DOE/EH-0644

SUMMARY
SITE ENVIRONMENTAL REPORT
RADIOLOGICAL DOSES AND RELEASES
1990 - 1994

September 2001

DOE Office of Environmental Policy and Guidance

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EXECUTIVE SUMMARY

Background and Purpose

Each year, U.S. Department of Energy (DOE) facilities prepare annual Site Environmental Reports (ASERs) to meet the requirements in DOE Order 5400.1, “General Environmental Protection Program (DOE 1990a) and the reporting requirements of DOE Order 231.1, “Environment, Safety and Health Reporting” (DOE 1996). The purposes of ASERs are to characterize site environmental management performance; including data on effluent releases, environmental monitoring, and estimates of radiological doses to the public; confirm compliance with environmental standards and requirements; and describe significant programs and efforts. ASERs annually demonstrate compliance with the required public protection dose limits and other radiological emissions and monitoring requirements of DOE Order 5400.5, “Radiation Protection of the Public and the Environment” (DOE 1990b). ASERs also document the potential radiological and nonradiological impacts of DOE operations on the public and environment near each site.

The purpose of this Summary Report is to provide a DOE-wide overview of the offsite radiological releases, and doses calculated based on those releases, resulting from operations at DOE sites. This report summarizes the radiological data from the 1990 through 1994 ASERs for 50 DOE sites, including sites from the Formerly Utilized Sites Remedial Action Program (FUSRAP), which were under DOE responsibility during the reporting period covered by this report. The reporting period corresponds to the first five years that the requirements for reporting radiological release and dose information of DOE Order 5400.5 were in effect. The report provides an overview of routine as well as unplanned radioactive releases that occurred during these years at each DOE operating nuclear and radiological site, as well as a summary of potential doses received by individuals and the surrounding populations. Summary reports for subsequent year's data are planned for the future.

Summary of Data

Offsite radiation exposures from most DOE nuclear and radiological sites are typically so small that they cannot be determined by direct measurements. As a result, these exposures are calculated based on measured effluent data. Therefore, the maximum radiation doses reported in ASERs are potential doses rather than actual doses because they were calculated from effluent data and environmental pathway models. The methodology for calculating radiation exposure to the public from DOE nuclear and radiological sites is inherently conservative and depicts the maximum potential exposure. Thus, the dose data summarized in this report are generally overestimates of the actual dose likely received by the public.

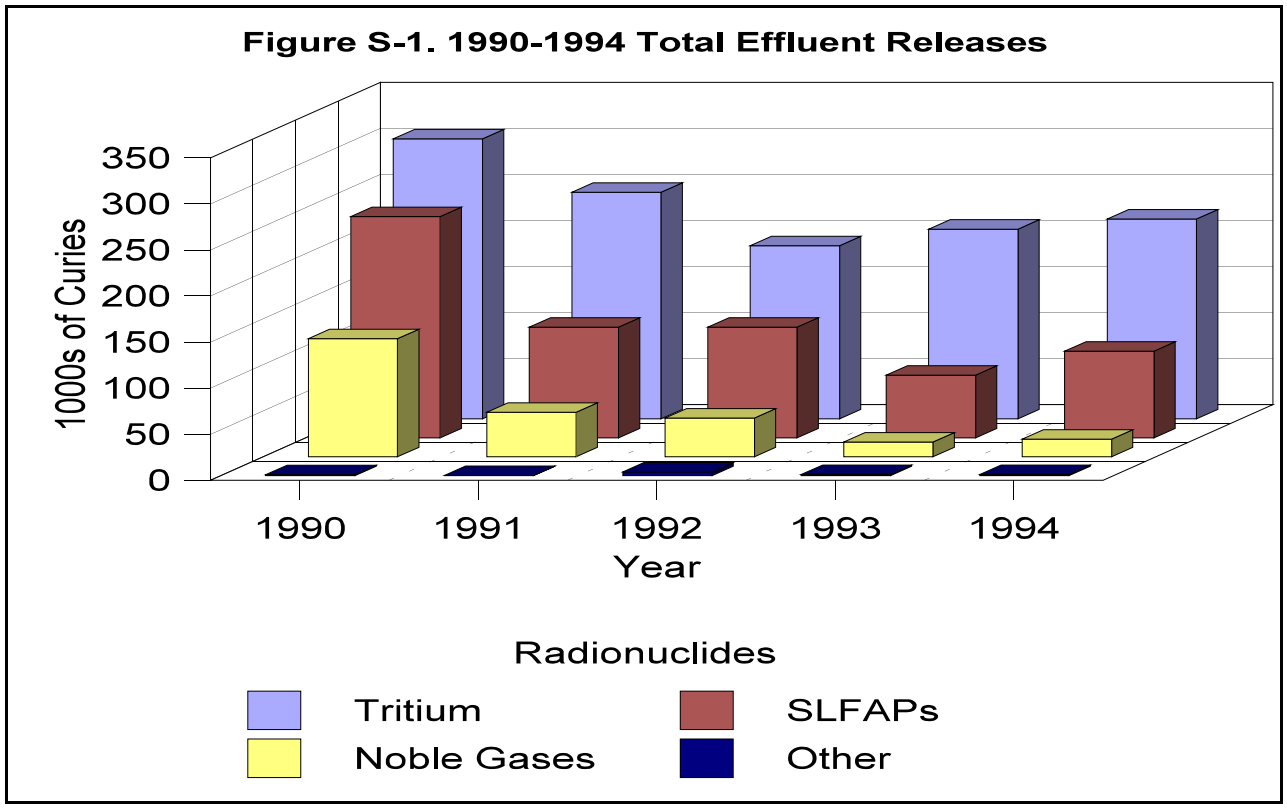
During CY 1990 through 1994, operations at DOE nuclear facilities annually discharged between 300,000 curies (Ci) and 670,000 Ci of radionuclides to the air and water (Table S-1). As shown in Figure S-1, of the total amount of radioactive material (in curies) released from DOE facilities in 1990 through 1994, the largest percentage was from tritium, followed by short-lived fission and activation products (SLFAPs), and noble gases. Annually less than 1% of the radioactivity was a mixture of longer-lived fission and activation products.

Some operating facilities at some sites had unplanned radiological releases (non-routine releases) in addition to their routine discharges. Unplanned radiological releases occurred at

one DOE site during 1990 and 1991, four sites during 1992, three sites during 1993, and two sites during 1994.

Table S-1. Total Radionuclides Released from DOE Sites to the Air and Water (in Curies (Ci))

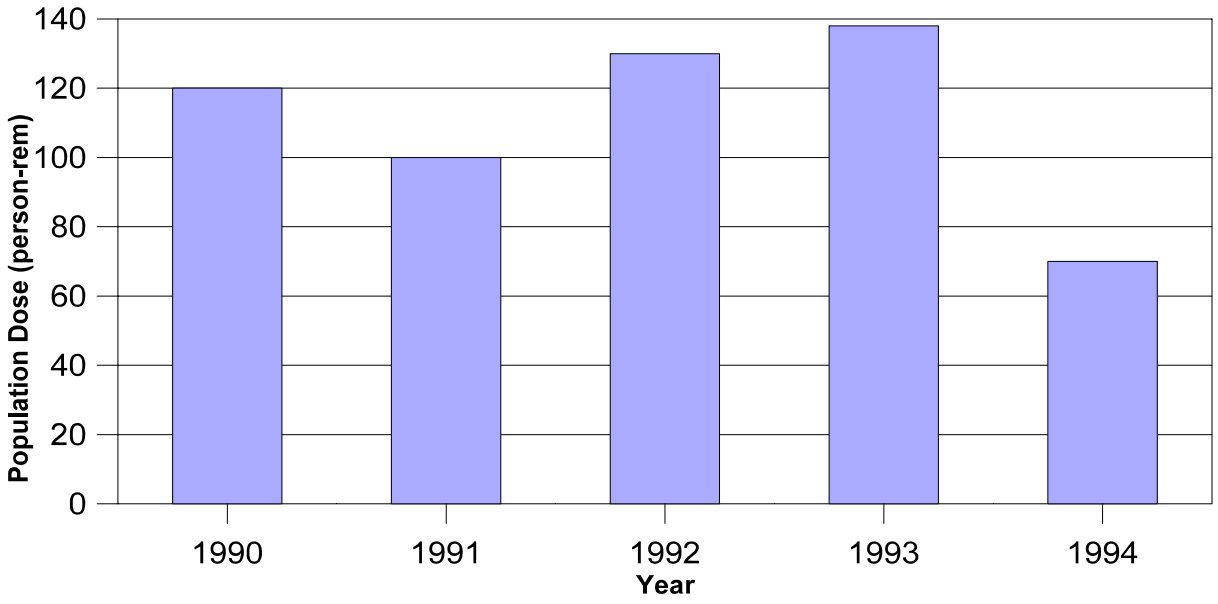
Year	Liquid Effluents	Atmospheric Releases	Total
1990	24,000	650,000	670,000
1991	16,000	390,000	410,000
1992	18,000	330,000	350,000
1993	16,000	280,000	300,000
1994	57,000	280,000	340,000



The DOE limit for the maximum dose to any member of the public from all sources and all pathways of radiological release from DOE sites is 100 millirem (mrem) per year, (DOE 1990b). By way of comparison, the approximate daily dose from natural and manmade radiation, including radon is 1 mrem (or 365 mrem per year). The majority of DOE nuclear and radiological sites reported doses to the maximally exposed individual (MEI) of <1 mrem (<1% of the DOE limit). Over the 5-year period covered by this report, a few sites reported potential doses in excess of 30 mrem/yr; however, these estimates were based on conservative calculations and are not representative of actual conditions.

Although there are no regulatory limits for population doses (also called collective dose), such doses provide an indication of the overall performance of DOE operations. The population dose for a site is typically calculated for the population residing within 80 kilometers (50 miles) of the site. The 80 kilometer (km) population dose (expressed as person-rem) is estimated by summing the average collective doses from all directional sectors within a 50 mile (mi) radius of the center of the site. The estimated population dose received during 1990-1994 by the total population residing within 80 km (50 mi) of all DOE nuclear or radiological facilities is shown in Figure S-2.

Figure S-2. Estimated Population Dose from Operating DOE Sites 1990-1994



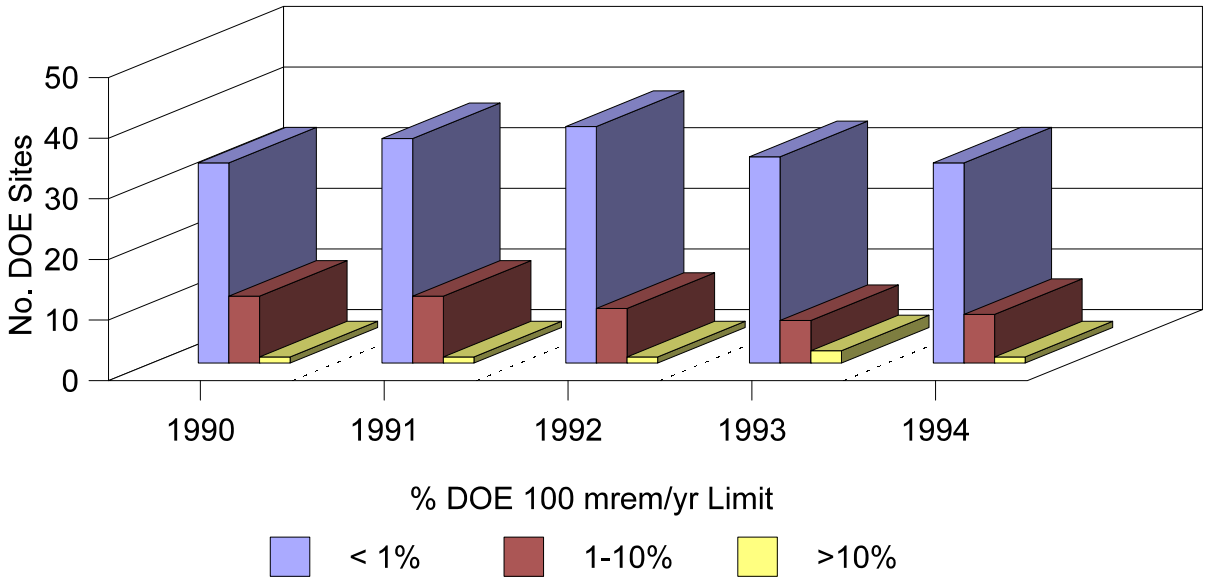
Conclusions

A few conclusions can be drawn from this summary of ASER radiological dose and release data for 1990 through 1994. The first is that the total dose from exposure to radiological releases from routine DOE operations is a small fraction of that received from natural sources. For example, the natural background dose to the population within 50 mi (80 km) of the Lawrence Livermore National Laboratory in Livermore, California, was nearly 2 million person-rem. Similarly, background doses for the population around Argonne National Laboratory was about 2.4 million person-rem annually. Comparing these to population doses of less than 140 person-rem per year from DOE operations (see figure S-2), it is apparent that exposure to background doses of radiation are several orders of magnitude higher than the population dose from all DOE sites combined during 1990-1994. Annual collective doses remained generally constant and very low over the 5-year period.

A second conclusion is that among the radionuclides released from DOE facilities tritium is usually the most prevalent. Tritium, an isotope of hydrogen, is produced in several ways and used for various purposes at DOE facilities. Like normal hydrogen, tritium can bond with oxygen to form water. When this happens, the resulting water (called tritium oxide or tritiated water) is also radioactive. Because tritiated water is chemically identical to normal water, it cannot be filtered out by treatment technology, which accounts, in part for the magnitude of the release from DOE sites. Tritium, however, is among the least hazardous of radionuclides because most of the tritiated water that enters the body immediately mixes with the body fluids and is eliminated rapidly like normal water. Further, tritium decays rapidly and only deposits a small amount of energy when it decays. Consequently, although relatively large amounts of tritium are released compared to other radionuclides, the potential hazard to the public is very small.

This Summary Report also shows that all DOE sites maintained exposures below the applicable DOE limits for radiological exposures to the public (100 mrem/yr from all sources and all pathways) per DOE Order 5400.5 (DOE 1990b). Figure S-3 shows that the majority of DOE nuclear and radiological sites maintained exposures at less than 1% of the limit. Only a few sites annually exceeded 10% of the limit from 1990-1994, and for the most part, the doses were the result of conservative procedures used to calculate the MEI dose.

Figure S-3. DOE Site Compliance With 100 mrem/yr Limit



Finally, during 1990 through 1994, non-routine releases at DOE nuclear and radiological sites generally involved small amounts of radiological materials and short duration events. Consequently, non-routine releases of radioactive materials at DOE sites accounted for only a small fraction of the radioactivity routinely released from DOE sites during this time frame.

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ACRONYMS

ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
BCL	Battelle Columbus Laboratories
BET	Bettis Atomic Power Laboratory
BNL	Brookhaven National Laboratory
CEBAF	Continuous Electron Beam Accelerator Facility
CISS	Colonie Interim Storage Site
CY	calendar year
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FUSRAP	Formerly Utilized Sites Remedial Action Project
HANF	Hanford Site
HISS	Hazelwood Interim Storage Site
ICRP	International Commission on Radiological Protection
INEL	Idaho National Engineering Laboratory
ITRI	Inhalation Toxicology Research Institute
KAPL-1	Knolls Atomic Power Laboratory - Knolls
KAPL-2	Knolls Atomic Power Laboratory - Kesserling
KAPL-3	Knolls Atomic Power Laboratory - Windsor

LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory (currently known as Lawrence Berkeley National Laboratory [LBNL])
LEHR	Laboratory for Energy-Related Health Research
LLNL	Lawrence Livermore National Laboratory
LLNL-3	Lawrence Livermore National Laboratory - Site 300
MEI	Maximally Exposed Individual
MISS	Maywood Interim Storage Site
MIT	Massachusetts Institute of Technology
MLM	Mound Laboratory
MMTS	Monticello Mill Tailings Site
MSP	Middlesex Sampling Plant
NBS	New Brunswick Site
NCRP	National Council on Radiation Protection and Measurements
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NFSS	Niagra Falls Storage Site
NG	noble gases
NPDES	National Pollutant Discharge Elimination System
NREL	National Renewable Energy Laboratory
NRF	Naval Reactor Facility
NTS	Nevada Test Site
ORR	Oak Ridge Reservation
ORNL	Oak Ridge National Laboratory
PANX	Pantex Plant
PGDP	Paducah Gaseous Diffusion Plant

PIN	Pinellas Plant
PGDP	Portsmouth Gaseous Diffusion Plant
PPPL	Princeton Plasma Physics Laboratory
RFP	Rocky Flats Plant
RI-1	Rockwell International - DeSoto Lab
RI-2	Rockwell International - Santa Susana Field Lab
RMI	RMI Company Extrusion Plant
SLAC	Stanford Linear Accelerator Center
SLFAP	short-lived fission and activation products
SNL	Sandia National Laboratories
SNLA	Sandia National Laboratories - Albuquerque
SNLL	Sandia National Laboratories - Livermore
SNLT	Sandia National Laboratories - Tonopah
SRS	Savannah River Site
TLD	thermoluminescent dosimeter
UMTRAP	Uranium Mill Tailings Remedial Action Program
WISS	Wayne Interim Storage Site
WSS	Weldon Spring Site
WVDP	West Valley Demonstration Project

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1.0 INTRODUCTION

Each year, the U.S. Department of Energy (DOE) prepares annual Site Environmental Reports (ASERs) to meet the substantive requirements in DOE Order 5400.1, "General Environmental Protection Program (DOE 1990a), and the reporting requirements of DOE Order 231.1, "Environmental, Safety and Health Reporting" (DOE 1996). The purposes of ASERs are to characterize site environmental management performance, confirm compliance with environmental standards and requirements, and highlight significant programs and efforts. Also, the ASERs annually demonstrate compliance with the required public protection dose limits and other radiological emissions and monitoring requirements of DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (DOE 1990b). The ASERs document the potential radiological and nonradiological impacts of DOE operations on the public and environment near each site. This document summarizes the radiological data from the Site Environmental Reports prepared for DOE for the years 1990 through 1994. Its purpose is to provide an overview of the information provided in the site reports. It includes data on radiological releases, doses calculated based on the releases, and descriptions of program and operational changes taken from individual site reports. The reporting period corresponds to the first five years that the requirements for reporting radiological release and dose information of DOE Order 5400.5 were in effect. Summary reports for subsequent year's data are planned for the future.

The DOE requires its contractors to conduct environmental monitoring and surveillance programs at DOE facilities where radioactive materials are produced, used, or disposed of, or where the public may be exposed to radiation from DOE operations (DOE 1990a). These programs aid in determining whether facility operations are functioning as designed and are properly controlling releases of radioactive and nonradioactive materials to the environment. They also provide a means to document compliance with applicable environmental radiation protection standards. Additionally, programs to reduce levels of radioactive releases to as low as reasonably achievable (ALARA) are documented. Managers at each DOE facility report annually in Site Environmental Reports on their environmental programs and the estimated environmental impacts of operations. These reports include estimates of the radiation dose to both individual members of the public and the general population as a whole that could have resulted from operations at the site during the year. The reports also describe nonradioactive effluents released to the environment, as well as releases from some disposal and cleanup operations involving radioactive and chemically hazardous materials. This summary only addresses the radiological aspects of the reports.

Monitoring of releases from DOE facilities takes place at both the point of release (effluent monitoring) and in the environment (environmental surveillance) and is used to ensure compliance with applicable environmental standards and effluent control requirements. For most facilities, however, releases of radioactive material are not measurable in the environment beyond the DOE site boundary. Therefore, doses to the public must be calculated (i.e., estimated) rather than obtained through direct measurement. These calculations are based on monitoring data taken from liquid effluent release points or airborne discharge locations. Mathematical models are used to predict the dispersion of the radionuclides throughout the environment, and dose estimations are based on the calculated concentrations in the environment. For facilities such as accelerators, whose primary contribution to public dose is external radiation, measurements from onsite and offsite thermoluminescent dosimeters (TLDs) are used as the basis for dose calculations. The dose estimates are then compared with EPA

and DOE standards to assess the performance at the sites (EPA 1977). Throughout this document, all reported maximum radiation doses are potential doses rather than actual doses because they are not measured but are calculated from effluent data and environmental pathway models using reasonably conservative assumptions.

Table 1.1 lists the DOE sites included in this report that were operating during 1990 through 1994. The abbreviation used in the summary for each site, the operations office under which it functions, the location, and the principal DOE activity at the site at the time of the respective Site Environmental Reports are included. Under each DOE Operations Office in the table, the specific sites are arranged alphabetically; this arrangement is followed throughout the report. Figure 1.1 is a map showing the locations of the operating DOE radiological/nuclear sites.

Sections 2.0 and 3.0 of this report summarize the estimated doses and releases, respectively, from operating DOE facilities. Section 2.0 discusses estimated doses for both the maximum individual and the general population. Section 3.0 summarizes estimated releases of radioactive materials to the air and water at operating DOE sites.

Appendix A provides a list of site, Field, and Operations Office contacts where information regarding the ASERs used to prepare this report may be obtained. For interested readers, the ASERs provide more detail on all aspects of site operations, including site geography, quantity and identity of the radionuclides and chemicals released, radioactive and chemically hazardous material handling and cleanup, and facility descriptions. Appendix B provides a brief description of the operations at each of the DOE sites addressed in this report. Appendix C provides an overview of sites' environmental programs at the operating facilities. Appendix D is a glossary of terms used in the report.

TABLE 1.1. Major Operating U.S. Department of Energy Sites by Operations Office and Location[1]

Operations Office and Site Abbreviations	Contractor Site	Location	Principal Activity
Albuquerque Office			
GJPO[2]	Grand Junction Project Office	Grand Junction, CO	Restoration Research
MMTS	Monticello Mill Tailings Site	Monticello, UT	Remedial Action Site
ITRI[3]	Inhalation Toxicology Research Institute	Albuquerque, NM	Health Effects Research
LANL	Los Alamos National Laboratory	Los Alamos, NM	Research & Stockpile Stewardship
PANX	Pantex Plant	Amarillo, TX	Stockpile Stewardship
PIN	Pinellas Plant	St. Petersburg, FL	Custodial
SNLA	Sandia National Laboratories	Albuquerque, NM	Stockpile Stewardship
SNLL	Sandia National Laboratories	Livermore, CA	Weapons Development
SNLT	Sandia National Laboratories	Tonopah, NV	Weapons Deployment Test Range

Table 1.1. (Cont'd.)

Operations Office and Site Abbreviations	Contractor Site	Location	Principal Activity
Chicago Office			
Ames	Ames Laboratory	Ames, IA	Energy Research
ANL	Argonne National Laboratory	Argonne, IL	Energy Research
Bates	MIT Bates Linear Accelerator	Middleton, MA	Energy Research
BNL	Brookhaven National Laboratory	Upton, NY	Energy Research
Fermilab	Fermi National Accelerator Lab	Batavia, IL	Physics Research
PPPL	Princeton Plasma Physics Lab	Princeton, NJ	Fusion Research
Golden Field Office			
NREL	National Renewable Energy Lab	Golden, CO	Energy Research
Idaho Office			
INEL	Idaho National Engineering Lab	Idaho Falls, ID	Research
Nevada Office			
NTS	Nevada Test Site	Mercury, NV	Weapons Testing (current moratorium)
Oakland Operations Office			
LBL	Lawrence Berkeley Laboratory	Berkeley, CA	Energy Research
LEHR	Laboratory for Energy-Related Health Research	Davis, CA	Environmental Restoration
LLNL	Lawrence Livermore National Lab	Livermore, CA	Weapons Development
LLNL-3	Lawrence Livermore Natl. Lab - Site 300	Livermore, CA	Weapons Development
RI-1 (ETEC)	Rockwell International - DeSoto Site	Conga Park, CA	Energy Research & Environmental Restoration
RI-2 (ETEC)	Rockwell International - Santa Susana Site	Conga Park, CA	Energy Research & Environmental Restoration
SLAC	Stanford Linear Accelerator Center	Stanford, CA	Energy Research
Oak Ridge Office			
CEBAF	Continuous Electron Beam Accelerator Facility	Newport News, VA	Research
ORR	Oak Ridge Reservation: Y-12 Plant K-25 Gaseous Diffusion Plant Oak Ridge National Laboratory	Oak Ridge, KY	Weapons Research, Fuel Fabrication & Enrichment
PGDP	Paducah Gaseous Diffusion Plant	Paducah, KY	Fuel Fabrication & Enrichment
POR	Portsmouth Gaseous Diffusion Plant	Portsmouth, OH	Fuel Fabrication & Enrichment
Ohio Field Office			
FEMP	Fernald Environmental Management Project	Fernald, OH	Fuel Fabrication & Enrichment
BCL	Battelle Columbus Laboratories	Columbus, OH	Energy Research
RMI	RMI Company Extrusion Plant	Astubula, OH	Fuel Fabrication & Enrichment
MLM[4]	Mound Plant	Miamisburg, OH	Weapons Develop (non-nuclear)
WVDP	West Valley Demonstration Project	West Valley, NY	Environmental Restoration
Richland Office			
HANF	Hanford Site	Richland, WA	Research & Environmental Restoration*

Table 1.1. (Cont'd.)

Operations Office and Site Abbreviations	Contractor Site	Location	Principal Activity
Rocky Flats Field Office			
RFP	Rocky Flats Plant	Golden, CO	Weapons Development & Environmental Restoration*
Savannah River Office			
SRS	Savannah River Site	Aiken, SC	Research & Environmental Restoration*
Remedial Action Sites			
CISS	Colonie Interim Storage Site	Colonie, NY	Environmental Restoration*
HISS	Hazelwood Interim Storage Site	Hazelwood, MO	Environmental Restoration*
MISS	Maywood Interim Storage Site	Bergen County, NY	Environmental Restoration*
MSP	Middlesex Sampling Plant	Middlesex, NJ	Environmental Restoration*
NBS	New Brunswick Site	New Brunswick, NJ	Environmental Restoration*
NFSS	Niagra Falls Storage Site	Lewiston Twp, NY	Environmental Restoration*
WISS	Wayne Interim Storage Site	Wayne Twp, NJ	Environmental Restoration*
WSS	Weldon Spring Site	St. Charles Co, MO	Environmental Restoration*
Naval Reactors Office			
BET	Bettis Atomic Power Laboratory	West Mifflin, PA	Naval Research
KAPL-1 (Knolls)	Knolls Atomic Power Laboratory	Schenectady, NY	Naval Research
KAPL-2 (Kesselring)	Knolls Atomic Power Laboratory	West Milton, NY	Naval Research
KAPL-3 (Windsor)	Knolls Atomic Power Laboratory	Windsor, CT	Environmental Restoration*
NRF	Naval Reactor Facility	Idaho Falls, ID	Naval Research

* Environmental Restoration, as used in this table, refers to sites with buildings or environmental media that contain radioactive materials. These materials are being removed, through decontamination or decommissioning, to release the facility or area for other non-DOE uses.

1. As used in this context, "major" means those operations offices/sites/contractors that are required to prepare an Annual Site Environmental Report per DOE Order 5400.1.
2. Currently known as the Grand Junction Office and planned for transfer to private ownership in CY2000
3. Currently a private organization known as ITL
4. The Mound Plant reported to the Albuquerque Operations Office during the majority of 1990-1994.

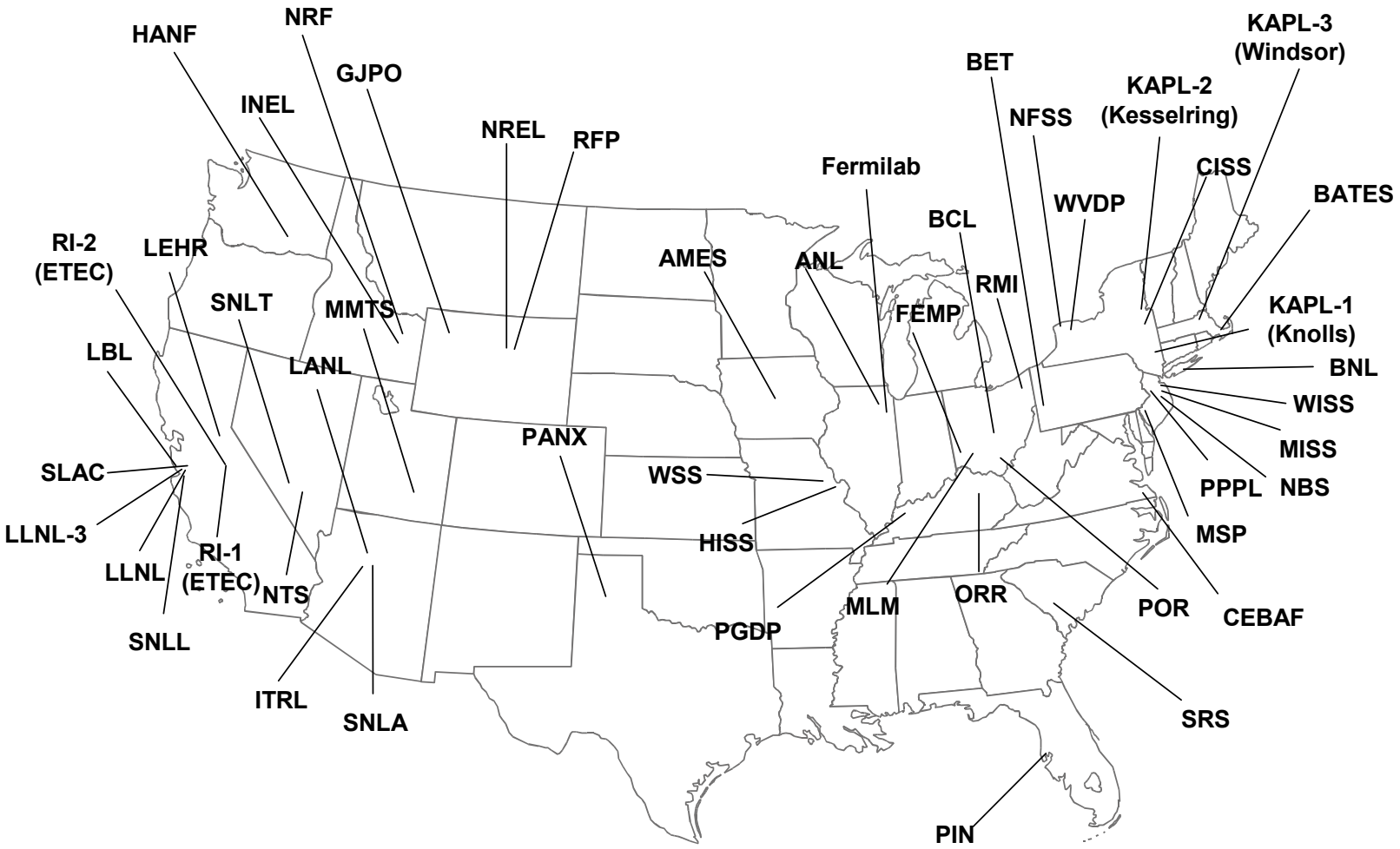

Figure 1.1. Locations of Operating U.S. Department of Energy Radiological and Nuclear Sites 1990-1994

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2.0 ESTIMATED RADIATION DOSES FROM RADIOLOGICAL/NUCLEAR FACILITY OPERATIONS

For each DOE site, the annual Site Environmental Reports provide two sets of calculations for the doses received from DOE operations: the dose to the potentially maximally exposed individual (MEI) and the estimated total (collective) dose to the population living within 80 kilometers (50 miles) of the DOE site. The following sections discuss the estimates for both doses. The doses to internal organs from inhalation and ingestion of radioactive materials have been calculated using appropriate Federal guidance and DOE approved dose conversion factors (DOE 1988a, EPA 1988). External doses are estimated through exposure measurement and using Federal guidance and dose factors (DOE 1988b, EPA 1993). These factors are based on recommendations of the International Commission on Radiological Protection (ICRP) in its Publication 30 (ICRP 1978).

2.1 MAXIMUM INDIVIDUAL DOSE ESTIMATES

The dose to the maximally exposed individual is reported annually for each DOE site. This dose provides a representative and reasonably conservative estimate of the radiation dose that might have been received by members of the public. Because conservative assumptions are used, the calculated dose is usually greater than the dose any member of the public might actually receive from the DOE site.

Each site calculates the effective dose equivalent to the maximally exposed individual (member of the public) for each radionuclide and appropriate exposure pathways for that site. For example, Mound calculates the effective dose equivalent values for ^{238}Pu and ^{3}H exposures from the air, water, and vegetation (foodstuffs) pathways. Each site determines who the maximally exposed individual is; for example, the individual is assumed to reside at a point at the site boundary that is downwind of the facility with the greatest potential for release of airborne radionuclides.

With the issuance of DOE Order 5400.5 (DOE 1990b), DOE required facilities to estimate doses to the MEI and indicated these estimates should be conservative but as realistic as possible. In doing so, DOE was discouraging the use of "fenceline" dose estimates (i.e., assuming a member of the public spent 365 days/yr, 24 hr/day at the fenceline) that were typical under DOE Order 5480.1A Chapter XI, "Environmental Protection, Safety and Health Program for DOE Operations" (DOE 1981) compliance assessments. Between 1990 and 1994, facilities were transitioning to this methodology. As a result, the doses summarized here range from those based on extremely conservative assumptions (e.g., fenceline dose) to those using conservative but more realistic assumptions.

For the air pathway, most sites use the EPA CAP88-PC model to calculate committed effective dose equivalent. Some sites, such as the Savannah River Site (SRS), use a computer model specifically developed for their site. Some of the smaller sites, such as the National Renewable Energy Laboratory, where there are no nuclear operations and only minor use of radioisotopes, use EPA's COMPLY or AIRDOS computer models that use screening codes (presumed release scenarios) to develop dose estimates, which are generally more conservative than the doses calculated with the CAP88-PC model.

The DOE dose limit for an individual in the vicinity of a DOE facility during 1990 through 1994 was 100 mrem/yr (1 mSv/yr) effective dose equivalent for all pathways and all sources of exposure (DOE 1990a, DOE 1990b). Because this is an "all sources" dose limit, DOE facilities must maintain doses at a fraction of the limit to be sure that the dose to a member of the public is not exceeding the limit. Generally, DOE assumes that if the DOE all pathway dose to the MEI is less than one-third to one-fourth the 100 mrem limit, sites are complying with the "all sources" limit. Otherwise, sites would need to consider doses from other sources in their evaluation to be sure the MEI is not exposed to doses exceeding the 100 mrem/yr limit.

In addition, the EPA National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations limit the dose from airborne radionuclide emissions to 10 mrem/yr (40 CFR 61, Subpart H). Although each site must stay below these limits (100 mrem/yr and 10 mrem/yr), it must also strive to maintain doses that are as low as reasonably achievable (ALARA).

Table 2.1 lists the estimated maximum potential doses to individuals from each DOE radiological/nuclear site; the table also indicates what percentage of the DOE 100-mrem limit this dose represents. These values range from less than 1 mrem (0.01 mSv) to 40 mrem (0.40 mSv).

In 1990, 33 DOE sites reported doses to the MEI of less than 1 mrem (< 1 mrem), 11 sites reported a dose between 1 and 10 mrem, and 1 site, Fermi National Accelerator Laboratory, reported a dose greater than 10 mrem (> 10 mrem). The dose at Fermilab (16 mrem) was principally due to direct exposure from high-energy muons, similar to those found in cosmic rays, that resulted from experiments using high-energy protons. The dose associated with airborne emissions was 0.03 mrem. Fermilab's principal facility is a proton synchrotron used to conduct research in high-energy physics. The 16 mrem dose reflects the maximum dose from operation of the MW Beamline at the site boundary. The dose to the MEI at the nearest residence within the MW Beamline radiation field (8 mrem) was only half the dose at the site boundary. The dose at Fermilab dropped in 1991-1992 due to a modification in operation going from a fixed target to a collider mode. This greatly reduced the muon dose contribution. From 1992 through 1994 doses were less than 1 mrem/yr.

In 1991, 37 DOE sites reported doses to the MEI of < 1 mrem, 11 sites reported a dose of between 1 and 10 mrem, and 1 site, Monticello Mill Tailings Site, reported a dose >10 mrem. The dose at Monticello (31 mrem) was principally the result of a conservative analytical methodology whereby gamma radiation measurements from thermoluminescent dosimeters were used in the calculation of offsite dose, and assuming the individual was located at the boundary sampling point 24 hours a day, 365 days a year. At Monticello, residues from vanadium and uranium milling (approximately 2 million m^3 of contaminated material) have been covered with soil and are being managed to minimize offsite migration of the contaminated material. For the purposes of this report, the radon source term has been excluded from the MEI dose estimation because radon is generally not used as a source term in such calculations.

In 1992, 39 DOE sites reported doses to the MEI of < 1 mrem, 9 sites reported a dose of between 1 and 10 mrem, and 1 site (Monticello) reported a dose >10 mrem. As noted above, the dose at Monticello reflects a conservative analytical methodology.

In 1993, 34 DOE sites reported doses to the MEI of < 1 mrem, 7 sites reported a dose of between 1 and 10 mrem, and 2 sites (Monticello and the Stanford Linear Accelerator Center) reported a dose >10 mrem. While Monticello's dose estimate (12 mrem) reflects a conservative analytical methodology for calculation of total dose (described above), the dose calculation at the Stanford Linear Accelerator Center (40 mrem) uses a conservative assumption that the MEI will be located at the Laboratory boundary continuously, 24 hours/day, 365 days/year. Further, the dose at the boundary was calculated to be between 20 and 40 mrem, with the 40 mrem dose being reported in the ASER to provide an upper bound for the potential fenceline dose. The dose at the Stanford Linear Accelerator Center was principally from airborne emissions of short-lived radionuclides from the linear particle accelerator. Stanford Linear Accelerator Center is a large research laboratory devoted to theoretical and experimental research in elementary particle physics and chemistry using synchrotron radiation from accelerated electron beams. As discussed earlier, Stanford used a conservative method for calculating dose to an exposed individual at the fenceline (site boundary). The use of "fenceline" dose was common practice in the past, however, DOE Order 5400.5 (DOE 1990b) requirements directed facility operators to conduct more realistic dose assessments for locations where exposure might actually occur. The dose at the nearest offsite residence would likely be much lower. For example, in 1994, when the MEI dose was based on the closest locations of the general public to the facility, as opposed to the fenceline, the dose was estimated to be 7.6 mrem.

In 1994, 33 DOE sites reported doses to the MEI of < 1 mrem, 8 sites reported a dose of between 1 and 10 mrem, and 1 site (Monticello) reported a dose >10 mrem. The dose reported for Monticello was 20 mrem. As described above, the methodology for calculating dose at Monticello results in very conservative estimates.

In Report 94 of the National Council on Radiation Protection and Measurements (NCRP 1987), the typical annual effective dose equivalent received by members of the population in the United States and Canada from natural sources of radiation was estimated to be approximately 300 mrem (3 mSv). Although natural background radiation varies(1) site to site, all DOE-related doses are a small fraction of background. As discussed above, most DOE facilities report a dose to the MEI that is less than 1 mrem/yr, and all report doses that are a small fraction of the NCRP's estimated dose from naturally occurring sources of radiation.

2.2 POPULATION DOSE ESTIMATES

Although there are no regulatory limits for population doses (also called collective dose), such doses are included in ASERs and provide an indication of the overall impact of DOE operations. Doses to the population living within 50 mi (80 km) of each site are calculated. The 50 mi population dose is estimated by summing the average collective doses from all directional sectors within a 50 mi radius of the center of the site. Typically, the 50 mi distance from the site is divided into ten progressively larger radii out to 50 miles, with 16 cone-shaped directional sectors to account for wind direction within a 360^0 radius.

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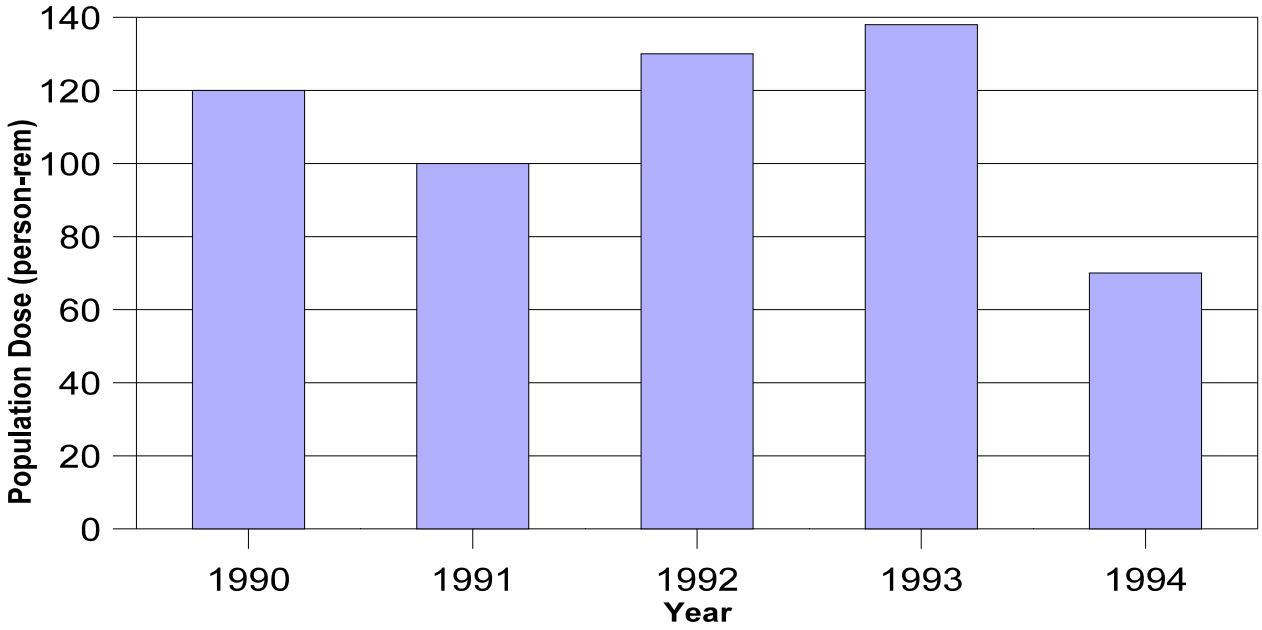
(1) Much of this dose results from the dose to the lung from the decay products of radon inhaled from indoor air (e.g., in offices and homes). Natural environmental radiation levels can vary widely from location to location. Differences occur in the exposure pathways available to the maximally exposed individual and in the calculation methods used to estimate the dose from background radiation at various DOE sites. As a result, estimates of background doses to members of the public are not always directly comparable from site to site.

Estimated doses for the population surrounding each site are shown in Table 2.1. The largest population dose for a single site in 1990 was 30 person-rem at the Oak Ridge Reservation (ORR), 29 person-rem at ORR in 1991, 43 person-rem at ORR in 1992, 48 person-rem at the Stanford Linear Accelerator Center in 1993, and 19 person-rem at ORR in 1994. The estimated population dose to the same population from natural radiation sources during those years was about 300,000 person-rem at ORR, and 28,000 person-rem at Stanford Linear Accelerator Center. The dose from operations at all DOE radiological and nuclear facilities was much less than 1% of that received from natural radiation in the environment. Table 2.1 provides an estimated population dose (in person-mrem) due to natural radiation at all DOE sites during 1990 through 1994.

As shown in Figure 2.1, the total estimated population dose received by all individuals residing within 50 mi (80 km) of a DOE radiological/nuclear facility ranged between approximately 70 and 140 person-rem/yr during 1990-1994.

The total dose from DOE operations would be a small fraction of that received from natural sources. For example, the natural background dose to the population within 50 mi

Figure 2.1. Estimated Population Dose from Operating DOE Sites* 1990-1994



*Excludes Monticello Mill Tailings Site. - see Table 2.1, footnote "c"

(80 km) of the Lawrence Livermore National Laboratory in Livermore, California, by itself was nearly 2 million person-rem (approximately 2.0E+06 person-rem[2]). Similarly, background doses for the population around Argonne National Laboratory is about 2.4E+06 (2.4 million) person-rem annually. These are several orders of magnitude higher than the population dose from all DOE

(2) Scientific notation is used throughout the remainder of this report to facilitate the presentation of a wide range of numeric values (e.g., 4,000,000 = 4.0E+06, 0.000004 = 4.0E-06).

sites combined. If the natural background radiation dose were summed for any given year for the general population within 50 miles of all DOE sites, that dose would be many orders of magnitude greater than the total sum of the population dose collectively received from the activities at all DOE sites.

In general, population dose (collective dose) are small and remain constant over the five-year review period. The largest change, the decrease between 1993 and 1994, was primarily due to reductions at a few sites where the population dose decreased by as much as 90%. Most notably, the Stanford Linear Accelerator Center population dose fell by approximately 44 person-rem (48 person-rem in 1993 to 3.9 person-rem in 1994). The reason for the drop between 1993 and 1994 was the result of improved (more realistic and less conservative) calculation methods. Between 1993 and 1994, SLAC increased the integration area for calculating population dose from 6 km (3.8 miles) to 80 km (50 miles) and adjusted the dose model to reflect more realistic parameters versus the conservative assumptions employed in the past. The 1994 model used a more realistic distance where the population is located, rather than the previously used (conservative) distance to the site boundary. This extra, but real distance, provided a larger attenuation factor thereby more appropriately reflecting realistic estimates of the population dose.

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
Albuquerque Operations Office					
Grand Junction Project Office					
1990	1.4E-01	<1	(b)	(b)	(b)
1991	1.7E-01	<1	2.0E-02	6.6E+04	7.7E+03
1992	5.7E-02	<1	9.5E-03	8.5E+04	(b)
1993	2.2E-03	<1	9.9E-02	8.5E+04	(b)
1994	1.9E-02	<1	2.3E+00	8.5E+04	(b)
Monticello Mill Tailings Site					
1990	(b)	(b)	(c)	2.5E+03	2.9E+02
1991	3.1E+01	31.0	(c)	2.5E+03	2.9E+02
1992	2.7E+01	27.0	(c)	2.5E+03	2.9E+02
1993	1.2E+01	12.0	(c)	2.5E+03	(b)
1994	2.0E+01	20.0	(c)	2.5E+03	(b)
Inhalation Toxicology Research Institute					
1990	4.0E-04	<1	(b)	(b)	(b)
1991	3.6E-06	<1	(b)	(b)	(b)
1992	1.6E-05	<1	(b)	(b)	(b)
1993	3.2E-05	<1	(b)	5.5E+05	(b)
1994	4.7E-04	<1	(b)	5.0E+05	(b)
Los Alamos National Laboratory					
1990	3.1E+00	3.1	3.1E+00	2.1E+05	7.0E+04
1991	4.4E+00	4.4	1.1E+00	2.2E+05	7.1E+04
1992	6.1E+00	6.1	1.4E+00	2.2E+05	7.2E+04
1993	3.1E+00	3.1	3.0E+00	2.1E+05	7.2E+04
1994	3.5E+00	3.5	4.0E+00	2.3E+05	7.2E+04
Pantex Plant					
1990	1.6E-01	<1	2.1E-01	2.6E+05	2.9E+04
1991	1.2E-05	<1	6.5E-05	2.7E+05	2.9E+04
1992	2.7E-05	<1	5.0E-05	2.7E+05	2.9E+04
1993	5.7E-05	<1	1.0E-04	2.7E+05	2.4E+04
1994	5.8E-05	<1	1.4E-04	2.7E+05	2.6E+04
Pinellas Plant					
1990	9.8E-02	<1	2.7E+00	2.5E+06	9.0E+05
1991	5.5E-03	<1	9.1E-01	2.5E+06	9.0E+05
1992	7.4E-03	<1	1.9E-01	2.5E+06	9.1E+05
1993	2.3E-03	<1	4.3E-02	2.5E+06	9.1E+05
1994	5.6E-03	<1	9.7E-02	2.5E+06	9.1E+05
Sandia National Laboratories Albuquerque					
1990	2.0E-03	<1	8.2E-01	5.7E+05	5.7E+04
1991	1.4E-03	<1	5.2E-01	5.7E+05	5.7E+04
1992	4.3E-03	<1	2.0E-02	5.7E+05	5.7E+04
1993	1.6E-03	<1	2.7E-02	5.7E+05	5.7E+04
1994	5.3E-04	<1	1.2E-02	5.7E+05	5.7E+04
Sandia National Laboratories Livermore					
1990	1.5E-01	<1	(b)	6.3E+06	1.9E+06
1991	2.5E-01	<1	(b)	6.3E+06	1.9E+06

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
1992	2.0E-01	<1	9.0E-01	6.3E+06	1.9E+06
1993	2.6E-02	<1	1.4E+00	6.3E+06	1.9E+06
1994	1.3E-02	<1	7.0E-01	6.3E+06	1.9E+06
Sandia National Laboratories Tonopah					
1990	0.0E+00	0.0	0.0E+00	9.3E+03	(b)
1991	0.0E+00	0.0	0.0E+00	9.3E+03	(b)
1992	1.9E-05	<1	(b)	9.3E+03	(b)
1993	2.9E+00	2.9	3.8E-04	6.0E+03	2.8E+03
1994	1.7E+00	1.7	4.2E-04	9.3E+03	(b)
Chicago Operations Office					
Ames Laboratory					
1990	4.0E-04	<1	(b)	(b)	(b)
1991	6.3E-08	<1	(b)	(b)	(b)
1992	6.3E-08	<1	(b)	(b)	(b)
1993	0.0E+00	0.0	0.0E+00	(b)	(b)
1994	0.0E+00	0.0	0.0E+00	(b)	(b)
Argonne National Laboratory					
1990	4.1E-01	<1	1.5E+01	7.9E+06	2.4E+06
1991	3.0E-01	<1	1.5E+01	7.9E+06	2.4E+06
1992	3.4E-01	<1	1.7E+01	7.9E+06	2.4E+06
1993	2.4E-01	<1	1.3E+01	7.9E+06	2.4E+06
1994	1.2E-01	<1	5.8E+00	7.9E+06	2.4E+06
MIT Bates Linear Accelerator					
1990					
1991	3.0E-01	<1	(b)	(b)	(b)
1992	0.0E+00	<1	(b)	(b)	(b)
1993					
1994					
Brookhaven National Laboratory					
1990	9.2E-01	<1	1.8E+00	5.0E+06	2.9E+05
1991	9.2E-01	<1	3.6E+00	5.0E+06	2.9E+05
1992	1.0E+00	1.0	3.2E+00	5.0E+06	2.9E+05
1993	9.8E-01	<1	5.1E+00	5.0E+06	2.9E+05
1994	1.0E+00	1.0	4.0E+00	5.0E+06	2.9E+05
Fermi National Accelerator Laboratory					
1990	1.6E+01	16.0	8.0E+00	8.0E+06	2.4E+06
1991	7.2E+00	7.2	8.0E+00	8.0E+06	2.4E+06
1992	3.0E-01	<1	2.3E-02	8.0E+06	2.4E+06
1993	6.5E-03	<1	1.5E-02	8.0E+06	2.4E+06
1994	3.9E-01	<1	2.6E-02	8.0E+06	2.4E+06
Princeton Plasma Physics Laboratory					
1990	1.8E-02	<1	5.0E-02	1.6E+07	1.6E+06
1991	1.2E-02	<1	3.3E-02	1.6E+07	1.6E+06
1992	1.9E-02	<1	4.1E-02	1.6E+07	1.6E+06
1993	1.8E-02	<1	9.9E-01	1.6E+07	1.6E+06
1994	3.0E-01	<1	4.6E+00	1.6E+07	1.6E+06

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
Golden Field Office					
National Renewable Energy Laboratory					
1990	6.3E-04	<1	(b)	(b)	(b)
1991	1.1E-03	<1	(b)	(b)	(b)
1992	4.7E-03	<1	(b)	(b)	(b)
1993	1.7E-03	<1	(b)	(b)	(b)
1994	1.5E-03	<1	(b)	(b)	(b)
Idaho Operations Office					
Idaho National Engineering Laboratory					
1990(d)	6.0E-03	<1	4.2E-02	1.2E+05	4.2E+04
1991(d)	2.0E-02	<1	6.1E-02	1.2E+05	4.2E+04
1992(d)	4.0E-03	<1	3.0E-02	1.2E+05	4.3E+04
1993(d)	3.0E-02	<1	3.0E-01	1.2E+05	4.3E+04
1994(d)	7.0E-03	<1	5.9E-02	1.2E+05	4.3E+04
Nevada Operations Office					
Nevada Test Site					
1990	6.0E-03	<1	1.5E-02	7.7E+03	9.5E+02
1991	8.6E-03	<1	4.2E-02	2.2E+04	1.7E+03
1992	1.2E-02	<1	2.9E-02	2.2E+04	1.1E+03
1993	3.8E-03	<1	1.2E-02	2.0E+04	1.8E+03
1994	1.5E-01	<1	5.2E-01	3.3E+04	3.3E+03
Oakland Operations Office					
Lawrence Berkeley Laboratory					
1990	1.8E+00	1.8	8.0E+00	6.0E+06	1.5E+06
1991	2.1E+00	2.1	5.0E+00(e)	6.0E+06	1.5E+06
1992	2.3E+00	2.3	3.4E+00(e)	6.0E+06	1.8E+06
1993	3.0E+00	3.0	1.3E+00	6.0E+06	1.5E+06
1994	1.6E+00	1.6	1.8E+00	6.0E+06	1.5E+06
Laboratory for Energy-Related Health Research					
1990	(b)	(b)	(b)	(b)	(b)
1991	4.0E-05	<1	6.9E-03	(b)	(b)
1992	3.2E-03	<1	6.8E-01	(b)	(b)
1993	3.2E-03	<1	6.8E-03	(b)	(b)
1994	5.5E-02	<1	9.9E-01	(b)	(b)
Lawrence Livermore National Laboratory					
1990	2.8E-01(f)	<1	2.8E-01	6.0E+06	1.8E+06
1991	1.6E-01	<1	3.8E-01	6.0E+06	1.8E+06
1992	7.9E-02	<1	1.5E+00	6.3E+06	1.9E+06
1993	6.6E-02	<1	9.8E-01	6.3E+06	1.9E+06
1994	6.5E-02	<1	7.6E-01	6.3E+06	1.9E+06
Lawrence Livermore National Laboratory - Site 300					
1990	5.7E-02	<1	0.0E+00	5.4E+06	1.6E+06
1991	8.6E-03	<1	1.9E-07	5.4E+06	1.6E+06
1992	2.1E-02	<1	7.1E+00	5.4E+06	1.6E+06
1993	3.7E-02	<1	6.9E+00	5.4E+06	1.6E+06
1994	8.1E-02	<1	1.7E+01	5.4E+06	1.6E+06

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
Rockwell International - DeSoto Site					
1990	0.0E+00	0.0	(b)	(b)	1.9E+06
1991	5.2E-01	<1	(b)	(b)	1.9E+06
1992	2.1E-01	<1	9.0E-05	8.9E+06	2.0E+06
1993	5.3E-02	<1	6.6E-05	8.9E+06	3.0E+06
1994	3.5E-06	<1	1.6E-04	(b)	3.0E+06
Rockwell International - Santa Susana Site					
1990	2.4E-02	<1	4.8E-05	8.9E+06	1.9E+06
1991	6.8E-02	<1	5.8E-04	8.9E+06	1.9E+06
1992	1.0E-04	<1	2.7E-04	8.9E+06	2.0E+06
1993	3.5E-02	<1	1.6E-03	8.9E+06	3.0E+06
1994	1.7E-04	<1	5.7E-04	8.9E+06	3.0E+06
Stanford Linear Accelerator Center					
1990	2.0E+00	2.0	(b)	(b)	(b)
1991	2.0E+00(g)	2.0	1.8E+01(h)	(b)	(b)
1992	2.0E+00	2.0	1.8E+01(h)	(b)	(b)
1993	4.0E+01(i)	40.0	4.8E+01	9.2E+04(j)	2.8E+04
1994	7.6E+00(k)	7.6	3.9E+00	4.9E+06	1.5E+06
Oak Ridge Operations Office					
Continuous Electron Beam Accelerator Facility					
1990					
1991	The site did not begin operation or produce a Site Environmental Report until 1992				
1992	5.3E-05	<1	4.0E-04	(b)	(b)
1993	5.3E-05	<1	4.0E-04	(b)	(b)
1994	2.0E-04	<1	7.3E-04	(b)	(b)
Oak Ridge Reservation					
1990	2.0E+00	2.0	3.0E+01	9.4E+05	2.8E+05
1991	1.7E+00	1.7	2.9E+01	8.8E+05	2.6E+05
1992	1.4E+00	1.4	4.3E+01	8.8E+05	2.6E+05
1993	3.0E+00	3.0	2.6E+01	8.8E+05	2.6E+05
1994	1.7E+00	1.7	1.9E+01	8.8E+05	2.6E+05
Paducah Gaseous Diffusion Plant					
1990	6.2E+00	6.2	1.5E-03	5.4E+05	2.0E+05
1991	3.8E+00	3.8	3.9E-03	5.0E+05	2.0E+05
1992	4.0E+00	4.0	1.7E-03	5.0E+05	2.0E+05
1993	2.1E+00	2.1	1.1E-02	5.0E+05	2.0E+05
1994	5.6E+00	5.6	(b)	5.0E+05	2.0E+05
Portsmouth Gaseous Diffusion Plant					
1990	6.0E-02	<1	4.0E-01	6.0E+05	1.8E+05
1991	5.0E-02	<1	3.0E-01	9.2E+05	2.8E+05
1992	3.0E-01	<1	3.0E+00	9.2E+05	2.8E+05
1993	9.0E-01	<1	1.2E+01	9.0E+06	2.8E+05
1994	1.6E-02	<1	6.0E-01	(b)	(b)
Ohio Field Office					
Fernald Environmental Management Project					
1990	1.0E+01	10.0	(b)	2.7E+06	2.7E+05

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
1991	9.1E+00	9.1	1.2E+00(l)	2.7E+06	2.7E+05
1992	1.0E+00(m)	1.0	1.3E+00	2.7E+06	2.7E+05
1993(n)	1.0E+00	1.0	3.0E-01	2.7E+06	3.0E+05
1994(n)	7.0E-01	<1	2.1E+00	2.7E+06	3.0E+05
Battelle Columbus Laboratories					
1990	2.6E-03	<1	3.8E-03	1.7E+06	2.3E+05
1991	6.6E-03	<1	(b)	1.7E+06	2.3E+05
1992	6.1E-02	<1	9.8E-02	1.9E+06	2.3E+05
1993(n)	3.7E-02	<1	1.4E-01	1.9E+06	6.3E+05
1994(n)(o)	2.1E-03	<1	7.6E-03	2.1E+06	6.3E+05
RMI Company Extrusion Plant					
1990	9.0E-05	<1	4.0E-04	1.6E+06	2.3E+05
1991	4.1E-03	<1	8.0E-03	1.4E+06	1.1E+05
1992	9.2E-03	<1	6.8E-04	1.4E+06	1.5E+05
1993	1.0E-01	<1	6.8E-04	1.4E+06	1.2E+05
1994	<5.8E-04	<1	1.9E-04	1.4E+06	8.7E+04
Mound					
1990	2.5E-01	<1	5.3E+00	3.0E+06	1.0E+06
1991	2.8E-01	<1	3.6E+00	3.0E+06	1.0E+06
1992	2.2E-01	<1	2.6E+00	3.0E+06	1.0E+06
1993	2.6E-01	<1	2.1E+00	3.0E+06	1.0E+06
1994	3.0E-02	<1	1.9E+00	3.0E+06	1.0E+06
West Valley Demonstration Project					
1990	2.3E-01	<1	5.6E-02	1.7E+06	5.1E+05
1991	5.5E-02	<1	1.6E-02	1.7E+06	5.1E+05
1992	4.6E-02	<1	1.1E-02	1.7E+06	5.1E+05
1993	3.3E-02	<1	7.0E-02	1.7E+06	5.1E+05
1994	2.3E-02	<1	8.4E-02	1.7E+06	5.1E+05
Richland Operations Office					
Hanford Site					
1990	3.0E-02	<1	2.0E+00	3.4E+05	1.1E+05
1991	2.0E-02	<1	9.0E-01	3.8E+05	1.1E+05
1992	2.0E-02	<1	8.0E-01	3.8E+05	1.1E+05
1993	3.0E-02	<1	4.0E-01	3.8E+05	1.1E+05
1994	5.0E-02	<1	6.0E-01	3.8E+05	1.1E+05
Rocky Flats Field Office					
Rocky Flats Plant					
1990	5.2E-01	<1	2.0E+01	2.2E+06	8.0E+05
1991	3.2E-01	<1	9.0E-01	2.1E+06	7.0E+05
1992	4.6E-01	<1	1.0E-01	2.1E+06	7.0E+05
1993(n)	4.8E-01	<1	1.0E-01	2.2E+06	7.7E+05
1994(n)	1.0E-01	<1	2.6E-01	2.2E+06	7.8E+05
Savannah River Site					
Savannah River Site					
1990	3.6E-01	<1	9.6E+00	5.5E+05	2.4E+05
1991	4.6E-01	<1	7.1E+00(p)	5.5E+05	2.6E+05

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
1992	2.2E-01	<1	6.4E+00	6.2E+05	2.0E+05
1993	2.5E-01	<1	7.6E+00(q)	6.2E+05	2.0E+05
1994	2.3E-01	<1	6.3E+00(r)	6.2E+05	2.0E+05
Remedial Action Sites					
Colonie Interim Storage Site (s)					
1990	1.5E+00	1.5	3.9E-04	7.5E+05	4.4E+04
1991	2.3E-01	<1	4.3E-03	7.8E+05	4.9E+04
1992	4.0E-01	<1	4.0E+00	7.8E+05	3.9E+04
1993					
1994	No Site Environmental Report prepared for 1993 or 1994				
Hazelwood Interim Storage Site (s)					
1990	9.0E-01	<1	1.6E+00	2.5E+06	2.0E+05
1991	1.0E-01	<1	1.0E-02	2.5E+06	2.0E+05
1992	1.3E-01	<1	1.1E-01	2.6E+06	3.0E+05
1993					
1994	No Site Environmental Report prepared for 1993 or 1994				
Maywood Interim Storage Site (s)					
1990	1.3E+00	1.3	2.5E+00	1.0E+07	5.4E+06
1991	1.2E+00	1.2	1.6E+00	1.0E+07	6.0E+05
1992	6.3E-01	<1	4.5E+00	1.0E+07	7.4E+05
1993					
1994	No Site Environmental Report prepared for 1993 or 1994				
Middlesex Sampling Plant (s)					
1990	2.6E+00	2.6	2.8E-01	1.5E+07	9.6E+05
1991	2.3E+00	2.3	“negligible”(t)	1.5E+07	1.1E+06
1992	3.0E-01	<1	(b)	1.5E+07	1.0E+06
1993	2.3E-01	<1	(b)	(b)	(b)
1994	No Site Environmental Report prepared for 1994				
New Brunswick Site					
1990					
1991	1.0E-01	<1	4.0E-02	1.5E+06	1.0E+06
1992					
1993					
1994	No Site Environmental Report prepared for 1993 or 1994				
Niagara Falls Storage Site (s)					
1990	4.4E-01	<1	3.0E-01	2.3E+05	1.5E+04
1991	3.0E-01	<1	5.7E-04	2.5E+05	1.9E+04
1992	3.0E-05	<1	7.7E-02	2.5E+05	2.0E+04
1993					
1994	No Site Environmental Report prepared for 1993 or 1994				
Wayne Interim Storage Site (s)					
1990	8.4E-01	<1	8.0E-02	(b)	6.2E+06
1991	6.0E-01	<1	2.2E-02	1.0E+07	7.8E+05
1992	“negligible”(t)	<1	“negligible”(t)	1.0E+07	8.2E+05
1993					
1994	No Site Environmental Report prepared for 1993 or 1994				

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
Weldon Spring Site					
1990	3.9E+00	3.9	5.9E-02	(b)	(b)
1991	2.4E+00	2.4	6.9E-02	(b)	(b)
1992	1.9E+00	1.9	2.1E-02	(b)	(b)
1993	3.0E-02	<1	1.2E-01	(b)	(b)
1994	7.3E-01	<1	7.2E-02	(b)	3.0E+02
Naval Reactors					
Bettis Atomic Power Laboratory					
1990	2.6E+00	2.6	4.8E+00	3.2E+06	9.6E+05
1991	2.7E+00	2.7	4.8E+00	3.2E+06	9.6E+05
1992	2.8E+00	2.8	6.2E+00	3.2E+06	9.6E+05
1993	2.6E+00	2.6	3.0E+00	3.2E+06	9.6E+05
1994	2.6E+00	2.6	2.2E+00	3.0E+06	9.6E+05
Knolls Atomic Power Laboratory -Knolls					
1990	1.0E-01	<1	1.0E-01	1.3E+06	7.9E+04
1991	1.0E-01	<1	1.0E-01	1.3E+06	8.4E+04
1992	1.0E-01	<1	1.0E-01	1.3E+06	8.5E+04
1993	1.0E-01	<1	1.0E-01	1.3E+06	8.1E+04
1994	1.0E-01	<1	1.0E-01	1.3E+06	8.8E+04
Knolls Atomic Power Laboratory - Kesselring					
1990	1.0E-01	<1	2.0E-01	1.1E+06	8.2E+04
1991	1.0E-01	<1	1.0E-01	1.1E+06	8.2E+04
1992	1.0E-01	<1	1.0E-01	1.2E+06	8.5E+04
1993	1.0E-01	<1	1.0E-01	1.2E+06	8.5E+04
1994	1.0E-01	<1	1.0E-01	1.2E+06	8.3E+04
Knolls Atomic Power Laboratory - Windsor					
1990	1.0E-01	<1	1.0E-01	3.2E+06	2.3E+05
1991	1.0E-01	<1	1.0E-01	3.2E+06	2.3E+05
1992	1.0E-01	<1	1.0E-01	3.4E+06	2.5E+05
1993	1.0E-01	<1	1.0E-01	3.4E+06	2.4E+05
1994	1.0E-01	<1	1.0E-01	3.4E+06	2.5E+05
Naval Reactor Facility					
1990	5.7E-04	<1	(b)	1.2E+05	4.2E+04
1991	5.8E-04	<1	(b)	1.2E+05	4.2E+04
1992	1.1E-04	<1	(b)	1.2E+05	4.2E+04
1993	6.2E-04	<1	(b)	1.2E+05	4.2E+04
1994	2.7E-04	<1	(b)	1.2E+05	4.2E+04

(a) 100 mrem = 1mSv.

(b) Data not presented in SER.

(c) Population dose was not specifically calculated by Monticello from 1990 through 1992. Rather, the site relied on data collected during 1981 through 1987 reported in a 1990 RI/FS-EA showing estimated average individual doses that include radon and are higher than the dose to MEI during those years, which is clearly an overestimate. The 1993 and 1994 values also included radon. As a result, the population dose values for 1990-1994 have been excluded.

Table 2.1. 1990-1994 Estimated Effective Dose Equivalents and Populations for Operating DOE Sites

Year	Dose to Maximally Exposed Individual (mrem)(a)	% of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	Population in 80 km	Estimated Natural Radiation Population Dose (person-rem)
(d) MEI and Population Doses were calculated using the site-specific MESODIF computer code, which produces a more conservative estimate of dose than CAP-88.					
(e) Total population dose reported in SER includes penetrating radiation from accelerator operations and radionunclide releases.					
(f) MEI dose reported in SER includes 2.4E-01 mrem from air pathway.					
(g) MEI dose includes 6.8E-02 mrem from radionuclide emissions.					
(h) Based on population within 1.6 km.					
(i) MEI dose includes 9.3E-03 mrem from radionuclide emissions.					
(j) Based on population within 6km					
(k) MEI dose includes 3.1E-04 mrem from radionuclide emissions.					
(l) Excluding Radon. Radon dose rate at site perimeter is 69 mrem (0.69 mSv) per year, continuous occupancy.					
(m) Excluding Radon. Radon dose rate at site perimeter is 0.5 mSv (51 mrem) per year, continuous occupancy.					
(n) Remedial Action Site.					
(o) Data presented is for the West Jefferson Site because limited information available for modeling dose at King Avenue Site.					
(p) Population dose shown is only from air pathway. SER also identified 3.2E+00 person-rem dose from liquid effluent releases.					
(q) Population dose shown is only from air pathway. SER also identified 1.5E+00 person-rem dose from liquid effluent releases.					
(r) Population dose shown is only from air pathway. SER also identified 1.7E+00 person-rem dose from liquid effluent releases.					
(s) Responsibilities for management and clean up of this remedial action site transferred to the U.S. Army Corps of Engineers in 1997.					
(t) No numeric value given. SER indicated dose was “negligible.”					
Blank = Data not available at this time.					

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3.0 RELEASES OF RADIOACTIVE MATERIALS TO AIR AND WATER

The operating facilities at DOE radiological/nuclear sites routinely release limited amounts of radioactive material to the environment via airborne and aqueous effluents. Doses to the public from these releases must be as low as reasonably achievable (ALARA) and not exceed the dose limits specified in DOE Order 5400.5 (DOE 1990b) and 40 CFR 61. Each DOE contractor typically applies working limits and controls to its effluent streams to provide an adequate margin below any applicable dose limits, and aid in operational control. While operating facilities at some sites may have had unplanned releases in addition to their routine discharges, none of these nonroutine releases resulted in radiation doses exceeding DOE or other regulatory limits.

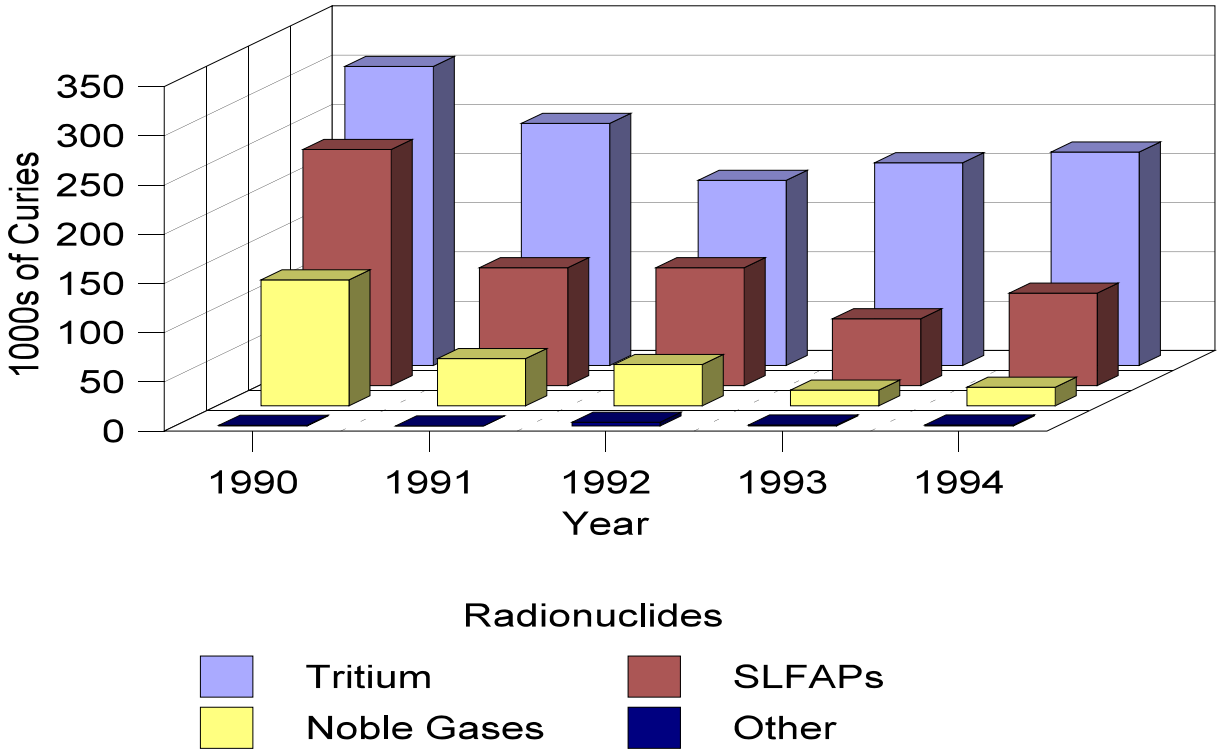
Releases from DOE sites are reported in terms of the number of curies of each radionuclide discharged; this provides a common basis for discussion. Care should be exercised, however, in attempting to correlate the quantities of radionuclides released with estimates of radiation doses. Releases may comprise several different radionuclides, each with distinct properties (such as half-life, mode of decay, chemical characteristics, radiological toxicity, and physical form). Dispersion mechanisms and exposure pathways also vary widely among the sites. Each of these properties influences the dose a particular radionuclide might deliver. It is not uncommon for the radionuclide discharged in the greatest quantity to be responsible for only a small portion of the calculated radiation dose. For example, Krypton-85 (^{85}Kr) can account for a significant percentage of the total quantity of radioactive materials discharged to the environment by a DOE site, yet contribute a very small percentage of the total population dose. This small contribution to dose occurs because ^{85}Kr is a noble gas, which does not concentrate in the body, and emits mostly beta particles, which contribute only slightly to the effective dose.

3.1 TOTAL RELEASES

Tables 3.1 and 3.3 list the quantities of specific radionuclides or classes of radionuclides released to the air and water, respectively, from DOE radiological/nuclear sites during 1990 through 1994. Tables 3.2 and 3.4 show total releases by category for all of the sites for those same years for atmospheric and liquid effluents. The categories shown encompass more than 90 different radionuclides. The magnitude of the releases varied from site to site, reflecting the diversity of radiological and nuclear operations. For example, at Pantex, which is a weapons assembly and disassembly plant, the releases are small and primarily tritium and small quantities of uranium. By comparison, the operations at the Savannah River Site range from the production of special nuclear materials to chemical separations; consequently, the emissions are larger and more diverse.

Figure 3.1 shows the annual amount of tritium, short-lived fission and activation products (SLFAPs), noble gases, and all other radionuclides (e.g., uranium, plutonium, and other actinides) released from DOE nuclear and radiological sites during 1990 through 1994. These totals include both liquid and atmospheric releases.

Figure 3.1. 1990-1994 Total Effluent Releases



During 1990, 1991, 1992, 1993, and 1994 approximately 6.7E+05 Ci, 4.1E+05 Ci, 3.5E+05 Ci, 3.0E+05 Ci, and 3.4E+05 Ci, respectively, of radionuclides were discharged to the air and water from DOE sites. As in the past, the atmospheric releases consisted principally of tritium, noble gases, and short-lived fission and activation products (see Table 3.2), while liquid releases were principally tritium and much smaller amounts of various fission and activation products (see Table 3.4). By far, tritium was the dominant radionuclide released by DOE sites during 1990 through 1994. For each year 1990 through 1994, the largest atmospheric releases of tritium occurred at the Savannah River Site (see Table 3.1). The highest liquid effluent releases of tritium occurred at the Savannah River site during 1990 through 1993 and at Los Alamos National Laboratory in 1994 (see Table 3.3). Tritium is produced by ternary (three-way) fission of uranium and plutonium. It is also produced by neutron reactions with lithium-6 and boron-10. Tritium (hydrogen) can readily diffuse through metals and other materials and exchange with normal hydrogen atoms in water to form tritiated water (HTO or T_2O) which is almost indistinguishable from regular water. Because of its diffusivity and reaction with water, tritium is extremely difficult to remove and contain which accounts in part for the magnitude of the releases from DOE sites.

Although tritium is one of the most abundant radionuclides released from DOE facilities, very little tritium is absorbed by the body from airborne releases of tritiated hydrogen (HT or T_2) as these compounds are not metabolized by the body. Airborne or liquid tritiated water are assimilated into the body if they are breathed or the body is immersed in them (they can

penetrate the skin). However, most of the tritium ingested as water is rapidly excreted from the body. Because most of the tritiated water is rapidly excreted and tritium only deposits a small amount of energy when it decays, it is among the least hazardous of any radionuclide. Consequently, although relatively large amounts of tritium are released compared to other radionuclides, the potential hazard to the public is very small.

As described in Chapter 2 of this summary report, in no instance did releases of atmospheric and liquid radionuclides from DOE sites to the environment result in doses to the public exceeding the limits established by DOE Order 5400.5 (100 mrem/yr all pathways - all sources).

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[a]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Albuquerque Operations Office												
Grand Junction Project Office												
1990			1.4E+02					1.1E-03		2.8E-03	8.2E-04	1.4E+02
1991			7.7E+01				3.6E-11	5.0E-07	1.4E-12	3.3E-07	4.7E-11	7.7E+01
1992												0.0E+00
1993	3.0E-10						2.1E-10	6.1E-07	1.6E-11	3.7E-07	1.4E-07	1.1E-06
1994	3.0E-10		1.2E+00				2.8E-01	4.7E-07	1.6E-11	1.7E-07	6.2E-07	1.5E+00
Monticello Mill Tailings Site												
1990												0.0E+00
1991			1.6E+03									1.6E+03
1992			1.6E+03									1.6E+03
1993			1.6E+03									1.6E+03
1994			1.6E+03									1.6E+03
Inhalation Toxicology Research Institute												
1990	1.8E-01											1.8E-01
1991			1.9E-01									1.9E-01
1992			1.9E-01									1.9E-01
1993			6.9E-02									6.9E-02
1994												0.0E+00
Los Alamos National Laboratory												
1990	6.4E+03		7.9E+02	1.2E+05	1.1E+01			2.4E-04	2.6E-05			1.3E+05
1991	4.7E+03		4.6E+02	5.7E+04	2.0E-01			3.4E-04	3.7E-05			6.2E+04
1992	1.3E+03	(b)	4.6E+02	5.7E+04	2.1E-01	(b)	(b)	2.4E-04	1.2E-05	5.6E-05	(b)	5.9E+04
1993	1.4E+03	(b)	(b)	3.3E+04	1.4E-03	(b)	(b)	2.7E-04	6.0E-06	(b)	(b)	3.4E+04
1994	1.1E+03	(b)	4.3E+02	4.6E+04	(b)	(b)	(b)	8.2E-03	1.2E-05	(b)	(b)	4.8E+04
Pantex Plant												
1990	2.6E+03											2.6E+03
1991	1.7E-01											1.7E-01
1992	1.3E-01							3.5E-07				1.3E-01
1993	3.1E-01											3.1E-01
1994	4.5E-01											4.5E-01

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[a]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Pinellas Plant												
1990	1.2E+02	1.0E+01										1.3E+02
1991	1.1E+02	4.0E+00										1.1E+02
1992	1.1E+02	4.0E+00										1.1E+02
1993	1.2E+01	1.9E+01										3.1E+01
1994	2.5E+01	1.3E+01										3.8E+01
Sandia National Laboratories Albuquerque												
1990	2.0E-02	4.0E-01	5.3E+00	3.1E-01	(b)	1.0E-05	(b)	(b)	(b)	(b)	(b)	6.0E+00
1991	2.0E-02	5.0E-01	3.6E+00	2.4E+00	1.0E-05	(b)	(b)	(b)	(b)	(b)	(b)	6.5E+00
1992	6.0E-02	1.6E+00	3.6E+00	2.3E+00	1.0E-05	1.8E-01	(b)	(b)	(b)	(b)	(b)	7.7E+00
1993	1.9E+00	7.4E-02	3.8E+00	6.3E-01	(b)	(b)	(b)	4.0E-12	6.0E-12	8.0E-11	(b)	6.4E+00
1994	2.9E-01	5.0E-02	3.0E+00	2.4E+00	(b)	(b)	(b)	(b)	(b)	1.0E-11	2.0E+00	7.7E+00
Sandia National Laboratories Livermore												
1990	3.0E+02											3.0E+02
1991	4.7E+02											4.7E+02
1992	2.6E+02											2.6E+02
1993	1.9E+02											1.9E+02
1994	9.5E+01											9.5E+01
Sandia National Laboratories Tonopah												
1990												0.0E+00
1991												0.0E+00
1992												0.0E+00
1993									2.5E-01			2.5E-01
1994									3.2E-01			3.2E-01
Chicago Operations Office												
Ames Laboratory												
1990								2.0E-07	3.0E-07			5.0E-07
1991								5.0E-10				5.0E-10
1992												0.0E+00
1993												0.0E+00
1994												0.0E+00

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[a]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Argonne National Laboratory												
1990	2.0E+01	5.2E+00	2.6E+03	9.4E+01	1.4E-04			8.4E-06	2.0E-03	3.1E-05	(b)	2.7E+03
1991	4.6E+01	6.8E+00	3.0E+03	9.0E+01	8.0E-05			1.2E-07	1.9E-04			3.1E+03
1992	1.1E+01	4.6E+00	3.0E+03	2.0E+02	(b)			8.2E-09	3.4E-05	3.5E-05	9E+03(c)	3.2E+03
1993	3.5E+01	1.3E+01	2.0E+03	3.2E+02	1.2E-05			2.2E-08	2.6E-05			2.4E+03
1994	1.1E+02	2.1E+01	1.8E+03	3.5E+02				3.2E-08	8.0E-08		(b)	2.3E+03
MIT Bates Linear Accelerator												
1990	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	1.6E+02	1.6E+02
1991				1.6E+02								1.6E+02
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993	(b)	(b)	(b)	(b)	(b)		(b)			(b)	(b)	0.0E+00
1994	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
Brookhaven National Laboratory												
1990	3.2E+01		1.0E+03	7.0E+02	1.7E-01	2.0E-03						1.7E+03
1991	1.2E+02		1.8E+03	9.4E+02	1.4E-02	1.1E-04	1.5E-05					2.9E+03
1992	7.0E+01	(b)	1.8E+03	9.4E+02	9.5E-03	1.3E-04	(b)	(b)	(b)	(b)	(b)	2.8E+03
1993	6.8E+01		2.1E+03	4.1E+02	6.6E-04							2.6E+03
1994	8.1E+01	(b)	2.0E+03	3.9E+02	9.6E-03	3.5E-03	(b)	(b)	(b)	(b)	(b)	2.5E+03
Fermi National Accelerator Laboratory												
1990(d)	1.8E-03			7.8E+01								7.8E+01
1991				1.1E+02								1.1E+02
1992			4.1E+01	6.6E+01								1.1E+02
1993			5.7E-01	2.1E-01								7.8E-01
1994	1.6E-03		1.2E+00	3.3E+01								3.4E+01
Princeton Plasma Physics Laboratory												
1990	1.1E+00		1.9E+00									3.0E+00
1991	7.5E-02		1.3E-01									2.1E-01
1992	9.7E-01		1.6E-01									1.1E+00
1993	3.0E+01		1.8E+00	1.2E+01								4.4E+01
1994	1.4E+02		1.4E+01	1.3E+01								1.7E+02

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[(a)]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Golden Field Office												
National Renewable Energy Laboratory												
1990	Due to extremely small quantity of radioactive material stored and used at NREL, no radiological emissions monitoring is required or performed											
1991												
1992												
1993												
1994												
Idaho Operations Office												
Idaho National Engineering Laboratory												
1990	4.0E+00	<2.0E+04	4.5E+03	2.0E+00	3.5E-01	8.9E-03	5.7E-06	(b)	2.7E-08	(b)	1.2E-01	4.5E+03
1991	4.4E+01	<1.0E+04	3.8E+03	3.0E+00	1.6E-01	6.7E-02	2.8E-03	(b)	2.9E-09	(b)	1.1E-02	3.8E+03
1992	1.5E+00	<2.0E+04	3.8E+03	1.1E+02	1.6E-01	1.3E-02	2.4E-04	(b)	4.9E-06	(b)	3.0E-03	3.9E+03
1993	1.0E+02	2.7E+02	2.3E+03	3.1E+01	2.1E-02	1.0E-01	1.1E-03	(b)	2.5E-09	(b)	2.1E-03	2.7E+03
1994	3.3E+01	3.4E+02	1.9E+03	1.5E+01	8.4E-01	1.6E-02	4.5E-03	(b)	5.7E-07	(b)	2.5E+00	2.3E+03
Nevada Operations Office												
Nevada Test Site												
1990	2.8E+01	4.4E+00	3.4E+01		1.3E-03	1.5E-03						6.6E+01
1991	6.8E-01	6.6E-03	1.3E+01		2.1E-04	1.3E-04						1.4E+01
1992	1.0E+00	2.8E+02	2.9E+00	(b)	(b)	1.9E-05	(b)	(b)	2.5E-03	(b)	(b)	2.8E+02
1993	4.0E+00	1.6E+02	(b)	(b)	(b)	(b)	(b)	(b)	1.8E-03	(b)	(b)	1.6E+02
1994	6.3E-01	2.0E+02	1.2E-01	(b)	1.2E-01	(b)	(b)	(b)	2.8E-01	(b)	(b)	2.0E+02
Oakland Operations Office												
Lawrence Berkeley Laboratory												
1990	1.6E+02	(b)	(b)	(b)	4.3E-03	8.0E-04				1.0E-06		1.6E+02
1991	8.4E+01	(b)	1.2E-01	2.3E+01	1.2E-02	3.0E-04						1.1E+02
1992	8.7E+01	(b)	1.0E-01	1.7E+01	2.2E-03	3.0E-04	(b)	(b)	(b)	(b)		1.0E+02
1993	1.0E+02	(b)	1.0E-01	8.7E+00	4.0E-04	3.5E-05	9.3E-06	5.1E-08	(b)	(b)		1.1E+02
1994	1.2E+02	(b)	8.0E-02	7.4E+00	1.3E-03	1.0E-04	4.0E-05	2.4E-07	(b)	(b)		1.3E+02
Laboratory for Energy-Related Health Research												
1990												0.0E+00
1991												0.0E+00
1992												0.0E+00

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[(a)]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
1993	6.7E-04						3.3E-04		5.4E-11			1.0E-03
1994												0.0E+00
Lawrence Livermore National Laboratory												
1990	1.3E+03			4.8E+01								1.3E+03
1991	1.1E+03			1.2E+01								1.1E+03
1992	1.8E+02			0.0E+00								1.8E+02
1993	2.4E+02			7.0E+00						1.6E+01		2.6E+02
1994	1.4E+02			7.0E+00				8.4E-02				1.5E+02
Lawrence Livermore National Laboratory - Site 300												
1990				8.0E-02								8.0E-02
1991	3.0E-03			1.2E-01								1.2E-01
1992				5.6E-02								5.6E-02
1993	1.2E+00			4.0E-02								1.2E+00
1994	1.1E+00			8.4E-02								1.2E+00
Rockwell International - DeSoto Site												
1990					3.4E-08			3.4E-08	1.9E-11	3.1E-11		6.8E-08
1991					1.3E-07			4.0E-07	1.0E-09	4.7E-11		5.3E-07
1992												0.0E+00
1993												0.0E+00
1994(e)							2.5E-07	7.0E-09	5.0E-09	3.0E-09	3.8E-06	4.1E-06
Rockwell International - Santa Susana Site												
1990					5.3E-06		1.1E-07	6.9E-10	3.3E-09	1.1E-16		5.4E-06
1991					3.8E-05		1.0E-06	9.3E-08	1.3E-07	5.2E-09		3.9E-05
1992												0.0E+00
1993												0.0E+00
1994					1.5E-07			2.6E-08				1.8E-07
Stanford Linear Accelerator Center												
1990				2.7E+00								2.7E+00
1991			2.7E-01	2.8E+01								2.8E+01
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993												0.0E+00
1994	(b)	(b)	1.4E-01	8.0E-02	(b)	(b)	(b)	(b)	(b)	(b)	(b)	2.2E-01

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[a]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Oak Ridge Operations Office												
Continuous Electron Beam Accelerator Facility												
1990	The site did not begin operation or produce a Site Environmental Report until 1992											
1991												
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1994	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
Oak Ridge Reservation												
1990	1.2E+04	1.5E+04	7.5E+04	1.4E-06	1.5E-01	6.1E-02	1.1E-04	8.2E-02	1.1E-06	6.8E-03		1.0E+05
1991	1.6E+04	5.5E+03	3.1E+03		4.3E+00	1.4E-01	3.4E-05	8.6E-02	8.9E-05	2.2E-01		2.5E+04
1992	2.1E+03	1.7E+02	3.4E+03	6.5E-04	4.0E-01	3.4E+00	1.1E-05	6.4E-02	7.4E-04	2.0E+00		5.7E+03
1993	8.0E+01	(b)	1.8E+03	(b)	(b)	1.6E+00	4.3E-05	5.5E-02	9.8E-06	(b)		1.9E+03
1994	2.2E+02	1.2E+03	3.0E+03	(b)	1.3E+03	9.3E-01	9.0E-05	5.6E-02	2.6E-05	1.6E-01		5.7E+03
Paducah Gaseous Diffusion Plant												
1990					3.9E-04			3.4E-05				4.2E-04
1991					3.1E-03			6.6E-06	3.0E-06	4.4E-06		3.1E-03
1992								2.1E-03		2.1E-04	2.0E-04	2.5E-03
1993								1.2E-03	2.6E-06	6.1E-06	3.3E-03	4.5E-03
1994(g)												0.0E+00
Portsmouth Gaseous Diffusion Plant												
1990					5.4E-02			4.2E-02				9.6E-02
1991					4.6E-02			1.5E-02				6.1E-02
1992					4.4E-02			1.4E-01		2.0E-03		1.9E-01
1993					7.8E+00			6.2E-02		(b)		7.9E+00
1994					1.2E-01			3.3E-02		(b)		1.5E-01
Ohio Field Office												
Fernald Environmental Management Project												
1990	(b)	(b)	(b)	1.0E-05	1.6E-04	(b)	3.4E-06	2.0E-03	9.0E-06	6.0E-03	(b)	8.2E-03
1991	(b)	(b)	(b)	2.1E-06	8.1E-05	(b)	6.7E-07	1.7E-04	1.8E-06	9.9E-04	(b)	1.2E-03
1992	(b)	(b)	(b)	2.1E-06	5.8E-05	(b)	6.7E-07	1.5E-04	1.4E-06	1.0E-03	(b)	1.2E-03
1993					1.5E-06			1.2E-04		3.2E-04		4.4E-04
1994	(b)	(b)	(b)	(b)	1.5E-06	(b)	(b)	8.7E-04	(b)	1.1E-03		2.0E-03

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[(a)]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Battelle Columbus Laboratories												
1990	(b)	(b)	(b)	(b)	1.4E-05	(b)	2.1E-07	1.1E-05	1.0E-08	1.3E-06	(b)	2.7E-05
1991	(b)	(b)	(b)	(b)	1.5E-05	(b)	1.3E-07	4.7E-06	5.0E-08	1.8E-06	(b)	2.2E-05
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993	(b)	(b)	(b)	(b)	(b)	(b)	2.0E-08	2.5E-04	3.0E-08	(b)	(b)	2.5E-04
1994	(b)	(b)	(b)	(b)	2.4E-06	(b)	6.4E-07	1.6E-05	1.6E-08	1.2E-06	(b)	2.0E-05
RMI Company Extrusion Plant												
1990								<1.4E-06				1.4E-06
1991								<3.2E-05				3.2E-05
1992								9.9E-07				9.9E-07
1993								<2.5E-05				2.5E-05
1994								<2.0E-05				2.0E-05
Mound												
1990	1.8E+02	(b)	(b)	(b)	(b)	(b)	(b)	1.2E-07	1.8E-05	(b)	(b)	1.8E+02
1991	1.2E+03	(b)	(b)	(b)	(b)	(b)	(b)	5.1E-08	1.5E-05	(b)	(b)	1.2E+03
1992	8.3E+02	(b)	(b)	(b)	(b)	(b)	(b)	3.5E-08	5.6E-06	(b)	(b)	8.3E+02
1993	6.6E+02	(b)	1.1E+00	(b)	(b)	(b)	(b)	1.2E-07	1.2E-05	(b)	(b)	6.6E+02
1994	4.9E+02	(b)	2.5E+00	(b)	(b)	(b)	(b)	1.6E-08	1.5E-05	(b)	(b)	4.9E+02
West Valley Demonstration Project												
1990	1.6E-01				6.0E-05	5.7E-05	6.2E-05	1.4E-07	1.3E-06	1.6E-06		1.6E-01
1991	1.1E-01				2.3E-05	5.1E-05	1.3E-05	1.6E-07	3.0E-07	5.4E-07		1.1E-01
1992	5.5E-02				1.8E-05	6.6E-06	4.7E-06	1.1E-07	1.1E-07	1.5E-07		5.5E-02
1993	3.1E-02				1.3E-05	1.9E-05	5.1E-06	1.3E-07	2.7E-07	3.2E-07		3.1E-02
1994	3.2E-02				2.1E-05	3.4E-05	1.0E-05	6.8E-08	4.1E-07	4.7E-07		3.2E-02
Richland Operations Office												
Hanford Site												
1990	3.2E+01	(b)	4.1E+02	3.3E-01	5.7E-01	1.1E-01	5.9E-03	4.6E-08	1.5E-03	8.1E-05	(b)	4.4E+02
1991	8.5E+01	(b)	6.0E+01	(b)	8.7E-02	4.8E-02	2.9E-03	3.0E-06	2.6E-03	4.5E-04	(b)	1.5E+02
1992	4.5E+01	(b)	6.0E+01	(b)	2.8E-03	3.0E-02	6.6E-04	9.7E-07	3.9E-03	3.2E-03	(b)	1.1E+02
1993	2.3E+01	(b)	9.9E+01	(b)	2.0E-03	4.8E-03	3.7E-04	1.2E-08	4.0E-03	1.3E-04	(b)	1.2E+02
1994	1.2E+01	4.1E+00	1.6E+02	(b)	7.1E-04	1.4E-02	2.0E-04	7.1E-07	2.6E-03	8.5E-05	(b)	1.8E+02

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[a]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Rocky Flats Field Office												
Rocky Flats Plant												
1990	3.9E-03	(b)	(b)	(b)	(b)	(b)	(b)	6.1E-07	1.1E-06	4.0E-07	(b)	3.9E-03
1991	4.8E-03	(b)	(b)	(b)	(b)	(b)	(b)	1.6E-06	8.7E-07	1.5E-07	(b)	4.8E-03
1992	8.7E-02	(b)	(b)	(b)	(b)	(b)	(b)	6.4E-07	4.0E-07	1.5E-07	(b)	8.7E-02
1993	3.7E-03	(b)	(b)	(b)	(b)	(b)	(b)	1.6E-06	1.6E-07	1.6E-07	(b)	3.7E-03
1994	3.3E-03	(b)	(b)	(b)	(b)	(b)	(b)	2.6E-06	2.1E-07	1.1E-07	(b)	3.3E-03
Savannah River Site												
Savannah River Site												
1990	2.5E+05	3.0E+03	(b)	1.2E-03	6.7E-01	1.5E-02	8.0E-03	5.2E-03	3.3E-03	1.5E-04	(b)	2.5E+05
1991	2.0E+05	1.0E+04	(b)	(b)	6.2E-01	1.0E-02	4.0E-03	2.7E-03	7.4E-04	1.9E-04	(b)	2.1E+05
1992	1.6E+05	5.0E+01	(b)	1.0E-02	6.2E-01	1.4E-01	2.0E-03	1.6E-03	1.2E-03	1.4E-04	(b)	1.6E+05
1993	1.9E+05	(b)	3.2E-02	(b)	1.8E-02	7.0E-03	2.3E-03	1.9E-03	2.3E-03	2.0E-04	(b)	1.9E+05
1994	1.6E+05	(b)	2.2E-02	(b)	1.6E-04	3.0E-01	2.1E-03	2.2E-03	2.4E-03	7.2E-05	3.7E-02	1.6E+05
Remedial Action Sites												
Colonie Interim Storage Site												
1990								9.5E-08				9.5E-08
1991								1.9E-07		3.1E-07		5.0E-07
1992								(b)		(f)	(f)	0.0E+00
1993	No Site Environmental Report prepared for 1993 or 1994											
1994												
Hazelwood Interim Storage Site												
1990					4.8E-06			1.3E-05		1.1E-04		1.3E-04
1991					1.9E-07			6.6E-07		6.0E-07		1.5E-06
1992					(b)			(b)		(b)		0.0E+00
1993	No Site Environmental Report prepared for 1993 or 1994											
1994												

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[(a)]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Maywood Interim Storage Site												
1990					8.2E-07			4.4E-06		4.1E-06		9.3E-06
1991					6.0E-07			2.5E-06		2.6E-06		5.7E-06
1992					(b)			(b)		(b)		0.0E+00
1993												
1994	No Site Environmental Report prepared for 1993 or 1994											
Middlesex Sampling Plant												
1990					1.6E-06			3.6E-06		4.0E-08		5.2E-06
1991												0.0E+00
1992					(b)			(b)		(b)		0.0E+00
1993					(b)			(b)		(b)		0.0E+00
1994	No Site Environmental Report prepared for 1994											
New Brunswick Site												
1990	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1991					2.0E-08			2.5E-07				2.7E-07
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993												
1994	No Site Environmental Report prepared for 1993 or 1994											
Niagara Falls Storage Site												
1990					3.4E-04			1.1E-05				3.5E-04
1991					3.7E-06			1.0E-07				3.8E-06
1992					(b)			(b)		(b)	(b)	0.0E+00
1993												
1994	No Site Environmental Report prepared for 1993 or 1994											
Wayne Interim Storage Site												
1990					1.7E-08			1.3E-08		1.5E-07		1.8E-07
1991					4.7E-09			3.5E-08		4.0E-08		8.0E-08
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993												
1994	No Site Environmental Report prepared for 1993 or 1994											

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[(a)]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Weldon Spring Site												
1990			1.6E+01		2.1E-06			5.9E-06		2.8E-06		1.6E+01
1991			1.4E+01									1.4E+01
1992												0.0E+00
1993								1.1E-03				1.1E-03
1994			1.2E+02					3.7E-04				1.2E+02
Naval Reactors												
Bettis Atomic Power Laboratory												
1990		1.5E-01	9.0E+02		5.7E-06	4.2E-06		(b)	(b)		5.3E-06	9.0E+02
1991		1.7E-01	8.7E+02		6.9E-06	4.2E-06		5.7E-09	2.9E-09		6.5E-06	8.7E+02
1992		3.5E-01	(b)		4.4E-06	4.2E-06		1.6E-08	4.3E-09		4.2E-06	3.5E-01
1993			(b)		3.6E-06	2.9E-06		1.2E-08	9.6E-09		5.0E-06	1.2E-05
1994			(b)		3.2E-06	2.6E-06		2.1E-08	2.1E-09		4.0E-06	9.8E-06
Knolls Atomic Power Laboratory - Knolls												
1990		4.0E-01	1.0E-01		1.0E-04	1.0E-04		1.0E-05	1.0E-06			5.0E-01
1991		7.0E-01	1.0E-01		1.0E-04	1.0E-04		1.0E-05	1.0E-06			8.0E-01
1992		1.0E+00	1.0E-01		1.0E-04	1.0E-04		1.0E-05	1.0E-06			1.1E+00
1993		7.3E-01	1.0E-01		1.0E-04	1.0E-04		1.0E-05	1.0E-06			8.3E-01
1994		5.0E-01			1.0E-04	1.0E-04		1.0E-05	1.0E-06			5.0E-01
Knolls Atomic Power Laboratory - Kesselring												
1990	1.0E-01	1.0E-03	4.1E+00		1.4E+00							5.6E+00
1991	1.0E-01	1.0E-03	1.9E+00		8.0E-01							2.8E+00
1992	1.0E-01	1.0E-03	1.4E+00		4.0E-01							1.9E+00
1993	1.4E-01	1.0E-03	1.4E+00		4.6E-01							2.0E+00
1994	2.0E-01	1.0E-03	1.0E+00		1.0E+00							2.2E+00
Knolls Atomic Power Laboratory - Windsor												
1990	2.0E-02	1.0E-03	1.0E-01		6.1E-02							1.8E-01
1991	2.0E-02	1.0E-03	1.0E-01		6.1E-02							1.8E-01
1992	2.0E-02	1.0E-03	2.0E-01		6.1E-02							2.8E-01
1993	5.0E-03	1.0E-03	1.0E-01		1.3E-02							1.2E-01
1994	9.0E-03				1.0E-03							1.0E-02

Table 3.1. Atmospheric Releases of Radioactive Material (in Curies)[a]

Year	Tritium	85Kr	Noble Gases (T1/2 <40 days)	Short-Lived Fission and Activation Products (T1/2 <3 hr)	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
Naval Reactor Facility												
1990	5.0E-02	4.0E-04	3.0E+00		4.0E-04	6.0E-05					2.0E-01	3.3E+00
1991	9.0E-02	3.0E-01	3.0E-01		6.0E-05	6.0E-06					1.0E-01	7.9E-01
1992	1.0E-01		3.0E-01		6.0E-05	5.0E-06					2.0E-01	6.0E-01
1993	6.6E-02		3.2E-01		6.7E-05	4.6E-06					9.1E-01	1.3E+00
1994	6.7E-02	7.9E-01	2.4E-01		1.2E-05	5.1E-06					5.0E-01	1.6E+00

(a) 1 Bq = 2.7 x 10^{-11} Ci.

(b) Data not specified in SER.

(c) Release of radon-220, not included as noble gas.

(d) Short-lived fission and activation products are radionuclides from Antiprotein sources. Total also includes 41 Ar.

(e) 1994 data did not differentiate between RI-1 and RI-2. Only one set of data for “RI” was given.

(f) Only small amounts of radium-226 and thorium-232 were present. Therefore, no monitoring was conducted.

(g) All air sources of radionuclides in 1994 were under the jurisdiction of USEC (not reported in SER).

Gray shading = no significant release of radionuclides in this category

Table 3.2. 1990-1994 Summary of Atmospheric Releases of Radioactive Material from DOE Radiological and Nuclear Sites (in curies)

Year	Tritium	^{85}Kr	Noble Gases ($T_{1/2}$ <40 days)	Short-Lived Fission and Activation Products ($T_{1/2}$ <3 hr)	Fission and Activation Products ($T_{1/2}$ >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Plutonium	Other Actinides	Other	Annual Site Totals
1990	2.8E+05	3.8E+04	9.0E+04	2.4E+05	2.6E+01	2.0E-01	1.4E-02	1.3E-01	8.9E-03	1.9E-02	3.2E+02	6.5E+05
1991	2.3E+05	2.6E+04	2.2E+04	1.2E+05	6.5E+00	2.7E-01	9.8E-03	1.0E-01	3.9E-03	2.2E-01	1.1E-01	3.9E+05
1992	1.7E+05	2.1E+04	2.1E+04	1.2E+05	2.1E+00	3.9E+00	2.9E-03	2.1E-01	8.4E-03	2.0E+00	3.8E+03	3.3E+05
1993	1.9E+05	4.9E+02	1.6E+04	6.8E+04	8.3E+00	1.7E+00	4.2E-03	1.8E-01	5.1E-01	1.6E+01	9.2E-01	2.8E+05
1994	1.6E+05	1.8E+03	1.7E+04	9.4E+04	1.3E+03	1.3E+00	5.7E-01	2.1E-01	9.3E-01	1.6E-01	7.0E+00	2.8E+05

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Albuquerque Operations Office								
Grand Junction Project Office								
1990	(b)	(b)			(b)	(b)	(b)	0.0E+00
1991(c)								0.0E+00
1992								0.0E+00
1993 (d)								0.0E+00
1994 (d)								0.0E+00
Monticello Mill Tailings Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00
Inhalation Toxicology Research Institute								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994		5.9E-13				6.5E-14	2.7E-13	9.3E-13
Los Alamos National Laboratory								
1990	1.2E+01	5.9E-01		2.5E-01	7.0E-05	8.0E-05	2.7E-03	1.3E+01
1991	1.1E+01	1.2E-01		1.2E-01	7.0E-05	1.3E-03	1.1E-03	1.1E+01
1992	1.1E+01	5.0E-04		1.7E-02	5.0E-05	7.0E-04	3.0E-01	1.1E+01
1993	2.8E+00	8.2E-03		7.6E-02	1.2E-04	1.1E-03	1.1E-02	2.9E+00
1994	2.2E+04	8.5E+00		3.7E+01	1.2E-01	3.3E+00	3.1E+00	2.2E+04
Pantex Plant								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Pinellas Plant								
1990	5.6E-01							5.6E-01
1991	6.7E-01							6.7E-01
1992	7.0E-01							7.0E-01
1993	4.3E-01							4.3E-01
1994	2.8E-01							2.8E-01
Sandia National Laboratories - Albuquerque								
1990	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1991	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1994	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
Sandia National Laboratories - Livermore								
1990	2.0E-01							2.0E-01
1991	2.1E-01							2.1E-01
1992	6.1E-02							6.1E-02
1993	6.8E-02							6.8E-02
1994	5.9E-02							5.9E-02
Sandia National Laboratories - Tonopah								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00
Chicago Operations Office								
Ames Laboratory								
1990								0.0E+00
1991								0.0E+00
1992	1.4E-04	3.2E-06					3.0E-07	1.4E-04
1993								0.0E+00
1994								0.0E+00

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Argonne National Laboratory								
1990	3.5E-01	3.0E-03		1.4E-03		2.0E-04	1.4E-04	3.5E-01
1991	1.4E+00	3.0E-03		8.0E-04		4.8E-05	4.5E-05	1.4E+00
1992	2.5E+00	(b)	(b)	8.0E-04	(b)	9.3E-06	2.8E-05	2.5E+00
1993	1.9E+01	5.9E-01	(b)	8.2E-02	(b)	1.2E-03	1.0E-03	2.0E+01
1994	1.1E+00	8.3E-03	(b)	3.3E-03	(b)	1.3E-05	2.4E-05	1.1E+00
MIT Bates Linear Accelerator								
1990	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1991	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1994	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
Brookhaven National Laboratory								
1990	1.4E+00	1.0E-02	1.2E-03	1.1E-04	(b)	(b)	(b)	1.4E+00
1991	2.1E+00	6.8E-03	(b)	6.3E-05	(b)	(b)	(b)	2.1E+00
1992	3.0E+00	2.4E-04	(b)	(b)	(b)	(b)	(b)	3.0E+00
1993	3.2E+00	1.7E-03						3.2E+00
1994	1.6E+00	1.4E-03	2.7E-05	(b)	(b)	(b)	(b)	1.6E+00
Fermi National Accelerator Laboratory								
1990	2.0E+00							2.0E+00
1991	3.6E+00							3.6E+00
1992	2.0E-01	2.7E-04						2.0E-01
1993	5.8E-01							5.8E-01
1994	9.8E-02	2.7E-04						9.8E-02
Princeton Plasma Physics Laboratory								
1990	4.9E-04							4.9E-04
1991	4.9E-04							4.9E-04
1992	1.6E-02							1.6E-02
1993	5.2E-03							5.2E-03
1994	2.9E-01							2.9E-01

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Golden Field Office								
National Renewable Energy Laboratory								
1990	Due to the extremely small quantity of radioactive material stored and used at NREL, no radiological emissions monitoring is required or performed.							
1991								
1992								
1993								
1994								
Idaho Operations Office								
Idaho National Engineering Laboratory								
1990	1.8E+02	3.7E+00	(b)	3.3E-02	(b)	4.8E-04	1.1E+00	1.8E+02
1991	1.7E+02	2.6E+00	1.3E-02	1.2E-02	(b)	3.7E-04	4.3E-01	1.7E+02
1992	1.8E+02	3.6E+00	1.2E-02	2.3E-02	(b)	8.5E-05	9.4E-01	1.8E+02
1993	1.2E+02	4.3E+00	(b)	2.2E-01	(b)	4.8E-05	1.6E+00	1.3E+02
1994	4.7E+01	2.6E+00	(b)	7.6E-01	(b)	(b)	3.7E-01	5.1E+01
Nevada Operations Office								
Nevada Test Site								
1990	6.7E+02	1.2E-02	5.8E-04	8.0E-02		2.7E-04		6.7E+02
1991	1.8E+03	1.3E-02		5.6E-04		3.0E-04		1.8E+03
1992	2.2E+03	3.2E-02	(b)	6.4E-04		3.0E-04	(b)	2.2E+03
1993	7.1E+02	(b)	(b)	2.0E-04		1.8E-04	7.8E-04	7.1E+02
1994	4.7E+01	1.7E-03	(b)	8.6E-05		1.8E-04	(b)	4.7E+01
Oakland Operations Office								
Lawrence Berkeley Laboratory								
1990	2.9E-01	7.0E-03	1.1E-02					3.1E-01
1991	(b)	3.0E-01						3.0E-01
1992	(b)	1.2E-01	(b)	(b)	(b)	(b)	(b)	1.2E-01
1993	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1994	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
Laboratory for Energy-Related Health Research								
1990								0.0E+00
1991								0.0E+00
1992	1.2E-03			3.8E-04		4.0E-07		1.6E-03
1993	6.7E-04	(b)	(b)	2.8E-04	(b)	(b)	(b)	9.5E-04

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
1994	(b)			(b)				0.0E+00
Lawrence Livermore National Laboratory								
1990	4.8E-01	4.8E-05				6.3E-06		4.8E-01
1991	6.9E-01	1.3E-04				1.6E-05		6.9E-01
1992	1.5E-01	6.0E-05				5.1E-05		1.5E-01
1993	2.7E-01	3.6E-05				7.0E-06		2.7E-01
1994	1.3E-01	1.3E-05				5.2E-06		1.3E-01
Lawrence Livermore National Laboratory - Site 300								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00
Rockwell International - DeSoto Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00
Rockwell International - Santa Susana Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00
Stanford Linear Accelerator Center								
1990	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1991	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1992	4.1E-02	(b)	(b)	(b)	(b)	(b)	(b)	4.1E-02
1993	2.5E-03	(b)	(b)	(b)	(b)	(b)	(b)	2.5E-03
1994	1.7E-03	(b)	(b)	(b)	(b)	(b)	(b)	1.7E-03

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Oak Ridge Operations Office								
Continuous Electron Beam Accelerator Facility								
1990								
1991	The site did not begin operation or prepare a Site Environmental Report until 1992.							
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1994	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
Oak Ridge Reservation								
1990	6.6E+03	3.3E+00		6.5E+00	2.7E-01	(b)	(b)	6.6E+03
1991	2.5E+03	2.0E+00		3.2E+00	2.4E-01	(b)	(b)	2.5E+03
1992	2.0E+03	3.6E+00		2.2E+00	1.5E-02	1.9E-03	1.3E-01	2.0E+03
1993	1.6E+03	4.0E+00		2.1E+00	1.1E-01	2.7E-04	(b)	1.6E+03
1994	2.5E+03	2.5E-01		2.8E+00	2.4E-01	(b)	1.2E-01	2.5E+03
Paducah Gaseous Diffusion Plant								
1990		8.2E-01			1.3E-01			9.5E-01
1991		8.6E-02			1.7E-01			2.6E-01
1992		(b)			(b)			0.0E+00
1993		(b)			(b)			0.0E+00
1994	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
Portsmouth Gaseous Diffusion Plant								
1990		1.4E+00			3.6E-01		(b)	1.8E+00
1991		5.0E-01			3.5E-01		(b)	8.5E-01
1992		(b)			1.7E-01		2.1E-01	3.8E-01
1993		5.8E+01			1.2E-01		(b)	5.8E+01
1994		1.7E-01			1.1E-01		(b)	2.8E-01
Ohio Field Office								
Fernald Environmental Management Project								
1990	(b)	(b)	(b)	1.4E-04	4.6E-01	(b)	2.6E-01	7.2E-01
1991	(b)	(b)	(b)	(b)	4.0E-01	(b)	2.2E-01	6.2E-01
1992	(b)	(b)	(b)	(b)	2.5E-01	(b)	1.0E-01	3.5E-01
1993					2.7E-01		1.6E-01	4.3E-01
1994	(b)	8.8E-04	(b)	(b)	2.1E-01	(b)	1.2E-01	3.3E-01

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Battelle Columbus Laboratories								
1990	(b)	1.0E-02	1.6E-04	2.5E-05	2.6E-03	6.5E-06	2.0E-04	1.3E-02
1991	(b)	1.8E-03	1.4E-04	2.5E-05	7.0E-03	5.2E-06	4.0E-04	9.4E-03
1992	(b)	3.0E-02	2.3E-04	2.6E-05	4.2E-02	8.3E-06	5.1E-03	7.7E-02
1993	(b)	(b)	1.6E-04	1.9E-05	1.2E-04	1.0E-05	(b)	3.1E-04
1994	(b)	4.4E-04	1.6E-04	1.1E-05	1.1E-03	1.4E-06	1.1E-04	1.8E-03
RMI Company Extrusion Plant								
1990					8.3E-03			8.3E-03
1991					5.0E-04			5.0E-04
1992					3.1E-03			3.1E-03
1993					3.4E-03			3.4E-03
1994					2.9E-03			2.9E-03
Mound								
1990	4.9E+00	(b)	(b)	(b)	4.5E-04	6.7E-04	(b)	4.9E+00
1991	3.2E+00	(b)	(b)	(b)	3.4E-04	4.6E-04	(b)	3.2E+00
1992	3.2E+00	(b)	(b)	(b)	3.5E-04	4.7E-04	(b)	3.2E+00
1993	3.4E+00	(b)	(b)	(b)	3.5E-04	2.5E-04	(b)	3.4E+00
1994	1.1E+01	(b)	(b)	(b)	7.0E-04	2.2E-04	(b)	1.1E+01
West Valley Demonstration Project								
1990	4.4E+00	1.2E-02	3.9E-04	2.5E-03	7.8E-04	6.2E-06	7.7E-06	4.4E+00
1991	1.1E+00	8.4E-03	5.2E-04	3.5E-03	2.8E-04	4.6E-06	8.5E-06	1.1E+00
1992	4.7E-01	9.6E-03	1.8E-04	3.5E-03	6.2E-04	4.2E-06	2.5E-06	4.8E-01
1993	9.9E-01	5.5E-02	2.0E-04	9.2E-03	1.1E-03	1.0E-05	1.2E-03	1.1E+00
1994	1.0E+00	9.7E-02	1.8E-04	9.9E-03	1.1E-03	1.7E-05	4.8E-06	1.1E+00
Richland Operations Office								
Hanford Site								
1990	8.1E+01	2.0E+01	1.3E-03	1.6E+01	2.6E-03	2.1E-01	2.0E-01	1.2E+02
1991	4.1E+01	8.6E-01	(b)	5.8E+01	3.4E-03	5.4E-01	(b)	1.0E+02
1992	3.4E+00	3.6E-01	(b)	3.1E-01	4.6E-03	1.2E-01	4.1E-03	4.2E+00
1993	1.5E+01	2.7E+01	(b)	1.0E-01	5.4E-02	1.3E-01	1.4E-01	4.2E+01
1994	5.9E+00	8.4E-02	(b)	4.4E-01	3.4E-02	3.7E-02	1.1E-01	6.6E+00

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Rocky Flats Field Office								
Rocky Flats Plant								
1990	(b)	(b)	(b)	(b)	2.0E-03	1.3E-06	3.1E-06	2.0E-03
1991	(b)	(b)	(b)	(b)	9.2E-04	1.9E-06	6.4E-06	9.3E-04
1992	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.0E+00
1993	(b)	(b)	(b)	(b)	6.5E-04	1.2E-06	3.0E-06	6.5E-04
1994	(b)	(b)	(b)	(b)	4.1E-04	9.5E-07	1.4E-06	4.1E-04
Savannah River Site								
Savannah River Site								
1990	1.6E+04	1.2E-01	2.2E-02	4.3E-01	1.4E-03	2.3E-02	(b)	1.6E+04
1991	1.1E+04	3.3E-02	2.2E-02	8.9E-02	3.2E-03	2.0E-02	(b)	1.1E+04
1992	1.4E+04	1.3E-01	2.2E-02	7.9E-01	1.9E-03	1.6E-02	(b)	1.4E+04
1993	1.3E+04	2.5E-01	2.2E-02	4.8E-01	1.1E-05	9.6E-03	(b)	1.3E+04
1994	1.0E+04	1.5E-01	7.4E-02	3.9E-01	1.0E-05	1.4E-02	(b)	1.0E+04
Remedial Action Sites								
Colonie Interim Storage Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993	No Site Environmental Report prepared for 1993 or 1994							
1994								
Hazelwood Interim Storage Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993	No Site Environmental Report prepared for 1993 or 1994							
1994								
Maywood Interim Storage Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
1993								
1994	No Site Environmental Report prepared for 1993 or 1994							
Middlesex Sampling Plant								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994	No Site Environmental Report prepared for 1994							
New Brunswick Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								
1994	No Site Environmental Report prepared for 1993 or 1994							
Niagara Falls Storage Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								
1994	No Site Environmental Report prepared for 1993 or 1994							
Wayne Interim Storage Site								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								
1994	No Site Environmental Report prepared for 1993 or 1994							
Weldon Spring Site								
1990					3.7E-02			3.7E-02
1991					6.0E-02			6.0E-02
1992								0.0E+00
1993					1.8E-02			1.8E-02
1994					7.1E-02			7.1E-02

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[a]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
Naval Reactors								
Bettis Atomic Power Laboratory								
1990								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00
Knolls Atomic Power Laboratory - Knolls								
1990		1.0E-03			1.0E-06	1.0E-06		1.0E-03
1991		1.0E-03			1.0E-06	1.0E-06		1.0E-03
1992		1.0E-03			1.0E-06	1.0E-06		1.0E-03
1993		1.0E-03			1.0E-06	1.0E-06		1.0E-03
1994		1.0E-03			1.0E-06	1.0E-06		1.0E-03
Knolls Atomic Power Laboratory - Kesserling								
1990	6.0E-02	1.0E-03						6.1E-02
1991	3.0E-02	1.0E-03						3.1E-02
1992	1.0E-02	1.0E-03						1.1E-02
1993	1.0E-02	1.0E-03						1.1E-02
1994	2.0E-02	1.0E-03						2.1E-02
Knolls Atomic Power Laboratory - Windsor								
1990	3.0E-02	1.0E-03						3.1E-02
1991	2.0E-02	1.0E-03						2.1E-02
1992	2.0E-02	1.0E-03						2.1E-02
1993	2.0E-02	1.0E-03						2.1E-02
1994	2.0E-02	1.0E-03						2.1E-02
Naval Reactor Facility								
1990(e)								0.0E+00
1991								0.0E+00
1992								0.0E+00
1993								0.0E+00
1994								0.0E+00

(a) 1 Bq = 2.7 x 10^{-11} Ci

(b) Data not specified in SER.

Table 3.3. Liquid Effluent Releases of Radioactive Material (in Curies)[(a)]

Year	Tritium	Fission and Activation Products (T1/2 >3 hr)	Total Radio-iodine	Total Radio-strontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
(c) No measured release. Estimated 2.0E-05 total curies released.								
(d) Data not presented because of the numerous isotopes and elements discharged, their small quantities, and because individual isotopes and elements usually were not measured in the effluent.								
(e) A water reuse system was used whereby liquids containing radioactivity were collected, processed and reused rather than intentionally discharged to the environment.								
Gray Shading = no significant release of radionuclides in this category.								

TABLE 3.4. 1990-1994 Summary of Liquid Effluent Releases of Radioactive Material from DOE Radiological and Nuclear Sites (in curies)

Year	Tritium	Fission and Activation Products ($T_{1/2}$ >3 hr)	Total Radioiodine	Total Radiostrontium	Total Uranium	Total Plutonium	Other Actinides	Annual Site Totals
1990	2.4E+04	1.3E+02	1.0E+02	1.3E+02	1.0E+02	1.0E+02	1.0E+02	2.4E+04
1991	1.6E+04	6.7E+00	3.5E-02	6.2E+01	1.2E+00	5.6E-01	6.5E-01	1.6E+04
1992	1.8E+04	7.9E+00	3.4E-02	3.4E+00	4.9E-01	1.4E-01	2.0E+00	1.8E+04
1993	1.6E+04	3.1E+02	2.1E+02	2.2E+02	2.1E+02	2.1E+02	2.1E+02	1.6E+04
1994	5.7E+04	2.0E+01	7.4E-02	7.8E+01	9.1E-01	6.7E+00	6.9E+00	5.7E+04

3.2 NON-ROUTINE RELEASES

Non-routine releases (unplanned radiological releases) can occur as a result of leaks, spills, equipment malfunctions, or accidents involving radiological materials. During 1990 through 1994, non-routine releases at DOE nuclear and radiological sites generally involved small amounts of radiological materials and short duration events. Consequently, non-routine releases accounted for only a small fraction of the radioactivity routinely released from DOE sites during this time frame.

According to the information reported in the ASERs, unplanned radiological releases occurred at one DOE site during 1990 and 1991, four sites during 1992, three sites during 1993, and two sites during 1994. Non-routine releases reported in ASERs are described below.

For 1990:
Savannah River Site

In 1990, the Savannah River Site had one non-routine atmospheric and two non-routine liquid releases. The atmospheric release occurred over a four-hour period from a stack in K Area. This was the result of approximately 100 Ci of tritium oxide (HTO) that was spilled in K-Reactor. This release had a calculated offsite dose to the MEI of 3.0E-03 mrem.

A release of potentially contaminated water occurred in D Area when a 60 mL moderator sample was disposed of down a laboratory drain and into a process sewer that flows untreated into Beaver Dam Creek. No increase in radioactivity was observed in samples taken from Beaver Dam Creek, and no offsite dose was calculated.

In the second non-routine liquid release, approximately 3.7 Ci of tritium was released through the D Area process sewer. The release resulted in slightly elevated levels of tritium (1.4E-05 µCi/mL) in Beaver Dam Creek (process sewer receiving water body). No offsite dose was calculated.

For 1991:
Savannah River Site

In 1991 the Savannah River Site had two non-routine releases. In September, 0.11 Ci of ^{137}Cs and 0.12 Ci of $^{89,90}Sr$ were released resulting in an offsite dose to the MEI of 4.7E-03 mrem. In December, 5700 Ci of tritium were released over a three-day period resulting in an offsite dose of 3.5E-02 mrem.

For 1992:
Los Alamos National Laboratory

A total of 6 unplanned releases occurred at the Los Alamos Lab and collectively included 40 Ci of tritium, 0.0 45 µCi of ^{242}Pu, 0.6 µCi of ^{238}U, 9.9 µCi of ^{232}Th, and 5.5 mCi of mixed gaseous activation products. For each of the six events, doses were less than 0.1 mrem.

Savannah River Site

In 1992 Savannah River had four nonroutine events. Two releases were atmospheric, and two were liquid. Only one of the atmospheric releases resulted in offsite concentrations large enough to calculate a dose; this maximum offsite dose was calculated as 0.05 mrem (0.0005 mSv).

Hanford Site

There were four unplanned radiological releases at Hanford during 1992 which were characterized as those incidents having the most potential for environmental impact, all classified as unusual environmental occurrences. These were: 1) a small release to the ground from a leaking fitting; 2) an accidental discharge to the Columbia River; 3) a radioactive waste tank leak; and 4) a leak at the tank farm. These occurrences did not result in an additional dose to the public.

Idaho National Engineering Laboratory

On April 2, 1992, internal deposits of ammonium nitrate in a stack at the Chemical Processing Plant began to flake off and were deposited downwind of the facility, resulting in low level contamination of the ground. The contamination was cleaned up, and no deposits occurred outside the facility boundary. There was no public dose associated with the release.

For 1993:
Los Alamos National Laboratory

An estimated 7 micrograms of depleted uranium was inadvertently released during an open burn on June 23, 1993. The estimated dose to nearby employees was 2.6E-07 mrem (2.6E-09 mSv), and the dose to LANL's MEI was 3.6E-11mrem (3.6E-13 mSv).

During the period of August 30 to September 3, 1993, a total of 35.8 Ci of tritium was released from Building 86. The estimated dose to nearby employees was 1.0 mrem (1.0E-02 mSv). The calculated public dose to LANL's MEI was 1.3E-04 mrem (1.3E-06 mSv).

Lawrence Berkeley Laboratory

In August 1993, tritium began to leak through the silica gel bed used by the National Tritium Labeling Facility to adsorb tritium from the exhaust air stream. Approximately 44 curies of tritium were released in this event. Based on CAP88-PC computer modeling, the dose impact from this unplanned release is estimated to have been about 5.1E-02 mrem (5.1E-04 mSv) to the MEI 110 meters northwest of Building 75.

Savannah River Site

In December 1993 there was an atmospheric release of plutonium from F-Area. The release was estimated to be 188 μCi of ^{238}Pu and 24 μCi of ^{239}Pu which occurred December 26 through 30. Emergency response models estimated a hypothetical maximum exposure of 1.9E-03 mrem at the site boundary.

For 1994:
Los Alamos National Laboratory

On January 25, 1994, an estimated 340 Ci (13 Tbq) of tritium were released during a pumping and sampling operation performed for a planned safe shutdown maintenance procedure at the high-pressure tritium laboratory (TA-33, Building 86). Potential doses were estimated using the meteorological conditions during the time of the release. The estimated dose to the nearest public receptor was 3.3E-04 mrem (3.3E-06 mSv). The calculated dose to LANL's MEI location was 1.0E-03 mrem (1.0E-05 mSv), which is a boundary dose assuming 100% occupancy at the boundary.

On February 7, 1994, a HEPA filter was changed out of Building 4, FE-3, at the DP Site West (TA-21). The changeout resulted in a higher-than-normal stack release of ^{238}U. Approximately 160 µCi (5.9 Mbq) were released during the week of February 4 to February 11, 1994. Potential doses were estimated using an EPA-approved dispersion code to be 3.44E-02 mrem (3.44E-04 mSv) to the nearest public receptor and 3.6E-03 mrem (3.6E-05 mSv) to the LANL MEI.

On December 5, 1994, during a process to recover ^{68}Ge from a target, containment of the distillation process was lost, resulting in a stack release of 1.2 mCi (44MBq) from the radiochemistry site (TA-48, building 1). Potential doses were estimated to be 3.03E-06 mrem (3.03E-08 mSv) to the nearest public receptor and 5.02E-08 mrem (5.02E-10 mSv) to the LANL MEI.

Pinellas Plant

On July 23, 1994, approximately 4 Ci (0.15 Tbq) of tritium were released to the main stack during leak checking of tritium processing equipment. The release was quantified by the flow through ionization chamber and the daily and monthly silica gel columns. Dispersion modeling using the HOTSPOT computer model was conducted, and the total external effective dose equivalent at the fenceline was estimated at 1.2E-04 mSv. Administrative controls were put in place to prevent this release from recurring.

4.0 REFERENCES

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ICRP I978 — International Commission on Radiological Protection, *Limits for Intakes of Radionuclides by Workers*, ICRP Publication 30, Pergamon Press, New York, 1978.

NCRP 1987 — National Council on Radiation Protection and Measurements, *Exposure of the Population in the United States and Canada from Natural Background Radiation*, NCRP Report No. 94, Bethesda, Maryland, 1987.

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APPENDIX A

CONTACT LIST FOR SITE ENVIRONMENTAL REPORTS

CONTACT LIST FOR SITE ENVIRONMENTAL REPORTS

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Albuquerque Operations Office				
Operations Office	Soden, Constance	505-845-5586	csoden@doeal.gov	U.S. Department of Energy Albuquerque Operations Office P.O. Box 5400 Pennsylvania & H Street Kirtland Air Force Base Albuquerque, NM 87185
	Borders, R.	505-845-5076	Rborders@doeal.gov	
	Harrell, William Battley, Vicki	505-845-4300 806-477-3189	wharrell@doeal.gov vbattley@doeal.gov	
Grand Junction Project Office	Tucker, Michael Plessinger, Tracy	970-248-6004 970-248-6197	michael.tucker@gjo.doe.gov tracy.plessinger@gjo.doe.gov	U.S. Department of Energy Grand Junction Office 2597 B 3/4 Road Grand Junction, CO 81503
Monticello Mill Tailings Site	Tucker, Michael Plessinger, Tracy Rondinella, Mary Ann Berwick, Joel	970-248-6004 970-248-6197 970-248-6077 970-248-6020	michael.tucker@gjo.doe.gov tracy.plessinger@gjo.doe.gov joel.berwick@gjo.doe.gov	U.S. Department of Energy Grand Junction Office 2597 B 3/4 Road Grand Junction, CO 81503
Inhalation Toxicology Research Institute (Not an operating DOE site)	(See Operations Office Contacts)			

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Los Alamos National Laboratory	Huchton, John Johansen, Matthew	505-665-3204 505-665-5046	hutchton@lanl.gov mjohansen@doe.lanl.gov	
	Johnston, Julie	505-665-0231	juliej@lanl.gov	Los Alamos National Laboratory MS M887, ESH-20: Ecology Los Alamos, NM 87545
Los Alamos National Laboratory	Anderman, Linda	505-665-4400		Los Alamos National Laboratory Community Relations Office P.O. Box 1663 Mail Stop A117 Los Alamos, NM 87545
Pantex Plant	Thompson, Priscilla	806-477-5567	pthompso@pantex.com	
	McGrath, Dan	806-477-5567	dmcgrath@pantex.com	
	Baumgartner, John	806-477-6124	jbaumgar@pantex.com	
	Mattingly, Patricia	806-477-6740		
Pinellas Plant (Not an operating DOE site)	(See Operations Office contacts)			
Sandia National Laboratories - Albuquerque	Bowman, Alan W.	806-477-6640	wbowman@pantex.com	Mason & Hanger Corp. P.O. Box 30020 Bldg. T-9060 Amarillo, TX 79120-0020
	Zimpel, Vicki	505-845-5245		

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Sandia National Laboratories - Livermore	Zimpel, Vicki	505-845-5245		
Sandia National Laboratories - Tonopah	Zimpel, Vicki	505-845-5245		
Chicago Operations Office				
Operations Office	Neeson, Paul Green, Donna Chiu, Ken Marcantonio, Debra	630-252-2258 630-252-2264 630-252-2376 630-252-2154	paul.neeson@ch.doe.gov donna.green@ch.doe.gov ken.chiu@ch.doe.gov debra.marcantonio@ch.doe.gov	U.S. Department of Energy Chicago Operations Office 9800 South Cass Avenue Argonne, IL 60439
	Monhart, Jane	630-840-3281	Jane.Monhart@ch.doe.gov	(Fermi Group)
	Buchar, James	630-252-2402	James.Buchar@ch.doe.gov	(Ames Group)
Ames Laboratory	Kayser, Dan	515-294-7923	kayser@ameslab.gov	Ames Laboratory Environmental, Safety, Health and Assurance G40 TASF Iowa State University Ames, IA 50011-3400
Argonne National Laboratory	Golchert, Norbert	630-252-3912	ngolchert@anl.gov	Argonne National Laboratory 9700 South Cass Ave. Argonne, IL 6043
MIT Bates Linear Accelerator	Fallon, Gerry	617-253-9272		Bates Radiation Project Office P.O. Box 95 21 Manning Rd. Middleton, MA 01949-0195

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Brookhaven National Laboratory	Schroeder, Gary	631-344-7045	schroeder@bnl.gov	Brookhaven National Laboratory Environmental Services Building 911A Upton, NY 11973
	Granzen, Jerry	631-344-4089	jerryg@bnl.gov	(Brookhaven Group)
	Paquette, Douglas	631-344-7046	paquette@bnl.gov	
	Genzer, Pete	631-344-2345	genzer@bnl.gov	Brookhaven National Laboratory Public Affairs Office Building 134 P.O. Box 5000 Upton, NY 11973-5000
	Zimmerman, Bet	631-344-4225	zimmerman@bnl.gov	Brookhaven National Laboratory Environmental Services Division Building 535 Upton, NY 11973-5000
	Lee, Robert	631-344-3146	blee@bnl.gov	
	Hooda, Benny	631-344-8107	bhooda@bnl.gov	
Fermi National Accelerator Laboratory	Robertson, George	630-840-8529		Fermi National Accelerator Laboratory, Office of Public Affairs P.O. Box 500 Mail Station 105 Batavia, Il 60510-0500

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Princeton Plasma Physics Laboratory	Wrigley, Allen Finley, Virginia	609-243-3710 609-243-2746	awrigley@pppl.gov vfinley@pppl.gov	Princeton Plasma Physics Laboratory James Forrestal Campus P.O. Box 451 MS 1 Princeton, NJ 08543
Golden Field Office				
Field Office	Baker, Jeffrey	303-275-4785	jeff.baker@go.doe.gov	U.S. Department of Energy Golden Field Office 1617 Cole Boulevard Golden, CO 80401-3393
National Renewable Energy Laboratory	Baker, Jeffrey	303-275-4785	jeff.baker@go.doe.gov	
Idaho Operations Office				
Operations Office	Sato, Walter	208-526-0193	satown@id.doe.gov	U.S. Department of Energy Idaho Operations Office 850 Energy Drive Idaho Falls, ID 83401
	Kraupp, Amy	krauppaj@inel.gov	krauppaj@id.doe.gov	
	Scovill, Van R.	scovilvr@id.doe.gov	Scovilvr@id.doe.gov	
	Carlson, Roy		carlsord@id.doe.gov	
	Jonker, Betsy Lantz, Sue	208-526-9855 208-526-5546	jonkerbs@id.doe.gov lantzbs@inel.gov	

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
	Evans, Roy	208-525-7102		Environ. Science and Research Foundation, Inc. 101 S. Park Avenue Suite 2 P.O. Box 51838 Idaho Falls, ID 83405-1838
Nevada Operations Office				
Operations Office	Hoar, Kenneth Skougard, Michael	702-295-1428 702-295-1759	hoar@nv.doe.gov skougard@nv.doe.gov	U.S. Department of Energy Nevada Operations Office 232 Energy Way North Las Vegas, NV 89030-4199
Nevada Test Site	Van Etten, Don	702-295-2446	vanettdm@nv.doe.gov	
Oakland Operations Office				
Operations Office	Black, Steven	510-637-1595	steve.black@oak.doe.gov	U.S.Department of Energy Oakland Operations Office 1301 Clay Street MS: 700N Oakland, CA 94612-5208
Lawrence Berkeley Laboratory	Ruggieri, Michael R.	510-486-5440	mrruggieri@lbl.gov	Lawrence Berkeley Lab One Cyclotron Rd. MS B75B-101 Berkeley, CA 94720
	Pauer, Ronald		ropauer@lbl.gov	

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Laboratory for Energy-Related Health Research	Devany, Bob	510-450-6144	rod@weiss.com	Weiss Associates 5801 Christi Ave Suite 600 Emeryville, CA 94608
Lawrence Livermore National Laboratory (LLNL) and LLNL-Site 300	Larson, Jennifer	925-423-8887	larson17@llnl.gov	
	Harrach, Robert	925-422-2348	harrach@llnl.gov	
	Tate, Paula		tate2@llnl.gov	
	Cleland, Lynn		cleland2@llnl.gov	
	Galles, Harry		galles1@llnl.gov	
Rockwell International - DeSoto Site	Rutherford, P.D.	818-586-6140	philip.d.rutherford@boeing.com	The Boeing Company Roketdyne Propulsion & Power 6633 Conoga Ave. P.O. Box 7922 Conoga Park, CA 91309
Rockwell International - Santa Susana Site	Rutherford, P.D.	818-586-6140	philip.d.rutherford@boeing.com	The Boeing Company Roketdyne Propulsion & Power 6633 Conoga Ave. P.O. Box 7922 Conoga Park, CA 91309
Stanford Linear Accelerator Center	Grissom, Mike Osugi, Dave	650-926-2346 650-926-3305	mikeg@slac.stanford.edu dave.osugi@oak.doe.gov	Stanford Linear Accelerator Center MS 84 2575 Sand Hill Rd. Menlo Park, CA 94025

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Oak Ridge Operations Office				
Operations Office	Donnelly, James	865-574-6260	donnellyjp@oro.doe.gov	U.S. Department of Energy Oak Ridge Operations Office 200 Administration Road Oak Ridge, TN 37831
	Joseph, Timothy	865-576-1582	josepht@oro.doe.gov	
	Poe, Robert W.	865-576-0891	poerw@oro.doe.gov	
Continuous Electron Beam Accelerator Facility	Morgan, Barbara M.	757-269-7140	bmorgan@jlab.org	ES&H Manager Jefferson Lab Site Office 12000 Jefferson Avenue Newport News, VA 23606
Oak Ridge Reservation	Braunstein, Helen	865-576-6616	braunsteinhm@ornl.gov	
	Hamilton, Laury	865-576-4526	lum@ornl.gov	Oak Ridge National Lab P.O. Box 2008 Oak Ridge, TN 37832-6285
	Hughes, Joan	865-574-6649	thu@ornl.gov	
	McMahon, Wayne	865-574-6649	eih@ornl.gov	
	Murphy, John	865-576-7929	jmu@ornl.gov	
	Smith, Linda L.	865-576-1200	SmithLS@oro.doe.gov	
Paducah Gaseous Diffusion Plant	Tidwell, David	270-441-6807	tidwellwd@oro.doe.gov	
Portsmouth Gaseous Diffusion Plant	Robinson, Sharon	740-897-2001	robinsons@oro.doe.gov	

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Ohio Field Office				
Field Office	Brechbill, Susan R.	937-865-3977	susan.brechbill@ohio.doe.gov	U.S. Department of Energy Ohio Field Office 1 Mound Rd. Miamisburg, OH 45342
	Boada-Clista, Lydia	937-865-4164	lydia.boada-clista@ohio.doe.gov	
	Smiley, Susan	937-865-3984	sue.smiley@ohio.doe.gov	
	Brechlin, Patricia	937-865-3809	patricia.brechlin@ohio.doe.gov	
	Ganz, John	440-993-2017	john.gan@ohio.doe.gov	
	Nickel, Kathi	513-648-3166	kathi.nickel@ohio.doe.gov	
Fernald Environmental Management Project (FEMP)	Kroger, Eric J. Reising, Johnny Stenger, Gary	513-648-7563 513-648-3139 513-648-3153	eric.Kroger@fernald.gov	FEMP Public Enviro./Tech. Information, 10995 Hamilton/Cleves Highway Harrison, OH 45030
Battelle Columbus Laboratories	Chance, Tracy	614-424-7876	chancet@battelle.org	Battelle Memorial Institute 505 King Avenue Columbus, OH 43201
	Baillieul, Thomas	614-760-7372	thomas.a.baillieul@ohio.doe.gov	U.S. DOE 555 Metro Place N. Suite 415 Dublin, OH 43017
RMI Company Extrusion Plant	Marsh, Eric Smiley, Sue	440-993-1909 937-865-3984	eric_marsh@earthlinetech.com	RMI P.O. Box 579 Ashtabula, OH 44005-0579

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Mound Laboratory	Greenwalt, Jane	937-865-3116	jane.greenwalt@doe-md.gov	Public Affairs Office Miamisburg Environmental Management Project One Mound Rd. P.O. Box 66 Miamisburg, OH 45343
	Provencher, Richard	937-865-3252	richard.provencher@ohio.doe.gov	(Miamisburg Environ. Management Project)
West Valley Demonstration Project	Nagel, Anthony	716-942-2157	nagel@wv.doe.gov	
	Fox, Jim	716-942-2997	gfoxjr@wv.doe.gov	
	Picazo, E.O.	716-942-2568	picazoe@wv.doe.gov	
	Maloney, Moira N.	716-942-4255	moira.n.maloney@wv.doe.gov	U.S. Department of Energy West Valley Demonstration Project, Public & Employee 10282 Rock Springs Rd. West Valley, NY 14171-9799
Richland Operations Office				
Operations Office	Ward, Dana	509-327-1261	dana_c_ward@rl.gov	U.S. Department of Energy Richland Operations Office P.O.Box 550 825 Jadwin Avenue Richland, WA 99352

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Hanford Site	Clarke, Suzanne E.	509-372-4931	suzanne_e_clarke@rl.gov	Room 619 Building 825 JADWIN Mail Stop A6-38 Richland, WA 99352
	Hanf, R.W. (Bill)	509-376-8264	rwh@pnl.gov	
	Poston, Ted	509-376-5078	ted.poston@pnl.gov	Pacific Northwest National Laboratory P.O. Box 999 Richland, WA 99352
	Dirkes, Roger	509-376-8177	rl_dirkes@pnl.gov	
	Diediker, Larry		Larry_p_diediker@rl.gov	
	Bryce, Robert	509-372-2228	rwbryce@pnl.gov	
	Glines, Wayne	509-376-6506	wayne_m_glines@rl.gov	
	Wisness, Steven	509-376-5363	steven_h_wisness@rl.gov	
	Rosselli, Robert		robert_m_rosselli@rl.gov	
	Johnson, Sandra		sandra_l_doe_johnson@rl.gov	
	Knollmeyer, Peter		peter_m_knollmeyer@rl.gov	
Rocky Flats Field Office				
Field Office	Rampe, John	303-966-6246	john.rampe@rf.doe.gov	U.S. Department of Energy Rocky Flats Field Office 10808 Highway 93, Unit A Golden, CO 80403
	Legare, Joseph	303-966-5918	Joe.Legare@rf.doe.gov	

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Rocky Flats Plant	Hill, Gail	303-966-7000	gail.hill@rfets.gov	
Savannah River Operations Office				
Operations Office	Heenan, Thomas	803-725-8074		U.S. Department of Energy Savannah River Operations Office Road 1A Aiken, SC 29801
Savannah River Site	Arnett, Margaret	803-725-2654	margaret.arnett@srs.gov	Westinghouse Savannah River Company Room 133 Building 735-11A Aiken, SC 29808
	Lorenz, Robert	803-725-3556	robert.lorenz@srs.gov	Environmental Sampling and Reporting Westinghouse Savannah River Company Room 7 Building 735-16A Aiken, SC 29808
	Mamatey, Albert	803-725-3363	albert.mamatey@srs.gov	Westinghouse Savannah River Company Room 117 Building 735-11A Aiken, SC 29808
	Baranek, Mary	803-725-8014	mary-m.baranek@srs.gov	
	Whitney, Gail	803-725-1447	gail.whitney@srs.gov	
	Heffner, James	803-725-1447	james.heffner@srs.gov	
	Gould, Arthur	803-725-3969	arthurb.gould@srs.gov	

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Remedial Action Sites				
Responsible Operation/Field Office	(see Oak Ridge Operations Office contacts)			
Colonie Interim Storage Site				
Hazelwood Interim Storage Site				
Maywood Interim Storage Site				
Middlesex Sampling Plant				
New Brunswick Site				
Niagara Falls Storage Site				
Wayne Interim Storage Site				
Weldon Spring Site	Thompson, Pamela	636-441-8978	pthompson@wssrap.com	
Naval Reactors				
Bettis Atomic Power Laboratory	Shollenberger, E.D.	412-476-7290	shollenb@bettis.gov	Bettis Atomic Power Laboratory 814 Pittsburgh-McKeesport Blvd. West Mifflin, PA 15122-0079
Knolls Atomic Power Laboratory - Knolls	Seepo, A.R.	518-395-6366	seepoan@snrmail.kapl.gov	Knolls Atomic Power Laboratory PO Box 1069 Schenectady, NY 12301-1069

Site Name	Contact Name	Telephone No.	E-mail Address	Street Address
Knolls Atomic Power Laboratory - Kesserling	Seepo, A.R.	518-395-6366	seepoan@snrmail.kapl.gov	Knolls Atomic Power Laboratory PO Box 1069 Schenectady, NY 12301-1069
Knolls Atomic Power Laboratory - Windsor	Seepo, A.R.	518-395-6366	seepoan@snrmail.kapl.gov	Knolls Atomic Power Laboratory PO Box 1069 Schenectady, NY 12301-1069
Naval Reactor Facility	Knoll, Daniel	208-526-1470	knoldr@inel.gov	Bettis Atomic Power Laboratory Naval Reactors Facility PO Box 2068 Idaho Falls, ID 83403-2068

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APPENDIX B

SITE DESCRIPTIONS

APPENDIX B

SITE DESCRIPTIONS

The following site descriptions are intended to reflect the sites as they existed during 1990 through 1994, the years for which doses and releases are summarized in this report. Significant changes have occurred at some sites since 1994 and are not reflected in these descriptions.

ALBUQUERQUE OPERATIONS OFFICE

GJPO Grand Junction Project Office. The Grand Junction Project Office is located on a 23-hectare (56-acre) site adjacent to the Gunnison River in western Colorado immediately south of the city of Grand Junction. The Grand Junction Project Office is a Federally owned site that provides the scientific, technical, engineering, and project integration skills to support national environmental restoration, geophysical, and energy programs. GJPO provides support of environmental restoration in the areas of site characterization, project management, project integration and coordination, remedial design, remedial action, research and development, independent verification, decontamination and decommissioning, and laboratory sampling and analysis. Specialized facilities include the Analytical Laboratory, Environmental Sciences Laboratory, Petrology Laboratory, Electronics Laboratory/Instrument Calibration Facilities, and Sample Preparation Laboratory.

MMTS Monticello Mill Tailings Site. The Monticello Mill Tailings Site is located near the City of Monticello in San Juan County, Utah. The Monticello Mill Tailings Site comprises three operable units: the mill site, a 44-hectare (108-acre) tract located along Montezuma Creek south of the City of Monticello; 25 peripheral properties located north and south of the mill site; and the surface (Montezuma Creek) and ground water located beneath and extending beyond the mill site. Residues from vanadium and uranium milling, known as mill tailings, were left in place at the mill site. Although the milling process recovered about 93 percent of the uranium, the tailings that remain contain several radioactive elements, including uranium, thorium, radium, polonium, and radon. The total volume of tailings, process-related contaminated material, and tailings-contaminated soil is estimated at 2.0 million cubic meters (2.6 million cubic yards) throughout the Monticello sites. The tailings piles at the mill site were stabilized and covered with soil in 1961 to limit their dispersal or use. However, uranium mill tailings and byproduct materials, which were produced during uranium milling, contaminated the mill site, peripheral properties, and surface and ground water. The mission of the Monticello Projects is to ensure that the environmental impacts associated with past activities at the site are identified and investigated and that appropriate action is taken to protect public health and welfare and

the environment. The Grand Junction Projects Office is responsible for remediating the Monticello Projects.

ITRI Inhalation Toxicology Research Institute. The Inhalation Toxicology Research Institute occupies approximately 18,600 m^2 of laboratory space on the south edge of Kirkland Air Force Base in Albuquerque, New Mexico. Fewer than 1,000 people live within 8 km (5 mi) of the Institute. The site is on a high mountain desert bordered by an Air Force base and an Indian reservation. The laboratory houses up to 15,000 research animals and conducts studies on the health effects of inhaled fission products, fuel cycle actinides, insulating materials, coal combustion effluents, and diesel exhaust emissions.

LANL Los Alamos National Laboratory. The Los Alamos National Laboratory's primary mission is nuclear weapons research and stewardship, but it also has other research programs in laser fusion, nuclear materials, and laser isotope separation. The laboratory is operated by the University of California for the U.S. Department of Energy. It is situated about 100 km (63 mi) north-northeast of Albuquerque and 40 km (25 mi) northwest of Santa Fe in north central New Mexico. The 111-km^2 (43-mi^2) site and adjacent communities are located in a region of numerous mesas and canyons. The surrounding area is undeveloped and is used principally for recreation.

PANX Pantex Plant. The Pantex Plant's principal activity was the assembly of nuclear weapons. This involves the fabrication and testing of chemical high-explosive components; modification, repair, and retirement of nuclear weapons; and stockpile surveillance and interim storage of plutonium components of retired weapons. The Pantex Plant was operated for DOE by Mason and Hanger-Silas Mason Co., Inc. with environmental, health, and safety programs subcontracted to Battelle Memorial Institute. The plant site occupies 4,100 hectares (10,000 acres) in the Texas Panhandle, about 27 km (17 mi) northeast of Amarillo, Texas. The area is not densely populated; most of the surrounding residents live in small communities or on farms and ranches. Cattle ranching and agriculture are predominant.

PIN Pinellas Plant. The Pinellas Plant stopped production of weapons-related components late in 1994. Lockheed Martin Specialty Components operated the Pinellas Plant for DOE. The 40-ha (100-acre) plant site is in Pinellas County, Florida, on a peninsula between Tampa Bay and the Gulf of Mexico, several kilometers from St. Petersburg. On September 30, 1994, the DOE Defense Program mission ended. In December 1994 DOE announced it had agreed to sell the Pinellas Plant to the Pinellas County Industrial Council effective March 1995.

SNLA Sandia National Laboratories, Albuquerque. Sandia National Laboratories designs arming, fusing, and firing systems for nuclear weaponization of nuclear explosives; safety and development of studies for reactors; and special nuclear material transport and storage systems. Additional activities at the laboratory include development of waste disposal techniques and research on solar energy use, thermonuclear fusion, fossil fuels, and geothermal energy. The laboratory is surrounded by the Kirkland Air Force Base in Albuquerque, New Mexico, and is operated by the Sandia Corporation, a wholly owned subsidiary of the Lockheed Martin Corp. The laboratory facilities, which are on high mesas bounded by dry arroyos, are bordered by the Manzano Mountains on the east and the Isleta Indian Reservation to the south. SNLA is approximately 6.5 miles

east of downtown Albuquerque. The mountainous region is mostly used for forestry, and the Indian reservation is used primarily for grazing.

SNLL Sandia National Laboratories, Livermore. The primary mission of Sandia National Laboratories, Livermore, is research and development in the national interest. The laboratory is located 65 km (40 mi) southeast of San Francisco in the Central California Coastal Range Province, along the southeastern portion of the Livermore Valley midway between the Pacific Ocean and the San Joaquin Valley. The SNLL site is situated on 170 hectares (413 acres) of land located east of Livermore. On October 1, 1993, Martin Marietta Corp. assumed operating responsibilities for the site from AT&T, which had managed the site since 1949.

SNLT Sandia National Laboratories, Tonopah. Sandia National Laboratories has responsibility for the Tonopah Test Range. The test range covers 1620 km^2 (624 mi^2) in the high desert region of west central Nevada, approximately 225 air km (140 mi) northwest of Las Vegas. The site was used as a bombing range throughout World War II. Test activities associated with flying sorties, rocket/missile flights, and air drops were conducted in 1994.

CHICAGO OPERATIONS OFFICE

Ames Ames Laboratory. The Ames Laboratory is located on the campus of Iowa State University (ISU). The laboratory conducts basic and intermediate-range applied research in physical, mathematical, and engineering sciences to solve complex materials problems in energy production and use. The laboratory also transfers the information and technologies it produces to the private sector and other governmental units. The ISU campus is surrounded by the city of Ames, Iowa; approximately 50,000 people live within 8 km (5 mi) of the campus.

ANL Argonne National Laboratory. Argonne National Laboratory conducts a broad research program in basic energy and related sciences (physical, chemical, material, nuclear, biomedical, and environmental) and serves as an engineering center for the study of nuclear and non-nuclear energy sources. The laboratory occupies 607 hectares (1,500 acres) and is operated for the DOE by the University of Chicago. It is 43 km (27 mi) southwest of downtown Chicago. The area immediately surrounding the site is the Waterfall Glen Forest Preserve, a 907 hectare (approximately 2,240 acre) site previously owned by the laboratory.

Bates Bates Linear Accelerator. The Massachusetts Institute of Technology Bates Linear Accelerator Laboratory occupies a rural, 91 hectare (150 acre) site in Middleton, Massachusetts, approximately 32 km (20 mi) northeast of Boston. The laboratory comprises an accelerator vault, a beam switchyard, and three experimental areas. Experiments conducted at the accelerator include electron and proton scattering studies and polarized electron studies. The site is bounded on the south and west by undeveloped county land and on the north and east by private holdings. The laboratory is situated on a glacial drumlin 61 m (190 ft) above sea level that rises 30 m (92 ft) above the surrounding terrain.

BNL Brookhaven National Laboratory. Brookhaven National Laboratory is a multidisciplinary scientific research center operated during 1994 by Associated Universities, Inc. Its programs include research and development; high-energy nuclear and solid state physics; fundamental material and structural properties and interactions of matter; nuclear medicine, biomedical, and environmental sciences; and selected energy technologies. Situated in Suffolk County on Long Island, BNL is approximately 97 km (61 mi) east of New York City and is bordered by forested and cultivated land with increasing residential housing development. The site occupies 2130 hectares (5260 acres).

Fermi Fermi National Accelerator Laboratory. The major facility at Fermi National Accelerator Laboratory is a proton synchrotron, which is used for fundamental research in high-energy physics and related disciplines. Fermi Laboratory was operated during 1994 by Universities Research Association, Inc. It occupies a 2,750-ha (6,800-acre) tract of land approximately 48 km (30 mi) from Chicago. The surrounding area is rapidly becoming residential.

PPPL Princeton Plasma Physics Laboratory. The Princeton Plasma Physics Laboratory has conducted fusion energy research since 1951. One of two tokamak devices was operated in 1994. The goal of the Magnetic Fusion Energy Research Program is to develop and demonstrate the practical application of fusion power as an alternate energy source. The PPPL is located in Middlesex County, New Jersey, on the James Forrestal Research Campus of Princeton University. The site, which is approximately 4.8 km (3 mi) east of the main campus, is surrounded by largely undisturbed areas that contain forest, open grass areas, an airplane runway, and a small brook. The closest urban areas are New Brunswick, 23 km (14 mi) to the northeast, and Trenton, 19 km (12 mi) to the southwest. Major metropolitan areas, including New York City, Philadelphia, and Newark, are within 80 km (50 mi) of the site.

GOLDEN FIELD OFFICE

NREL National Renewable Energy Laboratory. NREL's major research facilities are located in Golden, Colorado. NREL began operations in 1977 as the Solar Energy Research Institute. It achieved national laboratory status in 1991 and is a contractor-operated laboratory owned by the US Department of Energy. NREL supports R&D programs in basic energy research, photovoltaics, wind energy, advanced vehicle technologies, biofuels, biomass electric, fuels utilization, solar industrial technologies, building technologies, solar thermal electric, municipal solid waste, hydrogen, geothermal power, and superconductivity. These R&D activities support the DOE Office of Energy Efficiency and Renewable Energy.

IDAHO OPERATIONS OFFICE

INEL Idaho National Engineering Laboratory. The DOE's Idaho National Engineering Laboratory mission is to develop, demonstrate, and deploy advanced engineering technology and systems to benefit government programs and public life. In August 1994 DOE awarded management of major INEL facilities to Lockheed Idaho Technologies

Company. The Argonne National Laboratory-West reactor located at this site is operated by the University of Chicago. The Naval reactor facility is operated by Westinghouse Electric. The 2,300-km^2 (890-mi^2) site is on the high desert plains of southeastern Idaho. It is approximately 35 km (22 mi) west of Idaho Falls and 71 km (44 mi) northwest of Pocatello. The mostly arid area around the site is desert, foothills, or used for agriculture.

NEVADA OPERATIONS OFFICE

NTS NEVADA TEST SITE. The major programs at the Nevada Test Site include nuclear weapons testing, weapons safety, radioactive and mixed waste storage and disposal, basic research in high-energy nuclear physics, and studies of high-level waste storage. No nuclear explosives tests were conducted in 1994. A nuclear testing moratorium has been in effect since late 1992. The site is located in Nye County, Nevada, and is surrounded on three sides by exclusion areas of the Nellis Air Force Range. Beatty, Nevada, is the nearest (40 mi), largest population center (population 1500) in the vicinity of NTS; Las Vegas is approximately 100 km (63 mi) to the southeast. The arid, rugged terrain near the site is used infrequently, except for mining and grazing.

OAKLAND OPERATIONS OFFICE

LBL Lawrence Berkeley Laboratory. Lawrence Berkeley Laboratory, operated by the University of California, conducts a wide-ranging program of general research in the physical and biological sciences. The laboratory's facilities include several accelerators, various radiochemical laboratories, and a tritium-labeling laboratory. The laboratory is in the hills east of the Berkeley campus of the University of California and within a densely populated residential area in the cities of Berkeley and Oakland.

LEHR Laboratory for Energy-Related Health Research. The Laboratory for Energy-Related Health Research is a 6.1-hectare (15-acre) parcel owned by the Regents of the University of California, west of Sacramento in Solono County, California. It is 2.4 km (1.5 mi) south of the main UC Davis campus in a rural agricultural area adjacent to the South Fork of Putah Creek. The site consists of 15 buildings, including a main administration and office building, two animal hospitals, a laboratory and support buildings. Historical use of specific facilities and/or areas at the site had an environmental impact. Research at LEHR through the mid-1980s focused on the health effects from chronic exposures to radionuclides, primarily ^{90}Sr and ^{226}Ra, simulating radiation effects on humans by using beagles. In the early 1970s, the ^{60}Co irradiator facility was constructed on the site to study the effects on beagles of chronic exposure to gamma radiation. Former facilities requiring environmental remediation include: radioactive fluid waste treatment systems, a radioactive waste burial area, outdoor dog pens, and several domestic septic systems. Research at LEHR ceased in 1989, and only decontamination and decommissioning activities have taken place since then. In addition to the DOE area remediation, UC Davis is evaluating potential environmental impacts from the inactive campus landfill units and numerous inactive campus low-level radioactive disposal sites (trenches and holes) used to dispose waste.

LLNL Lawrence Livermore National Laboratory. Lawrence Livermore National Laboratory is operated by the University of California. Nuclear weapons research and development are its prime functions, though it has additional programs in magnetic fusion research, laser isotope separation, non-nuclear energy research and development, biomedical studies, and laser fusion research. The 250-ha (620-acre) site is in the Livermore Valley 5 km (3 mi) east of Livermore. An additional site (Site 300), approximately 16 km (10 mi) southeast of LLNL, is used for materials testing and high explosives diagnostic work. This site, which occupies 2,700 hectares (6,700 acres), is in the sparsely populated hills of the Diablo Range.

RI Rockwell International. Rockwell operates several facilities in the San Fernando Valley/Simi Valley area for manufacturing, testing, research, and development. It is located approximately 48 km (30 mi) NW of downtown Los Angeles. Prior to 1987, tasks included development, fabrication, and disassembly of nuclear reactors, reactor fuel, and other radioactive materials. Subsequently, all radiological work has been directed toward D&D of the previously used nuclear facilities and site areas. There are two manufacturing and test operations areas: the Santa Susana Field Laboratory (SSFL) site (RI-2) and the DeSoto site (RI-1). The DeSoto site is essentially light industry with some laboratory scale R&D. The SSFL site has four areas used for research, development, and test operations, as well as a buffer zone. Only one of the SSFL areas has been used for work with nuclear materials. The Radioactive Materials Disposal Facility (RMDF) is located at the SSFL site and has been used for storage of sealed irradiated fuel and is currently used for packaging radioactive wastes resulting from the D&D operations. No nuclear fuel has been present at RMDF since May 1989. The Rockwell International Hot Laboratory and the radiation instrumentation calibration laboratory are also located at the SSFL site. The Energy Technology Engineering Center conducts research for DOE at the SSFL site. At the DeSoto site, irradiation operation in the Gamma Irradiation Facility was terminated in 1994, and radiation sources were shipped offsite.

SLAC Stanford Linear Accelerator. The Stanford Linear Accelerator is in a large research laboratory devoted to theoretical and experimental research in elementary particle physics, the development of new techniques in high-energy particle detection, and research in atomic and solid state physics, chemistry, and biology using synchrotron radiation from accelerated electron beams. The 170 hectares (420-acre) SLAC site is operated by Stanford University. The laboratory is 3.2 km (2.0 mi) west of the Stanford University campus in San Mateo County, California, approximately 32 km (20 mi) southeast of San Francisco. Adjacent land includes both commercial, residential, and farming areas.

OAK RIDGE OPERATIONS OFFICE

CEBAF Continuous Electron Beam Accelerator Facility. CEBAF is a national laboratory (accelerator complex and experimental halls) managed by the Southeastern Universities Research Association, Inc., for DOE. CEBAF's mission evolved from the nuclear science community's recognition of the need for a state-of-the-art electron accelerator with a continuous high current electron beam and electron energies in the multi-billion electron volt region. CEBAF is used to study quark structures and behaviors and the

forces governing the clustering of individual nucleons in the nuclear medium. The site is comprised of 66 hectares (162 acres) in the northern section of Newport News, Virginia. It is bounded on the east by the City of Hampton and York County; on the north by the City of Williamsburg and James City County; on the west by the James River; and on the south by the Hampton Roads and the City of Norfolk.

ORR Oak Ridge Reservation. DOE's Oak Ridge Reservation includes three major facilities, all operated in 1994 by Martin Marietta Energy Systems, Inc. The Oak Ridge National Laboratory is a large multipurpose research laboratory; the K-25 Gaseous Diffusion Plant enriches uranium for reactor fuels; and the Y-12 Plant produces nuclear weapons components and provides support for weapons design laboratories. The Oak Ridge Reservation is in a broad valley in eastern Tennessee between the Cumberland and Great Smoky Mountains. The surrounding area is largely forested and rural. It is used for residences, recreation, and farming. There are a few small towns near the site, and a major metropolitan area, Knoxville, is approximately 40 km (25 mi) to the east.

PGDP Paducah Gaseous Diffusion Plant. The Paducah Gaseous Diffusion Plant is DOE-owned and was operated in 1994 by Martin Marietta Energy Systems, Inc. It is a uranium enrichment plant with associated manufacturing and support facilities. The site occupies about 300 hectares (740 acres) in McCracken County, Kentucky, approximately 6 km (4 mi) south of the Ohio River and 32 km (20 mi) east of the confluence of the Ohio and Mississippi Rivers. The city of Paducah is 19 km (12 mi) to the east. The surrounding area is largely agricultural.

POR Portsmouth Gaseous Diffusion Plant. The Portsmouth Gaseous Diffusion Plant was operated in 1994 for DOE by Martin Marietta Energy Systems. The principal process at the plant is the separation of uranium isotopes by gaseous diffusion. Support operations include the decontamination of equipment and the recovery of uranium from various waste materials. The plant is in sparsely populated Pike County, Ohio, on a 1,600-ha (4,000-acre) site 2 km (1.3 mi) east of the Scioto River Valley. The terrain surrounding the plant is primarily farmland among densely forested hills. The Scioto River Valley is farmed extensively, particularly with grain crops.

OHIO FIELD OFFICE

FEMP Fernald Environmental Management Project. The site was formerly a uranium metals processing facility, but it is now undergoing environmental restoration. Production was suspended in July 1989, and in October 1990 the DOE transferred management responsibility for the site from its Defense Programs to the Office of Environmental Restoration and Waste Management. The formal end to production occurred in June 1991, and the site was renamed the Fernald Environmental Management Project (FEMP). From 1986 until 1992, Westinghouse Materials Company of Ohio operated the site. On December 1, 1992, Fernald Environmental Restoration Management Corporation (FERMCO), a wholly owned subsidiary of Fluor Daniel, Inc., assumed responsibilities for managing the environmental restoration of the site. The site is 27 km (17 mi) NW of downtown Cincinnati, Ohio, in an area of farming and dairy/beef cattle production.

BCL Battelle Columbus Laboratories. The Battelle Columbus Laboratories (operated by Battelle Memorial Institute) perform a number of energy-related research and development activities at the King Avenue and West Jefferson (WJ) sites. The West Jefferson site (Nuclear Science Area) is on a 440-ha (1,100-acre) tract approximately 8 km (5 mi) west of Columbus, Ohio. The area surrounding the site has a low population density and few industries. The main project at this site is the study of the properties of irradiated materials. The WJ Site includes the Hot Cell Laboratory (awaiting decommissioning), an administrative building with areas awaiting decommissioning, areas used to assay routine health physics and environmental samples, a vault used to store special nuclear material (SNM) where storage ended in May 1994, and a retired research reactor awaiting waste removal.

The 4-ha (10-acre) King Avenue site is next to the Ohio State University in the heart of Columbus. Activities involving contract work and licensed nuclear materials were limited to receiving, storing, processing, and packaging source and low-level waste materials. Formerly, a ^{235}U handling facility was operated at the King Avenue Site. Decommissioning of this facility was completed in September 1994. The King Avenue Site is in a densely populated residential area.

RMI RMI Company Extrusion Plant. The RMI Extrusion Plant was subcontracted to WMCO until 1991 when RMI became a prime contractor, and it holds a Nuclear Regulatory Commission source material license. The Nuclear Regulatory Commission license became an Ohio Department of Health license in November 1999. The principal activity of the Extrusion Plant has been to extrude depleted and slightly enriched uranium ingots into rod or tube shapes. The site is comprised of eight buildings on 10.5 hectares (26 acres) and is located near the northern edge of Ashtabula County, Ohio, approximately 5 km (3.1 mi) east of the Ashtabula city center. The plant is located in a sparsely populated industrial community of chemical production and metal conversion plants. The site is fenced to maintain a restricted area in the prevailing wind direction (north-northeast). During 1988, RMI fenced off an additional 2.4 hectares (5.9 acres) north of the site to control access to monitoring wells, uranium contaminated soils, and water in a low-lying ponded area.

MLM Mound. Mound's principal mission includes research, development, and manufacture of non-nuclear explosive components for nuclear weapons that are assembled elsewhere. In addition, Mound Laboratories separates, purifies, and sells stable isotopes; develops and manufactures small chemical heat sources; recovers and purifies tritium from scrap materials; develops and manufactures radioisotopic heat sources to provide power sources for space projects; and surveys explosive and radioactive weapons components received from other DOE sites. The laboratory is operated by the Monsanto Research Corporation. It occupies 1.24 km^2 (306 acres) of land in Miamisburg, Ohio, approximately 16 km (10 mi) southwest of Dayton. The area is predominantly farmland, though there are light industries and scattered residential communities.

WVDP West Valley Demonstration Project. The West Valley Demonstration Project site is located in a rural setting approximately 50 km (30 mi) south of Buffalo, New York, at an average elevation of 400 m (1300 ft) on New York State's western plateau. The plant facilities used by the Project occupy approximately 63 hectares (156 acres) of an area within the 1350 hectares (3300-acre) reservation of the Western New York Nuclear

Service Center. The communities of West Valley, Riceville, and Asheford Hollow and the village of Springfield are located near the site. The land near the site is primarily used for agriculture.

RICHLAND OPERATIONS OFFICE

HANF Hanford Site. The Hanford Site is in a largely rural area of southeastern Washington state. Formerly dedicated to the production of plutonium, the mission in 1994 included research and development in the areas of energy, waste management, and environmental restoration. Principle operating contractors for major facilities at the site in 1994 included Westinghouse Hanford Company, Battelle Memorial Institute, Hanford Environmental Health Foundation, and Bechtel Hanford Inc. The Columbia River flows through the 1,450-km^2 (560-mi^2) site and forms part of its eastern boundary. The cities of Richland, Kennewick, and Pasco, with a combined population of over 100,000 people, adjoin the Hanford Site to the southeast. Although located in an arid climate, the region around the site is now intensively irrigated and cultivated, and the river is used for recreation.

ROCKY FLATS FIELD OFFICE

RFP Rocky Flats Plant. Formerly, the primary mission of the Rocky Flats Plant was the production of nuclear weapons components. In early 1992 the mission of Rocky Flats was changed when certain planned weapons systems were canceled. Production of non-nuclear components continued through September 1994. Rocky Flats is in a transitional phase with clean-up and D&D. Since 1990 the prime operating contractor has been EG&G Rocky Flats. The plant is in Jefferson County, Colorado, about 26 km (16 mi) northwest of downtown Denver. The 2600-ha (6500-acre) site is about equidistant from the cities of Boulder, Golden, and Arvada. Adjacent to the site, land use is a mixture of agriculture, mining, open industrial, and low-density residential housing. In July 1994, RFP was officially redesginated Rocky Flats Environmental Technology Site.

SAVANNAH RIVER SITE

SRS Savannah River Site. The Savannah River Site mission is to assure site environmental quality, support a secure national defense, reduce nuclear danger, and enhance industrial competitiveness and economic development. Westinghouse Savannah River Company (WSRC) replaced DuPont in 1989 as the operating contractor, and the site name was changed from Savannah River Plant to Savannah River Site. In 1994 test runs for a new high-level waste processing facility were completed. Major facilities include five nuclear reactors (one remains in cold standby, and four are permanently shutdown), two fuel fabrication facilities, and two chemical separations facilities where fuel for space missions was processed in 1994. An extensive research program is conducted in the associated Savannah River Laboratory and Savannah River Ecology Laboratory. The 803 km^2 (310 mi^2) site is along the Savannah River, principally in Aiken and Barnwell counties of South Carolina. The surrounding area is primarily forested and

rural with various industrial manufacturing and farming operations. Augusta, Georgia, located approximately 40 km (25 mi) to the northwest, is the nearest metropolitan area.

REMEDIAL ACTION SITES

CISS Colonie Interim Storage Site. The Colonie Interim Storage Site (CISS) is located in Colonie, New York, approximately 6.4 km (4 mi) northwest of downtown Albany and about 4.8 km (3 mi) southeast of the village of Colonie. The CISS consists of property and buildings formerly used for the manufacture of a variety of uranium products, primarily using depleted uranium. Small quantities of natural and enriched uranium were also used in selected manufacturing processes. Approximately 0.8 hectares (2 acres) of land northwest of this property are also included in the site, which comprises a total of 4.5 hectares (11 acres). Several properties in the vicinity are also radioactively contaminated as a result of airborne releases of uranium compounds during operations at the site. Land use in the vicinity of the site is primarily industrial and residential. It is bordered by open land and an electrical substation to the northwest and west and by commercial properties to the southeast and east. The populations of Colonie and Albany are about 8,019 and 101,700, respectively.

HISS Hazelwood Interim Storage Site. The Hazelwood Interim Storage Site is a former storage site for ore residues and uranium- and radium-bearing process wastes previously stored at the St. Louis Airport Site (SLAPS). It is located in Hazelwood, Missouri, 0.8 km (0.5 mi) north of the SLAPS, and is situated on a broad, shallow bedrock depression, portions of which are located in the 100-year floodplain. Most of the land within 0.8 km (0.5 mi) of the site is the Lambert-St. Louis International Airport. The residential areas nearest the site are approximately 0.5 km (0.3 mi) east in Hazelwood, which in 1980 had a population of approximately 8,800. While land use in the vicinity is predominantly industrial, land immediately adjacent to the site is also used for commercial and recreational purposes.

MISS Maywood Interim Storage Site. The Maywood Interim Storage Site (MISS) is located in Bergen County, New Jersey, approximately 19 km (12 mi) north-northwest of Manhattan (New York City) and 20 km (13 mi) northeast of Newark, New Jersey. MISS includes commercial and residential properties in the Boroughs of Maywood and Lodi and the Township of Rochelle Park. The site occupies 4.7 hectares (12 acres) of a 12-ha (30-acre) property owned by the Stepan Company (formerly Maywood Chemical Works). Contamination at the properties resulted from rare earths and thorium processing activities conducted at the Maywood Chemical Works, 100 W. Hunter Ave., Maywood, from the early 1900s through 1959. Soils containing thorium, radium, and uranium are located on the site. Contamination occurred through past disposal practices and was moved off the site via the nearby Lodi Brook or through placement of fill material. The Stepan Company property is currently used for chemical processing activities.

MSP Middlesex Sampling Plant. The Middlesex Sampling Plant site occupies 3.9 hectares (9.6 acres) in Middlesex, New Jersey. The site is currently used for interim storage of contaminated soils excavated from vicinity properties, including the Middlesex Municipal Landfill. Following remedial action at the landfill in 1986, 50,600 m^3 (1.78 million ft^3) of contaminated soils were stored on an interim storage pad at the site. The storage pad

includes a leachate collection system to prevent the release of contaminants to waters in the area. Land use in the vicinity of the site is primarily residential and industrial. An expanse of vacant land borders the southern end of the site. Numerous public water supply wells are located within 1.6 km (1 mi) of the site, and a public well field lies 2 km (1.3 mi) northwest. The 1980 population of Middlesex was approximately 13,500; approximately 15 million people live within 80 km (50 mi) of Middlesex.

NBS New Brunswick Site. The New Brunswick Site occupies 2.3 hectares (5.6 acres) in Middlesex County, New Jersey, approximately 48 km (30 mi) southwest of New York City and approximately 3.2 km (2 mi) southwest of downtown New Brunswick, New Jersey. The site consists of three of the original building pads and a parking area. The fenced site is vacant and grass-covered, and it lies in an urban, industrialized setting. During its 29 years of operation as a DOE (AEC) facility, the site included laboratory and support structures that utilized nuclear materials such as thorium and uranium ores, high-purity plutonium, and americium and uranium enriched with ^{233}U and ^{235}U. There were contamination incidents, and liquid waste containing various radionuclides were discharged into the sanitary sewer system. Remedial action activities were initiated in 1978.

NFSS Niagara Falls Storage Site. The Niagara Falls Storage Site occupies approximately 77.4 hectares (191 acres) located in northwestern New York within the Township of Lewiston. The site is approximately 6.4 km (4 mi) south of Lake Ontario, 16 km (10 mi) north of the City of Niagara Falls, and in a rural setting. The NFSS was developed as an interim storage area for radioactive residues from pitchblende processing and radium contaminated sand, soil, and building rubble. Groundwater is used to supply approximately 10% of the population needs in Niagara and Erie Counties. Land in the vicinity of the site is used for truck farms, orchards, and single-family dwellings.

WISS Wayne Interim Storage Site. The Wayne Interim Storage Site is located in Wayne Township, New Jersey, 1.6 km (1.0 mi) east of Pompton Plains. The site is situated on a 2.6 hectare (6.4 acre) parcel that includes an office building and an interim waste storage area. Processing wastes were previously stored in waste pits on the site, which are located in the Piedmont Plateau in north-central New Jersey, and rises from 61 to 70 m (200 to 230 ft) above mean sea level. Ground water under the site provides water for public and industrial use in Wanaque, Pompton Lakes, and along the western edge of Wayne Township. These residential areas are all within 6.5 km (4.0 mi) of the site. The population of Wayne Township was approximately 46,500 in 1980.

WSS Weldon Spring Site. The Weldon Spring Site is located in St. Charles County, Missouri, approximately 48 km (30 mi) west of St. Louis. Uranium and thorium residues, waste materials, and contaminated rubble are stored at the WSS. In addition to environmental monitoring activities, engineering activities are being conducted to minimize the migration of contaminants from these facilities into surface water and groundwater. There are three major areas at WSS: Weldon Spring Raffinate Pits, Weldon Spring Chemical Plant, and Weldon Spring Quarry. These three areas total 91.5 hectares (226 acres).

NAVAL REACTORS

BET Bettis Atomic Power Laboratory. The Bettis Atomic Power Laboratory, operated by the Westinghouse Electric Corporation during 1990–1994, is engaged in the design and development of naval nuclear propulsion plants. The laboratory is on an approximately 80 hectare (200 acre) tract of land in the borough of West Mifflin, approximately 13 km (8 mi) southeast of Pittsburgh, Pennsylvania. The area around the site is industrial, residential, and recreational. Radiation sources at the site include small specimens of irradiated and unirradiated fuel materials which are handled, processed, and stored at Bettis. There are no nuclear reactors onsite.

KAPL Knolls Atomic Power Laboratory. The Knolls Atomic Power Laboratory (operated by the General Electric Company until 1993 and currently operated by KAPL, Inc., a Lockheed Martin company) consists of three sites: the Knolls Site, the Kesselring Site, and the Windsor Site. The principal function at KAPL is research and development in the design and operation of naval nuclear propulsion plants. The Kesselring Site is used for the training of personnel in the operation of these plants. The naval nuclear propulsion prototype plant at the Windsor Site was also used for training of personnel until it was permanently shut down in 1993. The 70 hectare (170 acre) Knolls Site (KAPL-1) is located approximately 3.2 km (2 mi) east of Schenectady, New York, on the south bank of the Mohawk River. The surrounding area is open land, light industry, small farms, a closed municipal landfill, and suburban residential areas. The Kesselring Site (KAPL-2) is located near West Milton, New York, approximately 27 km (17 mi) north of Schenectady on a 1600 hectare (3,900 acre) site. The Kesselring Site contains four pressurized water naval nuclear propulsion plants and support facilities. One of the plants was permanently shutdown in 1991. The surrounding area is a rural, sparsely populated region of wooded lands. The Windsor Site (KAPL-3) is located on 4 hectares (10 acres) of land near Windsor, Connecticut. It is approximately 8 km (5 mi) north of Hartford. Surrounding the site are rural farming, light industry, and suburban residential areas.

NRF Naval Reactor Facility. The Naval Reactor Facility (NRF) is a U.S. Naval Nuclear Propulsion Program facility located at the Idaho National Engineering Laboratory (INEL) in southeastern Idaho, 10.7 km (6.7 mi) from the nearest INEL boundary. The developed portion of the site within the security fence covers approximately 34 of the site's total 1800 hectares (4400 acres). The site is used for operating naval reactor prototypes to test advanced naval reactor components and materials. The prototype plants are also used as training platforms for U.S. Navy personnel who are to serve aboard nuclear-powered warships. Developmental nuclear fuel material samples, irradiated naval fuel, and reactor plant components and materials are examined at the Expended Core Facility within NRF, which also prepares naval fuel for transport to INEL's Idaho Chemical Processing Plant.

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APPENDIX C

SUMMARY OF RADIOLOGICAL ENVIRONMENTAL PROGRAMS

APPENDIX C

SUMMARY OF RADIOLOGICAL ENVIRONMENTAL PROGRAMS

The following section is intended to reflect site radiological environmental monitoring programs as they existed during 1990 through 1994. Since 1994, significant changes may have occurred to the monitoring programs described herein. The requirements for all environmental monitoring activities are contained in the 5400 series of the DOE Orders. Chapter II of DOE Order 5484.1 (DOE 1981) identifies specific effluent monitoring requirements.

Albuquerque Operations Office

GRAND JUNCTION PROJECT OFFICE

Radioactive effluent is released from the GJPO facility in the form of liquid sewage discharged to the city of Grand Junction sewage treatment facility, air particulate emissions, and atmospheric radon.

Liquid sewage effluent samples were analyzed for gross alpha and gross beta. Analysis of individual isotopes was conducted only if the total gross alpha plus gross beta activity in any sample was close to or greater than 5 times the DCG reference value of plutonium-240 (30 pCi/l). In 1993, individual isotopes were measured twice.

The sources of radioparticulates included the Analytical Chemistry Laboratory, ORNL Sample Preparation Trailer (in 1993), baghouse ventilation exhaust system, and the uranium mill tailings associated with GJPORAP remedial actions. Estimated release rates from these facilities were used to model offsite doses.

The major source of radon emission from GJPO were the uranium mill tailings and associated contaminated soil. Tailings-contaminated soil was eliminated as of June 1994.

Monitoring programs for atmospheric radon, air particulates, direct gamma radiation, surface water, ground water, and biota were conducted (ground water and biota were not monitored in 1990). Atmospheric radon was sampled at 13 locations on- and offsite. Ambient air particulate emissions were monitored by three high-volume air particulate samplers. Radiological sampling was performed for radium-226, thorium-230, and total uranium. Direct gamma radiation was measured at 15 locations on and adjacent to GJPO during 1993 and 1994.

Surface water analytes included gross alpha, ^{226}Ra, ^{234}U, and ^{238}U during 1990, as well as ^{228}Ra, ^{230}Th, ^{232}Th, and ^{235}U during 1992 through 1994. Groundwater analytes were the same as surface water. No groundwater sampling was performed in 1990.

In 1993, biota sampling was performed for ^{226}Ra, ^{230}Th, and uranium in onsite and background aquatic organisms.

MONTICELLO MILL TAILINGS SITE

The only significant radioactive effluent released from MMTS was ^{222}Ra, which has a half-life of 0.01 years. Monitoring of radiological air particulates indicated that levels of uranium, ^{226}Ra, and ^{230}Th were well below DCGs.

In 1990, surface water analytes included ^{226}Ra, ^{228}Ra, ^{234}U, ^{238}U, and gross alpha. In 1991, surface water and groundwater analytes were the same as the surface water analytes during 1990, plus ^{230}Th. ^{210}Pu and gross beta were added to the analytes in 1992. ^{210}Pb and ^{235}U were added in 1993 and 1994. In 1994, sediments were analyzed for ^{40}K, ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{232}Th.

During 1990 through the first half of 1993, radon sampling was conducted at 8 locations. In the third quarter of 1993 and in 1994, monitoring was conducted at 2 onsite and 13 offsite locations. In 1992, two Pylon AB-5 real-time radon monitors were installed at downwind residential locations adjacent to the mill site to monitor the effect of increased construction activity on ambient radon concentrations.

During 1990 through 1993, particulate sampling was conducted every sixth day for 24 hours using three high-volume samplers, weather permitting. In late 1993 seven low-volume radioparticulate samplers were installed adjacent to the mill site. These samplers were operated 24 hours a day, 7 days a week. Four weekly filter samples were combined and analyzed as one sample.

Direct gamma radiation monitoring occurred during 1990 through 1992 using TLDs at 13 monitoring locations on- and offsite. In 1993 seven TLDs were added to the sampling network. During 1994, TLDs measured radiation at 19 locations on a quarterly basis.

Surface water sampling was performed during 1990 and 1991 at three onsite locations, with 2 locations added in 1992. Four upstream and seven downstream locations on Montezuma Creek were also sampled.

Groundwater sampling during 1990 and 1991 occurred in the Montezuma Creek alluvial aquifer at two upgradient, one downgradient, and eight onsite wells. One well in the Burro Canyon aquifer was also sampled. Radiological sampling was performed for ^{226}Ra,^{228}Ra, ^{234}U, ^{238}U, and gross alpha. During 1992, samples were collected from the alluvial aquifer at three upgradient wells, seven onsite wells, and six downgradient wells. Samples from three upgradient, three downgradient, and three onsite wells in Burro Canyon were also sampled. Radionuclide sampling was performed for ^{210}Pu, $^{226/228}Ra$, $^{230/232}Th$, $^{234/238}U$, and ^{222}Ra. In 1993, alluvial aquifer sampling occurred at three upgradient, nine onsite, and six downgradient wells. Burro Canyon aquifer sampling occurred at three upgradient, three onsite, and three downgradient wells. Radionuclide sampling was performed for ^{210}Pb, ^{210}Po, $^{226/228}Ra$, $^{230/232}Th$, $^{234/235/238}U$, and gross beta. In 1994, alluvial aquifer sampling occurred at three upgradient, eight onsite, and six downgradient wells. Burro Canyon aquifer was sampled at three upgradient, one

onsite, and three downgradient wells. Radionuclide sampling was performed for ^{210}Pb, ^{210}Po, $^{226/228}$Ra, $^{230/232}$Th, $^{234/235/238}$U, gross alpha, gross beta, and ^{222}Ra.

In 1994, sediment samples were collected at varying depths from 16 locations along Montezuma Creek and two ponds. Samples were analyzed for metals and radionuclides to support data used in the Operable Unit III Remedial Investigation/Feasibility Study.

INHALATION TOXICOLOGY RESEARCH INSTITUTE

Inhalation Toxicology Research Institute (ITRI) monitored air, lagoon water and lagoon sediment for radiological and nonradiological analytes in the effluent. Environmental sampling of air, soil, and penetrating radiation, and groundwater was also performed. For air sampling, air filters from continuous air samplers located around ITRI were changed monthly and counted for gross alpha and beta activity. At the end of 1991, 16 filters were analyzed radiochemically by a contract laboratory. In 1992, 1993, and 1994, 12 filters were analyzed for ^{238}Pu, $^{239/240}$Pu, ^{241}Am, ^{226}Ra, ^{232}U, and ^{63}Ni. Monitoring for $^{233/234}$U, ^{235}U, and ^{238}U was not conducted due to greatly limited handling of these materials. In addition, the effluent from exhausters and ventilation systems (15 stacks) that serve high-level radioisotope laboratories were collected and analyzed for particulate airborne radioactivity (gross alpha and gross beta). In 1990 and 1991, lagoon water and sediment, and soil samples from 6 locations along the facility perimeter, were sampled annually and analyzed for ^{238}Pu, ^{239}Pu, ^{241}Am, ^{244}Cm, ^{90}Sr, ^{226}Ra, and ^{137}Cs. During 1992 through 1994, lagoon water and sediment were sampled annually and analyzed for gross alpha/beta, uranium isotopes, ^{3}H, ^{14}C, ^{238}Pu, $^{239/240}$Pu, ^{241}Am, and ^{226}Ra. Soil samples were taken annually at six perimeter locations and one offsite location and were analyzed for ^{241}Am, ^{226}Ra, ^{238}U, $^{239/240}$Pu, ^{90}Sr, ^{137}Cs, ^{235}U, and ^{40}K. Environmental gamma radiation monitoring using TLD-100 TLDs were performed to determine radiation levels at one offsite and six site boundary locations. The 19 groundwater monitoring wells at ITRI were located within 1 mi of the site sewage lagoon. These wells were sampled quarterly. Native vegetation was collected annually at 6 perimeter locations. No measurements were done on these samples unless a documented release occurred.

LOS ALAMOS NATIONAL LABORATORY

The environmental pathways by which radioactive and nonradioactive materials may have been transported from the Los Alamos National Laboratory (LANL) site to nearby populations include passage directly through atmospheric transport from stacks and small point sources, indirectly through soils, food stuffs, or animals, and from batch releases of treated liquid effluent. The environmental surveillance program for LANL and vicinity included the collection and analysis of samples from more than 450 sampling stations including all potential exposure pathways. Air and groundwater were routinely monitored for radioactivity and nonradioactive contaminants at a number of onsite, boundary, and distant locations. Environmental radiation exposure rates were also measured at onsite, boundary, and distant locations. Measurements at boundary and onsite locations were compared to measurements at regional locations to assess the impact of LANL operations on the environment.

In 1990 and 1991, airborne radioactivity was monitored by a network of 12 onsite, 12 perimeter, and three regional samplers. Effluent samples were also obtained at

87 discharge points. Analyses were performed to detect gross alpha and beta-gamma radioactivity, and for specific radionuclides such as ^{3}H, ^{32}P, ^{41}Ar, uranium, plutonium, gaseous mixed activation products, mixed fission products, and particulate/vapor activation products. Environmental air samples were analyzed as follows: 14 locations for particulate, eight locations for tritium oxide, four for radioiodine, and one for ^{14}C as carbon dioxide. In addition, rainfall and dry deposition samples were obtained at eight onsite and four perimeter locations. Two additional rainfall sites were sampled during periods of significant precipitation. Rainwater was analyzed for ^{3}H and gross alpha- and beta-emitters.

During 1992 through 1994, airborne radioactivity was monitored by a network of 31 onsite and 19 offsite samplers. Analyses were performed to detect gross alpha and beta-gamma radioactivity and for specific radionuclides such as tritium, americium, uranium, plutonium, gaseous mixed activation products, mixed fission products, and particulate/vapor activation products.

In 1990 and 1991, surface and groundwater sampling was conducted at 37 onsite, 32 perimeter, and six regional locations. In addition, samples were collected and analyzed from 22 water supply and 33 special surface water and groundwater stations, whose primary purpose was a geothermal project. Analyses were performed for ^{3}H, ^{85}Sr, ^{89}Sr, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, and gross radioactivity.

During 1992 through 1994, surface and groundwater sampling was conducted at 46 onsite, and 48 offsite locations. Analyses were performed for ^{3}H, ^{90}Sr, ^{137}Cs, U, ^{238}Pu, ^{239}Pu, ^{241}Am, and gross radioactivity. Sediments and soil were also sampled for the same list of nuclides.

In 1990 and 1991, foodstuffs were sampled at 11 onsite, eight perimeter, and 10 regional locations. Items sampled include fruits, vegetables, fish, bees, and honey.

During 1992 through 1994, foodstuffs were sampled at 22 onsite and 24 offsite locations. Items sampled include fruits, vegetables, grains, fish, honey, game, and milk.

External gamma, x-ray, and charged particle radiation doses were monitored in 1990 and 1991 using TLDs at each of 147 onsite locations, and at regional and perimeter locations. During 1992 through 1994, monitoring occurred at each of 139 onsite and 27 offsite locations.

PANTEX PLANT

The environmental radiological program at Pantex evaluated air, water, groundwater, soil, vegetation, and specific fauna samples. Analyses of area samples were specific for radionuclides that were alpha- or beta-emitters, ^{239}Pu, ^{234}U, ^{238}U and ^{3}H as well as naturally occurring ^{226}Ra. Due to analysis limitations, calculation of $^{238}U/^{234}U$ ratios were substituted for analysis of ^{235}U in the 1991 and 1992 SERs.

Ten offsite air-sampling locations and seven onsite locations were used. Each sample station had both a high-volume particulate and a low-volume tritium sampler. Air samples were collected weekly and analyzed weekly. Particulate samples were collected weekly and composited samples monthly for measurement. $^{234,238}U$, ^{239}Pu, ^{3}H, and alpha and gross beta

contamination were monitored. In 1994, 16 new perimeter air sampling stations were added. These new perimeter stations monitored for U isotopes, Pu isotopes, elemental and oxidized tritium, gross alpha, and gross beta.

There are no streams or rivers that flow through or near the plant site. Most industrial effluent, sanitary wastewater, and surface drainage were discharged to ditches and playas. The industrial discharges from the west side of Zone 11 were collected and sampled in playas. Groundwater sampling included 13 monitored wells and five drinking water production wells. Sampling was done monthly to semi-annually.

In 1990 and 1991, soil samples were gathered from 32 offsite and 19 plant-site locations to measure radioactive content in the soil for comparison with perimeter samples. Offsite soil samples were collected quarterly and plant-site samples were collected monthly. All samples were sent to an offsite laboratory for analysis of ^{234}U, ^{238}U, and ^{239}U. During 1992 through 1994, soil samples were gathered from 17 offsite and 31 onsite locations. Offsite soil samples were collected quarterly and onsite samples were collected monthly. All samples were sent to an offsite laboratory for analysis of ^{234}U, ^{238}U, $^{239/240}Pu$, and ^{3}H.

Vegetation samples were collected quarterly from 17 offsite and monthly from five plant-site locations. Analysis of vegetation was used to determine whether unusual uptake of ^{234}U, ^{238}U, or ^{3}H occurred from the soil or air.

In 1990 and 1991, jack rabbits were analyzed for the presence of ^{234}U, ^{238}U, ^{239}Pu, and ^{3}H. No animal sampling was performed during 1992 through 1994.

In 1992, 9 environmental TLDs (2 offsite, 1 onsite, and 6 site perimeter) using LiB and Ca_2SO_4 crystals were located near some of the air monitoring locations, and others were co-located with the Texas Department of Health's environmental TLDs. In 1993 and 1994, 23 environmental TLDs (ten offsite, seven onsite, and six site perimeter) were used. TLDs were measured quarterly.

PINELLAS

The radioactive environmental monitoring program at Pinellas monitored the release of tritium gas, tritium oxide, and ^{85}Kr discharges. Tritium gas and tritium oxide discharges were monitored at four exhaust stacks. ^{85}Kr was monitored at the Building 100 main exhaust stack. In 1990 and 1991, 6 onsite and 5 offsite sampling stations monitored the atmospheric levels of tritium gas and tritium oxide. During 1992 through 1994, 7 onsite and 6 offsite sampling stations monitored the atmospheric levels of tritium gas and tritium oxide. In the buildings where plutonium capsules were handled, the ventilation discharge continued to be monitored for plutonium. Plutonium heat sources were removed in February 1991, though monitoring for plutonium continued. Four site perimeter and five offsite plutonium monitoring stations were operated continuously. The liquid effluent from the Pinellas Plant was monitored daily for tritium. Surface water samples were collected and analyzed from 3 onsite and 26 offsite locations and were analyzed for tritium. Soil samples from two onsite and four offsite locations were also collected and analyzed for plutonium.

SANDIA NATIONAL LABORATORIES, ALBUQUERQUE

Soil, arroyo sediment, vegetation, and water were monitored for radionuclides, primarily gamma emitters (e.g., ^{137}Cs) and ^{3}H. Soil and sediment were also analyzed for total uranium. Gross alpha and beta screening, gamma spectroscopy, and uranium/tritium analysis were performed on water samples. A radiological surveillance program using TLDs measured ambient levels of external penetrating radiation around each facility quarterly. The environmental surveillance locations remained essentially the same from year to year. The selection of these sampling locations was based on all potential releases, past contamination areas, and other potential impacts to the offsite residents and the surrounding environment. Vegetation was normally collected and analyzed for ^{3}H, ^{137}Cs, and ^{40}K for 18 SNLA, eight perimeter, and five community samples. The same number of soil samples were taken and analyzed for ^{137}Cs and ^{3}H.

SANDIA NATIONAL LABORATORIES, LIVERMORE

Sandia National Laboratories, Livermore (SNLL) conducted the environmental monitoring program to measure the impact of any of the operations on the public or environment. Sandia National Laboratories, Livermore and LLNL conducted this program jointly because the two facilities are adjacent and have similar operations.

SANDIA NATIONAL LABORATORIES, TONOPAH

During 1990 through 1992 the EPA conducted the largest portion of the environmental monitoring program at Sandia National Laboratories, Tonopah (SNLT), including TLDs that measure gamma radiation and are exchanged quarterly; air monitoring for noble gases, tritium, and other radionuclides; and water monitoring for radionuclides. Soil sampling was not performed routinely by EPA. This site was included in the EPA's Long-Term Hydrologic Monitoring Program, established to monitor water sources for radioactivity in areas where nuclear tests had been conducted. A continuous particulate air monitoring station was located at SNLT as part of the EPA Air Surveillance Network. Air filters were exchanged three times per week and analyzed by gamma spectrometry.

In 1993 and 1994 the environmental monitoring program at SNLT included 1) air monitoring for gross alpha, gross beta, Pu nuclides, total uranium, and γ-spec, and 2) water monitoring for radionuclides. A long-term TLD network was established in January 1994. Environmental sampling included soil sampling (14 offsite, 5 perimeter, and 79 onsite locations), PM_{10} air samples (3 locations), August and September air samples, and drinking water from the main SNLT well. The TLD program monitored 5 offsite locations, 4 perimeter locations, and 13 onsite locations. The EPA conducted routine monitoring around SNLT and NTS (TLD, PIC, and air monitoring of noble gases, tritium, and other radionuclides and water monitoring for radionuclides). Many EPA sampling activities were placed on standby in 1994.

Chicago Operations Office

AMES LABORATORY

Liquid aqueous wastes, generated at the Ames Laboratory's Radioactive Waste Disposal Facility were analyzed for radioactivity before their infrequent release (e.g., 2 releases in 1992) to the sanitary sewer. Samples were collected before release and analyzed for radioactive content using gamma ray spectroscopy, gas proportional counting for gross beta and alpha activity, and liquid scintillation. Groundwater testing, initiated in 1990, was also conducted.

ARGONNE NATIONAL LABORATORY

Weekly collections of air filter samples at 13 site perimeter and 5 offsite locations were made for specific radiochemical analyses and for alpha, beta and gamma emitters. Additionally, plutonium sampling was performed at one offsite and two site perimeter locations. Argonne wastewater was discharged directly and indirectly to Sawmill Creek, which runs through the ANL grounds, drains surface water from the site, and flows into the Des Plaines River. The creek was sampled upstream from the ANL site and downstream from the wastewater outfall to determine if radioactivity was added to the stream. Surface water samples were collected and counted for alpha and beta activities and analyzed for uranium, transuranic and tritium. Upstream samples were collected monthly, and downstream samples were collected daily. Portions of the daily samples were composited weekly for analysis. Monthly and bi-monthly samples were taken from the Des Plaines River.

The radioactive content of soil, grass, and bottom sediment was measured at the site perimeter and offsite. Levels of external penetrating radiation at the site (6 onsite and 8 perimeter locations) and 5 offsite locations were measured with TLDs.

BROOKHAVEN NATIONAL LABORATORY

The environmental surveillance program for BNL and vicinity included the collection and analysis of samples from air and liquid effluents, ambient air, groundwater, surface water, soil, vegetation, fish, fauna, and sediment. Air and groundwater were routinely monitored for radioactivity and nonradioactive contaminants at a number of onsite, boundary, and distant locations. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of BNL operations on the environment.

Airborne radioactivity was monitored by collection of air samplers at five effluent release points and 16 perimeter stations to measure ambient air. Rainfall was collected at two locations and analyzed for gross alpha and beta, ^{3}H, ^{90}Sr, and gamma-emitters. Tritium was monitored continuously at 18 locations. Weekly ambient air particulate samples from 5 onsite locations were composited monthly and analyzed for gamma-emitters. The weekly samples were monitored for gross alpha and gross beta.

For surface water sampling, the Peconic River was sampled at 3 onsite locations within the recharge area and 4 locations between the site boundary and the mouth of the river. In addition, the Carmans River was sampled as the background location. Samples were analyzed

for gross alpha and beta, ^{3}H, ^{90}Sr, and gamma-emitters. For groundwater samples, 98 wells were monitored for radioactivity.

Commercially and locally grown produce were sampled annually. Fish samples were collected from the Peconic River at Donahue's Pond, Forge Pond, the upstream part of Swan Pond, and the Carmans River control location. Samples were analyzed by gamma spectroscopy. External gamma radiation doses were monitored using TLDs at 52 locations onsite and offsite.

FERMI NATIONAL ACCELERATOR LAB

The Fermi environmental program monitored potential external exposure from direct penetrating radiation and airborne, short-lived radionuclides as well as internal exposure from ^{3}H and ^{22}Na in water, primarily potential drinking water. For airborne effluent, continuously operating stack monitors recorded the concentration released from stacks. Surface water and groundwater samples were analyzed to determine concentrations of tritium and other accelerator-produced radionuclides. Soil and sediment monitoring was conducted at 10 sample sites. Approximately 70 TLDs were analyzed quarterly for penetrating radiation levels.

BATES LINEAR ACCELERATOR

Monitoring equipment was located at the east boundary station, continually monitoring leakage of gamma and neutron radiation scattered from beam and dump areas. The exhaust gas was continuously monitored for gamma radiation in the stack base prior to release. Emission of ^{15}O and ^{13}N were calculated by correcting the release for the specific radionuclide contribution determined through half-life separation studies. Water samples were obtained quarterly at locations on Nichols Brook. Gamma spectroscopy and liquid scintillation counting were used for analysis. Outside air was sampled by drawing continuously through a 2-in. millipore filter at 1 cfm. The samples were analyzed by both multi-channel gamma-ray spectroscopy and beta proportional counting.

PRINCETON PLASMA PHYSICS LABORATORY

The pathways monitored at Princeton Plasma Physics Laboratory (PPPL) included external exposure from direct penetrating radiation, airborne radionuclides such as ^{41}Ar, ^{13}N, ^{16}N, and internal exposure from radionuclides such as ^{3}H in air and water.

During 1990 through 1992 there were four - two in 1993 and 1994 - real-time site-boundary pressurized ionization chambers and ^{3}He-moderated neutron detectors placed at the Tokamak Fusion Test Reactor (TFTR) exclusion zone boundary. An additional eight ionization chambers of lower sensitivity were located with neutron monitors nearer the TFTR device. Tritium emissions (elemental and oxie) from TFTR were monitored continuously from its release stack and at 11 ambient air sampling locations.

During 1990 through 1992 surface water was sampled at eight locations (four onsite and four offsite) and analyzed for tritium and photon emitters. Two existing onsite wells were sampled during 1990 through 1992.

In 1993 and 1994 surface water was sampled at 9 locations (3 onsite and 6 offsite) and analyzed for tritium. Five existing onsite wells were sampled in 1993 and 1994. Because there were few dairies in the area, milk was not sampled. Because the fish population was scarce, vegetables and other biota from the surrounding area were substituted for reference data. Various biota were sampled and analyzed for tritium.

Golden Field Office

NATIONAL RENEWABLE ENERGY LABORATORY

The National Renewable Energy Lab (NREL) used only minor sources of radiation (e.g., X-ray machines) and small quantities of radioisotopes for biological labeling. Personal monitoring was performed in the laboratories where radioactive isotopes were used. TLDs were used to monitor NREL personnel working with any x-ray machines and in the laboratories where radioisotopes were handled or stored. The dosimeters were collected and analyzed on a quarterly basis. Surveys were also done on removable contamination following completion of experiments involving radioisotopes. In 1990 and 1991 groundwater was sampled and analyzed for gross alpha, gross beta, and ^{226}Ra. Groundwater sampling for radioactivity was discontinued in 1992 because the site was demonstratrably free of radioisotope contamination.

Idaho Operations Office

IDAHO NATIONAL ENGINEERING LABORATORY

Air and groundwater were routinely monitored for radioactivity at a number of onsite, boundary and distant locations. Airborne particulate radioactivity was monitored continuously by a network of 12 onsite air samplers and 11 air samplers outside the site boundaries. The filters from the low-volume air samplers were collected weekly and analyzed after decaying off short-lived radon and radon progeny. Nonspecific analyses were measured for gross alpha or gross beta. At the end of each quarter, the air filters were composited and submitted for gamma spectrometry and for analyses for alpha-emitting radionuclides and ^{90}Sr. Airborne tritium levels were monitored quarterly.

Water sampling was limited to onsite and offsite groundwater monitoring plus samples from the Snake River. Water samples were collected routinely to monitor the movement of waste substances, both radioactive and nonradioactive, through the aquifer. Drinking water was collected from boundary and distant communities and from the Snake River for gross alpha and beta and tritium analyses. Precipitation was also sampled at one onsite and one offsite location and analyzed for tritium.

Milk, wheat, leafy garden lettuce, potatoes, and muscle, liver and thyroid from sheep and game animals were sampled. Milk samples were analyzed for ^{129}I, ^{131}I, ^{90}Sr, and ^{3}H. Lettuce, potatoes, and wheat were analyzed for ^{90}Sr and gamma-emitting radionuclides. Animal muscle

and liver tissue samples were analyzed for gamma-emitting radionuclides, and thyroids from sheep and game animals were analyzed for ^{131}I.

Soil samples were collected onsite and offsite and analyzed for gamma-emitting radionuclides. Most were also analyzed for ^{90}Sr and alpha-emitting radionuclides.

In addition to sampling, TLDs were used to measure ionizing radiation exposures from natural radioactivity in the air and soil, cosmic radiation from outer space, fallout from nuclear weapons tests, radioactivity from fossil fuel burning, and radioactive effluent from site operations and other industrial processes.

Nevada Operations Office

NEVADA TEST SITE

Radiological air and liquid effluents were monitored at Nevada Test Site (NTS) during 1990 through 1994. NTS effluents may originate from tunnels, underground test event sites, or from facilities where radioactive materials were either used, processed, stored, or discharged. Monthly grab samples were collected and analyzed for tritium, gross beta, and gamma-emitters. Quarterly samples were taken for ^{238}Pu and $^{239/240}Pu$. An annual sample was analyzed for ^{90}Sr.

Air was sampled at 54 onsite stations, typically weekly. Weekly samples were monitored for gross beta and gamma-emitters. Monthly composites were analyzed for plutonium isotopes. Quarterly composites for plutonium analyses were begun in late 1994. Noble gases were monitored continuously at 10 locations. Tritium samplers were located at 19 locations and measured every two weeks.

Offsite air monitors were located at 30 stations within 130 km (80 mi) of the NTS. The air was monitored for one week each quarter. By the end of 1994, operations continued at only 14 stations due to the reduction of NTS activities and transfer of monitoring stations to other uses. Weekly particulate samplers were taken and analyzed for gross alpha and gross beta. Noble gases and tritium were also sampled offsite weekly.

Offsite water monitoring was primarily conducted on groundwater due to the absence of surface water in the region. Samples from specific locations were collected monthly, semiannually, annually, or biennially.

Milk from 15 dairies within 300 km (186 mi) of the NTS, which represented major milksheds, were monitored. Quarterly samples were analyzed for tritium, ^{89}Sr, ^{90}Sr, and beta-emitters. Locally grown crops and animals (cattle, mule deer, and chukar) were also sampled.

External exposure was monitored by a network of 201 fixed locations on the NTS. Offsite there were 36 TLD stations and 32 individuals monitored by personal dosimeters.

Oakland Operations Office

LAWRENCE BERKELEY LABORATORY

The environmental pathways by which radioactive and nonradioactive materials could have been transported from the LBL site to nearby populations included passage directly through atmospheric transport from stacks and small point sources; indirectly through soils, food stuffs, or animals; and from batch releases of treated liquid effluent. Air and groundwater were routinely monitored for radioactivity and nonradioactive contaminants, and environmental radiation exposure rates were measured at a number of onsite, boundary, and distant locations. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of LBL operations on the environment.

Airborne radioactivity was monitored by a network of 10 samplers located at the site, at eight locations on the perimeter or at near-site locations, and specifically at point source effluent locations. Effluent samples were analyzed weekly to detect gross alpha and beta-gamma radioactivity and for specific radionuclides being handled. Environmental air samples were analyzed as follows: 14 locations for particulates, eight locations for tritium oxide, four for radioiodine, and one for ^{14}C as carbon dioxide. In addition, monthly rainfall and dry-deposition samples were obtained at nine onsite and five perimeter locations. Two additional rainfall sites were sampled during periods of significant precipitation. Rainwater was analyzed for tritium and gross alpha- and beta-emitters.

Flow-proportional water sampling was conducted at the two sewer outfalls. Analyses were performed for tritium, radioiodines, gross alpha and beta emitters. In addition, groundwater was sampled monthly by collecting grab samples at six of the approximately 10 hydraugers (subsurface drains) onsite and weekly at the watershed drainage paths, Strawberry and Blackberry Creek. Samples were analyzed for tritium and gross alpha- and beta-emitters.

External gamma radiation doses were monitored using a telemetric system at each of four locations on the site boundary, at each major accelerator complex, and at the LBL waste storage yard where radioactive materials were staged prior to shipment for disposal.

LAWRENCE LIVERMORE NATIONAL LABORATORY

The Lawrence Livermore National Laboratory (LLNL) sampled air, sewage effluent, groundwater and surface water, soil, vegetation and foodstuff, and environmental radiation. SNLL lies along the southern LLNL border; therefore, this description is applicable to both sites.

The air monitoring program at LLNL was based on measurement of particles collected on filters or of vapor chemically trapped in air samples. There were six continuously operating high-volume air-particulate samplers on the site and 13 samplers in Livermore Valley. Air filters were analyzed for gross alpha and gross beta activity to screen and trend airborne radioactivity. In addition, the samples were analyzed for other radionuclides that may have been present or near the site.

The LLNL sewage outflow was continuously monitored and analyzed for compliance with permits and to assess the effectiveness of control systems. Concentrations of ^{3}H, ^{137}Cs and ^{239}Pu were measured in the sanitary sewer effluent.

Surface water, drinking water, and storm water from the Livermore site and surrounding areas were monitored for the presence of radioactive constituents and nonradiological pollutants. The waters monitored in the Livermore Valley included lakes and aqueducts, tap water, storm water runoff, and drinking water supply wells, and they were analyzed for alpha, beta, and tritium.

Soil was sampled at LLNL because of its potential to cause releases to the atmosphere or through liquid effluent. Soil-sampling locations were chosen to coincide with air-sampling locations or to give coverage of areas of known past contamination concern. After collection, samples were dried, ground, and blended, and ^{239}Pu content determined. In addition, alpha spectroscopy and gamma spectroscopy measurements were made.

Vegetation and foodstuff monitoring was performed at routine intervals. Vegetation (usually native grasses) were collected throughout the Livermore Valley. Water from the vegetation samples were collected, and the tritium content was measured. In addition to grass, wine and honey that was produced in the Livermore Valley was sampled and measured for tritium. Goat milk samples were also collected and analyzed.

External doses from gamma radiation were measured at 22 Livermore site perimeter locations and 55 offsite locations. Thermoluminescent dosimeters were used to measure external gamma radiation doses.

ROCKWELL INTERNATIONAL

Rockwell International includes the DeSoto (RI-1) and Santa Susanna (RI-2) Sites.

The Rocketdyne environmental monitoring program provided a measure of the effectiveness of safety procedures and the engineering safeguards incorporated in facility design. Except for the specific analyses for plutonium in soil, specific radionuclides in environmental samples were not routinely identified because of the extremely low radioactivity levels normally detected. Gross alpha and beta radiation analyses were performed for screening purposes on all other environmental samples. Facility atmospheric effluent sample filters were composited for specific radiochemistry analysis by a contractor. Sampling of vegetation for radioactivity analysis was terminated, and soil sampling frequency was reduced to quarterly after review of results of the environmental monitoring program in 1986. Occasional gamma-spectral analyses of bulk samples such as soil, water, and ambient air sample collection filters confirmed that the radionuclides were naturally occurring.

Surface and supply water samples were obtained monthly and analyzed. Air sampling was performed continuously with air samplers operating on a 24-hr sampling cycle. Airborne particulate radioactivity was collected on glass fiber filters which were automatically changed daily at the end of each sampling period. The samples were counted for alpha and beta radiation following a decay period. Monitoring for ambient radiation was performed with TLDs. The dosimeters were exchanged and evaluated quarterly.

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH

There were no radioactive effluent discharges from DOE-operated LEHR facilities during 1990 through 1994. Air sampling was conducted during 1992 through 1994 to monitor the effectiveness of engineering controls during demolition of Animal Hospital buildings. Periodic samples were taken of ambient air outside roof stacks. High volume air samplers took weekly samples of discharge points for the buildings' ventilation systems. Air samples were screened for alpha, beta, and gamma (primarily ^{226}Ra, ^{90}Sr, ^{137}Cs, and ^{241}Pu) activity. Ambient air monitoring was also performed at 20 to 35 locations using TLDs.

Groundwater sampling was performed quarterly at 23 wells during 1990 and 1991 and at 18 wells during 1992 through 1994. Groundwater samples were analyzed for tritium, ^{14}C, ^{90}Sr, gross alpha and beta radioactivity, and gamma emitters (e.g., ^{226}Ra, ^{232}Th, ^{137}Cs). Analyses for ^{241}Am and ^{241}Pu were added in 1994.

Surface water sampling was performed quarterly in Putah Creek upstream and downstream of the site. Surface water samples included analyses for the same parameters as groundwater samples.

Soil sampling was conducted at numerous locations in the former dog pens and the Old AEC Project site during 1990 and 1991. No soil sampling was performed in 1992 and 1993. In 1994, soil sampling was initiated for a remedial investigation. Six offsite and 19 onsite (western area of the dog pens) locations were sampled. Samples were analyzed for gross alpha, gross beta, ^{14}C, tritium, ^{60}Co, ^{137}Cs, ^{226}Ra, and ^{90}Sr.

STANFORD LINEAR ACCELERATOR

Accelerator beam dumps, switch yards, and position source areas were the locales where detectable radioactive gases were potentially emitted. Air monitoring of the Stanford Linear Accelerator (SLAC) Beam Switch Yard ventilation fan was provided by a radioactive gas detector, which collected particulate samples during venting. The effluent of the Positron Source and Final Focus System were also monitored continuously while the exhausters were running. Wastewater containing radioactivity was not routinely released from the site. Six peripheral monitoring stations provided continuously recorded data from radiation monitors located near SLAC boundaries.

Oak Ridge Operations Office

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

Accelerator operations can produce three types of radioactivity which can impact the general public: airborne radioactivity, groundwater radioactivity, and directly penetrating radiation. Potential pathways to the public from radioactive emissions were monitored based on the type of operations, radionuclides released, and the potential hazard. Monitoring of airborne radioactivity was carried out locally for control of personnel exposure.

Groundwater samples were analyzed from six monitoring wells and one groundwater discharge location four times each year. Surface water was monitored at the dewatering discharge and at sump discharge points and incorporated into the groundwater monitoring data. Samples were analyzed for accelerator-produced radionuclides such as ^{7}Be, ^{45}Ca, ^{54}Mn, and ^{22}Na, and for radionuclides from atmospheric nuclear weapons tests (e.g., ^{90}Sr).

Directly penetrating radiation was monitored by approximately 25 electronic radiation detectors and associated passive integrating detectors deployed around the accelerator site. The majority of the electronic detectors were connected to a central computer system which automatically recorded the radiation levels for subsequent examination. In addition, employees, contractors, and visitors wore appropriate detection devices to monitor for any sources of onsite radiation exposure.

OAK RIDGE RESERVATION

The Oak Ridge Reservation consists of three major facility sites: the Y-12 Plant, the Oak Ridge National Laboratory (ORNL), and the K-25 Gaseous Diffusion Plant (K-25 Site). All are located in a moderately populated area adjacent to the Clinch River 40 km from the metropolitan zone of Oak Ridge.

Y-12 Plant

Ambient airborne radioactivity was monitored by a network of 12 samplers located around the plant perimeter, with analyses for uranium particulates (all 12 samplers) and fluorides (11 of 12). Two additional stations located at the east and west ends of the site monitored continuously for total suspended particulates, and two stations at the plant monitor continuously for sulphur dioxide.

Water and sediment monitoring was conducted weekly at three locations, on the Upper Bear Creek and on the East Fork Poplar Creek. Analyses for surface waters were for ^{241}Am, ^{237}Np, plutonium, ^{99}Tc, uranium, and thorium.

Groundwater monitoring wells were located both up and down-gradient from each facility at about 25 locations for a total of about 244 wells. Samples were collected and analyzed quarterly to annually, based on regulatory requirements. Analyses were conducted for tritium, gamma-emitters, gross alpha and beta, and strontium, and included nonradiological parameters. By 1992, about 100 of these wells had been identified as being inappropriate to the program and were in the process of being approved for plugging and abandonment.

Oak Ridge National Laboratory

Ambient airborne radioactivity was measured biweekly and composited for long-lived isotope detection annually at a network of 19 samplers (27 stations read weekly, composited quarterly until 1992) located around the plant perimeter. Analyses were performed to detect iodine, gross alpha and beta, uranium, thorium, plutonium, ^{60}Co, and ^{137}Cs. Two of the stations provided remote monitoring and noble gas detection, and three monitored for ^{3}H only.

Water and/or sediment sampling was conducted weekly at 15 locations on the numerous creeks at the site and on the Clinch River. Analyses were conducted monthly at 12 of the sites for gamma-emitters, gross beta, gross alpha, strontium, tritium, uranium, and/or plutonium; analyses were conducted weekly at one location for tritium, gamma-emitters, gross alpha and beta, and strontium. Further analyses were conducted quarterly at two local community potable water treatment plants for the above parameters.

Groundwater was monitored using a network of wells both up- and down-gradient from each facility, in 11 hydrogeologically separate zones, for a total of about 162 wells. Samples were collected and analyzed quarterly to semiannually based on regulatory requirements. Analyses were conducted for tritium, gamma-emitters, gross alpha and beta, and strontium, and included nonradiological parameters. Six of the wells were plugged and abandoned in 1992.

K-25 Gaseous Diffusion Plant

Ambient airborne radioactivity was continuously monitored over 24 hours every sixth day at a network of five samplers located in the predominant wind directions. Analyses were performed to detect uranium and such nonradioactive parameters as total suspended particulates, chromium, nickel, and lead.

Water monitoring was conducted at seven site perimeter and seven outfall mixing locations on Poplar Creek, East Fork Poplar Creek, and the Clinch River. Sample locations were continuously monitored for pH and radioactivity, and both water and sediments were sampled quarterly at three of the locations. Other locations were composited over a 24-hour period then analyzed monthly. Samples were analyzed for gross alpha and gross beta-gamma radioactivity and for specific radionuclides significant for the site such as plutonium and uranium.

Groundwater was monitored using a network of wells both up- and down-gradient from each facility, in 14 hydrogeologically separate zones, for a total of about 191 wells, of which 111 were installed in 1992. Samples were collected and analyzed quarterly to semiannually, based on regulatory requirements. Analyses were conducted for tritium, gamma-emitters, gross alpha and beta, and strontium, and included nonradiological parameters.

Offsite or Combined

Besides the specific monitoring locations noted above for each facility, additional monitoring was conducted. Milk was sampled monthly in four nearby communities and at two remote locations and analyzed for ^{131}I and strontium. Fish were sampled at three locations semiannually. Deer harvests were surveyed and analyses conducted on bone, liver, and muscle. Fauna samples were analyzed for gamma-emitters, strontium, mercury, and PCBs. Vegetation was sampled at 16 pasture locations and six pine areas and analyzed for uranium, technetium, and fluoride.

Residential drinking water monitoring was initiated in September 1992 at 20 offsite wells to ensure that drinking water from aquifers met primary drinking water standards. Analyses were initially performed for metals such as mercury, lead, and selenium and for halides, nitrates, volatile organics and inorganics, gross alpha and beta, ^{99}Tc, strontium, ^{3}H, and gamma-emitters.

Sediments were sampled annually at six locations from Poplar Creek and two from the Clinch River. Analyses were performed for mercury, lead, fluorides, uranium, nickel, copper, zinc, chromium, manganese, aluminum, thorium, and cadmium. Soil samples were collected semiannually at the perimeter sampling stations of ORNL and the Y-12 Plant and at 14 locations around K-25 Site. Analyses were similar to those for sediments noted above.

External gamma radiation doses were monitored at 10-minute intervals at four locations on the perimeter of ORNL and 11 locations on the perimeter of the Oak Ridge Reservation. The Oak Ridge Reservation Perimeter Air Monitoring (PAM) system provides measurements used for calculating dose, which is reported in the SER. PAM results alone are reported in the annual airborne dose assessment report submitted in accordance with NESHAP requirements.

PADUCAH GASEOUS DIFFUSION PLANT

The environmental surveillance program for Paducah and vicinity included the collection and analysis of samples from all potential exposure pathways. Environmental radiation exposure rates were measured, and air, groundwater, and surface waters were routinely monitored for radioactivity and nonradioactive contaminants at a number of onsite, boundary and distant locations. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of Paducah operations on the environment.

Ambient airborne radioactivity was sampled continuously at a network of samplers with onsite samplers in the cardinal wind directions, plant boundary samplers north and east (the predominant wind directions), samplers 1.6 km (1 mi) from the site in the cardinal wind directions and in the southeast, and one sampler in the nearest community (2 km east of the site). Analyses were performed weekly to detect gross alpha and beta, uranium, technetium, and fluorides.

Surface water monitoring was conducted from a weekly compositor and a concurrent grab sample on the north-south diversion ditch, with an additional composite annually. Samples were obtained monthly upstream on Big Bayou Creek and both up- and downstream on the Ohio River. Runoff from both a residential and an inert landfill were monitored quarterly. Sampling at the residential landfill was terminated upon closure in 1990, when sampling was shifted to the new landfill. Analyses were conducted for uranium, uranium isotopic fraction, ^{237}Np, ^{239}Pu, ^{230}Th, gross alpha and beta, ^{99}Tc, and nonradioactive parameters.

Groundwater onsite was monitored using a network of 38 wells around various waste disposal areas and the plant perimeter. Analyses were conducted quarterly on all but five of the wells for alpha- and beta-emitters, uranium, and nonradiological parameters. Analyses were conducted on all the wells annually in the first calendar quarter for americium, radium, cesium, numerous metals, alkalinity, and dissolved solids.

Extensive groundwater offsite monitoring was initiated in 1988 in response to offsite detection of trichloroethylene (TCE) and technetium in groundwater monitored for specific spills caused by past practices. At the end of 1992, 257 residential wells were sampled around PGDP. Those showing detectable contamination were placed on a monthly or weekly monitoring schedule (based on usage and potential for unacceptable levels), with 19 more

remote wells on a bimonthly schedule. Two wells showing unacceptable levels were removed from service by providing community water.

Food crops, fish, wildlife, vegetation, soil, and sediments were sampled at 29 locations on and near the site to characterize the PGDP environs. Milk was sampled monthly in four nearby communities and at two remote locations and analyzed for ^{131}I and strontium. Animal tissue samples were obtained from deer, rabbit, raccoon, and squirrel. Fish were sampled at 18 locations in Big and Little Bayou Creeks and the Bayou/Ohio confluence area, Metropolis Lake (on the Ohio River, near PGDP), and five ponds in the wildlife management area surrounding PGDP. Samples were analyzed for gamma-emitters, strontium, mercury, and PCBs. Vegetation was sampled at 18 locations on a quarterly basis.

Soil was sampled annually at 10 locations, including four at the cardinal locations at the plant boundary, one 8 km distant, and two 13 and 15 km distant from PGDP. Sediments were sampled from 28 locations in and around PGDP. Analyses were performed for uranium, ^{99}Tc, and nonradioactive substances.

External gamma radiation doses were determined through use of TLDs at 15 locations, with four at the plant perimeter, two at the site boundary, five at 1.6 km distance, one at each of three nearby residences, and one quality control location 3 km distant from the site. In addition, there were two quality control locations at the site where a total of 10 control TLDs were placed.

PORTSMOUTH GASEOUS DIFFUSION PLANT

The environmental pathways by which radioactive and nonradioactive materials may have been transported from the Portsmouth Site to nearby populations included passage directly through atmospheric transport from stacks and small point sources; indirectly through soils, foodstuffs or animals; and from releases of treated liquid effluents. The environmental surveillance program for the site vicinity included the collection and analysis of samples from all potential exposure pathways. Environmental radiation exposure rates were measured, and air, groundwater, and surface waters were routinely monitored for radioactive and nonradioactive contaminants at a number of onsite, boundary, and distant locations. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of PORTS operations on the environment.

Ambient airborne radioactivity was sampled continuously at a network of samplers with five onsite, eight site boundary, and four near-site samplers. Analyses were performed monthly to detect gross alpha and beta, uranium, and technetium (dependent upon gross radioactivity results), with weekly analyses for fluorides. Samples were composited for annual analyses of specific radionuclides.

Surface water monitoring was conducted at four locations on Big and Little Beaver Creeks, three locations on Big Run Creek, and both up- and downstream on the Scioto River. Runoff from both a residential and an inert landfill were monitored quarterly. Sampling at the residential landfill was terminated upon closure in 1990, when sampling was shifted to the new landfill. Analyses were conducted for gross alpha and beta, uranium, ^{99}Tc, and nonradioactive parameters.

Groundwater onsite was monitored using a network of wells at eight locations around the site and at 10 local resident sanitary water systems. Sampling was conducted semiannually. Analyses were conducted for alpha- and beta-emitters, technetium, radium, uranium, and nonradiological parameters.

Biota (except wildlife) were sampled annually to characterize the PORTS environs. Food crop samples at 17 locations were collected. Milk sampling, discontinued in 1984 upon closure of the commercial dairies, was restarted in 1992, when four area dairy farms were found during the land use census. One egg sample location was started in 1992 from local produce. Milk and egg samples were analyzed for uranium and technetium, and egg samples were also analyzed for gross alpha radioactivity. Fish were sampled at all receiving streams surrounding PORTS, including Big and Little Beaver Creeks, Big Run Creek, and the Scioto River, and at upstream locations for background checks. All locations involved sport fishing, as there were no commercial fisheries near the site. Fish samples were analyzed for gross alpha, uranium, and technetium.

Soil and vegetation was sampled semiannually at 31 concurrent locations, with eight onsite locations. Offsite samples were divided into three groups, with nine locations on or adjacent to the site boundary, six locations near the site, and 13 distant locations. Sediments were sampled upstream and downstream of plant liquid discharge points semiannually. Soil, vegetation, and sediment analyses were for uranium, technetium, and alpha radioactivity.

External gamma radiation doses were determined through use of TLDs at 10 onsite and 23 offsite locations, with reference and control TLDs each in a separate onsite location. The TLDs were analyzed quarterly. One location showed elevated readings on the site near the site boundary; public dose was estimated based on calculations of allowed transit time for members of the public versus dose rate.

Ohio Field Office

FEED MATERIALS PRODUCTION CENTER

The environmental pathways by which radioactive and nonradioactive materials may have been transported from Feed Materials Production Center (FMPC) to nearby populations included passage directly through atmospheric transport from stacks and small point sources, indirectly through soils, food stuffs, or animals, and from releases of treated liquid effluents. The environmental surveillance program for the site vicinity included the collection and analysis of samples from all potential exposure pathways. Environmental radiation exposure rates were measured, and air, groundwater, and surface waters were routinely monitored for radioactivity and nonradioactive contaminants at a number of onsite, boundary, and distant locations. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of FMPC operations on the environment.

Ambient airborne radioactivity was sampled continuously at a network of samplers with two onsite in the prevailing wind direction, seven at the site boundary, five near-site (1 km to 4 km) of which two were in the prevailing wind direction, and two distant (10 km and 25 km). Analyses were performed weekly to detect gross beta and uranium, and nonradiological

parameters such as total particulates and opacity. Samples were composited for annual analyses of specific radionuclides such as radium, neptunium, plutonium, and thorium.

In addition to routine ambient air monitoring, FMPC monitored for radon and radon daughter products at 21 locations on the site boundary, 16 locations adjacent to storage silos, four other onsite locations, four sites co-located with offsite air monitoring stations, three placed at nearby residences, two control locations 20 km distant opposite the prevailing wind direction, and two control locations co-located with the control ambient air samplers.

Surface water was grab-sampled at one upstream (daily) and two downstream locations (one daily, one weekly) on the Great Miami River. Analyses were conducted weekly for uranium and for other nonradioactive parameters. River samples were composited monthly and analyzed for ^{226}Ra and ^{228}Ra. The monthly composites were in turn composited semiannually for analyses of ^{137}Cs, ^{90}Sr, and ^{99}Tc. Surface water samples were obtained weekly (when the wash had flow) at three onsite, one upstream, and two downstream locations on Paddy's Run. Composites at the upstream offsite (bimonthly) and downstream offsite (monthly) locations were analyzed for radium. Sediment samples were obtained at eight locations up- and downstream from FMPC on the Great Miami River and at 25 locations upstream and 18 locations downstream of the confluence of the plant outfall and Paddy's Run. Analyses were for ^{99}Tc, uranium, thorium, radium, and plutonium.

Groundwater onsite was monitored using a network of wells at 13 locations around the site and at 30 private wells offsite. Sampling was conducted monthly, quarterly, or annually based on regulatory requirements. Onsite analyses were conducted quarterly for uranium and semiannually for alpha- and beta-emitters and annually for nonradiological parameters. Offsite analyses were conducted monthly for uranium and nonradiological parameters similar to onsite samples.

Food crop samples at 17 locations were collected. Produce was sampled at 28 nearby and 13 control locations. Milk was sampled at the dairy facility adjacent to FMPC and at one control location. Fish were sampled from three locations on the Great Miami River. Samples were analyzed for uranium.

Soil and grasses were concurrently sampled semiannually at 20 locations prior to 1992 and at 30 locations by 1994. Analyses were for fluorides and uranium in grasses and for uranium in soils.

External gamma radiation doses were determined at the same locations as the ambient air monitoring stations.

BATTELLE COLUMBUS LABORATORIES

In-stack air samplers continuously monitored the exhaust stack effluent release from each Battelle Columbus Laboratories (BCL) facility to assess the effectiveness of systems controlling airborne emissions. Seven continuous stack monitors at the West Jefferson (WJ) site ensured detection of any inadvertent release of radioactive material and provided data for prompt assessment. Particulate samples were collected from each exhaust stack. WJ site Hot Cell stack air samples were upgraded in CY 1994. The filters, which were changed weekly and

analyzed for gross alpha and beta activities, were composited monthly for gamma analysis and quarterly for radiochemical analysis. Supplementary air sampling was continuously performed at four site perimeter locations and analyzed weekly for gross alpha and beta.

Sanitary liquid effluent was sampled with a continuous water-sampling system and analyzed weekly for gross alpha and beta activity in suspended and dissolved fractions. The weekly samples were held, composited, and spectrometrically analyzed for gamma activity as well as specifically for ^{239}Pu, ^{238}Pu, ^{129}I, ^{90}Sr, ^{226}Ra, and ^{228}Ra at the end of each month in 1990 and 1992 and quarterly for ^{239}Pu, ^{238}Pu, ^{90}Sr, and natural uranium during 1992 through 1994. Groundwater samples were collected from three wells and analyzed. Weekly tap water samples were collected at the Nuclear Sciences Area, composited, and analyzed monthly for gross alpha and beta activity.

Grass and food crop samples were collected from the surrounding area to detect uptake and concentration of radionuclides by plant or animal life. Sampling sites were chosen at locations of maximum deposition as predicted by meteorological studies. Grass and food crop (soybean or field corn) samples were also collected and analyzed for ^{239}Pu, ^{238}Pu, ^{90}Sr, and natural uranium. A qualitative analysis by gamma scan was also performed.

Sediment samples were routinely collected semiannually at two locations and analyzed for ^{239}Pu, ^{238}Pu, ^{90}Sr, and natural-U. During 1990 through 1992 soil samples were collected annually from 14 locations at varying distance and directions within a 5-mi radius. In 1993 and 1994 soil samples were collected annually from 20 locations at varying distance and directions within a 6-mi radius. These samples were analyzed for ^{239}Pu, ^{238}Pu, and ^{90}Sr. A qualitative gamma scan was also performed.

Fish were collected from Battelle Lake and Darby Creek and analyzed for radioactive material.

RMI EXTRUSION PLANT

The air effluent from uranium operations was discharged from two stacks that were continuously monitored when in operation. Variations in the number of samples from each stack occurred due to intermittent usage of production areas. Perimeter air samplers were located on the plant boundary fence line. Filters were changed every 7 to 10 days during regular plant operations. A TLD monitoring system was in place to determine radiation levels at the site perimeter. The RMI Extrusion Plant's wastewater system was sampled and analyzed for uranium and technetium. Annual soil samples in the area of the site were collected, analyzed for uranium, and compared to levels detected the previous year. Offsite soil sample locations were determined using 0.8-km (0.5-mi) concentric rings originating from the center of the plant and extending outward to 2.4 km (1.5 mi). Composite sediment samples were taken from the Fields Brook creek bed and analyzed for uranium content. A total of 38 monitoring wells were sampled quarterly until 1991 and then sampled annually and analyzed for uranium, technetium, and gross alpha and beta radiation.

MOUND

The Mound environmental program monitored air, water, vegetation, foodstuffs, and sediment samples that were collected from the environment up to 64 km (40 mi) from the boundaries. These samples were analyzed for specific radionuclides, primarily ^{3}H and ^{238}Pu.

Air was monitored both at the release point and offsite. During 1992 through 1994, this included 7 perimeter and 15 offsite locations. Stacks that potentially release radioactive materials at Mound were sampled continuously. The offsite air-sampling network consisted of 15 continuously operating air-sampling stations used for sampling tritium oxide and plutonium. Tritium samples were measured weekly, and weekly plutonium samples were measured as monthly composites for stations within 1 km of the site and as quarterly composites for more distant samples. In 1990 and 1991, 10 sampling stations were located within a 1.6-km (1-mi) radius of the site, four samplers were located in or adjacent to population centers, and the remaining sampler was approximately 45 km (28 mi) from Mound in the direction of least prevailing wind. During 1992 through 1994, 11 sampling stations were located within a 1.0-km (0.6-mi) radius of the site, three samplers were located in or adjacent to population centers, and the remaining sampler was approximately 45 km (28 mi) from Mound in the direction of least prevailing wind.

Water was sampled along the banks of the Great Miami River to provide samples that were representative of river water after mixing with the Mound effluent. In 1990 and 1991, samples were collected monthly and weekly and analyzed for ^{238}Pu and ^{3}H. In addition, ^{233}U, ^{234}U, ^{238}U were also monitored. Seven additional surface water locations, such as ponds, were sampled quarterly for plutonium and tritium. During 1992 through 1994, water samples were collected every 24 or 96 hours. Tritium water samples were analyzed four times a week, and Pu and U water samples were composited and analyzed every two weeks. Additional surface water locations, such as ponds, were sampled quarterly for plutonium and tritium. Drinking water from communities and private wells were sampled and analyzed for ^{3}H.

Various locally grown foodstuffs and vegetation were collected from the surrounding area to determine whether there was significant uptake and concentration of radionuclides in plant or animal life. Fish from the Greater Miami River were monitored on an infrequent basis.

WEST VALLEY DEMONSTRATION PROJECT

The effluent and environmental monitoring program provided data on surface waters, soils, sediments, food and produce, and the effluent air and liquids that could have provided pathways for the movement of radionuclides from the facility to the public. The primary focus of the monitoring program was on air and water pathways, as these could have been the major means of transport of radionuclides from the site.

Air sampling was performed at remote locations from the WVDP, at the perimeter of the site, and on the site itself. During 1990 through 1992, airborne particulate radioactive samples were collected continuously at five locations around the perimeter of the site and at four remote locations at Great Valley, West Valley, Springville, and Dunkirk, New York. In December 1992, a sixth perimeter location was added. Offsite and perimeter samples were analyzed weekly. Onsite, exhaust from each permitted fixed ventilation system serving the site's facilities was

continuously filtered, monitored, and sampled upon release to the atmosphere. Parameters measured include gross alpha and gross beta, tritium, and various isotopes such as ^{137}Cs and ^{90}Sr.

The largest single source of radioactivity released to surface waters from the Project was the discharge from the low-level waste treatment facility through the Lagoon 3 weir into Erdman Brook, a tributary of Frank's Creek. A water sampling station located on Frank's Creek, where Project site drainage leaves the security-fenced area, collected samples every half hour. Samples were retrieved weekly and composited both monthly and quarterly. Weekly samples were analyzed for tritium and gross alpha and beta radioactivity. The monthly composite was analyzed for strontium-90 and gamma-emitting isotopes and total uranium. A quarterly composite was analyzed for ^{14}C, ^{129}I, alpha-emitting isotopes, and total uranium. Several other sampling locations along site drainage collected samples for analysis to monitor surface runoff from the site. Offsite sampling was conducted on Cattaraugus Creek at Felton Bridge. Weekly samples from this location were analyzed for gross alpha, gross beta, and tritium. Monthly composites were analyzed for ^{90}Sr and gamma-emitting isotopes. Two surface water monitoring stations were also located upstream and downstream of the site on Buttermilk Creek. Samples from these locations were retrieved biweekly, composited monthly, and analyzed for tritium, gross alpha, and gross beta radioactivity. A quarterly composite was analyzed for gamma-emitting isotopes and ^{90}Sr. The quarterly composite from the upstream location was also analyzed for ^{14}C, ^{129}I, alpha isotopes, and total uranium.

Foodstuffs including fish, venison (deer meat), beef, milk, fruit, and vegetables were collected from near-site and remote locations and sampled for various isotopes including ^{90}Sr and ^{137}Cs.

Richland Operation Office

HANFORD

Environmental monitoring was performed in three surveillance zones: Nearby and distant community locations (up to 80 km from site), site perimeter (at the site boundary), and onsite (from operating facilities to the site perimeter).

The environmental pathways by which radioactive and nonradioactive materials may have been transported from the Hanford Site to nearby populations include passage directly through atmospheric transport from stacks and small point sources; indirectly through soils, foodstuffs, or animals; and from batch releases of treated liquid effluent. The environmental surveillance program for Hanford and vicinity included the collection and analysis of samples from all potential exposure pathways. Air, surface water, and groundwater were routinely monitored for radioactive and nonradioactive contaminants at a number of locations in the surveillance zones. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of Hanford operations on the environment.

Airborne radioactivity was monitored by collection of ambient air samples at each operating area and at 24 onsite, 14 perimeter, nine nearby community, and six distant community locations.

Surface water was sampled in the Columbia River upstream of the site and at Richland, Washington, where it was used for municipal drinking water. Irrigation water from the Columbia River was also monitored. There were two perimeter and two nearby community river-sampling locations, and one perimeter irrigation water, nine onsite, and five perimeter drinking water locations (including four offsite drinking water supplies). Ponds at three onsite locations were also sampled. Columbia River sediments were sampled at three perimeter locations and one each in nearby and distant communities. Water quality was also monitored by the U.S. Geological Survey at the Priest Rapids Dam for baseline environmental data (8-km upstream from the site) and at Richland. All samples were analyzed for gross alpha and beta, ^{3}H, ^{90}Sr, gamma-emitters, and various nonradioactive parameters.

Groundwater was sampled at wells located near operating areas and along potential transport pathways in the confined and unconfined aquifers located throughout the below-ground regions of the site. There were 567 onsite groundwater sampling locations. Previously, injection wells, and leaking tanks, and piping resulted in large-scale releases of tritium, plutonium, fission products, chlorinated solvents, and other (radioactive and nonradioactive) hazardous materials into the various aquifers, and monitoring was performed to track these plumes. All samples were analyzed for gross alpha and beta, ^{3}H, ^{90}Sr, gamma-emitters, and contaminants of interest.

Milk, crops, soil, and native vegetation were sampled at up to 38 local farming and onsite locations, and numerous wildlife and vegetation samples were obtained along access routes (such as river shorelines and aerial, roadway, and railroad beds) and at approximately 73 onsite waste disposal locations. Items sampled include all commercially and locally grown produce. Salmon and other fish samples were collected at the site perimeter in the Columbia River, All samples were analyzed for gross alpha and beta, ^{3}H, ^{90}Sr, gamma-emitters, and nonradioactive parameters such as conductivity, pH, and dissolved oxygen.

External gamma radiation doses were monitored using TLDs at approximately 34 onsite, 39 perimeter, and 15 offsite locations. Additionally, external radiation surveys were conducted at access routes and at approximately 73 onsite waste disposal locations.

Rocky Flats Field Office

ROCKY FLATS PLANT

Particulate air samples were taken from each of 13 ventilation exhaust systems points in research and production facilities and analyzed for alpha-emitting radionuclides (uranium, plutonium, and americium), tritium, and beryllium. At regular intervals, particulate samples from a continuous sampling system were removed from each exhaust system and radiometrically analyzed for long-lived alpha-emitters. At the end of each month, individual samples from each exhaust system were composited into larger samples by location. Ambient air samplers monitored airborne plutonium from stations located on RFP, along the property perimeter, and in nearby communities. Filters were collected biweekly from onsite samplers and analyzed for total long-lived alpha activity. Filters from perimeter and community samplers were collected biweekly, composited by location, and analyzed monthly for plutonium.

Discharges from ponds located on North Walnut Creek, South Walnut Creek, and Woman Creek were sampled and analyzed for chemical, biological, and radiological parameters.

Samples of raw water supply for RFP were taken from Ralston Reservoir and South Boulder Diversion Canal and analyzed for plutonium, uranium, americium, and tritium. Community water monitoring included sampling and analysis of public water supplies and tap water from several surrounding communities. The water was analyzed for plutonium, uranium, americium, and tritium concentrations. Groundwater samples were collected quarterly and analyzed for chemical and radionuclide parameters. Emphasis was placed on defining the magnitude and extent of contamination occurring at identified environmental restoration sites. Surface water sampling was conducted at 30 locations, and sediment sampling was conducted at 20 of those locations. Storm event monitoring was initiated through use of 13 stream gauges.

Soils were sampled at 40 sites located in two concentric circles of approximately 1.6-km and 3.2-km (1-mi and 2-mi) radii from the center of RFP.

Thermoluminescent dosimeters were used to measure external penetrating gamma radiation exposure at 46 locations in 1990 and 1991 and at 51 locations on and off RFP during 1992 through 1994.

Savannah River Site

SAVANNAH RIVER SITE

Environmental monitoring at Savannah River Site (SRS) was performed in three surveillance zones: Nearby and distant community locations (up to 80 km from site), site perimeter (at the site boundary), and onsite (from operating facilities to the site perimeter).

The environmental pathways by which radioactive and nonradioactive materials could have been transported from the SRS to nearby populations included passage directly through atmospheric transport from stacks and small point sources, indirectly through soils, food stuffs or animals, and from releases of treated liquid effluents. The environmental surveillance program for SRS and vicinity involved collecting and analyzing samples from all potential exposure pathways. Environmental radiation exposure rates were measured, and air, groundwater, and surface waters were routinely monitored for radioactivity and nonradioactive contaminants at a number of locations in each surveillance zone. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of operations on the environment.

Ambient airborne radioactivity was monitored by collection of ambient air samples at each operating area and at various site and near-site locations. Sample locations were monitored continuously and were analyzed weekly for alpha-, beta-, and gamma-emitters and ^{238}Pu, monthly for composites (^{239}Pu, ^{89}Sr, ^{90}Sr), and biweekly for tritium.

Surface water was sampled in the Savannah River upstream of the site and downstream, where it was used for municipal drinking water. Various ponds and six creeks at several onsite locations were continuously sampled, with monthly grab samples on seven stream locations and two Savannah River locations, as well as 76 active effluent outfalls within the site. Water quality was monitored continuously and analyzed weekly for gross alpha-emitters, beta-emitters, tritium, and $^{89/90}Sr$. Seepage basins were sampled quarterly for alpha- and beta-emitters and tritium. Groundwater was sampled quarterly and monthly, respectively, for alpha-, beta-, and gamma-emitters, ^{3}H, and total alpha-emitting Ra. Radium analyses were discontinued after the

first quarter of 1994. During 1994, 64 wells were removed from the groundwater monitoring program. Rainwater was monitored quarterly for alpha-, beta-, and gamma-emitters, $^{238/239}$Pu, $^{89/90}$Sr, and ^{3}H.

Milk, foods, drinking water, fish, waterfowl, game animals, and beaver, along with local vegetation and soils, were also sampled for radiological analyses. Milk was analyzed biweekly for ^{131}I, ^{137}Cs, and ^{3}H and quarterly for ^{90}Sr. Food was analyzed annually for gamma-emitters, uranium/plutonium ratios, and ^{90}Sr. Drinking water was sampled for alpha- and beta-emitters and for tritium on a monthly or quarterly basis for onsite, semiannually offsite, and daily for water treatment plants (with monthly analysis). All locations were analyzed annually for ^{90}Sr.

Items sampled included all commercially grown and any locally cultivated or gathered produce. Soils and sediments were sampled annually for $^{89/90}$Sr, $^{238/239}$Pu, and gamma-emitters. Vegetation was sampled quarterly or annually for alpha-, beta-, and gamma-emitters, ^{3}H, and $^{89/90}$Sr.

External gamma radiation doses were monitored with TLDs spaced at boundary locations at approximately 1.6-km (1-mi) intervals, except within 3.2 km (2 mi) of the A/M Area and the nearby Vogtle commercial nuclear facility, where the interval was about 0.4 km (0.25 mi). Thermoluminescent dosimeters were read quarterly. Additionally, external radiation surveys were conducted in the area within and surrounding the SRS, encompassing a survey area of about 20,500 km^2.

Remedial Action Sites

COLONIE INTERIM STORAGE SITE

Radiological environmental monitoring during 1990 and 1991 included sampling for external gamma radiation exposure and total uranium, ^{226}Ra, and ^{232}Th concentrations in surface, sediment, and groundwater. In 1992 the monitoring regime was revised: Monitoring for radioactivity in exhaust from the main building HEPA filter during clean up and pre-demolition activities was conducted, and monitoring for ^{226}Ra was not performed.

The monitoring system included onsite, property line, and offsite stations. External gamma radiation was measured using tissue-equivalent thermoluminescent dosimeters. One dosimeter was located onsite, ten were stationed on the property line, and four were located offsite.

Surface water was monitored in onsite drainage and upstream and downstream on Patroon Creek. Groundwater was sampled from a network of 22 wells including upgradient and downgradient wells. Samples of surface and groundwater were analyzed for total uranium, ^{226}Ra, and ^{226}Th.

Composite sediment samples were collected quarterly at surface water sampling locations where sediment was present (two upstream and two downstream locations). Samples were analyzed by gamma spectroscopy for total uranium, ^{226}Ra, and ^{232}Th.

In 1992, the number of external gamma radiation monitoring locations was reduced from 15 to 13 and sampled semiannually instead of quarterly. One surface water sampling location was eliminated from the monitoring program in 1992, and the frequency of sampling was changed from quarterly to semiannually. The frequency of groundwater monitoring at some of the network of wells was reduced, and ^{226}Ra analysis was eliminated.

HAZELWOOD INTERIM STORAGE SITE

Radiological environmental monitoring at Hazelwood included sampling for radon concentrations in air, external gamma radiation exposure, and total uranium, ^{226}Ra, and ^{230}Th concentrations in surface water, sediment, and groundwater. The monitoring systems included onsite, property line, and offsite stations.

Radon monitoring was performed quarterly using Alpha-Track detectors. The detectors measured radon concentrations at six onsite, five property line, and two offsite locations. In 1992, monitoring at one of the property line detectors (west side) was discontinued. In addition to measuring radon concentrations in air, radon flux data, which provides an indication of the rate at which radon is emitted from a surface, was collected from the surface of each interim storage pile.

External gamma radiation exposure rates were measured as part of the routine environmental monitoring program. Measurement was performed using tissue-equivalent thermoluminescent dosimeters stationed at the same locations as the radon detectors.

Surface water sampling was conducted quarterly for uranium, ^{226}Ra, and ^{230}Th at locations established on the basis of potential contaminant migration and discharge routes from the site. ^{226}Ra concentrations were determined by radon emanation. ^{230}Th concentrations were determined by the photon/electron-rejecting alpha liquid scintillation method. In 1992, the fluorometric method of measurement for uranium was replaced by kinetic phosphorescence.

Sediment sampling for total uranium, ^{230}Th, and ^{226}Ra concentrations was conducted quarterly at surface water sampling locations where sediment was present. Sediment sample analysis was performed using alpha spectrometry.

Groundwater was sampled quarterly for the same radionuclides using the same methods for surface water sampling. A network of twelve monitoring wells were used in 1990 and 1991. Five new wells were added to the network in 1992 as part of the St. Louis data gap sampling program.

MAYWOOD INTERIM STORAGE SITE

Radiological environmental monitoring at the Maywood site included sampling for the following: Radon and thoron (1991-92 only) concentrations in air; external gamma radiation exposure; and $^{226/228}$Ra, $^{230/232}$Th, and total uranium concentrations in surface water, sediment, and groundwater.

Radon and thoron (1991-92 only) detectors monitored radon and thoron concentrations on a quarterly basis at 2 onsite, 10 fence line, and 3 offsite locations.

External gamma radiation monitoring was conducted using tissue-equivalent thermoluminescent dosimeters at the same locations used for radon and thoron monitoring. Each dosimetry station contained a minimum of four dosimeters. One dosimeter in each station was exposed for a full year at the end of each quarter, at which time the exposed dosimeter was exchanged with a new dosimeter.

Surface water sampling was conducted quarterly at sampling locations both upstream and downstream of the site. Samples were analyzed for total uranium, ^{226}Ra, and ^{232}Th.

Sediment samples were collected quarterly at upstream and downstream surface water sampling locations where sediment was present. Sediment samples were analyzed for total uranium, ^{226}Ra, and ^{232}Th.

The groundwater monitoring network at the Maywood site consisted of 31 wells installed between 1984 and 1989. The network included 10 well pairs, a cluster of 3 wells, and 8 single wells. Each well pair consisted of a shallow well completed in the unconsolidated sediments (overburden) and a deeper well completed in competent bedrock. One well was replaced in 1992. During 1990 and 1991, groundwater radiological analysis consisted of quarterly analyses for total uranium, ^{226}Ra, and ^{232}Th. Based on the sampling results from prior years, in 1992 sampling was scaled back to the analysis of samples from 15 wells (7 overburden and 8 bedrock).

MIDDLESEX SAMPLING PLANT

Radiological environmental monitoring at the Middlesex Plant included sampling for the following: Radon and thoron (1991-92 only) concentrations in air; external gamma radiation exposure; and ^{226}Ra, ^{232}Th, and total uranium concentrations in surface water, sediment, and groundwater.

Radon and thoron (1991-92 only) monitoring was performed to obtain air concentrations on a quarterly basis. Radon and thoron detectors were maintained at 8 onsite, 17 site boundary, and 2 offsite locations. In 1992 the number of monitoring locations was reduced from 27 to 19. Radon flux from the storage piles was monitored during 1990 and 1991 using charcoal canisters placed on the piles for 24 hours then sealed and shipped for analysis.

External gamma radiation was measured using tissue-equivalent thermoluminescent dosimeters at the same 27 locations (reduced to 19 in 1992) where radon/thoron monitoring occurred. One dosimeter in each station was exposed for a full year at the end of each quarter, at which time the fully exposed dosimeter was exchanged with a new dosimeter.

Surface water sampling for total uranium, ^{226}Ra, and ^{232}Th was conducted quarterly at one upstream, three downstream, and one onsite location.

Sediment sampling was conducted on a quarterly basis at the surface water sampling locations. Sediment samples were analyzed for ^{226}Ra, ^{232}Th, and total uranium.

The groundwater monitoring network consisted of 12 shallow (about 10 feet deep), and 7 deep (about 50 feet) wells located upgradient and downgradient of the site. These wells were sampled quarterly and analyzed for ^{226}Ra, ^{232}Th, and total uranium in the same manner as surface water samples. In 1992 the scope of the groundwater sampling program was reduced form 19 wells to 7 based on the results from previous years analyses. The spectrum of radiological analyses, however, was unchanged.

NEW BRUNSWICK SITE

Radiological environmental monitoring at the New Brunswick Site included sampling for the following: Radon and thoron concentrations in air; external gamma radiation exposure; and $^{226/228}Ra$, $^{228/230/232}Th$, ^{137}Cs, ^{241}Am, ^{239}Pu, and total uranium concentrations in surface water, sediment, and groundwater.

Radon and thoron monitoring was conducted at 28 stations onsite (4 stations) and along the site perimeter (24 stations).

External gamma radiation was monitored quarterly using tissue-equivalent thermoluminescent dosimeters. The dosimeters were grouped in stations at the same locations as the radon and thoron detectors.

Surface water and sediment sampling was conducted at two locations downstream of where site runoff would be expected to enter a tributary of the Raritan River.

Groundwater sampling was conducted using a monitoring network of 13 onsite wells. Groundwater, surface water, and sediment samples were analyzed for total uranium, $^{226/228}Ra$, $^{228/230/232}Th$, ^{241}Am, ^{239}Pu, and ^{137}Cs.

NIAGARA FALLS STORAGE SITE

Radiological monitoring at the Niagara Falls Storage Site included monitoring for the following: Radon concentrations in air; onsite external gamma radiation exposure; and ^{226}Ra and total uranium concentrations in surface water, sediment, and groundwater.

Radon concentrations were obtained quarterly using radon detectors located at 18 onsite, 19 property-line, and 9 offsite stations. In 1992 the number of stations was reduced from 46 to 23 because of completed remediation activities that reduced residual radioactivity. Radon flux at the surface of the storage pile was measured twice a year as part of the NESHAP's compliance program. Measurements were taken using activated charcoal canisters placed on the surface of the pile for an exposure period of 24 hours.

External gamma radiation was monitored using tissue-equivalent thermoluminescent dosimeters at stations in the same locations as the radon detectors. Each station contained a minimum of four dosimeters, one of which was exposed for a full year at the end of each quarter.

Surface water samples were collected quarterly in 1990 and 1991 and annually in 1992. Sampling locations included one upstream, two onsite, and two downstream. Surface water samples were analyzed for total uranium and ^{226}Ra.

Sediment samples were collected at surface water sampling locations where sediment was present. Sediment samples were analyzed for total uranium and ^{226}Ra.

Groundwater was sampled quarterly from a monitoring network of 47 wells in 1990 and 1991. In 1992, based on past sampling results and the slow groundwater flow rate, the number of wells sampled was reduced to 20, and sampling frequency was changed to annually. Both the upper and lower groundwater systems upstream, downstream, and onsite were included in the monitoring well network. Groundwater samples were analyzed for ^{226}Ra and total uranium in the same manner as surface water samples.

WAYNE INTERIM STORAGE SITE

Radiological environmental monitoring at the Wayne Interim Storage Site included sampling for the following: Radon and thoron concentrations in air; external gamma radiation exposure; and ^{226}Ra, ^{228}Ra (1991 and 1992), ^{230}Th (1992 only), ^{232}Th, and total uranium concentrations in surface water sediment and groundwater.

Radon and thoron sampling was conducted quarterly at 2 onsite, 11 fence line, and 2 offsite locations. The locations were changed in 1992 to provide for more complete coverage of the site boundary.

External gamma radiation monitoring was conducted using tissue-equivalent thermoluminescent dosimeters at the same station locations as the radon and thoron monitoring. Each station contained four dosimeters, one of which was exposed for a full year at the end of each quarter, at which time the fully exposed dosimeter was exchanged with a new dosimeter.

Surface water and sediment sampling was conducted at three locations; one upstream and one downstream on Sheffield Brook, and one onsite. In 1992, the one upstream location was not sampled because it was often dry. Additionally, the normally quarterly sampling frequency was reduced to semiannually sampling, and the number of analytical sampling parameters was reduced because the concentrations detected were essentially at background levels during the previous five years.

Groundwater was sampled using a well network that included wells in the upper and lower groundwater systems. Quarterly sampling of 12 wells occurred in 1990, 17 wells in 1991, and 5 wells in 1992. The scope of the groundwater sampling program was reduced in 1992 by the deletion of all wells in bedrock and four wells in the overburden and by reducing the sampling frequency from quarterly to annually. This change was based on the results from past monitoring activities.

WELDON SPRINGS SITE

The radiological environmental program at the Weldon Springs Site included monitoring for radon, external gamma radiation, airborne radioactive particulates, and radioactive concentrations in surface water, and groundwater.

The radon gas monitoring program used a pair of radon detectors at each of 22 monitoring locations on- and offsite in 1990 and 1991, 30 locations in 1992, and 37 locations in 1993 and 1994. Radon concentrations were obtained quarterly.

Spherical environmental thermoluminescent dosimeters were used to monitor external gamma radiation exposure. The dosimeters were located at most of the same stations used for monitoring radon gas. Dosimeter data were collected quarterly.

Air particulate samplers were used to monitor radioactive air particulates at 11 locations in 1990 and 1991 and 17 locations during 1992 through 1994. Radioactive air particulate samples were collected on membrane filters that were exchanged on a weekly basis.

Surface water samples were collected and analyzed for radiological parameters from approximately 25 locations. Sampling sites were located near the Weldon Spring Chemical Plant/Weldon Spring raffinate pits and near the quarry. All samples were analyzed for uranium, and selected sites were analyzed for $^{226/228}$Ra, $^{228/230/232}$Th, gross alpha, and gross beta. Sampling periods ranged from bimonthly to annually at various locations.

Groundwater samples from the site well network were analyzed for total uranium, $^{230/232}$Th, $^{226/228}$Ra, and gross beta. The well network consisted of 23 offsite and 36 onsite wells in 1990, 23 offsite and 42 onsite in 1991 and 1992, 23 offsite and 49 onsite in 1993, and 23 offsite and 47 onsite in 1994. Sampling was performed primarily quarterly and annually with a few wells also providing semiannual samples.

Naval Reactors

BETTIS ATOMIC POWER LABORATORY

The environmental surveillance program for Bettis and vicinity included the collection and analysis of air, water, sediment, and vegetation samples. Air and groundwater were routinely monitored for radioactivity at a number of onsite, boundary and distant locations. Environmental radiation exposure rates were measured at a similar variety of locations. Measurements at boundary and onsite locations were compared to measurements at distant locations to assess the impact of Bettis operations on the environment.

Airborne radioactivity was continuously sampled by two particulate air samplers located at Large, Pennsylvania (8 km from the site), and West Mifflin, Pennsylvania (3 km from the site). Weekly samples were analyzed for gross alpha and gross beta activity. Onsite airborne effluent monitors were analyzed weekly to detect gross alpha and beta radioactivity and gaseous fission products (primarily ^{131}I and ^{125}Sb). Quarterly composites of onsite particulate samples from each exhaust point were analyzed for gross alpha-, beta-, and gamma-emitters. ^{220}Rn from thorium-handling areas was monitored annually.

Groundwater was sampled annually during 1990 through 1994 at approximately six onsite and three offsite spring locations. Analyses were performed for gross alpha and beta radioactivity, gamma-emitters and strontium at all spring monitoring locations. From 1992 through 1994, in addition to the above spring locations, groundwater was sampled annually at 11, 35, and 23 monitoring well locations, respectively. Wells were sampled and analyzed for gross alpha and beta radioactivity, gamma-emitters, radiostrontium and uranium. In 1992 and 1993, the samples were also analyzed for thorium.

From 1990 through 1994, stream sediment was sampled semiannually at approximately 12 locations along the Northeast Area, Bull Run/Thompson Run, and Streets Run (control sample) streams. These samples were analyzed for gross alpha and beta radioactivity, gamma-emitters and radiostrontium. During this period, vegetation samples were also collected annually at 9 locations along the above-mentioned streams and analyzed for radiostrontium and gamma-emitters. Background vegetation from streambeds was also collected from these same locations and analyzed for radiostrontium and gamma-emitters.

External gamma radiation doses were monitored with LiF TLDs at approximately 20 locations on or near the site boundary. Six TLDs were also located at offsite locations to measure the background radiation doses in the surrounding areas. The TLDs were read quarterly. Site perimeter radiation surveys were also conducted annually using a low energy survey meter.

KNOLLS ATOMIC POWER LABORATORY

The Knolls Atomic Power Laboratory consists of the Knolls Site, the Kesselring Site, and the Windsor Site.

Knolls Site

The radiological environmental monitoring program at the Knolls Site consisted of monitoring airborne and liquid effluents; Mohawk River water, sediment, and fish; groundwater; local municipal waters; and external gamma radiation levels at the site perimeter and selected offsite locations. Air was also sampled continuously at two stations, one located in the predominate upwind direction and the other located in the predominate downwind direction.

Airborne effluents were sampled for particulate radioactivity using particulate filter samplers, for iodine using activated charcoal cartridges, and for noble gas releases using continuous gas monitors, as appropriate. Sample filters from airborne effluents and from the upwind and downwind samplers are analyzed for gross alpha and gross beta, and activated charcoal cartridges are analyzed by gamma spectrometry.

Liquid effluent from the site is sampled at the outfalls and analyzed. Monthly samples are obtained and analyzed or combined into quarterly composite samples. Batch releases are sampled individually, and combined into monthly composite samples, and analyzed. Monthly samples are also obtained on local streams and combined into quarterly composite samples. Samples are analyzed for alpha, gross beta, ^{90}Sr, ^{137}Cs, ^{3}H, U, and Pu, as appropriate.

Mohawk River water and sediment are collected and analyzed quarterly at locations upstream and downstream (except when the river is frozen). Analyses include alpha, gross beta, ^{90}Sr, ^{137}Cs, ^{3}H, U, and Pu radioactivity, as appropriate. Mohawk River fish are collected annually at upstream and downstream locations and analyzed for ^{90}Sr, ^{137}Cs, and Pu radioactivity. Groundwater from the landfill area is sampled and analyzed quarterly; other wells are sampled and analyzed on an annual basis. Analyses include alpha, gross beta, ^{90}Sr, ^{137}Cs, and ^{3}H radioactivity. Local municipal waters are sampled monthly. The monthly samples are composited quarterly and analyzed. Analyses include alpha and gross beta radioactivity.

External gamma radiation levels were monitored with TLDs at each of 16 locations on the site boundary and at other selected offsite locations. The TLDs were changed and read quarterly.

Kesselring Site

The radiological environmental monitoring program at the Kesselring Site consisted of monitoring airborne and liquid effluents; Glowegee Creek water, sediment, and fish; groundwater; and external gamma radiation levels at the site perimeter and selected offsite locations. Air was also sampled continuously at two stations, one located in the predominant upwind direction and the other in the predominant downwind direction.

Airborne effluents were sampled for particulate radioactivity using particulate filter samplers, for iodine using activated charcoal cartridges, and for ^{14}C and ^{3}H releases using appropriate absorbers. Particulate sample filters and activated charcoal cartridges from airborne effluents and from the upwind and downwind samplers are analyzed are analyzed by gamma spectrometry. ^{14}C and ^{3}H absorbers are analyzed by liquid scintillation spectrometry. Noble gas releases are calculated based on reactor plant operating parameters.

Liquids containing radioactivity were collected and processed in batches. The batch samples were combined into monthly composite samples and analyzed by gamma spectrometry and for tritium.

Glowegee Creek water and sediment were collected and analyzed quarterly at upstream and downstream locations. Samples were analyzed by gamma spectrometry. Glowegee Creek fish were collected annually at upstream and downstream locations and analyzed by gamma spectrometry. Groundwater was sampled annually for radioactivity and analyzed by gamma spectrometry and for tritium.

External gamma radiation levels were monitored with TLDs at each of eight locations on the site boundary and at other selected offsite locations. The TLDs were changed and read quarterly.

Windsor Site

The radiological environmental monitoring program at the Windsor Site consisted of monitoring airborne and liquid effluents, drainage creek and Farmington River water and sediment, fish from the Farmington River, and external gamma radiation levels at the site perimeter and selected offsite locations. Air was also sampled continuously at two stations, one located in the predominate upwind direction and the other located in the predominate downwind direction.

Airborne effluents were sampled for particulate radioactivity using particulate filter samplers. Prior to the prototype plant being permanently shutdown, airborne effluents were also sampled for iodine using activated charcoal cartridges and monitored for ^{14}C and ^{3}H releases using appropriate absorbers. Noble gas releases were also calculated based on reactor plant operating parameters. Particulate sample filters and activated charcoal cartridges from airborne effluents and from the upwind and downwind samplers were analyzed by gamma spectrometry. ^{14}C and ^{3}H absorbers were analyzed by liquid scintillation spectrometry.

Liquids that might have contained radioactivity were collected and processed in batches. The majority of the water was reused in certain plant operations.

Quarterly, samples of water and sediment were collected and analyzed from the drainage brook, Goodwin Pond, which is the source of the brook, and the Farmington River (except when frozen). Samples were analyzed by gamma spectrometry. Farmington River fish were collected annually at upstream and downstream locations and analyzed by gamma spectrometry.

External gamma radiation levels were monitored with TLDs at each of 12 locations on the site boundary and at other selected offsite locations. The TLDs were changed and read quarterly.

NAVAL REACTORS FACILITY

Radiological environmental monitoring at the Naval Reactors Facility (NRF) included air and liquid effluent, groundwater, and soil, sediment, and vegetation monitoring.

Airborne effluents from the radiological facilities were monitored for particulate radioactivity by the use of fixed filter air samplers. Air discharged from the exhaust stacks was continuously drawn through a filter for a period of a month. The filter was then analyzed for radioactivity with a low-background alpha-beta counter. Tritium monitoring was also conducted at five locations.

Water samples were collected from the industrial waste ditch (IWD) sewage lagoons and cooling towers. The samples were analyzed for gross gamma radioactivity and tritium. Gamma spectrometry was performed to identify gamma-emitting radionuclides. Liquid scintillation was used to analyze for tritium.

Groundwater samples from the four NRF production wells within the security fence were collected quarterly and analyzed for gross alpha, gross beta, and tritium. In addition, 10 wells

outside the security fence were sampled for gross alpha and gross beta on a schedule consistent with plans outlined in NRF's Closure Plan for the IWD.

Soil and sediment samples were collected periodically from the areas surrounding the A1W and S1W seepage basins, the IWD, sewage lagoons, and areas downwind of exhaust stacks. Vegetation growing in and around the A1W and S1W seepage basins, the IWD, and areas downwind from exhaust stacks were collected at the same locations as the routine soil sampling locations. The vegetation samples were collected adjacent to but outside of the IWD stream bed. Samples were analyzed using gamma spectrometry.

Ionizing radiation levels at 17 locations along the site security fence and 8 other locations within the NRF property boundaries were also measured using thermoluminescent dosimeters. The dosimeters were collected and processed quarterly using an automated TLD processing system.

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APPENDIX D

GLOSSARY

GLOSSARY

absorbed dose - The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rad or gray (1 rad = 0.01 gray).

actinides - Elements in the periodic table with atomic number 89 (actinium) or greater, including thorium, uranium, and plutonium. All actinides are radioactive.

activation products - As cooling water circulates through a nuclear reactor or other high-energy research facility, certain impurities present in the water or construction materials can be converted into radioactive nuclides by exposure to neutrons. They become "activated." These activation products are usually distinguished from fission products (see fission products).

ALARA - Acronym for “as low as reasonably achievable.” The phrase describes an approach to radiation protection to control or manage exposures (both individual and collective to the work force and the general public) and releases of radioactive material to the environment as low as social, technical, economic, practical, and public policy considerations permit. As used in DOE Order 5400.5, ALARA is not a dose limit, but rather it is a process that has as its objective the attainment of dose levels as far below the applicable limits of the Order as practicable.

alpha particle (α) - A charged particle composed of two protons and two neutrons that is emitted during decay of certain radioactive atoms. Many naturally occurring radionuclides, such as isotopes of uranium and thorium, decay by emitting alpha particles. Alpha particles can be stopped by several centimeters of air or a sheet of paper.

background radiation - Ionizing radiation in an area from sources other than an operating nuclear facility. In this summary, it primarily refers to the natural radiation of the earth and its atmosphere, consisting of cosmic radiation and radioactive material in the earth, air, and water, and naturally occurring radioactive elements found in the human body and elsewhere.

becquerel (Bq) - One nuclear disintegration per second; the name for the SI unit of activity. 1 Bq = 2.7×10^{-11} Ci.

beta particle (β) - A charged particle, identical to an electron, that is emitted during the decay of certain radionuclides. Most beta particles can be stopped by clothing or a thin sheet of metal.

collective dose equivalent and collective effective dose equivalent - For the purposes of this report, the sum of the dose equivalents or effective dose equivalents of all individuals in an exposed population within an 80-km radius. They are expressed in units of person-rem or person-sievert. When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem or organ-sievert. For purposes of this report, the 80-km distance is measured from a point located centrally with respect to major facilities or DOE program activities.

committed dose equivalent - The predicted total dose equivalent to a tissue or organ over a 50-year period after a known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem or sievert.

committed effective dose equivalent - The sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem or sievert.

cosmic radiation - High-energy particulate and electromagnetic radiations that originate outside the earth's atmosphere. Cosmic radiation is part of the natural background radiation.

curie (Ci) - A unit of radioactivity. One curie equals 3.7×10^{10} (37 billion) nuclear transformations per second. For environmental monitoring, a curie is usually too large to work with conveniently, and fractional units are often used (see millicurie).

decay, radioactive - The spontaneous transformation of one radionuclide into a different nuclide, which may or may not be radioactive, or into a different energy state of the same radionuclide through the emission of alpha particles, beta particles, neutrons, and/or gamma rays.

deep dose equivalent - The dose equivalent in tissue at a depth of 1 cm deriving from external (penetrating) radiation.

dose - A general term denoting the quantity of radiation or energy absorbed. For specific purposes it must be appropriately qualified.

dose equivalent - The product of absorbed dose in rad (or gray) in tissue and a quality factor. Dose equivalent is expressed in units of rem or sievert (1 rem = 0.01 sievert).

dose rate - Absorbed dose delivered per unit time. The unit of absorbed dose rate is rad/h (Gy/h).

effective dose equivalent - The summation of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health-effects risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and from penetrating radiation from sources external to the body. Effective dose equivalent is expressed in units of rem or sievert.

effluent - A substance emitted from a facility into water, air, or ground.

effluent monitoring - The collection and analysis of samples or measurements of liquid and gaseous effluents.

environmental surveillance - The collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media from DOE sites and their environs and the measurement of external radiation.

exposure - A measure of the ionization produced in air by x or gamma radiation. The unit of exposure is the roentgen (see roentgen).

external radiation - Radiation originating from a source outside the body.

fence line dose - The dose calculated at the point of highest potential exposure of individuals at any point of uncontrolled public access.

fission products - Fission products are produced through the fission ("splitting") of larger atoms, such as uranium and plutonium, in a nuclear reaction. The fissioning of larger atoms results in smaller fission products and a release of energy. Most fission products have short radioactive half-lives.

gamma radiation (γ) - Electromagnetic radiation emitted from the nucleus during nuclear transitions or particle annihilation. Gamma rays have no mass and no charge, and are identical to x-rays except for their point of origin. Gamma radiation frequently accompanies the emission of alpha or beta particles. Other types of electromagnetic radiation includes microwaves, radio-waves, and visible light.

gray (Gy) - The unit of absorbed dose in the SI. 1 Gy = 1 joule-kg^{-1} = 100 rad.

half-life - The time required for the activity of a radionuclide to decrease to half its value through inherent radioactive decay. Each radionuclide has a unique half-life. These half-lives can range from a fraction of a second to millions of years. The half-life is represented by the symbol "$t_{1/2}$."

internal radiation - Radiation from a source within the body. Internal radiation results from the deposition of radionuclides in body tissues through ingestion, inhalation, absorption through skin, or implantation. Potassium-40, a naturally occurring radionuclide, is an example of a source of internal radiation in living organisms.

iodine, radioactive (I) - Radioactive isotopes of iodine are of interest in radiation dose assessment because iodine tends to concentrate in the thyroid (a relatively small but important organ) of humans and animals.

ionizing radiation - Electromagnetic or particulate radiation capable of producing ions, directly or indirectly, as it passes through matter.

isotopes - Nuclides having the same number of protons in their nuclei (hence, the same atomic number), but a different number of neutrons (therefore, a different mass number). For example, there are three major isotopes of uranium; uranium-234, -235, and -238; all have 92 protons in their nuclei. The chemical properties of all isotopes of a particular element are similar.

krypton-85 (^{85}Kr) - A noble gas. It is a radioactive isotope of krypton and a fission product.

maximally exposed individuals - Hypothetical individuals whose location and lifestyle are chosen to maximize the potential radiation dose through all relevant pathways from a given facility or operation.

maximum individual dose - The highest potential dose that can be estimated from exposure of individuals to radiation and radioactive materials resulting from site operations; generally estimated for public exposures offsite.

millicurie - Also written as "mCi," 1/1000 of a curie.

millirem - Also written as "mrem," 1/1000 of a rem.

naturally occurring radioactivity - The property of radioactivity exhibited by more than 50 radionuclides that exist naturally in the environment and in living organisms.

noble gases - The six elemental gases: helium, neon, argon, krypton, xenon, and radon. They are chemically unreactive, but radioactive isotopes of each of the noble gases can be produced through fission or activation reactions.

nuclide - A particular species of atom, characterized by the number of neutrons, number of protons, and energy content of its nucleus.

organ dose - A dose that involves exposure to a particular organ or set of organs.

outfall - The place where a storm sewer or effluent line discharges to the environment.

person-rem - The unit of population dose. It is equal to the sum of calculated individual doses for a given population or to the product of the population size and the average dose received by that population.

plutonium (Pu) - A radioactive, metallic chemical element. Its most important isotope, plutonium-239, is produced by irradiating uranium-238 with fast neutrons. This isotope is used as a nuclear reactor fuel. Plutonium is one of the most restrictively controlled radioactive materials.

population dose - The sum of the radiation doses to individuals in a population. It is expressed in units of person-rem. If 1000 people received an average radiation dose of 1 rem, the population dose (collective dose) would be 1000 person-rem.

rad - The special unit of absorbed dose of ionizing radiation. A dose of one rad equals the absorption of 100 ergs of ionizing energy per gram of absorbing material (see dose).

radiation - Particles or electromagnetic energy from atomic or nuclear processes.

radioactive material - A material which exhibits radioactivity.

radioactivity - The property or characteristic of radioactive material to spontaneously "disintegrate" with the emission of energy in the form of radiation. The unit of radioactivity is the curie or becquerel (1 Ci = 3.7 x 10 Bq).

radioisotope - A radioactive isotope of a specified element. Carbon-14 is a radioisotope of carbon.

radionuclide - A radioactive nuclide. There are several hundred known radionuclides, some of which are man-made and some of which exist naturally.

rem - The unit that expresses human biological dose equivalent as a result of exposure to ionizing radiation. By applying the proper multiplying factor, the absorbed dose (in rad) can be converted into the dose equivalent in rem if the type of radiation (alpha, beta, gamma, neutrons, etc.) is known.

roentgen (R) - A unit of radiation exposure expressed in terms of the amount of ionization produced by x-rays in a volume of air.

short-lived fission and activation products - For this report, those radionuclides produced through fission or activation processes that have half-lives of less than 3 hours (principally carbon-11, nitrogen-13, oxygen-15, manganese-56, and barium-135). Because they are short-lived, releases of such radionuclides generally pose less risk of exposure for humans than do the releases of longer-lived radionuclides.

terrestrial radiation - Radiation emitted by naturally occurring radionuclides, such as potassium-40; the natural decay chains of uranium-238, uranium-235, or thorium-232; or cosmic-ray-induced radionuclides in the soil or air.

uncontrolled area - Any area to which access by the general public is not restricted or controlled for purposes of limiting radiation exposure.

unstable (element) - An element that is capable of radioactive decay.

x-rays - Penetrating electromagnetic radiations. They may be produced by bombarding a metallic target with fast electrons or by certain nuclear or atomic interaction.