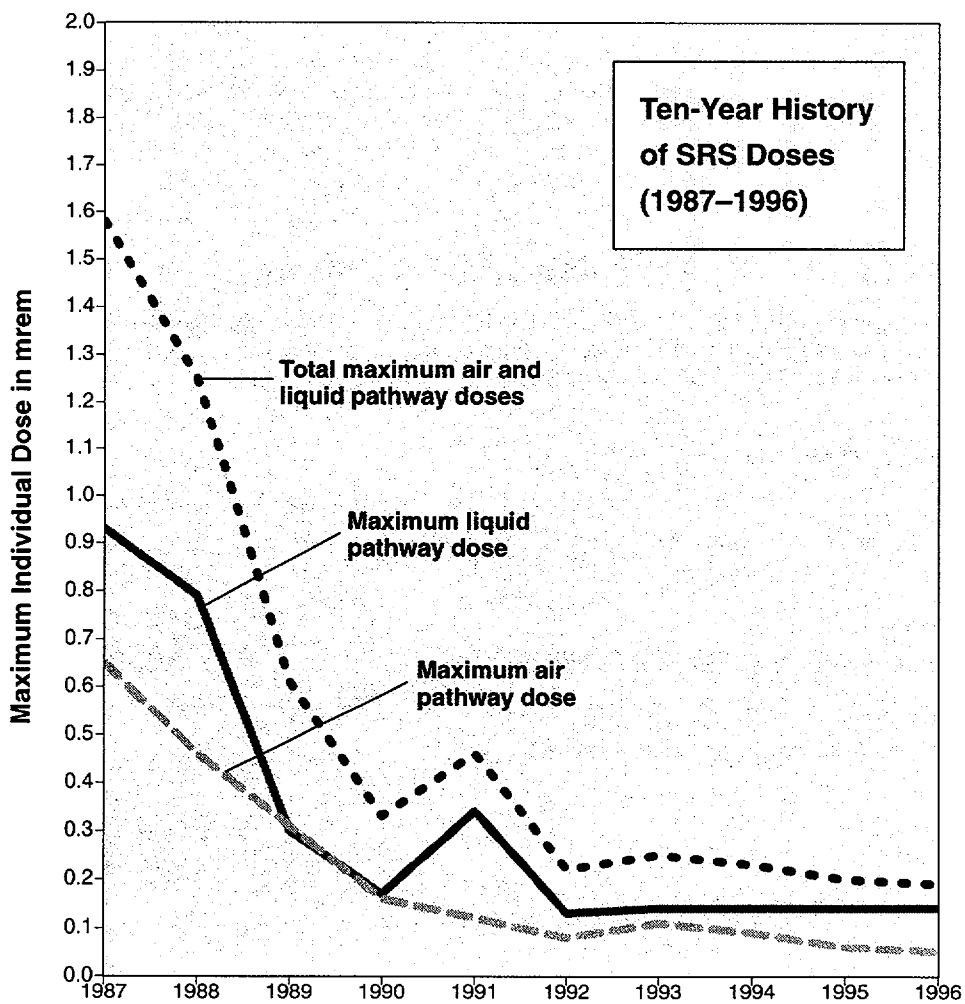
Dose to Public from SRS in 1996

Federal regulations state that the radiation dose the public can receive from nuclear facilities, like SRS, must not exceed 10 mrem per year from the air and 4 mrem per year from treated drinking water. The maximum limit for all types of exposure from a DOE facility is 100 mrem per year.

For 1996, the potential maximally exposed individual all-pathway dose from SRS was 0.19 mrem (0.05 mrem from the airborne pathway plus 0.14 mrem from the liquid pathway). As discussed on page 7, this amount is a tiny fraction of the typical exposure to the average individual.

Tritium and cesium releases accounted for most of the maximally exposed individual dose in 1996. Tritium releases to the surface water accounted for 41 percent of the total liquid pathways dose. Radioactive cesium in fish was the largest contributor, with more than 43 percent of the total dose from liquid pathways. Tritium was the largest contributor to dose from airborne pathways (68 percent) and from treated drinking water (75 percent).

Individual dose depends on many factors, including personal choices such as geographic location of the person, diet, and time spent outdoors. The average person in the United States receives a 300 times greater dose (300 mrem) from natural radiation than from radiation released from the nuclear industry.[1]



SRS Maximum Potential Doses to the Maximally Exposed Individual

Due to changes in site missions following the end of the Cold War, the SRS maximum potential doses to the maximally exposed individual have decreased to the current low level of 0.19 mrem and has remained far below the 100-mrem federal dose limit.

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Sportsman Dose

Some exposure pathways are not included in the maximally exposed individual dose calculation. These include unique situations (onsite animal hunts) or unlikely situations (fish caught only from the mouths of SRS streams).

There are more than 5,000 white-tailed deer on site, and SRS holds hunts each year to control the deer population. This is necessary because the deer within the site boundary have few natural predators. As they increase in number, the overall health of the herd suffers and there also is potential for more and more animal impact accidents. About 2,000 feral hogs exist on site, too, and they destroy valuable plant life, timber, and ecological research areas. They also are harvested during the deer hunts. Overpopulation of these animals can lead to their starvation.

Each animal killed is monitored for radioactive cesium, and the resulting dose from consumption is calculated for each animal. If the measurement shows that consumption of the animal, either alone or in combination with other animals killed by the hunter, would result in a dose of more than 99 mrem (100-mrem is DOE's all-pathway dose standard) to the hunter, the carcass is not allowed off site.

During 1996, 1,685 deer and 109 feral hogs were taken in 14 controlled hunts. One deer was confiscated and retained by SRS because its cesium-137 field measurement would have resulted in an exposure exceeding the all-pathway dose standard. Dose is determined using results from animals released to the hunters; therefore, the measurement for this deer was not included in the sportsman dose.

The maximum potential dose to an actual onsite hunter was 21 mrem, which is 21 percent of DOE's all-pathway dose standard. During the onsite deer hunts, this individual harvested six animals—the edible portion totaled about 111 kilograms (245 pounds)—and was assumed to have eaten all the meat himself.

The potential maximum dose for a recreational fisherman was based on the consumption of 19 kg (42 pounds)—the maximum adult consumption rate for fish—of Savannah River fish having the highest measured concentrations of radionuclides. In 1996, bass caught at the mouth of Steel Creek had the highest concentrations. Consumption of these bass could have resulted in a dose of 1.7 mrem, whch is less than the 2.5 mrem a person receives on a one-way airplane flight from New York to Los Angeles (page 15).

Estimated Risk from Various Activities and Exposures[4]

Note: These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation as a result of differences in individual lifestyle and biological factors. (For an explanation of how to understand the numbers under "Risk of Fatality,", see "Scientific Notation," page 2.)

Activity Per Year	Risk of Fatality
Riding or driving in a passenger vehicle (300 miles)	2E–06*
Home accidents	100E–06*
Drinking one can of beer or 4 ounces of wine per day	10E–06
Pleasure boating (accidents)	6E–06*
Firearms, sporting (accidents)	10E–06*
Smoking one pack of cigarettes per day (lung/heart/other diseases)	3,600E–06
Eating 4 tablespoons of peanut butter per day (liver cancer)	8E–06
Eating 90 pounds of charcoal-broiled steaks (gastrointestinal-tract cancer)	1E–06
Taking contraceptive pills (side effects)	8E–06
Natural background radiation dose (300 mrem)	0 to 150E–06
Dose of 1 mrem	0 to 0.5E–06
Dose to the maximally exposed individual living near SRS in 1996 (0.19 mrem)	0 to 0.1E–06

* Real actuarial values. Other values are predicted from statistical models. For radiation dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Comparison of Dose Levels

Dose	Description
0.19 mrem	Potential *annual* dose to maximally exposed individual from SRS operations.
1 mrem	Approximate *daily* dose from natural and manmade radiation, including radon.[5]
2.5 mrem	Cosmic-ray dose to a person on a one-way airplane flight from New York to Los Angeles.[5]
4 mrem	*Annual* limit set by EPA and DOE for manmade beta-gamma emitting radionuclides in community drinking water supplies.[10]
8 mrem	Typical dose from one chest x-ray using modern equipment.[6]
10 mrem	*Annual* limit, set by EPA, for exposures from airborne emissions from operations of nuclear fuel cycle facilities, including power plants, uranium mines, and mills.[10]
46 mrem	Estimate of the largest dose any offsite person could have received from the March 28, 1979, Three Mile Island nuclear accident.[1]
64 mrem	Average *annual* dose to people in the United States from manmade sources.[5]
100 mrem	*Annual* limit of dose from all DOE facilities to a member of the public who is not a radiation worker.[10]
110 mrem	Average occupational dose received by U.S. commercial radiation workers in 1980.[7]
170 mrem	Average *annual* dose to an airline flight crew member from cosmic radiation and transport of radioactive materials by air.[7]
244 mrem	Average dose from an upper gastrointestinal diagnostic x-ray series.[6]
300 mrem	Average *annual* dose to people in the United States from all sources of natural radiation.[5]
1,000–5,000 mrem	EPA's Protective Action Guidelines state that public officials should take emergency action when the dose to a member of the public from a nuclear accident is likely to reach this range.[11]
5,000 mrem	*Annual* limit for occupational exposure of radiation workers set by the U.S. Nuclear Regulatory Commission and DOE.[9,12]
10,000 mrem	The BEIR V report estimated that an acute dose at this level would result in a lifetime excess risk of death from cancer, caused by the radiation, of 0.8 percent.[3]
25,000 mrem	EPA's guideline for maximum dose to emergency workers volunteering for nonlifesaving work during an emergency.[11]
50,000–600,000 mrem	Doses in this range received over a short period of time will produce radiation sickness in varying degrees. At the lower end of this range, people are expected to recover completely, given proper medical attention; at the top of this range, most people will die within 60 days.[2]

Environmental Restoration

Determining the most environmentally sound method of cleaning up waste sites is a major component of the SRS environmental restoration program. "Environmental restoration" refers to the assessment and cleanup of inactive waste units and groundwater (remediation). "Cleanup" means actions taken to deal with previous releases or to control potential future releases of hazardous substances.

The site began its cleanup program in 1981, before many regulations requiring environmental restoration were written. The environmental restoration program at SRS was developed in 1990 to safely and efficiently remediate more than 400 inactive waste and groundwater units on site (467 have been identified) while protecting human health and the environment. The units include basins, pits, piles, burial grounds, landfills, tanks, and groundwater contaminations. Even though the site has had success in cleaning up some areas, a tremendous amount of environmental restoration work remains to be done. This process is expected to take decades.[15]

EPA and SCDHEC monitor environmental restoration activities at SRS. Two federal statutes govern these activities. The Resource Conservation and Recovery Act (RCRA) created a system for tracking and handling hazardous wastes from their creation to their disposal. This act also requires that releases of hazardous waste at an active or inactive site be addressed. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the Superfund, covers the cleanup of hazardous substances and protection of the environment.

Environmental Restoration 1996 Highlights

Environmental restoration highlights included

- placement of a "geosynthetic" closure cap that provides greater groundwater protection (the first approved by SCDHEC for a hazardous waste closure) over the Nonradioactive Waste Disposal Facility (55 acres)
- completion of another geosynthetic cap over two sections (5 acres) of the Low-Level Radioactive Waste Disposal Facility (also known as the Burial Ground)
- onset of interim capping with special soil at a 76-acre tract known as the Old Radioactive Waste Burial Ground (this is part of the largest and highest priority waste area at SRS and brings the total remediation acreage in progress from 90 to 250 out of a projected 500)
- removal of more than 350,000 pounds of waste organic solvents from more than 2.3 billion gallons of groundwater by the continuous operation of soil vapor extraction and sir stripper systems
- installation of an air stripper (A–2) in A-Area/M-Area to accelerate cleanup of groundwater contaminated by volatile organic compounds (VOCs)
- continuous operation of vacuum extraction vadose zone units that increased the removal rate of VOCs by 500 percent (the vadose zone is the soil zone above the water table)
- removal of more than 50 drums of contaminants at the D-Area oil seepage basin, which reduced the immediate health and environmental contact potential of the contaminant source
- removal of 260,000 pounds of radioactive vegetation from 4.5 acres at the H-Area retention basin, Warner's Pond, and the HP-52 outfall

Waste Management

DOE uses the term "waste management" to refer to safe, effective management of the waste generated on site. This waste resulted from manufacture of plutonium, tritium, and other nuclear materials required to support national defense.[19] SRS manages solid waste (sanitary, low-level, transuranic, hazardous, and mixed wastes) and high-level waste. Definitions and examples of the various kinds of wastes can be found on page 18. Some of the waste management facilities and processes are described below.

Approximately 34 million gallons of high-level liquid radioactive waste (about 496 million curies) is currently stored in 51 massive underground tanks grouped into two "tank farms." Each tank farm has an evaporator system that reduces the waste to about 25 percent of its original volume. Without these evaporator systems, SRS would have had to add 70 additional tanks to store the waste that had been produced over the site's lifetime.

A portion of the waste in the tanks settles on the bottom as a viscous, brown sludge. Resting above this sludge is a liquid layer containing a lot of salt and some soluble radioactive materials. This liquid is concentrated and precipitates (separates) into a wet, thick "salt cake." These two wastes, the sludge and the salt, are treated separately while still in the storage tanks before being sent to DWPF.[17]

The sludge is chemically treated and washed to remove aluminum and any remaining salt before it is sent to DWPF. The salt cake is treated in the tanks, using a process called In-Tank Precipitation. During this process, water is added to redissolve the salt, and chemicals are added to cause the dissolved radioactive materials to precipitate out of the solution as solids. These solids then are filtered out of the mixture and sent to DWPF. The remaining decontaminated salt solution is sent to the Saltstone facility.[17]

The Saltstone facility processes and disposes of the salt solution by mixing it with cement, flyash, and furnace slag and pumping the resulting "saltstone" into a large, concrete vault to cure. This material contains less than one-hundredth of one percent of the original waste's total radioactivity.[17]

DWPF then treats the sludge from the original waste and the highly radioactive material removed from the salt cake by combining them with glass. The mixture is heated until it melts and then poured into stainless steel canisters to cool. The solid that forms is easier to contain and handle. Another word for this process is "vitrification." The glass will be kept in the sealed canisters and will be stored at SRS until a federal repository is established.[17]

The CIF was designed to burn safely some wastes that could not be treated previously. By incinerating or burning at high temperatures certain wastes—including sludge, oils, paints, solvents, rags, and protective clothing—the CIF will reduce the volume of combustible waste by 90 percent. Currently, these waste items are simply stored at the site. Once they are incinerated, only the ashes will need to be stored. Ashes take up much less space than the waste products themselves.[14] The facility is scheduled for startup in 1997.

The Effluent Treatment Facility treats the low-level radioactive wastewater that was formerly sent to seepage basins. It was designed to remove heavy metals, organic chemicals, and corrosive chemicals, as well as cesium and other radiological contaminants from the wastewater. The treated wastewater is released to a permitted NPDES outfall.[13,18,19]

Waste Management 1996 Highlights

***Solid waste management highlights included the following*:**

- Sanitary waste— includes office waste, food, garbage, refuse, and other solid wastes that can be disposed of in landfills. During the year, 6,700 tons of the site's sanitary waste were disposed of at a permitted offsite commercial facility.
- Low-level waste—any radioactive waste not classified as high-level waste or transuranic waste. Examples of SRS low-level waste include protective clothing, equipment, tools, rags, and papers. The Solid Waste Management Department accepted 252,908 cubic feet of low-level waste for storage or disposal in the E-Area vaults. This waste was previously disposed of in trenches at the Solid Waste Disposal Facility (also known as the Radioactive Waste Burial Ground.
- Transuranic waste—radioactive waste contaminated with isotopes that have decay rates and activities exceeding defined levels and that require thousands of years of isolation. During the year, 5,815 cubic feet of solid transuranic waste were accepted for storage on transuranic waste pads. Solid waste program personnel are developing strategies to stabilize transuranic waste for disposal at the Waste Isolation Pilot Plant in Carlsbad, New Mexico.
- Hazardous waste—any toxic, corrosive, reactive, or ignitable material that could damage the environment or negatively affect human health. Examples of SRS hazardous wastes include oils, solvents, acids, metals, and pesticides. During the year, 3,519 cubic feet of hazardous waste were accepted for storage at the hazardous waste storage facilities.
- Mixed waste—both radioactive and hazardous material subject to regulations governing both waste types. During the year, 801 cubic feet of mixed waste were accepted for storage at SRS's mixed waste storage buildings.
- Construction of the CIF, completed in 1995, was followed by a pretrial burn, conducted in December 1996. (The facility is scheduled for startup in 1997 and is described on page 17.)
- Forty thousand pounds of highly radioactive solvent were removed and transferred safely from old single-walled tanks in the Burial Ground complex to new double-walled tanks near the CIF.

High-level waste management highlights included the following: (High-level waste is highly radioactive waste material resulting primarily from the reprocessing of special nuclear materials. It contains both transuranic waste and fission products in concentrations requiring permanent isolation from the environment.)

- DWPF began radioactive operations and produced 64 canisters of immobilized radioactive waste by the end of the fiscal year.
- The tank farm evaporators recovered more than 2 million gallons of tank space through evaporation of the watery "supernate" that floats atop the sludge in the tanks.
- Radioactive operations began at Saltstone in June 1990. Through December 1996, the facility had processed 2.1 million gallons of salt solutions, creating about 3.4 million gallons of "saltstone."
- SRS gained regulatory approval of its general closure plan for high-level waste tanks—the first such plan developed and approved in the DOE complex.

Public Involvement

SRS public outreach activities—such as public meetings, the Visitors Program, the Speakers Bureau, the Traveling Lecturers Program, and the Citizens Advisory Board—provide communication channels between the site and the public. Local newspaper, television, and radio advertisements also inform the public about environmental activities.

Site Tours

The SRS Visitors Program provides the public with a firsthand look at the site and its activities. Visitors to the site may take a drive-by tour that includes a nuclear reactor, cooling tower, chemical separations areas and waste disposal facilities, as well as some of the hundreds of square miles of woods and lakes that are a part of the site. In addition, visitors may have the opportunity to see such facilities as the Savannah River Ecology Laboratory (SREL) and Savannah River Forest Station (SRFS). Each tour is designed to meet the needs and interests of the visiting group. During 1996, the Visitors Program hosted 3,452 guests at SRS.

The program is open to all U.S. citizens at least 16 years of age. Groups consisting of visitors between the ages of 16 and 18 must be accompanied by one chaperone per 10 visitors. A minimum of 10 people is required per tour. Groups will be asked to provide names, home addresses, and social security numbers of each visitor in advance, and each visitor must bring a photo identification. Requests must be made 60 days before the desired date. No tours can be given on weekends or holidays. To arrange tours, contact

WSRC Media and Community Relations Department
Building 705–A
Aiken, SC 29808
Telephone: 803–725–0191

More information also can be obtained by contacting the WSRC Community Relations Department at 1–800–603–0970.

Citizens Advisory Board

The SRS Citizens Advisory Board, established in 1994 to increase public participation in decisions made at the site, is composed of 25 individuals from South Carolina and Georgia. Chosen by an independent panel of citizens from approximately 250 applicants, the board members reflect the cultural diversity of the population affected by SRS.

The board provides recommendations regarding site activities to DOE, EPA, and SCDHEC. During 1996, some major recommendations by the Citizens Advisory Board were

- that criteria be developed and a strategic plan drafted by September 30, 1996, for closure of the tank farm
- that the Waste Management Programmatic Environmental Impact Statement be made easier to read and understand
- that highest budget priority be given to items that affect the health and safety of workers and the public and to items that protect the environment
- that an urgent budget request be made to treat SRS transuranic waste
- that a soil cover be placed over the old Burial Ground as an interim action and, if possible, that the final remedy use this interim soil cover
- that SRS focus on the safe and secure interim storage of surplus plutonium
- that SRS remediate the old F-Area seepage basin
- that the feasibility of using retired high-level waste tanks for disposal of contaminated soil be assessed and that the highest-risk environmental restoration sites be remediated first

- that adequate funding be provided early in the decade for the site's Ten-Year Plan
- that an alternative disposal facility, preferably an engineered landfill, be designed at the Saltstone facility
- that the Consolidated Incinerator Facility begin operations by January 1997
- that a comparison of chemical processing to other alternatives for spent nuclear fuel be published
- that untreated transuranic waste be shipped to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, if transportation rules can be revised; if the rules cannot be revised, that a site facility be built to destroy the combustible fraction

At the close of 1996, action on all recommendations was either ongoing or pending. More information can be obtained by contacting DOE-Savannah River's Office of Environmental Quality at 803–725–5752.

Photograph by Bill Barley

The SRS Citizens Advisory Board is an independent group of citizens that provides recommendations to DOE, EPA, and SCDHEC about site activities. The members serve 2- or 3-year terms and represent the business sector, academia, local government, environmental and special interest groups, and the general public.

Education Outreach

SRS has long been involved in efforts to educate students and teachers. Several organizations, all funded in part by DOE's Savannah River Operations Office, contribute to these efforts. These include the Savannah River Archaeological Research Program (SRARP), SREL, SRFS and WSRC. In partnership with each other and with education institutions, these organizations offer hands-on programs for precollege students and teachers; unique research opportunities for students and faculty at SRS; work-based learning opportunities for high school students; and various workshops, tours, lectures, and demonstrations that enhance science, mathematics, engineering, and technology. More detailed information on these and other SRS education outreach programs can be obtained by calling the telephone numbers provided after each paragraph.

SRARP SRARP brings archaeology directly into the classroom with hands-on activities and display of artifacts of people who once lived in the area. Topics can include prehistoric archaeology, historic archaeology, scientific methods archaeologists use, and former communities of SRS. **(803–725–3623)**

SREL One of SREL's outreach activities is the Saturday Morning Workshop program, with topics on subjects such as reptiles and amphibians, nature photography, radiation and chemical ecology, and wetlands preservation and restoration. Nature topics, as well as a variety of live animals, are presented in the classroom in another program, Ecotalk. SREL also offers short- and long-term educational and research opportunities in ecology and environmental sciences for undergraduate and graduate students and university faculty. **(803–725–0156)**

SRFS The Natural Resources Science, Math, and Engineering Education Program, managed cooperatively by SRFS and the Ruth Patrick Science Education Center at the University of South Carolina-Aiken, provides hands-on experience in 13 natural settings, including a Carolina bay, a longleaf pine stand, a beaver pond, and the riparian zone (bank) of a local stream. The program also includes workshops for teachers. **(803–725–0072**

WSRC Competitions such as the Central Savannah River Area Science and Engineering Fair and the DOE Savannah River Regional Science Bowl encourage student interest in engineering, science, and mathematics. Education and career fairs that emphasize requirements for advanced skills and education are held in elementary, middle, and high schools. The School-to-Work Pilot Program, a partnership among WSRC, the Aiken County School District, and Aiken Technical College, provides students with first-hand knowledge of careers in science, mathematics, engineering, and technology by allowing them to work with mentors at SRS and use state-of-the-art technology. Environmental Awareness Day is a one-day workshop sponsored by the WSRC Environmental Restoration Department, DOE, and the Ruth Patrick Science Education Center that introduces students to the value of applied scientific principles, processes, and evidence in responsible decision making in environmental cleanup work. WSRC also offers educational and research opportunities to undergraduate, graduate, and post graduate students and to university faculty in a variety of assignments, predominately at the site's applied research and development laboratory, SRTC. **(803–652–1802)**

Photo Courtesy of *The Augusta Chronicle*

When four graves at a Wagener, South Carolina, graveyard were desecrated in November, authorities sought the expertise of SRARP archaeologists in determining the age of the graves and whether anything was stolen. The archaeologists recovered some fragmented bones from one of three graves marked by Confederate States of America headstones. The headstone of the fourth grave, separated from the others by a rusty, wire fence, was unmarked. The arm, pelvis, and vertebra discovered in this fourth grave were found to be of a 35- to 40-year-old female of European-American descent. Copper pennies had been placed on her eyes at burial, a custom outmoded for more than 100 years. The archaeologists also recovered some coffin hardware, but no other artifacts.

In addition to aiding the community, SRARP archaeologists have as their purpose making compliance recommendations to DOE that will facilitate the management of archaeological resources at SRS. Another of their functions is to reconstruct the environmental history of the site. The program expanded its heritage education activities in 1994 with a full schedule of classroom education, public outreach, and onsite tours.

Regulations

Compliance with federal and state environmental regulations and DOE orders is a critical part of SRS efforts to protect the environment and the public. Ensuring that onsite operations do not have an adverse impact is a top priority. All site activities are overseen by one or more regulators, including EPA and SCDHEC. The following are some of those regulations (years in which the regulations were enacted/updated are listed in some cases):

- Clean Air Act (CAA) — 1963, 1970, 1977, 1990
  - National Emission Standards for Hazardous Air Pollutants (NESHAP)
- Clean Water Act (CWA) — 1987
  - National Pollutant Discharge Elimination System (NPDES)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) — 1980, 1986
  - Superfund Amendments and Reauthorization Act (SARA)
  - Emergency Planning and Community Right-to-Know Act (EPCRA)
- Community Environmental Response Facilitation Act
- Endangered Species Act
- Executive Order 11988, "Floodplain Management"
- Executive Order 11990, "Protection of Wetlands"
- Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements"
- Federal Facility Compliance Act (FFCAct) — 1992
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) — 1948, 1972, 1975, 1982, 1988
- National Environmental Policy Act (NEPA) — 1969
- National Historic Preservation Act
- Resource Conservation and Recovery Act (RCRA) — 1976, 1979, 1984
- Safe Drinking Water Act (SDWA) — 1974, 1977
- South Carolina Hazardous Waste Management Act
- South Carolina Pollution Control Act
- South Carolina Safe Drinking Water Act
- Title 10 Code of Federal Regulations Part 1022, "Compliance with Floodplains/Wetlands Environmental Review Requirements"
- Toxic Substances Control Act (TSCA) — 1976
- DOE Order 5400.1, "General Environmental Protection Program"
- DOE Order 5400.5, "Radiation Protection of the Public and the Environment"

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4 *Hanford Site 1995Environmental Report*, PNNL–11139, Hanford Site, Richland, Wash., 1996.

5 National Council on Radiation Protection and Measurements, *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 93, Bethesda, Md., 1987.

6 National Council on Radiation Protection and Measurements, *Exposure of the U.S. Population from Diagnostic Medical Radiation*, NCRP Report No. 100, Bethesda, Md., 1989.

7 National Council on Radiation Protection and Measurements, *Exposure of the U.S. Population from Occupational Radiation*, NCRP Report No. 101, Bethesda, Md., 1989.

8 Teaching Radiation Energy and Technology, sponsored by U.S. Department of Energy in cooperation with Savannah State College, Westinghouse Savannah River Company, Ruth Patrick Science Education Center, Aiken, S.C., and Citizens for Environmental Justice, Savannah State College, Savannah, Ga., June 13–15 and 20–22, 1995.

9 U.S. Department of Energy, "Occupational Radiation Protection," Title 10 Code of Federal Regulations, Part 835, Washington, D.C.

10 U.S. Department of Energy Order 5400.5, "Radiation Protection of the Public and the Environment," Washington, D.C., 1990.

11 U.S. Environmental Protection Agency, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, EPA–400–R–92–001, Washington, D.C., October 1991.

12 U.S. Nuclear Regulatory Commission, "Standards for Protection against Radiation," Title 10 Code of Federal Regulations, Part 20, Washington, D.C.

13 Westinghouse Savannah River Company, "Effluent Treatment Facility," *Fact Sheet*, Savannah River Site, Aiken, S.C., 1993.

14 Westinghouse Savannah River Company, "Consolidated Incineration Facility," *Fact Sheet*, Savannah River Site, Aiken, S.C., 1995.

15 Westinghouse Savannah River Company, "Environmental Restoration," *Fact Sheet*, Savannah River Site, Aiken, S.C., 1995.

16 Westinghouse Savannah River Company, "SRS Tritium Facilities," *Fact Sheet*, Savannah River Site, Aiken, S.C., 1995.

17 Westinghouse Savannah River Company, "Defense Waste Processing Facility (DWPF)," *Fact Sheet*, Savannah River Site, Aiken, S.C., 1996.

18 Westinghouse Savannah River Company, "High-Level Waste Processing Facilities," *Fact Sheet*, Savannah River Site, Aiken, S.C., 1996.

19 Westinghouse Savannah River Company, "Waste Management," *Fact Sheet*, Savannah River Site, Aiken, S.C., 1996.

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For more information, please call Bob Lorenz - Manager, Environmental Sampling and Reporting, at 803-725-3556 or send an e-mail message to robert.lorenz@srs.gov.

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