DOE/EH-####

DOE Occupational Radiation Exposure

1999 Report

NEUTRON • AEDE • ELECTRON • TEDE • INTERNAL • CEDE • GAMMA • BETA • SHIELD • ALARA • NEUTRON • AEDE • ELECTRON • TEDE • INTERNAL • CEDE • GAMMA • B

http://rems.eh.doe.gov

This report has been reproduced directly from the best available copy.

Available to DOE and DOE Contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (865) 576-8401.

Available to the public from the U.S. Department of Commerce, Technology Administration, National Technical Information Service, Springfield, VA 22161, (703) 487-4650.

Printed with soy ink on recycled paper

DOE/EH-####

DOE Occupational Radiation Exposure

1999 Report

The U.S. Department of Energy
Assistant Secretary for Environment, Safety and Health
Office of Safety and Health

Foreword

Foreword

The goal of the U.S. Department of Energy (DOE) is to conduct its radiological operations to ensure the safety and health of all DOE employees including contractors and subcontractors. The DOE strives to maintain radiation exposures to its workers below administrative control levels and DOE limits and to further reduce these exposures and releases to levels that are "As Low As Reasonably Achievable" (ALARA).

The *1999 DOE Occupational Radiation Exposure Report* provides summary and analysis of the occupational radiation exposure received by individuals associated with DOE activities. The DOE mission includes stewardship of the nuclear weapons stockpile and the associated facilities, environmental restoration of DOE, and energy research.

Collective exposure at DOE has declined by 80% over the past decade due to a cessation in opportunities for exposure during the transition in DOE mission from weapons production to cleanup, deactivation and decommissioning, and changes in reporting requirements and dose calculation methodology. In 1999, the collective dose decreased by 2% from the 1998 value due to decreased doses at three of the six highest-dose DOE sites. These three sites attributed the decrease in collective dose to aggressive ALARA programs, a decontamination campaign at SRS to reduce source term, increased management awareness, improved work practices, and a delay in several projects at Idaho due to an accident in 1998 which resulted in corrective actions that affected the work control system. The average measurable TEDE increased by 4% from 1998 to 1999. Statistical analysis indicates that this is a result of a decrease in the number of individuals receiving measurable dose.

This report is intended to be a valuable tool for managers in their management of radiological safety programs and commitment of resources. The process of data collection, analysis, and report generation is streamlined to give managers a current assessment of the performance of the Department with respect to radiological operations. The cooperation of the sites in promptly and correctly reporting employee radiation exposure information is key to the timeliness of this report. Your feedback and comments are important to us to make this report meet your needs.

David Michaels, PhD, MPH
Assistant Secretary
Environment, Safety and Health

Joseph E. Fitzgerald, Jr.
Deputy Assistant Secretary
Office of Safety and Health

This page intentionally left blank.

Table of Contents

SECTION 4 — ALARA ACTIVITIES AT DOE

SECTION 5 — CONCLUSIONS

APPENDICES

LIST OF EXHIBITS

LIST OF EXHIBITS (continued)

TABLE OF ACRONYMS

10 CFR 820:	Title 10 Code of Federal Regulation Part 820 "Procedural Rules for DOE Nuclear Activities," August 17, 1993
10 CFR 835:	Title 10 Code of Federal Regulation Part 835 "Occupational Radiation Protection," December 14, 1993
10 CFR 835, Amendment:	Issued on November 4, 1998
10 CFR 835.402.d:	Amendment to be fully implemented by January 1, 2002
ACL:	Administrative Control Level
AEDE:	Annual Effective Dose Equivalent
ALAP:	As Low As Practicable
ALARA:	As Low As Reasonably Achievable
ANL-E:	Argonne National Laboratory - East
ANL-W:	Argonne National Laboratory - West
ANSI:	American National Standards Institute
ANSI N13.30-1996:	ANSI Note on Performance Criteria for Radioassay
BHI:	Bechtel Hanford, Inc.
BNL:	Brookhaven National Laboratory
CDE:	Committed Dose Equivalent
CEDE:	Committed Effective Dose Equivalent
CEDR:	Comprehensive Epidemiologic Data Resource
DAC:	Derived Air Concentration
D&D:	Decontamination and Decommissioning
DDE:	Deep Dose Equivalent
DNFSB:	Defense Nuclear Facilities Safety Board
DOE:	Department of Energy
DOE HQ:	DOE Headquarters
DOE M 231.1-1:	Manual for Environment, Safety and Health Reporting, September 10, 1995
DOE Notice 441.1:	Radiological Protection for DOE Activities, September 29, 1995
DOE Order 5480.11:	Radiation Protection for Occupational Workers, December, 1988
DOE Order 5484.1:	Environmental Protection, Safety, and Health Protection Information Reporting Requirements", February 24, 1981, Change 7, October 17, 1990
DOELAP:	DOE Laboratory Accreditation Program
EDE:	Effective Dose Equivalent
EH-52:	DOE Office of Worker Protection Policy and Programs
EPA:	Environmental Protection Agency
ES&H:	Environment, Safety & Health
ETTP:	East Tennessee Technology Park (formerly K-25)
EUO:	Enriched Uranium Operations
FERMCO:	Fernald Environmental Research Management Corporation
FERMI:	Enrico Fermi National Accelerator Laboratory
HEPA:	High-Efficiency Particulate Air (Filter)
ICRP:	International Commission on Radiological Protection
INEEL:	Idaho National Engineering & Environmental Laboratory
ISM:	Integrated Safety Management
LANL:	Los Alamos National Laboratory
LBNL:	Lawrence Berkeley National Laboratory
LDE:	Lens (of the eye) Dose Equivalent
LEHR:	Laboratory for Energy-Related Health Research
LLNL:	Lawrence Livermore National Laboratory
LLPIT:	Lessons Learned Process Improvement Team
MDA:	Minimum Detectable Activity
MSR:	Molten Salt Reactor

TABLE OF ACRONYMS (continued)

mSv:	MilliSievert
NAC:	Nuclear Assurance Corporation
NCRP:	National Council on Radiation Protection and Measurements
NRC:	Nuclear Regulatory Commission
NREL:	National Renewable Energy Laboratory
NTS:	Nevada Test Site
ORISE:	Oak Ridge Institute for Science & Education
ORNL:	Oak Ridge National Laboratory
PGDP:	Paducah Gaseous Diffusion Plant
PNNL:	Pacific Northwest National Laboratory
PORTS:	Portsmouth Gaseous Diffusion Plant
PP:	Pantex Plant
PSEs:	Planned Special Exposures
RadCon:	Radiological Control Manual, June 1992
RCS:	Radiological Control Technical Standard
REC:	Radiochemical Engineering Cells
REMS:	Radiation Exposure Monitoring System
RFETS:	Rocky Flats Environmental Technology Site
SDE:	Shallow Dose Equivalent
SDE-ME:	Shallow Dose Equivalent to the Maximally Exposed Extremity
SDE-WB:	Shallow Dose Equivalent to the Skin of the Whole-Body
SLAC:	Stanford Linear Accelerator Center
SNL:	Sandia National Laboratory
SOC:	Standard Occupational Classification
SRS:	Savannah River Site
TEDE:	Total Effective Dose Equivalent
TODE:	Total Organ Dose Equivalent
TRU:	Transuranic
UHPS:	Ultra High Pressure System
UMTRA:	Uranium Mill Tailings Remedial Action
UNSCEAR:	United Nations Scientific Committee on the Effects of Atomic Radiation
WVNS:	West Valley Nuclear Services

Executive Summary

The U.S. Department of Energy (DOE) Office of Safety and Health publishes the annual *DOE Occupational Radiation Exposure Report*. This report is intended to be a valuable tool for DOE and DOE contractor managers in managing radiological safety programs and to assist them in prioritizing resources. We appreciate the efforts and contributions from the various stakeholders within and outside DOE and hope we have succeeded in making the report more useful.

This report includes occupational radiation exposure information for all monitored DOE employees, contractors, subcontractors, and visitors. The exposure information is analyzed in terms of aggregate data, dose to individuals, and dose by site. For the purposes of examining trends, data for the past 5 years are included in the analysis.

As shown in *Exhibit ES-1*, between 1998 and 1999, the DOE collective Total Effective Dose Equivalent (TEDE) decreased by 1% primarily due to decreased doses at three of the six sites with the highest radiation dose. The average dose to workers with measurable dose increased by 5% from 0.074 rem (0.74 mSv) in 1998 to 0.078 rem (0.78 mSv) in 1999 as shown in *Exhibit ES-2* because of the decrease in the number of individuals receiving measurable dose. The percentage of monitored individuals receiving measurable dose decreased from 16% in 1998 to 15% in 1999, and there was one exposure of 6.719 rem which is over the DOE 5 rem (50 mSv) annual TEDE limit.

Eighty-three percent of the collective TEDE for the DOE complex was accrued at six DOE sites in 1999. These six sites are (in descending order of collective dose for 1999) Rocky Flats, Oak Ridge, Hanford, Savannah River Site (SRS), Los Alamos, and Idaho. Sites reporting under the category of weapons fabrication and testing account for the highest collective dose. Even though these sites are now primarily involved in nuclear materials stabilization and waste management, they still report under this facility type. For the past 4 years, technicians and production staff have received the highest collective dose of any specified labor category.

Exhibit ES-1:
Collective TEDE Dose (person-rem), 1995-1999.

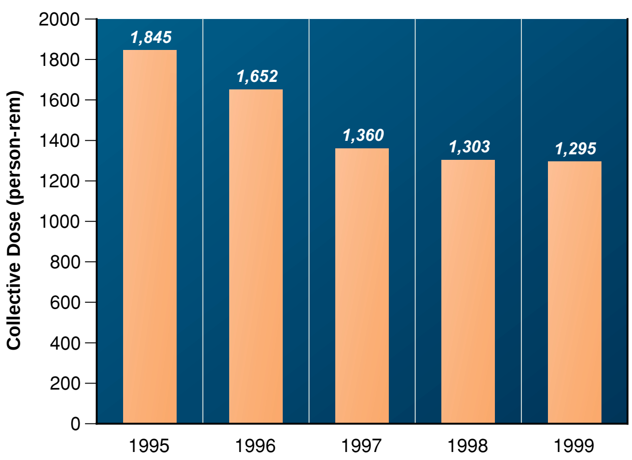
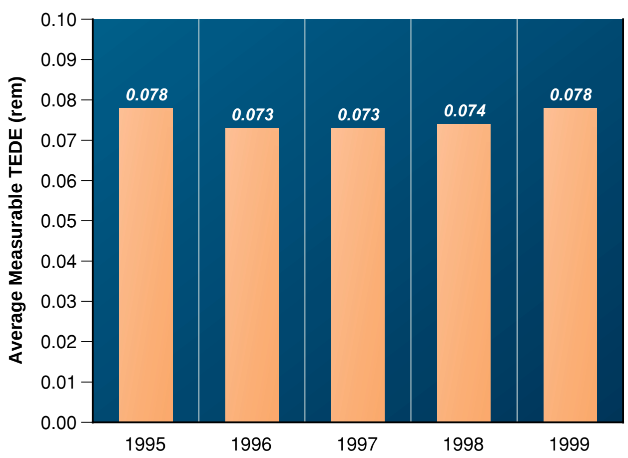


Exhibit ES-2:
Average Measurable TEDE (rem), 1995-1999.



The change in operational status of DOE facilities has had the largest impact on radiation exposure over the past 5 years due to the shift in mission from production to cleanup activities and the shutdown of certain facilities. Reports submitted by three of the sites that experienced decreases in the collective dose (Savannah River, Los Alamos, and Idaho) indicate that decreases in the collective dose were due to: aggressive ALARA programs, a decontamination campaign at SRS to reduce source term, increased management awareness, improved work practices, and a delay in several projects at Idaho due to an accident in 1998 which resulted in corrective actions that affected the work control system.

Statistical analysis reveals that, although the collective dose decreased by 1%, the logarithmic mean dose increased slightly from 0.028 rem in 1998 to 0.029 rem in 1999. This indicates that the drop in the collective dose reflects fewer workers exposed to radiation, rather than lower doses to individual workers. This is supported by the decrease in number of workers receiving measurable dose from 1998 to 1999.

Over the past 5 years, few occupational doses at DOE facilities in excess of the 2 rem (20 mSv) Administrative Control Level (ACL) and 5 rem (50 mSv) TEDE regulatory limit have occurred, as shown in *Exhibits ES-3* and *ES-4*. All of the doses in excess of 2 rem (20 mSv) in the past 5 years were due to internal dose, except one, which occurred in 1996 that was due to external dose (DDE). One individual received a dose in excess of the 5 rem (50 mSv) TEDE limit in 1999. The one individual that received a dose of 6.719 rem was reported as exceeding the 5 rem (50 mSv) TEDE limit in 1999 from an intake of americium and plutonium at the Savannah River Site due to a weld failure discovered during the transfer and repackaging of special nuclear material. In addition, there was an occurrence report submitted by Los Alamos concerning a 1998 event where an individual may have received a dose in excess of 5 rem (50 mSv) TEDE, but the final dose has not been assessed and therefore has not been included in this report.

Exhibit ES-3:
Number of Individuals Exceeding 2 rem TEDE, 1995-1999.

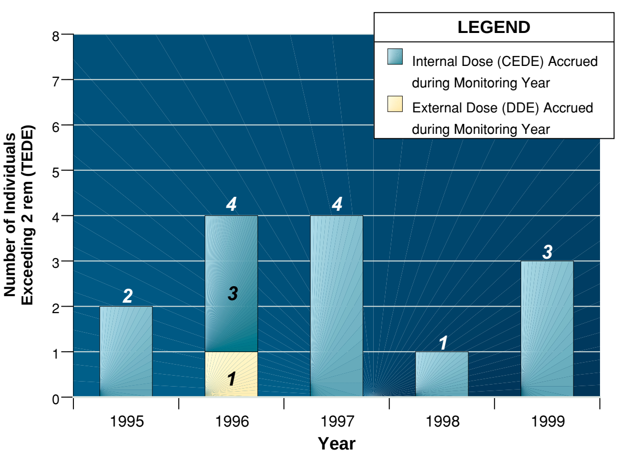
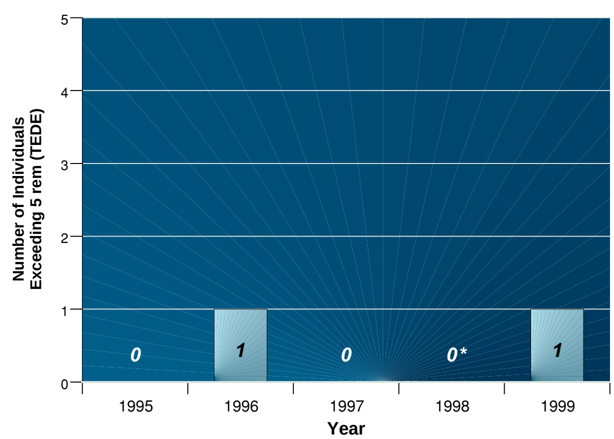


Exhibit ES-4:
Number of Individuals Exceeding 5 rem TEDE, 1995-1999.



* *A 1999 occurrence report indicates a potential exposure of 6.6 rem CEDE for an event that occurred in 1998 at LANL. The final dose has not been assigned, so this dose has not yet been reported to REMS and it has not been included in this report.*

The collective internal dose (CEDE) increased by 82% from 1998 to 1999 to a value of 152.9 person-rem (1,529 person mSv) for 1999. The increase in collective internal dose was primarily due to an increase in uranium doses at the Oak Ridge Y-12 site, where a large number of individuals were reported with relatively small internal doses from uranium. The collective CEDE for Y-12 increased by 260% from 1998 to 1999. The increased internal dose at the Y-12 site is due to the exposure of Enriched Uranium Operations (EUO) personnel to insoluble uranium and the use of more conservative internal dosimetry modeling parameters associated with uranium solubility.

An analysis was performed on the transient workforce at DOE. A transient worker is defined as an individual monitored at more than one DOE site in a year. The results of this analysis show that the number of transient workers monitored has increased by 51% over the past 5 years. From 1998 to 1999, the number of transients monitored increased by 4%, while the collective dose for these transients increased by 14%, resulting in a 4% increase in the average measurable dose to transients. However, the average measurable dose to transient workers has been less than the value for the overall DOE workforce for the past 5 years.

To access this report and other information on occupational radiation exposure at DOE, visit the web site at:

http://rems.eh.doe.gov

Section One
Introduction

1

Introduction

The *DOE Occupational Radiation Exposure Report, 1999* reports occupational radiation exposures incurred by individuals at DOE facilities during the calendar year 1999. This report includes occupational radiation exposure information for all DOE employees, contractors, subcontractors, and visitors. The 103 DOE organizations submitting radiation exposure reports for 1999 have been grouped into 29 geographic sites across the complex (see Appendix A.2). This information is analyzed and trended over time to provide a measure of DOE's performance in protecting its workers from radiation.

1.1 Report Organization

This report is organized into the five sections listed below. Supporting technical information, tables of data, and additional items that were identified by users as useful are provided in the appendices.

1.2 Report Availability

Requests for additional copies of this report, access to the data files, or individual dose records used to compile this report should be directed to:

Ms. Nirmala Rao
Radiation Exposure Monitoring System (REMS) Project Manager
U.S. Department of Energy
Office of Worker Protection Policy and Programs (EH-52)
Germantown, MD 20874

A discussion of the various methods of accessing DOE occupational radiation exposure information is presented in Appendix E. Visit the DOE Radiation Exposure web site for information concerning occupational radiation exposure in the DOE complex at:

http://rems.eh.doe.gov

Section One	Provides a description of the content and organization of this report.
Section Two	Provides a discussion of the radiation protection and dose reporting requirements and their impacts on data interpretation. Additional information on dose calculation methodologies, personnel monitoring methods and reporting thresholds, regulatory dose limits, and ALARA is included.
Section Three	Presents the occupational radiation dose data from monitored individuals at DOE facilities for 1999. The data are analyzed to show trends over the past 5 years.
Section Four	Includes examples of successful ALARA projects within the DOE complex.
Section Five	Presents conclusions based on the analysis contained in this report.

This page intentionally left blank.

Standards and Requirements

One of DOE's primary objectives is to provide a safe and healthy workplace for all employees and contractors. To meet this objective, DOE's Office of Worker Protection Policy and Programs establishes comprehensive and integrated programs for the protection of workers from hazards in the workplace, including ionizing radiation. The basic DOE standards are radiation dose limits, which establish maximum permissible doses to workers and the public. In addition to the requirement that radiation doses not exceed the limits, it is DOE's policy that doses also be maintained ALARA.

This section discusses the radiation protection standards and requirements that were in effect for the year 1999. The requirements leading up to this time period are also included to facilitate a better understanding of changes that have occurred in the recording and reporting of occupational dose.

2.1 Radiation Protection Requirements

DOE radiation protection standards are based on federal guidance for protection against occupational radiation exposure promulgated by the U.S. Environmental Protection Agency (EPA) in 1987 [1]. These standards are provided to ensure that DOE workers are adequately protected from exposure to ionizing radiation. This guidance, initially implemented by DOE in 1989, is based on the 1977 recommendations of the International Commission on Radiological Protection (ICRP) [2] and the 1987 recommendations of the National Council on Radiation Protection and Measurements (NCRP) [3]. This guidance recommended that internal organ dose (resulting from the intake of radionuclides) be added to the external whole-body dose to determine the Total Effective Dose Equivalent (TEDE). Prior to this, the whole-body dose and internal organ dose were each limited separately. The new DOE dose limits based on the TEDE were established from this guidance.

DOE became the first federal agency to implement the EPA guidance when it promulgated DOE Order 5480.11, "Radiation Protection for Occupational Workers," in December 1988 [4]. DOE Order 5480.11 was in effect from 1989 to 1995.

In June 1992, the "DOE Radiological Control (RadCon) Manual" [5] was issued and became effective in 1993. The "RadCon Manual" was the result of a Secretarial initiative to improve and standardize radiological protection practices throughout DOE and to achieve the goal of making DOE the pacesetter for radiological health and safety. The "RadCon Manual" is a comprehensive guidance document written for workers, line managers, and senior management. The "RadCon Manual" states DOE's views on the best practices currently available in the area of radiological control. The "RadCon Manual" was revised in 1994 in response to comments from the field and to enhance consistency with the requirements in 10 CFR 835 "Occupational Radiation Protection" [6]. In July 1999, the "RadCon Manual" was formally reissued as the Radiological Control Standard (RCS) [7]. The RCS incorporates changes resulting from the amendment to 10 CFR 835 issued on November 4, 1998.

10 CFR 835 became effective on January 13, 1994, and required full compliance by January 1, 1996. In general, 10 CFR 835 codified existing radiation protection requirements in DOE Order 5480.11. The rule provides nuclear safety requirements that, if violated, will provide a basis for the assessment of civil and criminal penalties under the Price-Anderson Amendments Act of 1988, Public Law 100-408, August 20, 1988 [8] as implemented by 10 CFR 820 "Procedural Rules for DOE Nuclear Activities," August 17, 1993. [9]

One and one-half years after the promulgation of 10 CFR 835, DOE Order 5480.11 was canceled and the "RadCon Manual" was made non-mandatory guidance with issuance of DOE Notice 441.1, "Radiological Protection for DOE Activities," [10] (applicable to defense nuclear facilities). This notice was issued to establish radiological protection program requirements that, combined with 10 CFR 835 and its associated non-mandatory implementation guidance, formed the basis for a comprehensive radiological protection program. DOE N 441.1 continued in effect until January 1, 2000 when compliance with the amendment to 10 CFR 835 (issued November 4, 1998) was required to be fully implemented.

During 1994 and 1995, DOE undertook an initiative to reduce the burden of unnecessary, repetitive, or conflicting requirements on DOE contractors. As a result, DOE Order 5484.1 [11] requirements for reporting radiation dose records are now located in the associated manual, DOE M 231.1-1, "Environment, Safety and Health Reporting" [12], which became effective September 30, 1995.

The requirements of DOE M 231.1-1 are basically the same as Order 5484.1; however, the dose terminology was revised to reflect the changes made in radiation protection standards and requirements. For 1995, DOE Order 5484.1 remained in effect. Most sites reported under the new DOE M 231.1-1 for 1996. Because each site implements the new requirements as operating contracts are issued or renegotiated, complete implementation will take several years.

2.1.1 Monitoring Requirements

10 CFR 835.402(a) requires that, for external monitoring, personnel dosimetry be provided to general employees likely to receive an effective dose equivalent to the whole-body greater than 0.1 rem (1 mSv) in a year or an effective dose equivalent to the skin or extremities, lens of the eye, or any organ or tissue greater than 10% of the corresponding annual limits. Monitoring for internal radiation exposure is also required when the general employee is likely to receive 0.1 rem (1 mSv) or more Committed Effective Dose Equivalent (CEDE), and/or 5 rems (50 mSv) or more Committed Dose Equivalent (CDE) to any organ or tissue in a year. Monitoring for minors and the public is required if the TEDE is likely to exceed 50% of the annual limit of 0.1 rem (1 mSv) TEDE. Monitoring of declared pregnant workers is required if the TEDE to the embryo/fetus is likely to exceed 10% of the limit of 0.5 rem (5 mSv) TEDE.

Monitoring for external exposures is also required for any individual entering a high or very high radiation area.

2.1.1.1 External Monitoring

External or personnel dosimeters are used to measure ionizing radiation from sources external to the individual. The choice of dosimeter is based on the type and energy of radiation that the individual is likely to encounter in the workplace. An algorithm is then used to convert the exposure readings into dose. External monitoring devices include photographic film (film badges), thermoluminescent dosimeters, pocket ionization chambers, electronic dosimeters, personnel nuclear accident dosimeters, bubble dosimeters, plastic dosimeters, and combinations of the above.

Beginning in 1990, the DOE Laboratory Accreditation Program (DOELAP) formalized accuracy and precision performance standards for external dosimeters and quality assurance/ quality control requirements on the overall external dosimetry programs for facilities within the DOE complex. All DOE facilities were DOELAP-accredited by the fall of 1995.

External dosimeters have a lower limit of detection of approximately 0.010 - 0.030 rem (0.10 - 0.30 mSv) per monitoring period. The differences are attributable to the particular type of dosimeter used and the types of radiation monitored. Monitoring periods are usually quarterly for individuals receiving less than 0.300 rem/year (3 mSv/year) and monthly for individuals who routinely receive higher doses or who enter higher radiation areas.

2.1.1.2 Internal Monitoring

Bioassay monitoring includes in-vitro (outside the body) and in-vivo (inside the body) sampling. In-vitro assays include urine and fecal samples, nose swipes, saliva samples, and hair samples. In-vivo assays include whole-body counting, thyroid counting, lung counting, and wound counting.

Monitoring intervals for internal dosimetry depend on the radionuclides being monitored and their concentrations in the work environment. Routine monitoring intervals may be monthly, quarterly, or annually, whereas special monitoring intervals following an incident may be daily or weekly. Detection thresholds for internal dosimetry are highly dependent on the monitoring methods, the monitoring intervals, the radionuclides in question, and their chemical form. Follow-up measurements and analysis may take many months to confirm preliminary findings. DOE has developed a Radiobioassay Accreditation Program in conjunction with the publication of American National Standards Institute (ANSI) N13.30-1996, "Performance Criteria for Radiobioassay". Implementation of the program began in November 1998 with the issuance of the amendments to 10 CFR 835.402.d, and must be fully implemented by January 1, 2002.

2.2 Radiation Dose Limits

Radiation dose limits are codified in 10 CFR 835.202, 204, 206, 207, 208 and are summarized in *Exhibit 2-1*. While some of these sections have been revised, the limits remain the same.

Under 835.204, Planned Special Exposures (PSEs) may be authorized under certain conditions allowing an individual to receive exposures in excess of the dose limits shown in *Exhibit 2-1*. With the appropriate prior authorization, the annual dose limit for an individual may be increased by an additional 5 rems (50 mSv) TEDE above the routine dose limit as long as the individual does not exceed a cumulative lifetime TEDE of 25 rems (250 mSv) from other PSEs and doses above the limits. PSE doses are required to be recorded separately and are only intended to be used in exceptional situations where dose reduction alternatives are unavailable or impractical. Restrictions on the use of PSEs are extensive; for this reason, they are expected to be rarely used at DOE. No PSEs occurred in 1999.

Exhibit 2-1:
DOE Dose Limits from 10 CFR 835

Personnel Category	Section of 10 CFR 835	Type of Exposure	Acronym	Annual Limit
General Employees	*§835.202*	*Total Effective Dose Equivalent*	*TEDE*	*5 rems*
		Deep Dose Equivalent + Committed Dose Equivalent to any organ or tissue (except lens of the eye). This is often referred to as the Total Organ Dose Equivalent	*DDE+CDE (TODE)*	*50 rems*
		Lens of the Eye Dose Equivalent	*LDE*	*15 rems*
		Shallow Dose Equivalent to the skin of the Whole-body or to any Extremity	*SDE-WB and SDE-ME*	*50 rems*
*Declared Pregnant Worker**	*§835.206*	*Total Effective Dose Equivalent*	*TEDE*	*0.5 rem per gestation period*
Minors	*§835.207*	*Total Effective Dose Equivalent*	*TEDE*	*0.1 rem*
Members of the Public	*§835.208*	*Total Effective Dose Equivalent*	*TEDE*	*0.1 rem*

**Limit applies to the embryo/fetus*

2.2.1 Administrative Control Levels

Administrative Control Levels (ACLs) were included in the "RadCon Manual". ACLs are established below the regulatory dose limits to administratively control and help reduce individual and collective radiation dose. ACLs are multi-tiered, with increasing levels of authority needed to approve a higher level of exposure.

The "RadCon Manual" recommends a DOE ACL of 2 rem (20 mSv) per year per person for all DOE activities. Prior to allowing an individual to exceed this level, approval from the appropriate Secretarial Officer or designee should be received. In addition, contractors are encouraged to establish an annual facility ACL. This control level is established by the contractor senior site executive and is based upon an evaluation of historical and projected radiation exposures, workload, and mission. The "RadCon Manual" suggests an annual facility ACL of 0.5 rem (5 mSv) or less; however, the Manual also states that a control level greater than 1.5 rem (15 mSv) is, in most cases, not sufficiently challenging. Approval by the contractor senior site executive must be received prior to an individual exceeding the facility ACL. In addition to the annual ACL, the Manual requires the establishment of a lifetime ACL of "N" rem, where N is the age of the person in years. Special Control Levels must be established for personnel who have doses exceeding N rem.

2.2.2 ALARA Principle

Until the 1970s, the fundamental radiation protection principle was to limit occupational radiation dose to quantities less than the regulatory limits and to be concerned mainly with high dose and high dose rate exposures. During the 1970s, there was a fundamental shift within the radiation protection community to be concerned with low dose and low dose rate exposures because it can be inferred from the linear no-threshold dose response hypothesis that there is an increased level of risk associated with any radiation exposure. The As Low As Practicable (ALAP) concept was initiated and became part of numerous guidance documents and radiation protection good practices. ALAP was eventually replaced by ALARA. DOE Order 5480.11, the "RadCon Manual", and 10 CFR 835 required that each DOE facility have an ALARA Program as part of its overall Radiation Protection Program.

The ALARA methodology considers both individual and group doses and generally involves a cost/benefit analysis. The analysis considers social, technical, economic, practical, and public policy aspects of the overall goal of dose reduction. Because it is not feasible to reduce all doses at DOE facilities to zero, ALARA cost/benefit analysis must be used to optimize levels of radiation dose reduction. According to the ALARA principle, resources spent to reduce dose need to be balanced against the risks avoided. Reducing doses below this point results in a misallocation of resources; the resources could be spent elsewhere and have a greater impact on health and safety.

To ensure that doses are maintained ALARA at DOE facilities, the DOE mandated in DOE Order 5480.11 and subsequently in the "RadCon Manual" that ALARA plans and procedures be implemented and documented. To help facilities meet this requirement, DOE developed a manual of good practices for reducing exposures to ALARA levels [13]. This document includes guidelines for administration of ALARA programs, techniques for performing ALARA calculations based on cost/benefit principles, guidelines for setting and evaluating ALARA goals, and methods for incorporating ALARA criteria into both radiological design and operations. The establishment of ALARA as a required practice at DOE facilities demonstrates DOE's commitment to ensure minimum risk to workers from the operation of its facilities.

2.3 Reporting Requirements

In 1987, DOE promulgated revised reporting requirements in DOE Order 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements." Previously, contractors were required to report only the number of individuals who received an occupational whole-body exposure in one of 16 dose equivalent ranges. The revised Order required the reporting of the results of radiation exposure monitoring for each employee and visitor. Required dose data reporting includes the TEDE, internal dose equivalent, Shallow Dose Equivalent (SDE) to the skin and extremities, and Deep Dose Equivalent (DDE). Other reported data include the individual's age, sex, monitoring status, and occupation, as well as the reporting organization and facility type.

Occupational radiation exposure reporting requirements are now included in DOE M 231.1-1, which became effective September 30, 1995. The reporting requirements under DOE M 231.1-1 are very similar to those under Order 5484.1.

2.4 Change in Internal Dose Methodology

Prior to 1989, intakes of radionuclides into the body were not reported as dose, but as body burden in units of activity of systemic burden, such as the percent of the maximum permissible body burden. The implementation of DOE Order 5480.11 in 1989 specified that the intakes of radionuclides be converted to internal dose and reported using the Annual Effective Dose Equivalent (AEDE) methodology.

With the implementation of the "RadCon Manual" in 1993, the required methodology used to calculate and report internal dose was changed from the AEDE to the 50-year CEDE. The change was made to provide consistency with scientific recommendations, facilitate the transfer of workers between DOE and Nuclear Regulatory Commission (NRC)-regulated facilities, and simplify record keeping by recording all dose in the year of intake. The CEDE methodology is now codified in 10 CFR 835.

Readers should note that the method of calculating internal dose changed from AEDE to CEDE between 1992 and 1993 when analyzing TEDE data prior to 1993.

This report primarily analyzes dose information for the past 5 years, from 1995 to 1999. During these years, the CEDE methodology was used to calculate internal dose; therefore, the change in methodology from AEDE to CEDE between 1992 and 1993 does not affect the analysis contained in this report. Readers should keep in mind the change in methodology if analyzing TEDE data prior to 1993.

This page intentionally left blank.

Occupational Radiation Dose at DOE

3

Occupational Radiation Dose at DOE

3.1 Analysis of the Data

Analysis and explanation of observed trends in occupational radiation dose data reveal opportunities to improve safety and demonstrate performance. Several indicators were identified from the data submitted to the central data repository that can be used to evaluate the occupational radiation exposures received at DOE facilities. Analysis of these indicators falls into three categories: aggregate, individual, and site. In addition, the key indicators are analyzed to identify and correlate parameters having an impact on radiation dose at DOE.

The key indicators for the analysis of aggregate data are: number of monitored individuals and individuals with measurable dose, collective dose, average measurable dose, and the dose distribution. Analysis of individual dose data includes an examination of doses exceeding DOE regulatory limits, and doses exceeding the 2 rem (20 mSv) DOE ACL. Analysis of site data includes comparisons by site, labor category, and facility type. Additional information is provided concerning activities at sites contributing to the collective dose. To determine the significance of trends, statistical analysis was performed on the data.

3.2 Analysis of Aggregate Data

3.2.1 Number of Monitored Individuals

The number of monitored individuals represents the size of the DOE worker population provided with dosimetry. The number represents the sum of all records for monitored individuals, including all DOE employees, contractors, subcontractors, visitors, and members of the public. The number of monitored individuals is determined from the number of monitoring records submitted by each site. Individuals may have more than one monitoring record and therefore may be counted more than once. The number of monitored individuals is an indication of the size of a dosimetry program, but it is not necessarily an indicator of the size of the exposed workforce. This is because of the conservative practice at some DOE facilities of providing dosimetry to individuals for reasons other than the potential for exposure to radiation and/or radioactive materials exceeding the monitoring thresholds. Many individuals are monitored for reasons such as security, administrative convenience, and legal liability. Some sites offer monitoring for any individual who requests monitoring, independent of the potential for exposure. For this reason, workers who receive a measurable dose represent the exposed workforce.

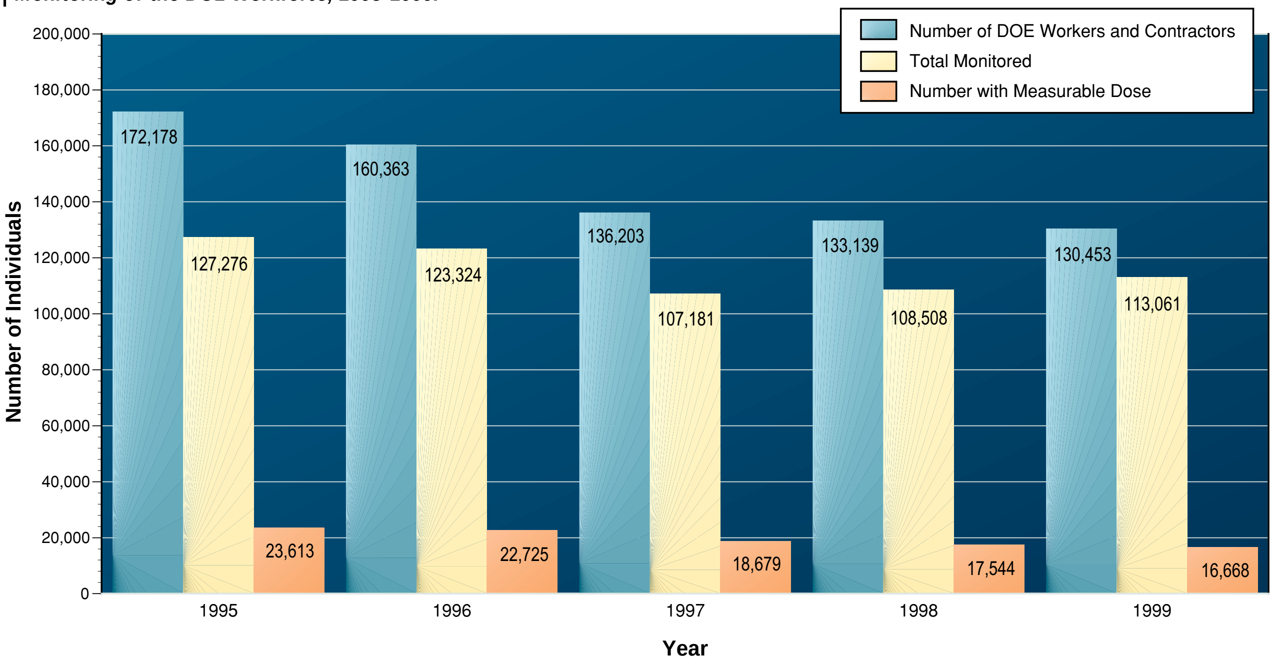
3.2.2 Number of Individuals with Measurable Dose

DOE uses the number of individuals receiving measurable dose to represent the exposed workforce size. The number of individuals with measurable dose includes any individuals with reported TEDE greater than zero.

Exhibit 3-1 shows the number of DOE workers and contractors, the total monitored and the number with measurable dose for the past 5 years. Although the total number of individuals monitored for radiation has decreased over the past 5 years by 11%, the percentage of the DOE workforce monitored for radiation exposure has increased by 13% from 1995 to 1999. However, most (83%) of the monitored individuals over the past 5 years did not receive any measurable radiation dose. An average of 17% of monitored individuals (less than 14% of the DOE workforce) received a measurable dose during the past 5 years. The percentage of monitored workers receiving measurable dose has decreased each year for the past 5 years from nearly 19% in 1995

Compared to 1998, more individuals were monitored for radiation exposure during 1999 but fewer workers received measurable radiation exposure.

Exhibit 3-1:
Monitoring of the DOE Workforce, 1995-1999.



to 15% in 1999. The overall DOE workforce has decreased by 24% over the past 5 years with decreases occurring each year. Compared to 1998, a larger percentage of the DOE workforce was monitored for radiation in 1999, while a smaller percentage of monitored individuals received a measurable dose. Members of the public account for nearly 2% of the individuals with measurable dose each year.

Sixteen of 29 of the reporting sites experienced decreases in the number of workers with measurable dose from 1998 to 1999, with the largest decreases occurring at Brookhaven National Laboratory and Los Alamos National Laboratory (LANL). The largest increase in the number of workers receiving measurable dose occurred at Oak Ridge primarily due to uranium operations. A discussion of activities at various facilities is included in Section 3.5.

The number of workers with measurable dose decreased from 17,544 in 1998 to 16,668 in 1999.

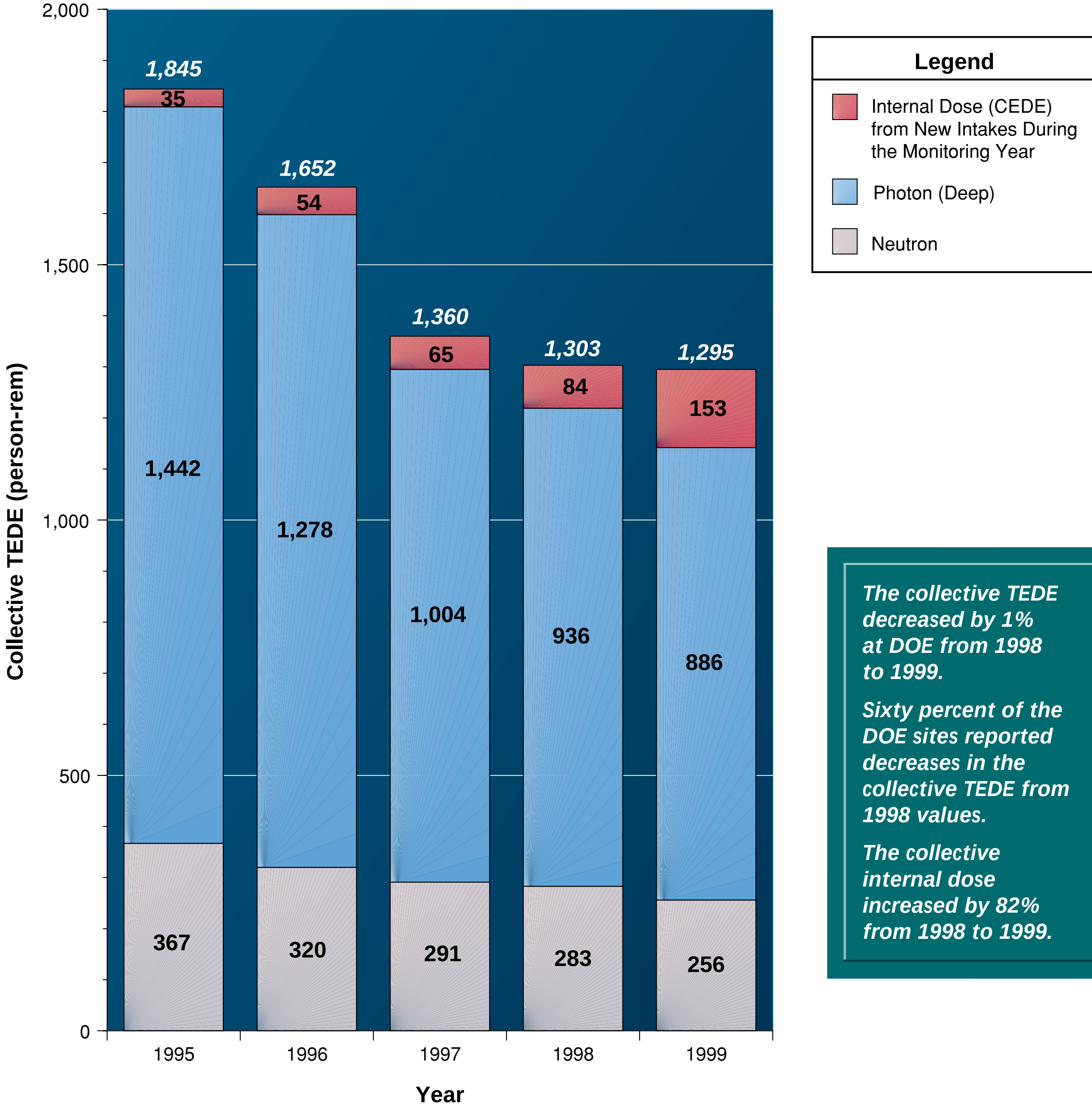
The percentage of monitored workers receiving measurable dose decreased by one percentage point from 16% in 1998 to 15% in 1999.

3.2.3 Collective Dose

The collective dose is the sum of the dose received by all individuals with measurable dose and is measured in units of person-rem. The collective dose is an indicator of the overall radiation exposure at DOE facilities and includes the dose to all DOE employees, contractors, and visitors. DOE monitors the collective dose as one measure of the overall performance of radiation protection programs to keep individual exposures and collective exposures ALARA.

As shown in *Exhibit 3-2*, the collective TEDE decreased at DOE by 1% from 1998 to 1999. Sixty percent of the DOE sites reported decreases in the collective TEDE from the 1998 values. Three out of six of the highest dose sites reported decreases in the collective TEDE, and one site had an increase of 1%. The six highest dose sites are (in descending order of collective dose) Rocky Flats, Oak Ridge, Hanford, Savannah River, Los Alamos, and Idaho. Statistical analysis of the collective TEDE reveals a slight increase in the mean TEDE from 1998 to 1999. This finding indicates that the collective dose has decreased due to a reduction in the number of individuals exposed to radiation, rather than reductions in dose to individuals. See

Exhibit 3-2:
Components of TEDE, 1995-1999



The collective TEDE decreased by 1% at DOE from 1998 to 1999.

Sixty percent of the DOE sites reported decreases in the collective TEDE from 1998 values.

The collective internal dose increased by 82% from 1998 to 1999.

Photon dose - the component of external dose from gamma or x-ray electromagnetic radiation.

Neutron dose - the component of external dose from neutrons ejected from the nucleus of an atom during nuclear reactions.

Internal dose - radiation dose resulting from radioactive material taken into the body.

Section 3.2.6 for more information on the statistical analysis, Section 3.5 for more information on activities contributing to the collective dose, and Section 4 for a discussion of notable ALARA activities.

It is important to note that the collective TEDE includes the components of external dose and internal dose. *Exhibit 3-2* shows the types of radiation and their contribution to the collective TEDE. The internal dose, photon, and neutron components are shown.

It should be noted that the internal dose shown in *Exhibit 3-2* for 1995 through 1999 is based on the 50-year CEDE methodology. The internal dose component increased by 82% from 1998 to 1999. This increase was largely a result of uranium intakes at Oak Ridge. The increase is due to Enriched Uranium Operations (EUO) personnel exposure to insoluble uranium and the use of more conservative internal dosimetry modeling parameters associated with uranium solubility.

The collective internal dose can vary from year to year due to the relatively small number of uptakes of radioactive material and the fact that they often involve long-lived radionuclides, such as plutonium which can result in relatively large committed doses. Due to the sporadic nature of these uptakes, care should be taken when attempting to identify trends from the internal dose records.

The external deep dose (comprised of photon and neutron dose) is shown in *Exhibit 3-2* in order to see the contribution of external dose to the collective TEDE. The photon dose decreased by 21% between 1996 and 1997 and 7% between 1997 and 1998 as a result of fewer workers and a reduced scope of work in some locations. The collective photon dose decreased by 5% between 1998 and 1999. Sites attributed the reduction in dose to: aggressive ALARA programs, a decontamination campaign at SRS to reduce source term, increased management awareness, improved work practices, and a delay in several projects at Idaho due to an accident in 1998 which resulted in corrective actions that affected the work control system. A discussion of the activities leading to this decrease is included in Section 3.5.

The neutron component of the TEDE decreased by 30% from 1995 to 1999. This is primarily due to decreases in the neutron dose at LANL and Savannah River. LANL contributed 31% of the neutron dose at the DOE during 1999. This is because LANL is one of the few remaining sites to actively handle plutonium. Working with plutonium in gloveboxes results in neutron dose from the alpha/neutron reaction and from spontaneous fission of the plutonium. Activities involving plutonium at LANL decreased in 1999, which resulted in decreased neutron dose from 87.8 person-rem (0.878 person-Sv) in 1998 to 79.6 person-rem (0.796 person-Sv) in 1999. The collective neutron dose for 1999 by site is shown in Appendix B-3. External deep dose (DDE) and TEDE for prior years (1974-1999) can be found in Appendix B-4.

3.2.4 Average Measurable Dose

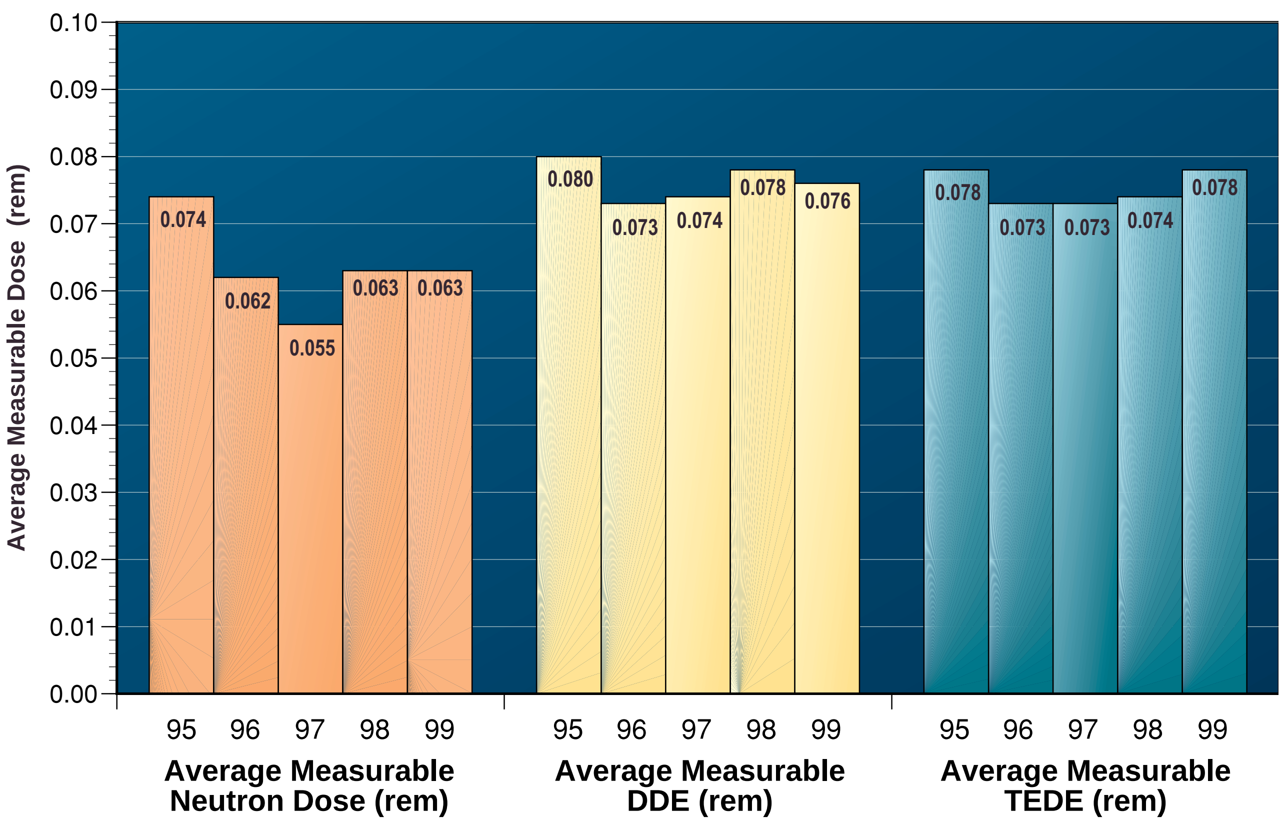
The average measurable dose to DOE workers presented in this report for TEDE, DDE, neutron, extremity, and CEDE are determined by dividing the collective dose for each dose type by the number of individuals with measurable dose for each dose type. This is one of the key indicators of the overall level of radiation dose received by DOE workers.

The average measurable neutron, DDE, and TEDE is shown in *Exhibit 3-3*. The average measurable neutron dose did not change between 1998 and 1999 after 3 years of decreases between 1995 to 1997. The average measurable neutron dose increased at LANL and Rocky Flats, but decreased at Savannah River and other sites. The average measurable DDE decreased by 3% from 1998 to 1999 due to a 5% decrease in the number of individuals with measurable DDE and a 6% decrease in the collective DDE. While both the collective TEDE and the number with measurable dose decreased, the collective TEDE decreased less relative to the number with measurable dose, which resulted in the increase in the average measurable TEDE. Statistical analysis indicates that the mean TEDE dose increased slightly from 1998 to 1999, indicating a decrease in the number of individuals receiving dose, rather than a reduction in dose to individuals (see Section 3.2.6). The average measurable neutron, DDE, and TEDE values are provided for trending purposes, not for comparison between them.

While the collective dose and average measurable dose serve as measures of the magnitude of the dose accrued by DOE workers, they do not indicate the distribution of doses among the worker population.

The average measurable TEDE increased by 5% from 1998 to 1999 while the average measurable DDE decreased by 3%.

Exhibit 3-3:
Average Measurable Neutron, DDE, and TEDE, 1995-1999



3.2.5 Dose Distribution

Exposure data are commonly analyzed in terms of dose intervals to depict the dose distribution among the worker population. *Exhibit 3-4* shows the number of individuals in each of 18 different dose ranges. The dose ranges are presented for the TEDE and DDE. The DDE is shown separately to allow for analysis of the dose independent of changes in internal dose, and includes the photon and neutron dose. The number of individuals receiving doses above 0.1 rem (1 mSv) is also included to show the number of individuals with doses above the monitoring threshold specified in 10 CFR 835.402(a) and (c).

Exhibit 3-4 shows that few individuals receive doses in the higher ranges, that the vast majority of doses are at low levels, and that the collective dose has decreased over the past 5 years. This is one indication that ALARA principles are being applied to keep doses at low levels. A few examples of successful ALARA practices are included in Section 4. Another way to examine the dose distribution is to analyze the percentage of the dose received above a certain dose value compared to the total collective dose.

Exhibit 3-4:
Distribution of Dose by Dose Range, 1995-1999

	Dose Ranges (rem)	1995		1996		1997		1998		1999	
		TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE
Number of Individuals in Each Dose Range*	Less than Measurable	103,663	104,793	100,599	101,529	88,502	89,805	90,964	92,803	96,393	98,122
	Measurable < 0.1	19,272	18,191	18,759	17,903	15,263	14,098	14,066	12,450	13,561	12,137
	0.10 - 0.25	2,543	2,513	2,441	2,405	2,142	2,046	2,253	2,120	1,898	1,763
	0.25 - 0.5	1,134	1,124	1,003	983	856	830	841	790	770	684
	0.5 - 0.75	374	371	339	335	265	258	268	245	238	206
	0.75 - 1.0	131	131	99	94	101	99	74	64	118	87
	1 - 2	157	153	80	74	48	45	41	36	80	62
	2 - 3			2	1	1		1		1	
	3 - 4	1		1		2				1	
	4 - 5	1				1					
	5 - 6										
	6 - 7									1	
	7 - 8										
	8 - 9										
	9 - 10										
	10 - 11										
	11 - 12				1						
	> 12										
Total Monitored		127,276	127,276	123,324	123,324	107,181	107,181	108,508	108,508	113,061	113,061
Number with Meas. Dose		23,613	22,483	22,725	21,795	18,679	17,376	17,544	15,705	16,668	14,939
Number with Dose >0.1rem		4,341	4,292	3,966	3,892	3,416	3,278	3,478	3,255	3,107	2,802
% of Individuals with Meas. Dose		19%	18%	18%	18%	17%	16%	16%	14%	15%	13%
Collective Dose (person-rem)		1,845	1,809	1,652	1,598	1,360	1,285	1,303	1,219	1,295	1,142
Average Measurable Dose (rem)		0.078	0.080	0.073	0.073	0.073	0.074	0.074	0.078	0.078	0.076

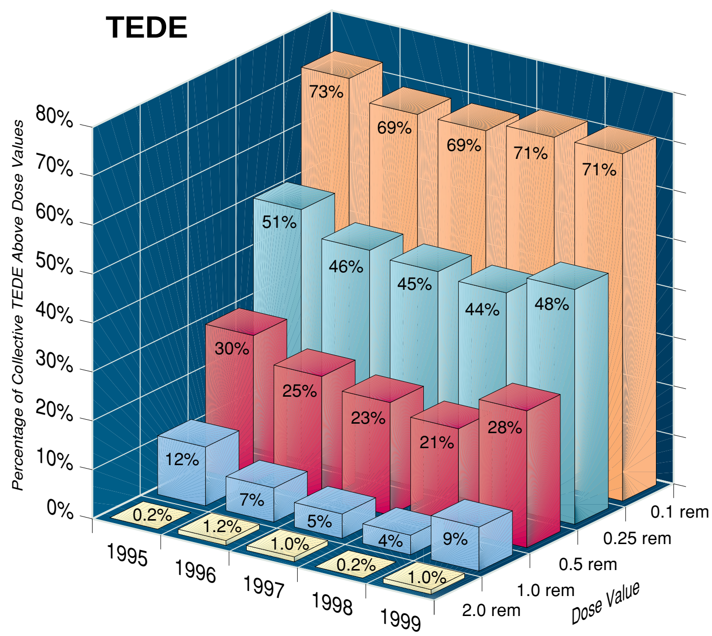
** Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.*

The United Nations Scientific Committee on the Effects of Atomic Radiation's (UNSCEAR) 1993 report entitled "Sources and Effects of Ionizing Radiation" [14] recommends the calculation of a parameter "SR" (previously referred to as CR or MR) to aid in the examination of the distribution of radiation exposure among workers. SR is defined to be the ratio of the annual collective dose incurred by workers whose annual doses exceed 1.5 rem (15 mSv) to the total annual collective dose. The UNSCEAR report notes that a dose level of 1.5 rem (15 mSv) may not be useful where doses are consistently lower than this level and they recommend that research organizations report SR values lower than 1.5 rem (15 mSv) where appropriate. For this reason, the DOE calculates and tracks the SR ratio at dose levels of 0.100 rem (1 mSv), 0.250 rem (2.5 mSv), 0.500 rem (5 mSv), 1.0 rem (10 mSv), and 2.0 rem (20 mSv). The SR values in this report were calculated by summing the TEDE to each individual that received a TEDE greater than or equal to the specified dose range divided by the total collective TEDE. This ratio is presented as a percentage rather than a decimal fraction.

Ideally, only a small percentage of the collective dose is delivered to individuals in the higher dose ranges. In addition, a trend in the percentage above a certain dose range decreasing over time may indicate the effectiveness of ALARA programs to reduce doses to individuals, or may indicate an overall reduction in activities involving radiation exposure.

Exhibit 3-5 shows the dose distribution given by percentage of collective TEDE and DDE above each of five dose values, from 0.1 rem (1 mSv) to 2 rem (20 mSv). This graph shows the two properties described above as the goal of effective ALARA programs at DOE: (1) a relatively small percentage of the collective dose accrued in the high dose ranges, and (2) a decreasing trend over time of the percentage of the collective dose accrued in the higher dose ranges. *Exhibit 3-5* shows that the percentages decreased for most of the TEDE ranges from 1995 to 1998. The percentages for the top four TEDE ranges increased between 1998 and 1999 primarily because of three individuals who received doses above 2.0 rem (20 mSv). See Section 3.3 for more information on these exposures.

Exhibit 3-5:
Percentage of Collective Dose above Dose Values During 1995-1999



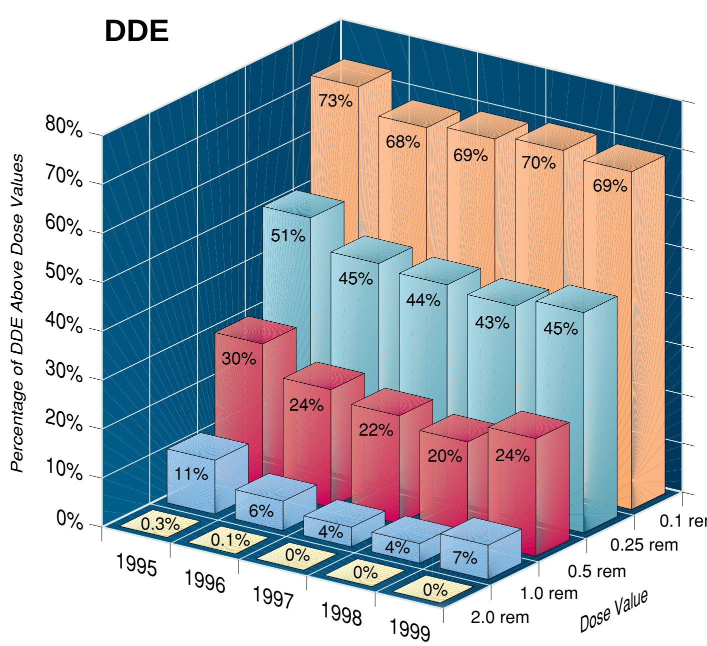


Exhibit 3-6:
Neutron Dose Distribution, 1995-1999

Year	No Meas. Dose	Meas. <0.100	0.10-0.25	0.25-0.50	0.5-0.75	0.75-1.0	1.0-2.0	>2.0	Total Monitored*	Number of Individuals with Meas. Dose	Collective Neutron DDE (person-rem)	Average Meas. Neutron DDE (rem)
1995	122,333	3,944	667	240	46	25	21		**127,276**	4,943	**367.446**	**0.074**
1996	118,154	4,282	677	156	32	11	12		123,324	5,170	320.320	0.062
1997	101,862	4,500	631	149	29	6	4		107,181	**5,319**	290.610	0.055
1998	103,998	3,680	629	155	34	4	8		108,508	4,510	283.078	0.063
1999	109,004	3,329	559	129	27	7	6		113,061	4,057	256.075	0.063

Note: Arrowed values indicate the greatest value in each column.

* *Represents the total number of records reported. The number of individuals monitored for neutron radiation is not known because there is no distinction made between zero dose and not monitored.*

In addition to the DDE and TEDE distribution, the neutron and extremity dose distributions are shown in *Exhibits 3-6* and *3-7*. The neutron dose is a component of the total DDE. Exposure to neutron radiation is much less common at DOE than photon dose. In 1999, 4,057 individuals (10% fewer than 1998) received measurable neutron dose, which is only 4% of the monitored individuals. The collective neutron dose represents 20% of the collective TEDE. All neutron doses were below 2 rem (20 mSv) for the past 5 years. While the number of individuals with measurable neutron dose increased during the 3 years from 1995 to 1997, it has decreased by 24% from 1997 to 1999. The collective neutron dose has decreased by 30% since 1995. The average measurable neutron dose remained unchanged from 1998 to 1999. Statistical analysis of the neutron dose (see Section 3.2.6) reveals that the logarithmic mean neutron dose has increased from 1998 to 1999, but the increase is not significant. This indicates that the decrease in the collective neutron dose is due to fewer individuals receiving neutron dose, rather than a reduction of neutron dose to individuals. The neutron dose distribution for 1999 by site is shown in Appendix B-3.

Exhibit 3-7 shows the distribution of extremity dose over the past 5 years. "Extremities" are defined as the hands and arms below the elbow, and the feet and legs below the knee. 10 CFR 835.402(a)(1)(ii) requires monitoring for an SDE to the extremities of 5 rem (50 mSv) or more in a year. As shown in *Exhibit 3-7*, a small percentage of individuals have received doses above the 5 rem (50 mSv) monitoring threshold. All of these exposures were for the upper extremities. The DOE annual limit for extremity dose is 50 rem (500 mSv). The higher dose limit is due to the lack of blood-forming organs in the extremities; therefore, extremity dose involves less health risk to the individual. No individual received an extremity dose above the regulatory limit of 50 rem (500 mSv) in the past 5 years. Despite the 50 rem DOE annual extremity limit, only one or two individuals each year reach extremity dose between 30 and 40 rem, and no one has gone above 40 rem in the

Exhibit 3-7:
Extremity Dose Distribution, 1995-1999

Year	No Meas. Dose	Meas. <0.1	0.1-1.0	1-5	5-10	10-20	20-30	30-40	>40	Total Monitored*	Number with Meas. Dose	No. Above Monitoring Threshold (5 rem)**	Collective Extremity Dose (person-rem)	Average Meas. Extremity Dose (rem)
1995	113,089	10,187	3,298	621	57	22	1	1		**127,276**	14,187	81	3,355.8	0.237
1996	108,458	10,576	3,583	646	50	9	1	1		123,324	**14,866**	61	3,272.8	0.220
1997	94,510	8,420	3,569	636	33	9	2	2		107,181	12,671	46	3,057.3	0.241
1998	95,436	8,347	3,938	722	56	8	1			108,508	13,072	65	3,390.1	0.259
1999	99,776	8,759	3,649	750	95	30	2			113,061	13,285	**127**	**3,988.6**	**0.300**

Note: Arrowed values indicate the greatest value in each column.

* *Represents the total number of records reported. The number of individuals monitored for extremity radiation is not known because there is no distinction made between zero dose and not monitored.*

** *DOE annual limit for extremities is 50 rem. 10 CFR 835.402(a)(1)(ii) requires extremity monitoring for a shallow dose equivalent to the skin or extremity of 5 rem or more in 1 year.*

past 5 years. During 1999, only two individuals received more than 20 rem (200 mSv) to the extremities. The number of individuals receiving a measurable extremity dose has increased by 2% from 1998 to 1999. Also, the average extremity dose has increased by 16% from 1998 to 1999. Much of this increase occurred at Rocky Flats and has been attributed to increased plutonium salts processing. While the collective extremity dose increased from 1998 to 1999, statistical analysis of the logarithmic mean extremity dose (see Section 3.2.6) has decreased. This indicates that although more individuals received dose, the dose to individuals decreased slightly from 1998 to 1999. The extremity dose distribution by site for 1998 is shown in Appendix B-23.

3.2.6 Five-Year Perspective

There are often differences in summary dose numbers from year to year, yet some of these differences may represent normal variations in a stable process, rather than significant changes. This section discusses the results of a statistical analysis to determine if there are statistically significant trends detectable over the last 5 years. The collective TEDE, neutron, and extremity doses were analyzed. Internal dose records have not been included because the number of records are too few.

This analysis includes only measurable doses received in each year, and used two types of tests to measure different characteristics of the distributions. The first test used pairwise T-tests to identify significant differences between statistical means for the years analyzed. Because the dose values do not fit a statistically normal distribution, this test used log-transformed data, which were approximately normal. Note that the logarithmic means used here are different from the average measurable dose discussed elsewhere in this report. The T-tests use a 95% confidence level to identify significant differences.

The second approach tested for differences in the distribution of dose (e.g., the shape of the distribution of dose among the worker population) from year to year. This is similar to testing whether the overall distribution of dose in *Exhibit 3-4* differed from year to year. Two non-parametric tests were used: 1) analysis of variance using ranks, and 2) the Kruskall-Wallis test.

These statistical tests reveal trends that are not apparent when considering only the collective and average doses. In addition, the statistical analysis reveals that some of these trends are significant. *Exhibit 3-8* shows the results of pairwise T-tests for the collective TEDE, neutron, and extremity dose DOE-wide. The error bars surrounding each data point represent the 95% confidence levels.

Exhibit 3-8:
DOE-Wide Summary Results for Statistical Tests, 1995 -1999

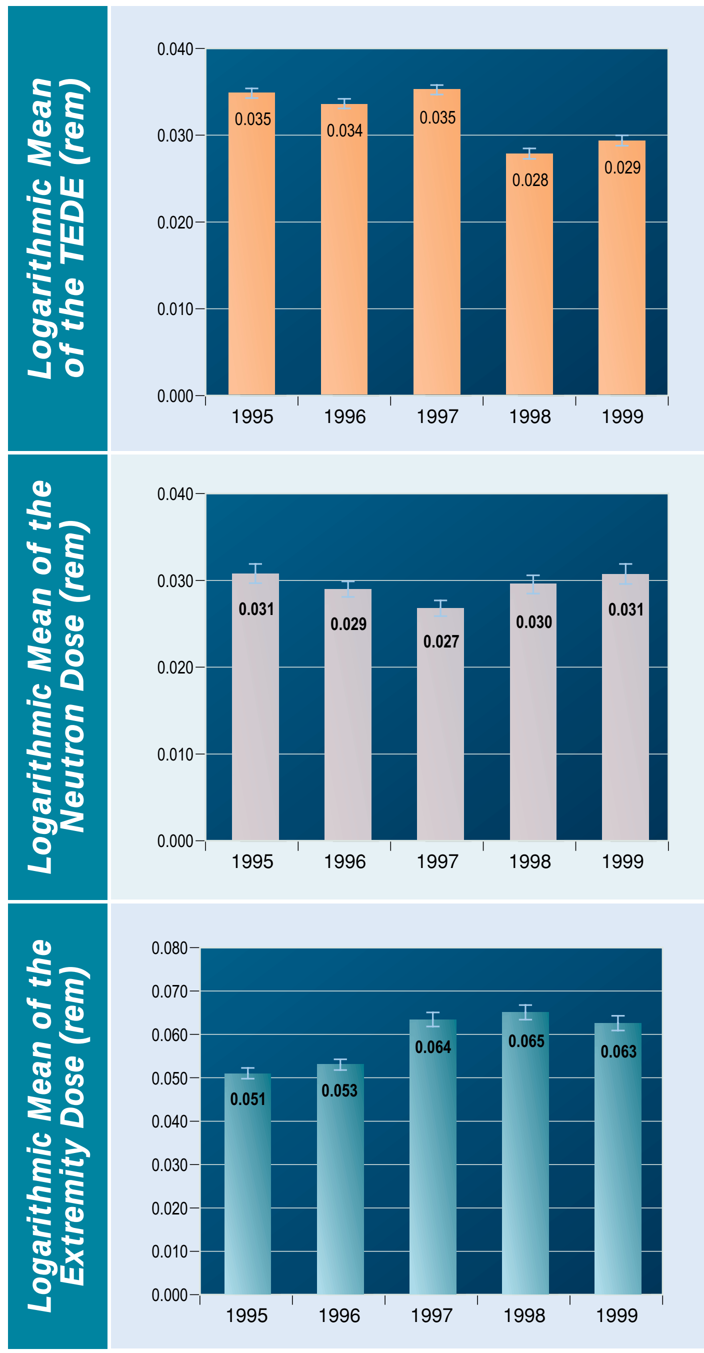
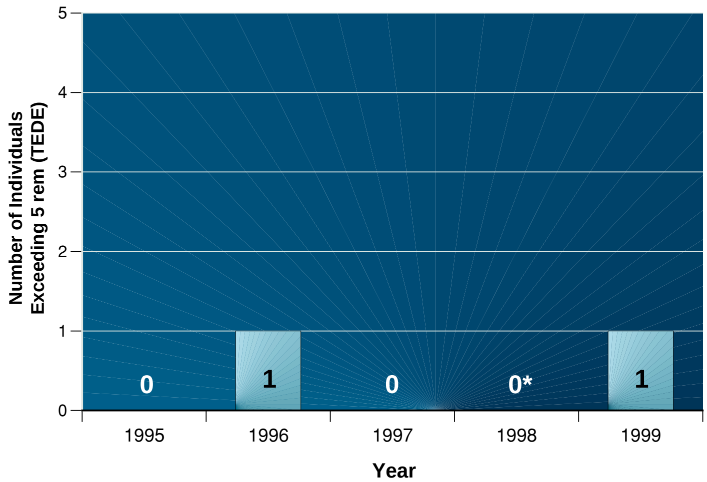


Exhibit 3-9:
Number of Individuals Exceeding 5 rem (TEDE), 1995-1999



* *A 1999 occurrence report indicates a potential exposure of 6.6 rem CEDE for an event that occurred in 1998 at LANL. The final dose has not been assigned, so this dose has not yet been reported to REMS and it has not been included in this report.*

For the collective TEDE, there were small but significant differences in all years with no apparent trends during the 5-year period. Although the collective dose decreased by 1% from 1998 to 1999, the logarithmic mean TEDE per worker increased by 0.001 rem. This suggests that the drop in collective dose reflects fewer workers, rather than lower doses to individual workers. Yet the TEDE per worker was significantly lower in 1998 and 1999 than in earlier years.

The apparent increase in the neutron dose from 1998 to 1999 was not significant. The mean neutron dose has remained near 0.030 rem for the past 5 years. The logarithmic mean measurable extremity dose showed a significant drop between 1998 and 1999, reversing the trend of significant increases observed from 1994 to 1997. However, the 1999 value of 0.063 rem remained significantly above the 1995 to 1996 levels (0.052-0.053 rem).

3.3 Analysis of Individual Dose Data

The above analysis is based on aggregate data for DOE. From an individual worker perspective as well as a regulatory perspective, it is important to closely examine the doses received by individuals in the elevated dose ranges to thoroughly understand the circumstances leading to these doses in the workplace and how these doses may be avoided in the future. The following analysis focuses on doses received by individuals that were in excess of the DOE limit (5 rem TEDE) (50 mSv) and the DOE ACL (2 rem TEDE) (20 mSv).

3.3.1 Doses in Excess of DOE Limits

Exhibit 3-9 shows the number of doses in excess of the TEDE regulatory limit (5 rem)(50 mSv) from 1995 through 1999. Further information concerning the individual dose, radionuclides involved, and site where the dose occurred is shown in *Exhibit 3-10*.

In 1999, there was one individual who exceeded the 5 rem (50 mSv) annual TEDE limit. An individual at the SRS received an estimated internal dose (CEDE) of 6.719 rem (67.19 mSv) from plutonium and americium. The reported dose is an estimate based on bioassay information available to date. The final dose assigned may differ from this estimate as further bioassay monitoring is performed and assessed. A brief summary of the event follows.

One individual received a dose of 6.719 rem which is in excess of the 5 rem (50 mSv) TEDE limit in 1999.

On September 1, 1999, seven workers in the FB-Line facility were exposed to airborne radioactivity in a vault room and an adjacent vestibule during routine operations involving the repackaging of plutonium. The FB-Line facility includes a bagless transfer system, which is a semi-automatic system that seal-welds material into a stainless steel container for storage. During operations one of the seal-welds failed, which caused material to be released and resulted in the intake of the material by operations personnel via inhalation. While all seven individuals received intakes during the occurrence, only one individual received an internal dose exceeding 5 rem (50 mSv). One of the other individuals involved received an internal dose (CEDE) of 1.978 rem (19.78 mSv) which, when combined with external dose received during the year, resulted in an annual TEDE of 2.040 rem (20.40 mSv) (see Section 3.3.2).

Exhibit 3-10:
Doses in Excess of DOE Limits, 1995-1999

Year	Year Uptake	TEDE (rem)	DDE (rem)	CEDE (rem)	Intake Nuclides	Facility Types	Site
1995					None Reported		
1996	1996	11.623	0.123	11.500	Pu-238, Pu-239, Pu-241	Fuel Processing	Savannah River
1997					None Reported		
1998					None Reported *		
1999	1999	6.964	0.245	6.719	Pu-238, Pu-239, Pu-241, Am-241	Weapon Fabrication and Testing	Savannah River

* *A 1999 occurrence report indicates a potential exposure of 6.6 rem CEDE for an event that occurred in 1998 at LANL. The final dose has not been assigned, so this dose has not yet been reported to REMS and it has not been included in this report.*

The direct cause of the event was attributed to the seal weld failure, although the root cause was attributed to management failure to implement effective controls to detect defective welds, and a failure to perform required radiological surveys. Fifty-two corrective action items have been initiated from this occurrence including, but not limited to: engineering evaluation, QA plan for weld process, surveillance, management briefings, revisions of procedures, and training. For more information and complete details of the event, see the Occurrence Report SR—WSRC-FBLINE-1999-0026.

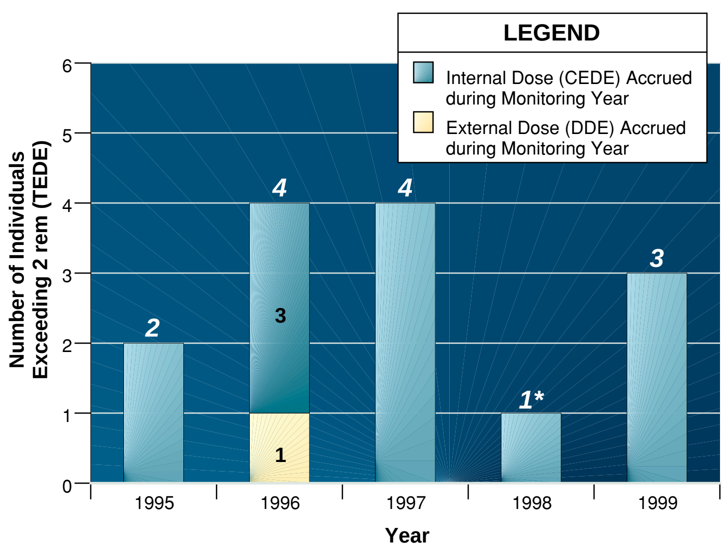
In December 1999, an occurrence report was submitted by LANL indicating that an individual may have received an internal dose in excess of 5 rem (50 mSv) from an intake received during 1998. However, a final dose for this individual has not yet been assigned, so the dose has not yet been reported to REMS and has not been included in the figures presented in this report. Future reports will be updated to incorporate this dose when the final dose has been determined. For more information, see the Occurrence Report ALO-LA-LANL-TA55-1999-0045.

3.3.2 Doses in Excess of Administrative Control Level

The "RadCon Manual" [5] recommends a 2 rem (20 mSv) ACL for TEDE, which is not to be exceeded without prior DOE approval. Each DOE site required to follow the "RadCon Manual" must establish its own, more restrictive ACL that requires contractor management approval to be exceeded. The number of individuals receiving doses in excess of the 2 rem (20 mSv) ACL is a measure of the effectiveness of DOE's radiation protection program.

As shown in *Exhibit 3-11*, three individuals received a TEDE above 2 rem (20 mSv) during 1998. One of the individuals also exceeded the 5 rem (50 mSv) TEDE limit as described in Section 3.3.1. The second individual was involved in the same occurrence as the individual who exceeded 5 rem (50 mSv) as described in Section 3.3.1.

Exhibit 3-11:
Number of Doses in Excess of the DOE 2 rem ACL, 1995-1999



* *A 1999 occurrence report indicates a potential exposure of 6.6 rem CEDE for an event that occurred in 1998 at LANL. The final dose has not been assigned, so this dose has not yet been reported to REMS and it has not been included in this report.*

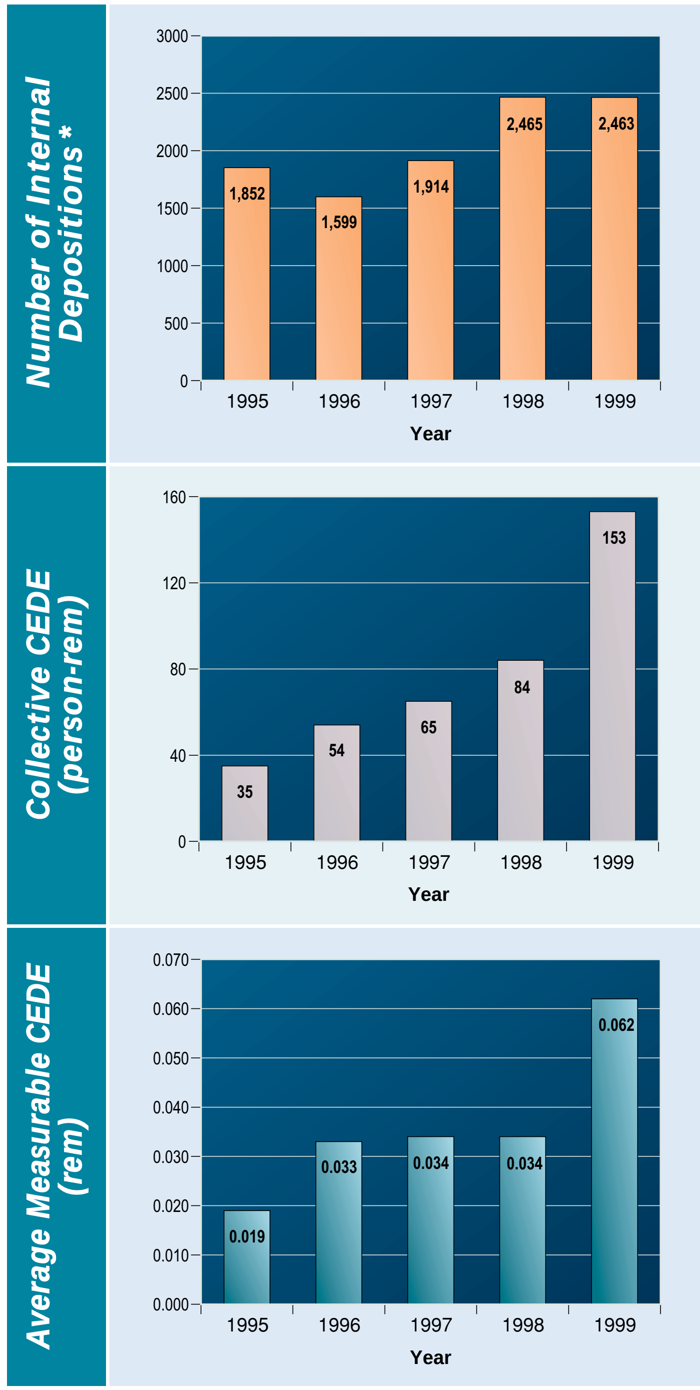
The third individual received a TEDE of 3.525 rem (35.25 mSv) in an incident at Rocky Flats. The individual was performing size reduction activities in a glovebox using a port-a-band saw and accidentally pushed the start button while moving the saw and cut his finger. An initial survey revealed the cut to be contaminated, and subsequent bioassay confirmed an intake of plutonium and americium from the wound. The root cause was attributed to personnel error, inattention to detail. A contributing cause was cited as a design problem with the saw, which did not include a safety switch. Corrective actions include a review of power tool usage and an evaluation and implementation of the use of Kevlar cut resistant gloves during cutting operations. For more information, see the Occurrence Report RFO- -KHLL-779OPS-1999-006. A similar incident concerning a contaminated hand wound during glovebox operations was reported in 1998 at Rocky Flats in Occurrence Report RFO- - KHLL-779OPS-1998-0029.

3.3.3 Internal Depositions of Radioactive Material

As discussed in Section 3.3.1, in the past, some of the highest doses to individuals have been the result of intakes of radioactive material. For this reason, DOE emphasizes the need to avoid intakes and tracks the number of intakes as a performance measure.

The number of internal depositions of radioactive material (otherwise known as worker intakes), collective CEDE, and average measurable CEDE for 1995-1999 is shown in *Exhibit 3-12*. The number of internal depositions decreased by less than 1% from 1998 to 1999. However, the collective CEDE has increased for the fifth year in a row, with an increase of 82% between 1998 and 1999. Due to the increase in the collective CEDE and decrease in the number of internal depositions, the average measurable CEDE increased by 82% from 1998 to 1999.

Exhibit 3-12:
Number of Internal Depositions, Collective CEDE, and Average Measurable CEDE, 1995-1999



* *The number of internal depositions represents the number of internal dose records reported for each individual.*

The number of internal depositions of radioactive material for 1997-1999 is shown in *Exhibit 3-13*. The internal depositions were categorized into nine radionuclide groups. Intakes involving multiple nuclides are listed as "mixed". Nuclides where fewer than 10 individuals had intakes over the 3-year period are grouped together as "other". Only those records with internal dose greater than zero are included in this analysis. It should be noted that the different nuclides have different radiological properties, resulting in varying minimum levels of detection and reporting.

The highest average CEDE is due to plutonium intakes, the majority of which occur at Savannah River and Rocky Flats. Both of these sites reported occurrences where individuals received internal dose from plutonium that exceeded 2 rem (20 mSv) CEDE, and Savannah River reported an occurrence where an individual exceeded 5 rem (50 mSv) from an intake of plutonium (see Section 3.3). Sixty-four percent of the collective CEDE from plutonium in 1999 is attributed to the intake events for these three individuals. Due to the radiological characteristics and retention of plutonium in the body, relatively small intakes result in large dose values when the CEDE is calculated over a 50-year period.

The highest collective CEDE and the largest number of intakes for 1999 is attributed to uranium exposures, primarily at the Oak Ridge Y-12 facility. The collective CEDE from uranium intakes at the Y-12 plant increased 260% from 1998 to 1999 as a result of continued operation and maintenance of the Enriched Uranium Operations (EUO) facilities. The increase is due to EUO personnel exposure to insoluble uranium and the use of more conservative internal dosimetry modeling parameters associated with uranium solubility. External dose also increased as a result of additional work activities associated with disassembly operations and storage, and depleted uranium operations at the site.

The number of intakes, collective CEDE, and average measurable CEDE for tritium intakes decreased for the third year in a row primarily from decreases in intakes at Savannah River and Brookhaven. These two sites account for 58% of the internal dose from tritium for 1999. Intakes from radon decreased from 1998 to 1999 because the Grand Junction site is no longer in operation.

It should be noted that relatively few workers receive measurable internal dose and therefore fluctuations in the number of workers and collective CEDE can occur from year to year.

Exhibit 3-13:
Number of Intakes, Collective Internal Dose, and Average Dose by Nuclides, 1997-1999

Nuclide	Number of Internal Depositions*			Collective CEDE (person-rem)			Average CEDE (rem)		
Year	**1997**	**1998**	**1999**	**1997**	**1998**	**1999**	**1997**	**1998**	**1999**
Hydrogen-3 (Tritium)	734	673	554	5.450	3.199	2.438	0.007	0.005	0.004
Technetium	8	2	1	0.009	0.006	0.007	0.001	0.003	0.007
Radon-222	270	280	39	**27.834** ◄	33.840	2.147	0.103	**0.121** ◄	0.055
Thorium	14	13	10	0.153	0.257	0.836	0.011	0.020	0.084
Uranium	**787** ◄	**1,326** ◄	**1,671** ◄	13.022	**35.404** ◄	**126.163** ◄	0.017	0.027	0.076
Plutonium	69	92	101	13.718	9.553	19.177	0.199	0.104	**0.190** ◄
Americium-241	9	15	16	0.564	1.219	1.681	0.063	0.076	0.105
Other	18	62	51	4.264	0.725	0.196	**0.237** ◄	0.012	0.004
Mixed	5	1	20	0.341	0.004	0.223	0.068	0.004	0.011
Totals	**1,914**	**2,465**	**2,463**	**65.355**	**84.207**	**152.868**	**0.034**	**0.034**	**0.062**

Note: Arrowed values indicate the greatest value in each column.
** The number of internal depositions represents the number of internal dose records reported for each individual.*

Exhibit 3-14 shows the distribution of the internal dose from 1995 to 1999. The total number of individuals with intakes in each dose range is the sum of all records of intake in subject dose range. The internal dose does not include doses from prior intakes (legacy AEDE dose). Individuals with multiple intakes during the year may be counted more than once. Doses below 0.020 rem (0.20 mSv) are shown as a separate dose range to show the large number of doses in this low-dose range. All but two of the internal doses were below 2 rem (20 mSv) in 1999.

The internal dose records indicate that the majority of the intakes reported are at very low doses. In 1999, 70% of the internal dose records were for doses below 0.020 rem (0.20 mSv) and represent only 6% of the collective internal dose. Over the 5-year period, internal doses from new intakes accounted for only 5% of the collective TEDE and only 7% of the individuals who received internal dose were above the monitoring threshold specified (100 mrem) in 10 CFR 835.402(c).

The internal dose records indicate that the majority of the intakes reported are at very low doses.

Over the 5-year period, internal doses accounted for only 5% of the collective TEDE.

The internal dose distribution can also be shown in terms of the percentage of the collective dose delivered above certain dose levels. *Exhibit 3-15* shows this information for the CEDE for each year from 1995 to 1999. While the fluctuations in internal dose prohibit definitive trend analysis, it appears from the graph that internal doses shifted from the higher dose ranges to the lower dose ranges from 1996 to 1998. The increase in the percentages above 2 rem (20 mSv) in 1999 is due to the two individuals that exceeded 2 rem (20 mSv) CEDE in 1999. The distribution of internal dose by site and nuclide for 1999 is presented in Appendix B-22.

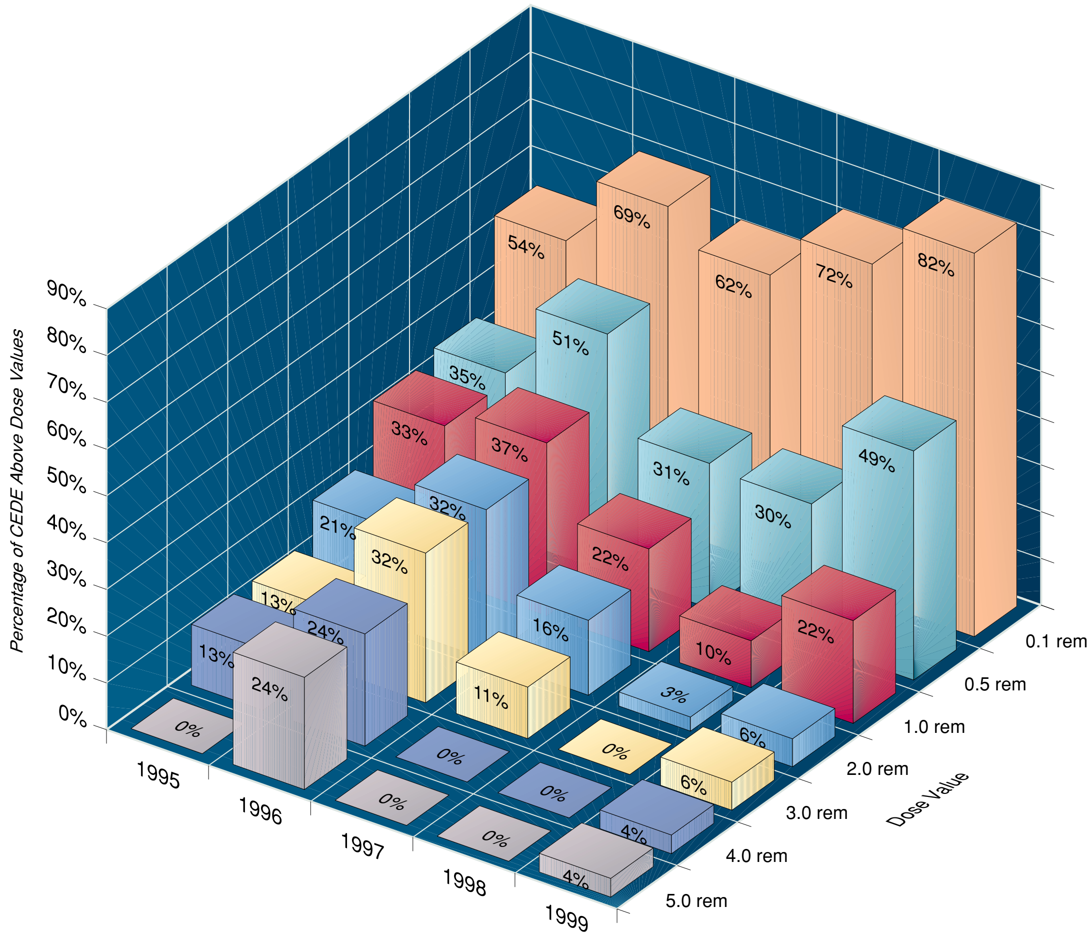
Exhibit 3-14:
Internal Dose Distribution from Intakes, 1995-1999

Number of Individuals with internal dose in each dose range (rem).*

Year	Meas. <0.020	0.020-0.100	0.100-0.250	0.250-0.500	0.500-0.750	0.750-1.000	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	>5.0	Total No. of Indiv.*	Total Collective Internal Dose CEDE (person-rem)
1995	1,564	245	33	4	1		3	1		1		1,852	35.312
1996	1,324	202	42	13	9	4	3		1		1	1,599	53.524
1997	1,422	359	100	18	8	1	3	1	2			1,914	65.355
1998	1,909	353	128	43	18	8	5	1				2,465	84.207
1999	1,726	443	137	78	32	26	19		1		1	2,463	152.868

Note: Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.
** Individuals may have multiple intakes in a year and, therefore, may be counted more than once.*

Exhibit 3-15:
Distribution of Collective CEDE vs. Dose Value, 1995-1999



When examining trends involving internal dose, several factors should be considered. Some of the largest changes in the number of reported intakes over the years resulted from changes in internal dosimetry practices. Periodically, sites may change monitoring practices or procedures, which may involve increasing the sensitivity of the detection equipment, thereby increasing the number of individuals with measurable internal doses. Conversely, sites may determine that internal monitoring is no longer required due to historically low levels of internal dose or a decreased potential for intake. There are relatively few intakes each year, and the CEDE method of calculating internal dose can result in large internal doses from the intake of long-lived nuclides. This can result in statistical variability of the internal dose data from year to year.

3.4 Analysis of Site Data

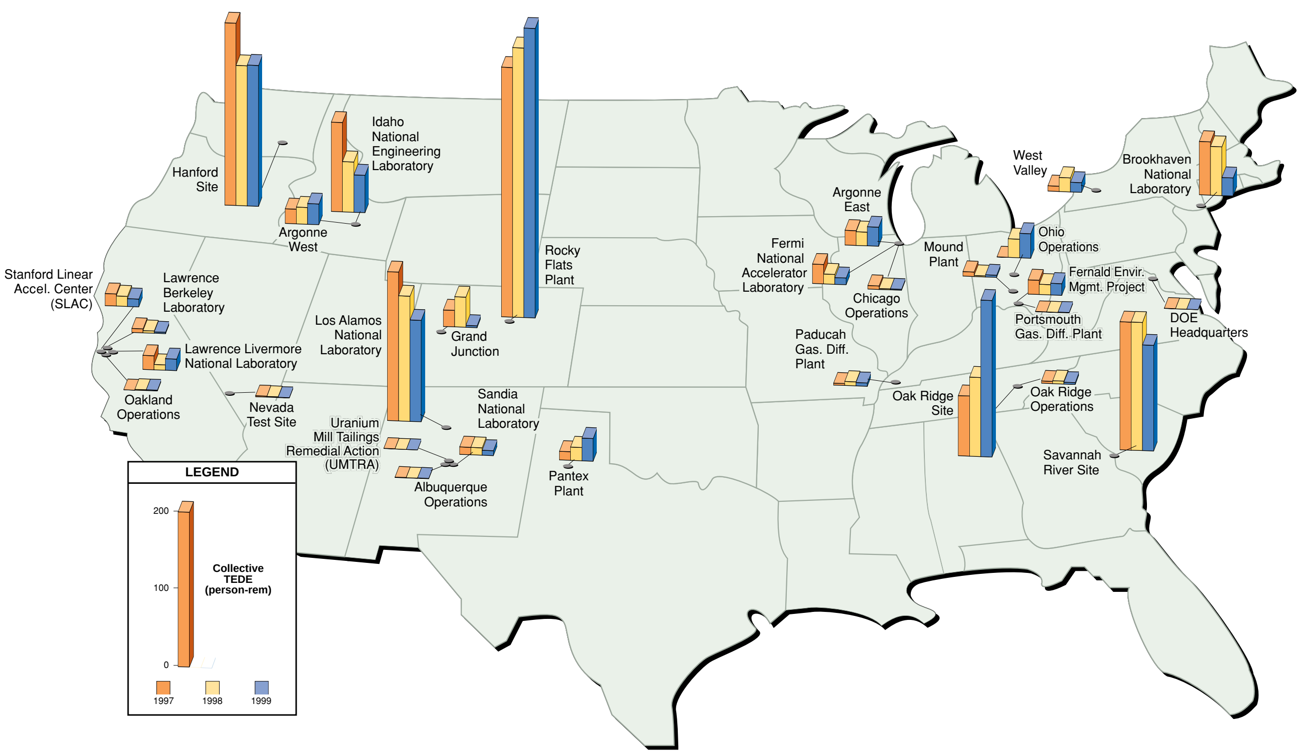
3.4.1 Collective TEDE by Site and Operations/Field Offices

The relative collective TEDE for 1997-1999 for the major DOE sites and Operations/Field Offices is shown in *Exhibit 3-16*. A list of the collective TEDE and number of individuals with measurable TEDE for the DOE Sites and Operations/Field Offices is shown in *Exhibit 3-17*. Operations/Field Office dose is shown separately from the site dose where it is reported separately. The collective TEDE decreased by 1% between 1998 and 1999, with six of the highest dose sites (Rocky Flats, Oak Ridge, Hanford, Savannah River, Los Alamos, and Idaho) contributing 83% of the total DOE collective TEDE.

3.4.2 Dose by Labor Category

DOE occupational exposures are tracked by labor category at each site to facilitate identification of exposure trends, which assist management in prioritizing ALARA activities.

Exhibit 3-16:
Relative Collective TEDE by Site for 1997-1999



Note: More complete details for each site, Operations/Field Office, and reporting organization can be found in Appendix B.

Exhibit 3-17:
Collective TEDE and Number of Individuals with Measurable TEDE by Site, 1997-1999

Operations/ Field Office	Site	1997 Collective TEDE (person-rem)	1997 Number with Meas. TEDE	1998 Collective TEDE (person-rem)	1998 Number with Meas. TEDE	1999 Collective TEDE (person-rem)	1999 Number with Meas. TEDE
Albuquerque	Ops. and Other Facilities	0.5	25	0.2	11	0.4	26
	Los Alamos National Lab. (LANL)	192.2	2,333	161.6	1,916	131.0	1,479
	Pantex Plant (PP)	11.1	213	17.2	312	29.3	353
	Sandia National Lab. (SNL)	9.7	196	9.5	181	6.4	120
	Uranium Mill Tailings Remedial Action (UMTRA) Project	0.3	36	0.0	0		
	Grand Junction			38.9	295	2.5	48
Chicago	Ops. and Other Facilities	3.4	105	1.2	44	1.5	82
	Argonne Nat'l. Lab. - East (ANL-E)	19.0	238	17.7	182	24.6	187
	Argonne Nat'l. Lab. - West (ANL-W)	18.9	249	21.7	236	26.7	299
	Brookhaven Nat'l. Lab.(BNL)	68.9	1,463	63.0	1,055	23.4	521
	Fermi Nat'l. Accelerator Lab.(FERMI)	25.0	859	12.8	441	8.7	227
DOE HQ	DOE Headquarters	0.2	5	0.0	2	0.0	4
	DOE North Korea Project	8.3	24	5.4	14		
	DOE Kazakhstan Project			0.4	13	0.1	3
Idaho	Idaho Site	115.3	1,141	64.9	743	48.3	729
Nevada	Nevada Test Site (NTS)	1.3	25	1.0	13	0.4	6
Oakland	Ops. and Other Facilities	1.4	50	1.0	45	1.0	85
	Lawrence Berkeley Lab. (LBL)	5.2	128	2.9	76	1.8	46
	Lawrence Livermore Nat'l. Lab. (LLNL)	22.1	190	6.9	107	14.9	137
	Stanford Linear Accelerator Center (SLAC)	14.2	117	13.1	157	10.2	104
Oak Ridge	Ops. and Other Facilities	6.6	135	3.8	195	2.4	109
	Oak Ridge Site	77.7	1,614	102.7	2,187	202.2	2,493
	Paducah Gaseous Diff. Plant (PGDP)	2.5	36	5.3	68	4.3	58
	Portsmouth Gaseous Diff. Plant (PORTS)	0.2	3	0.2	15	0.5	25
Ohio	Ops. and Other Facilities	1.2	31	24.1	78	31.6	104
	Fernald Environmental Management Project	18.4	520	13.3	559	15.1	458
	Mound Plant	5.8	197	1.3	106	2.7	197
	West Valley	6.9	174	18.2	260	12.5	243
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**323.2** ◄	3,187	**348.1** ◄	**3,298** ◄	**373.9** ◄	**3,517** ◄
Richland	Hanford Site	235.4	2,058	180.9	1,772	182.0	2,013
Savannah River	Savannah River Site (SRS)	165.3	**3,327** ◄	165.5	3,163	136.5	2,995
Totals		**1,360.2**	**18,679**	**1,303.1**	**17,544**	**1,295.2**	**16,668**

Note: Arrowed values indicate the greatest value in each column.

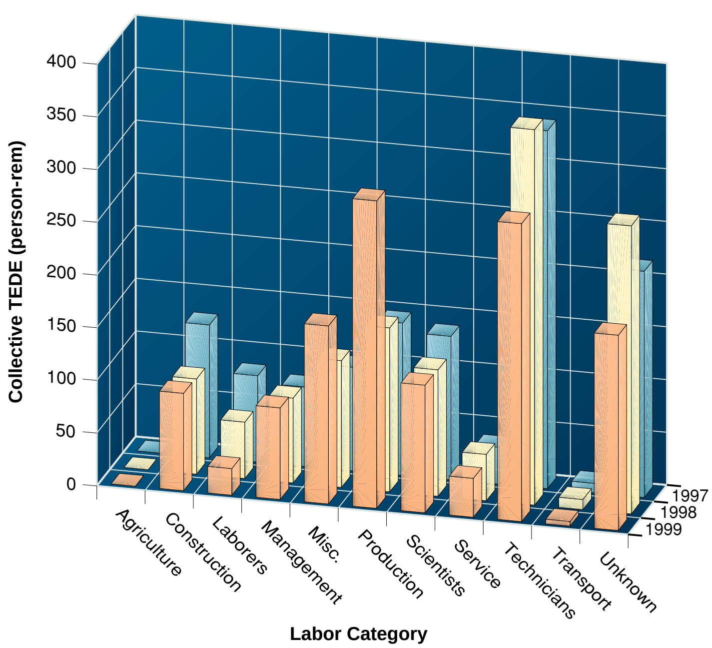
Exhibit 3-18:
Collective Dose by Labor Category, 1997-1999

Labor Category	Number with Meas. Dose			Collective TEDE (person-rem)			Average Meas. TEDE (rem)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
Agriculture	3	0	1	0.0	0.0	0.0	0.025	0.0	0.020
Construction	1,696	1,664	1,480	125.9	90.4	92.4	0.074	0.054	0.062
Laborers	509	492	285	81.9	53.6	25.2	**0.161** ◄	0.109	0.089
Management	1,402	1,395	1,755	75.4	80.5	86.9	0.054	0.058	0.050
Misc.	2,093	2,272	2,001	98.2	120.2	168.9	0.047	0.053	0.084
Production	1,796	1,783	2,263	144.5	155.5	**291.6** ◄	0.080	0.087	**0.129** ◄
Scientists	3,052	2,784	2,617	136.1	120.0	121.0	0.045	0.043	0.046
Service	634	665	829	35.0	43.9	36.8	0.055	0.066	0.044
Technicians	2,826	2,919	**2,690** ◄	**339.5** ◄	**356.2** ◄	282.6	0.120	**0.122** ◄	0.105
Transport	179	146	122	9.1	9.5	4.4	0.051	0.065	0.036
Unknown	**4,489** ◄	**3,424** ◄	2,625	214.5	273.2	185.2	0.070	0.080	0.071
Totals	**18,679**	**17,544**	**16,668**	**1,360.1**	**1,303.1**	**1,295.2**	**0.073**	**0.074**	**0.078**

Note: Arrowed values indicate the greatest value in each column.

Worker occupation codes are reported in accordance with DOE M 231.1-1 and are grouped into major labor categories in this report. The collective TEDE for each labor category for 1997-1999 is shown in *Exhibits 3-18* and *3-19*. Technicians and production staff have the highest collective TEDE (other than unknown) for the past 3 years because they generally handle more radioactive sources than individuals in the other labor categories. Fifty percent of the technician dose is attributed to radiation protection technicians. Fifty two percent of the dose to production personnel is attributed to plant operators.

Exhibit 3-19:
Graph of Collective Dose by Labor Category, 1997-1999



The 'unknown' and 'miscellaneous' categories have the next highest collective TEDE totals. Seventy-five percent of the dose in the "unknown" category for 1999 is attributed to LANL. Currently the LANL computer system does not maintain the data necessary to report occupation codes in accordance with DOE M 231.1-1. Other sites also report individuals with an occupation code of "unknown". Typically, these workers are subcontractors or temporary workers. Information concerning these workers tends to be limited.

As noted in the 1998 report, Idaho National Engineering and Environmental Laboratory (INEEL) had reported individuals with measurable dose under the labor category of "agriculture". Upon review, these workers were determined to actually be involved in operations, and were incorrectly reported under agriculture. These records have been corrected and the data for 1999 and all prior years have been updated to reflect this correction. The remaining individuals reported in this category are groundskeepers, who received minimal dose.

An examination of internal dose from intake by labor category from 1997 to 1999 is presented in Appendix B-20. In addition, Appendix B-21 shows the TEDE distribution by labor category and occupation for 1999.

3.4.3 Dose by Facility Type

DOE occupational exposures are tracked by facility type at each site to better understand the nature of exposure trends and to assist management in prioritizing ALARA activities. Contribution of certain facility types to the DOE collective TEDE is shown in *Exhibits 3-20* and *3-21*. The collective dose for each facility type at each major Site of each DOE Operations/Field Office is shown in Appendix B-8. An examination of internal dose from intake by facility type and nuclide for 1997 to 1999 is presented in Appendix B-18.

The collective TEDE for 1997-1999 was highest at weapons fabrication and testing facilities. Sixty-three percent of this dose was accrued at Rocky Flats, with 22% at the Oak Ridge Y-12 facility and 10% at Savannah River in 1999. It should be noted that, although weapons fabrication and testing facilities account for the highest collective dose, Rocky Flats and Savannah River account for the majority of this dose and these sites are now primarily involved in nuclear materials stabilization and waste management.

Exhibit 3-20:
Graph of Collective Dose by Facility Type, 1997-1999

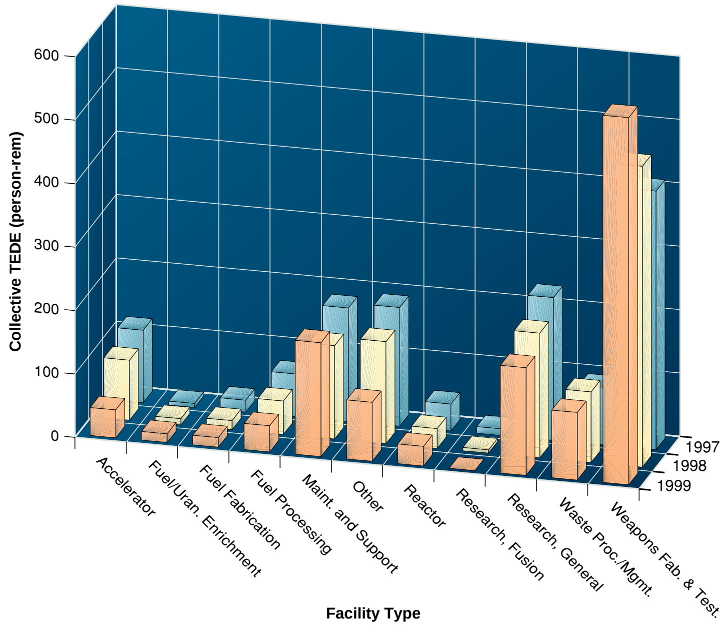


Exhibit 3-21:
Collective Dose by Facility Type, 1997-1999

Facility Type	Number with Meas. Dose			Collective TEDE* (person-rem)			Average Meas. TEDE (rem)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
Accelerator	2,562	1,618	907	114.4	94.7	44.0	0.045	0.059	0.049
Fuel/Uranium Enrichment	149	256	416	6.2	10.0	13.6	0.041	0.039	0.033
Fuel Fabrication	545	593	459	18.8	14.3	15.1	0.035	0.024	0.033
Fuel Processing	1,261	1,172	1,107	67.4	52.6	41.2	0.053	0.045	0.037
Maintenance and Support	2,177	1,728	2,083	180	147.3	179.5	0.083	0.085	0.086
Other	2,423	2,297	1,533	191.3	164.6	97.2	0.079	0.072	0.063
Reactor	729	619	629	42.3	31.4	31.0	0.058	0.051	0.049
Research, Fusion	132	75	50	10.5	5.2	6.0	0.080	0.070	**0.120** ◀
Research, General	2,681	2,410	2,224	226.0	196.6	170.0	0.084	0.082	0.076
Waste Processing/Mgmt.	1,609	1,512	1,475	94.5	111.4	106.6	0.059	0.074	0.072
Weapons Fab. and Testing	**4,411** ◀	**5,264** ◀	**5,785** ◀	**408.7** ◀	**475.0** ◀	**591.0** ◀	**0.093** ◀	**0.090** ◀	0.102
Totals	**18,679**	**17,544**	**16,668**	**1,360.1**	**1,303.1**	**1,295.2**	**0.073**	**0.074**	**0.078**

Note: Arrowed values indicate the greatest value in each column.

** 1997-1999 TEDE = CEDE + DDE*

3.4.4 Radiation Protection Occurrence Reports

In addition to the records of individual radiation exposure monitoring required by DOE M 231.1-1, sites are required to report certain unusual or off-normal occurrences involving radiation under DOE Order 232.1A . These reports are submitted to ORPS in accordance with the reporting criteria of DOE M 232.1-1A. Two of the occurrence categories are directly related to occupational exposure and are required to be reported under Section 9.3 as "Group 4" occurrences. Group 4A reports *radiation exposure* occurrences, and Group 4B reports *personnel contamination* occurrences. In one case reported in 1999, a *personnel contamination* (group 4B) occurrence resulted in *radiation exposure*, (group 4A) and this information is reported in both groups. The occurrence reporting requirements for DOE M 232.1-1A are summarized in *Exhibit 3-22*. These requirements became effective under DOE M 232.1-1 in September 1995, and have remained essentially unchanged under DOE M 232.1-1A which became effective in July 1997.

The number of reports submitted to ORPS is usually indicative of breaches or lapses in radiation protection practices resulting in unanticipated radiation exposure or contamination of personnel or clothing. Increases or decreases in the number of these occurrences may reflect radiation exposures, the effectiveness of DOE radiation protection programs, or changes to the reporting procedure or thresholds. These effects can result in statistical variability in the number of ORPS reports from year to year.

It is important to note that reports are submitted to ORPS for an occurrence or event. In some cases, one event could result in the contamination or exposure of multiple individuals. In ORPS, this is counted as one occurrence, even though multiple individuals were exposed. In addition, one occurrence report may involve the roll up of multiple similar occurrences. For the analysis included in this report, only the number of occurrences is considered.

The number of occurrences is broken down into two categories for *radiation exposure* and *personnel contamination* and is presented in *Exhibits 3-23* and *3-25*.

Exhibit 3-22:
Criteria for Radiation Exposure and Personnel Contamination Occurrence Reporting

Occurrence	Category	DOE M 232.1-1A Criteria
Radiation Exposure	*Unusual*	*Individuals receiving a dose in excess of the occupational exposure limits (see Exhibit 2-1) for on-site exposure or exceeding the limits in DOE 5400.5, Chapter II, Section 1 for off-site exposure to a member of the public.*
	Off-Normal	◆ *Any single occupational exposure that exceeds an expected exposure by 100 mrem.* ◆ *Any single unplanned exposure onsite to a minor, student, or member of the public that exceeds 50 mrem.* ◆ *Any dose that exceeds the limits specified in DOE 5400.5, Chapter II, Section 7 for off-site exposure to a member of the public.*
Personnel Contamination	*Unusual*	◆ *Any single occurrence resulting in the contamination of five or more personnel or clothing at a level exceeding the 10 CFR 835 Appendix D values for total contamination limits.* ◆ *Any occurrence requiring off-site medical assistance for contaminated personnel.* ◆ *Any measurement of personnel or clothing contamination offsite due to DOE operations.*
	Off-Normal	*Any measurement of personnel or clothing contamination at a level exceeding the 10 CFR 835 Appendix D total contamination limits.*

3.4.4.1 Radiation Exposure Occurrences

Radiation exposure occurrences are reported when individuals are exposed to radiation above anticipated levels. The number of *radiation exposure* occurrences decreased substantially from 1998 to 1999 to the lowest levels reported in the previous five years. One *radiation exposure* occurrence at LANL was classified as an unusual event and one *radiation exposure* classified as *personnel contamination* was categorized as an unusual event. One *personnel contamination* occurrence reported at Savannah River involved several people with one individual dose exceeding the DOE annual dose limit.

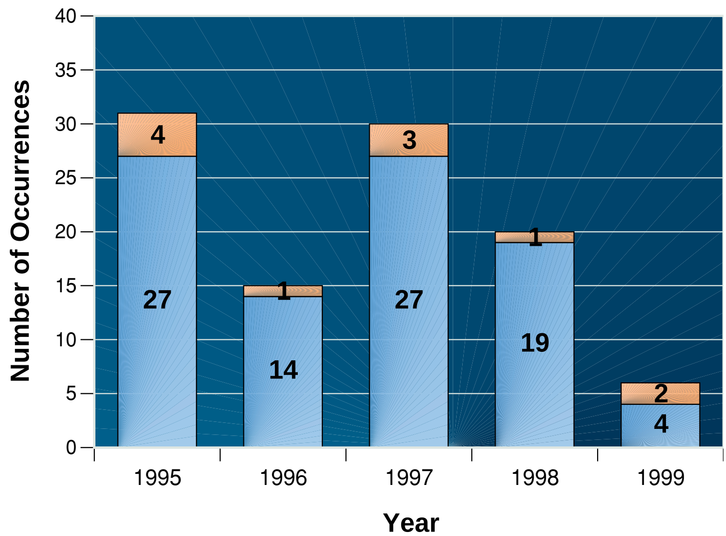
The decrease in the number of *radiation exposure* occurrences during 1999 likely reflects an overall improvement in the radiation protection arena rather than any reduction in production. It also reflects the assimilation of the more stringent reporting thresholds instituted during 1996.

The number of Radiation Exposure occurrences has decreased by 70% from 1998 and 81% since 1995.

In 1999, 4 of the 6 occurrences (67%) shown in *Exhibit 3-23* involved Off-Normal occurrences. Two of the 4 off-normal occurrences (50%) involved internal dose or potential internal dose, while 2 of the 4 off-normal occurrences (50%) involved external whole body dose or the potential to receive an external dose. Of the 6 *radiation exposure* occurrences, two were categorized as Unusual Occurrences because they involved individual total internal exposures exceeding the 5 rem (50 mSv) annual TEDE limit. One of those exposures was reported as a *personnel contamination* occurrence that caused an internal exposure exceeding 5 rem (50 mSv) CEDE. The event involved seven individuals receiving doses ranging from 0.8 rem (8 mSv) to 6.7 rem (67 mSv) CEDE.

Two of the internal exposures reported in 1999 occurred in 1995, two occurred in 1996, one in 1997 and two in 1998. Many of these previously unreported exposures resulted from revising the reporting sites "decision-level" downward subsequently triggering a reassessment of previously dismissed analytical results as intakes of radioactive material. The results are reported in the year that the intake occurred and represent the cumulative projected exposures for the next 50 years.

Exhibit 3-23:
Number of Radiation Exposure Occurrences, 1995-1999



None of the 102 *radiation exposure* occurrence reports submitted to ORPS from 1995 through 1999 have involved exposures to minors, members of the public, or pregnant workers. *Exhibit 3-24* shows the breakdown of occurrences for *radiation exposure* by site for the five-year period 1995 to 1999. Seventy-two (72%) percent of the *radiation exposure* occurrences were reported by five sites: Savannah River, Oak Ridge, Mound, Los Alamos, and Rocky Flats.

Exhibit 3-24:
Radiation Exposure Occurrences by Site, 1995-1999

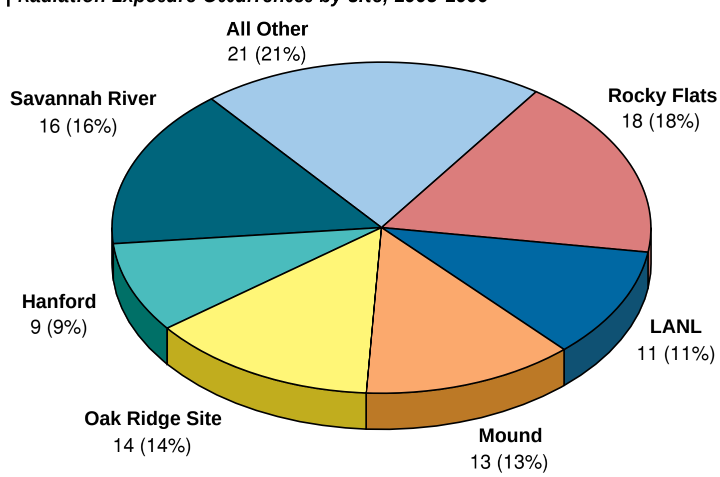
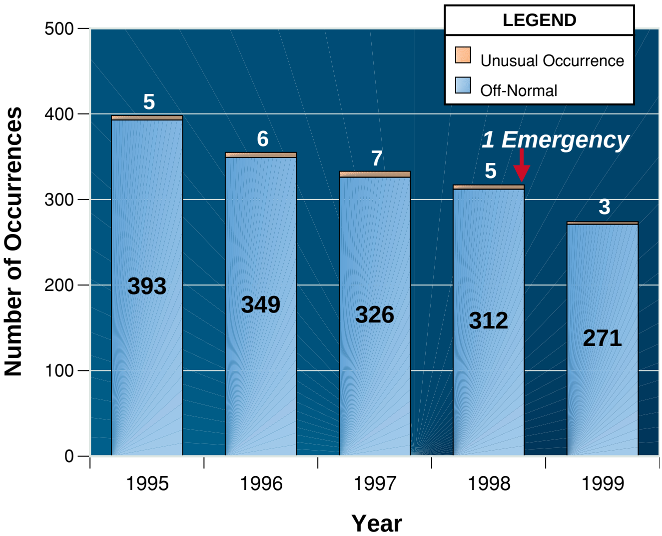


Exhibit 3-25:
Number of Personnel Contamination Occurrences, 1995-1999



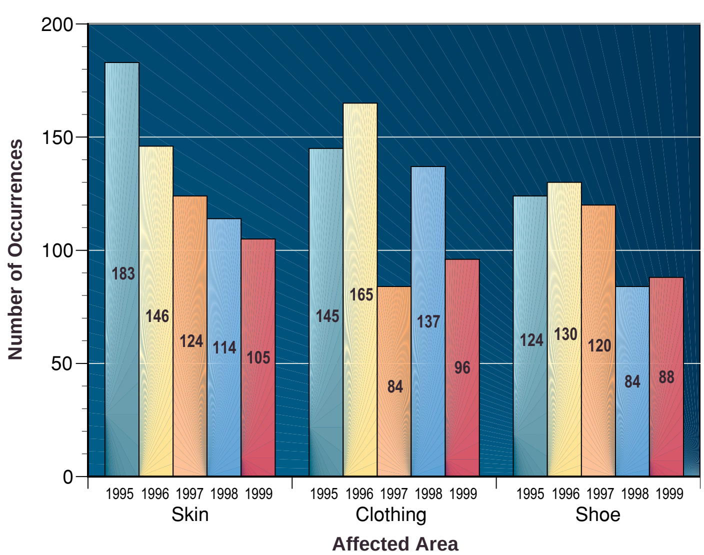
internal exposure exceeding 5 rem (50 mSv) CEDE, and two others resulted in internal exposures exceeding 2 rem (20 mSv) CEDE. In 1998, one *personnel contamination* occurrence was reported as an emergency. A seal failed during maintenance operations, allowing radioactive contamination to escape. An alert was declared by the ANL-West Emergency Action Manager as a precautionary measure to contain the spread of contamination within the Fuel Conditioning Facility. For more information, see the Occurrence Report CH-AA-ANLW-FCF-1998-0005.

The number of Personnel Contamination occurrences has decreased by 31%, or an average of 8% per year between 1995 and 1999.

3.4.4.2 Personnel Contamination Occurrences

Personnel contamination occurrences are reported when personnel or clothing are contaminated above established thresholds. The number of *personnel contamination* occurrences decreased by 14% from 1998 to 1999 continuing the downward trend that has resulted in an overall reduction in the number of reported *personnel contamination* occurrences of 31% since 1995 (see *Exhibit 3-25*). Three *personnel contamination* occurrences were classified as unusual events, down from 5 occurrences in 1998. One *personnel contamination* event resulted in an

Exhibit 3-26:
Personnel Contamination Occurrences by Affected Area, 1995-1999



Personnel contamination occurrences can involve contamination of the skin, clothing, or shoes. *Exhibit 3-26* shows the breakdown of occurrences by affected area from 1995 through 1999. The affected area is not recorded as part of the ORPS report and must be determined by reviewing the text of each report. Some occurrences may involve more than one affected area (i.e., protective clothing and the skin beneath it) and therefore may be counted in more than one category. Between 1995 and 1999, contamination occurrences involving the skin continued to decrease by an annual average of 10% per year. Skin contamination expressed as a percentage of total *personnel contamination* occurrences increased from 35% in 1998 to 38% in 1999. Clothing contamination events decreased by 30% from 1998 to 1999, but still were slightly higher than the number reported in 1997. A number of these events involved radioactive particles remaining loosely attached in protective clothing fibers after laundering. The percentage of personnel contamination occurrences involving clothing contamination expressed as a percentage of total personnel contamination occurrences decreased from 41% in 1998 to 35% in 1999. The number of shoe contamination events increased by 5% from 1998 to 1999, although the trend from 1995 – 1999 is an annual reduction averaging 7% per year. The percentage of shoe contamination occurrences increased from 25% in 1998 to 32% of the total *personnel contamination* occurrences in 1999. In at least one case a minor student had a contaminated shoe when he exited the tour area.

Exhibit 3-27:
Personnel Contamination Occurrences by Site, 1995-1999

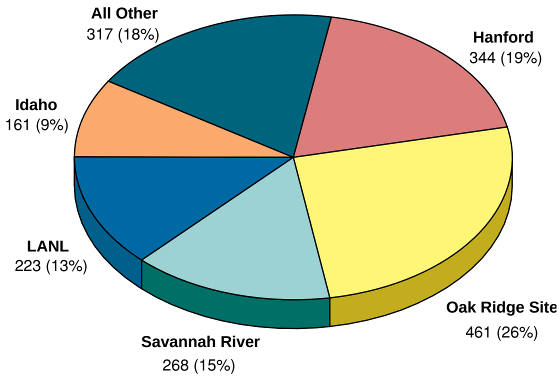


Exhibit 3-27 shows the breakdown of the total number of occurrences of *personnel contamination* by site for the five-year period 1995 to 1999. *Personnel contamination* occurrence reports are distributed among the sites, with Oak Ridge, Hanford, Savannah River, LANL, and Idaho submitting 82% of the reports.

3.4.4.3 Occurrence Cause

Exhibits 3-28 and *3-29* show the breakdown of *radiation exposure* and *personnel contamination* occurrence reports by root cause. For ORPS, the "root cause" is defined as that which, if corrected, would prevent similar occurrences. Only the four significant root cause categories are considered here. Over the past 3 years, management problems were the identified root cause for about 31% of the *radiation exposure* and *personnel contamination* occurrences. The most often-cited management problem in 1999 was work organization/planning deficiency. Other management problems in 1999 include inadequate administrative control, and inadequate policy definition and dissemination.

The number of *radiation exposure* and *personnel contamination* occurrences attributed to unknown sources of radiation dropped approximately 28% between 1998 and 1999, but remains the second largest category comprising nearly 27% of these occurrences over the last three years.

The number of personnel errors contributing to *radiation exposure* and *personnel contamination* decreased from 1998 to 1999; many of these were attributed to *personnel contamination* received during the doffing of personal protective equipment and clothing. Root causes identifying equipment or material failures or defects decreased from 1998 to 1999 and are identified in only about 0.5% of all of the *radiation exposure* and *personnel contamination* occurrences.

Further information concerning ORPS can be obtained by contacting Eugenia Boyle, of EH-33, or the ORPS web page at:

http://tis.eh.doe.gov/oeaf

Exhibit 3-28:
Radiation Exposure Occurrences by Root Cause, 1997-1999

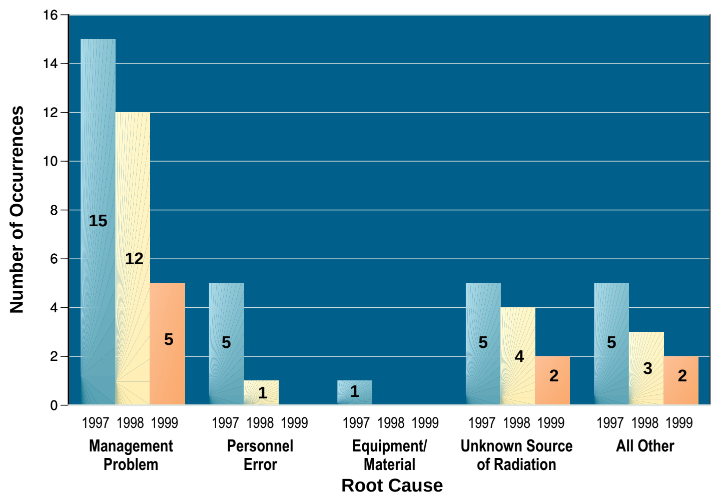
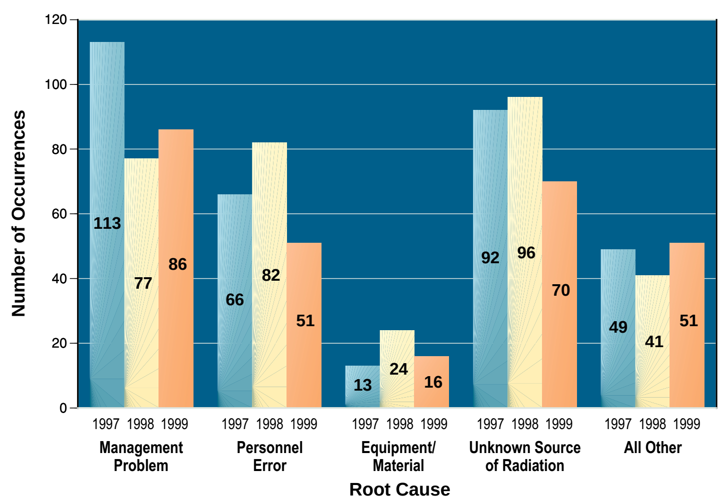


Exhibit 3-29:
Personnel Contamination Occurrences by Root Cause, 1997-1999



3.5 Activities Contributing to Collective Dose in 1999

In an effort to identify the reasons for changes in the collective dose at DOE, several of the larger sites were contacted to provide information on activities that contributed to the collective dose for 1999. These sites (Rocky Flats, Oak Ridge, Hanford, Savannah River, Los Alamos, and Idaho) were the top six sites in their contribution to the collective TEDE for 1999 and comprised 83% of the total DOE dose. Three of the six sites reported decreases in the collective TEDE, which resulted in a 1% decrease in the DOE collective dose in 1999. The six sites are shown in *Exhibit 3-30*, including a description of activities that contributed to the collective TEDE for 1999.

Exhibit 3-30:
Activities Contributing to Collective TEDE in 1999 for Six Sites

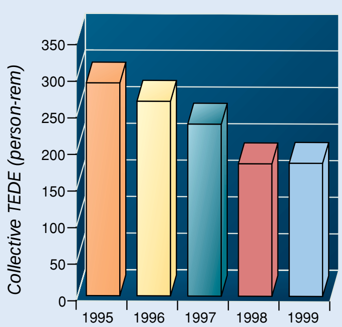
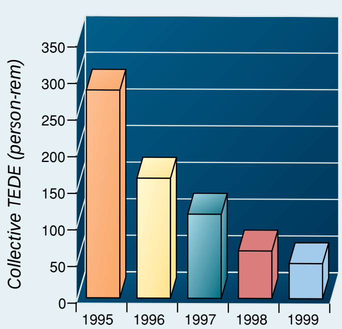
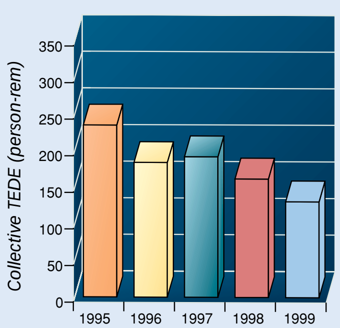
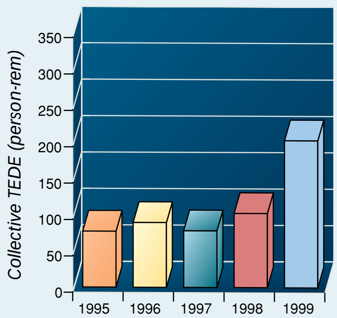
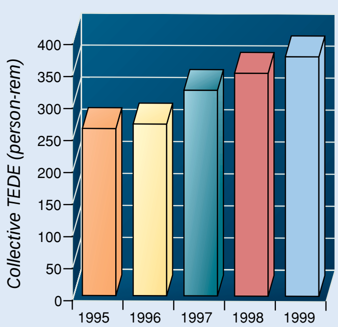
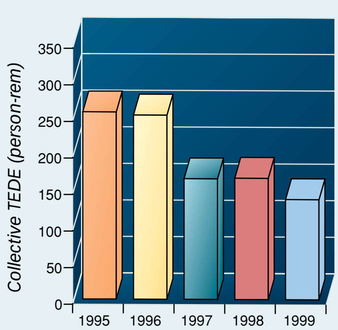
Site	Collective TEDE (person-rem)	Percent Change			Description of Activities at the Site
		98-99 (last yr.)	97-99 (3 yr.)	95-99 (5 yr.)	
Hanford		1% ↑	23% ↓	37% ↓	*The collective TEDE at Hanford increased by 1% from 1998 to 1999. The largest contributors to the collective TEDE at Hanford were thermal stabilization of plutonium-bearing materials at the Plutonium Finishing Plant (PFP) (30%), increased clean-out activities of the River Corridor/324 Facility B-Cell (26%) and Tank Farm work activities (12%). The overall percentage of collective dose attributed to D&D activities at Hanford was down significantly from 24% in 1998 to 2% in 1999 due to the completion of the N-Reactor project. The percentage of the total collective dose from neutrons increased from 9% in 1998 to 14% in 1999 as a result of increased plutonium stabilization work at the PFP.*
Idaho		26% ↓	58% ↓	83% ↓	*The collective TEDE at INEEL decreased by 26% from 1998 to 1999. In 1998, an unexpected activation of the high-pressure carbon dioxide fire suppression system occurred at the Test Reactor Area of INEEL. The accident resulted in one fatality, several life-threatening injuries, and significant risk to the safety of initial rescuers. In response to this accident, corrective actions were implemented that affected the work control system. The implementation of these extensive actions and the related training required considerable resources and time, and resulted in the delay of a significant portion of the radiological work that had been scheduled for 1999.*
Los Alamos National Lab.		19% ↓	32% ↓	44% ↓	*The collective TEDE at the LANL decreased by 19% from 1998 to 1999. The decrease in TEDE is part of a continuing trend to lower collective dose at LANL. Efforts include increased management awareness and improved work practices. The CEDE numbers differ only by about 10% and are consistent with expected statistical variation.*

Exhibit 3-30:
Activities Contributing to Collective TEDE in 1999 for Six Sites (continued)

Site	Collective TEDE (person-rem)	Percent Change			Description of Activities at the Site
		98-99 (last yr.)	97-99 (3 yr.)	95-99 (5 yr.)	
Oak Ridge Site		↑ 97%	↑ 141%	↑ 144%	*Exposures at the Oak Ridge Site increased 97% from 1998 to 1999. Oak Ridge Site includes Oak Ridge National Laboratory (ORNL), Y-12, and East Tennessee Technology Park (ETTP) (formerly K-25).* *The collective TEDE for the ORNL decreased by 17% from 53.0 person-rem in 1998 to 43.7 person-rem in 1999 due to a transfer of work and a decrease in the amount of radiochemical processing during the year. Some projects that attributed to exposure during 1999 include the Environmental Restoration work at the Molten Salt Reactor, Gunite Tank Farm, and Hydro Fracture Facility, radiochemical processing campaigns, and maintenance at the High Flux Isotope Reactor. The neutron dose at ORNL decreased by 48% from 1998 to 1999 due to a decrease in the amount of radiochemical processing that took place at the Radiochemical Engineering Development Center.* *The collective TEDE at the Y-12 plant increased by 227% from 45.8 person-rem in 1998 to 149.8 person-rem in 1999 as a result of continued operation and maintenance of the Enriched Uranium Operations (EUO) facilities. The increase is due to EUO personnel exposure to insoluble uranium and the use of more conservative internal dosimetry modeling parameters associated with uranium solubility. External dose also increased as a result of additional work activities associated with disassembly operations and storage, and depleted uranium operations at the site.* *The collective dose at the ETTP increased by 121% from 3.9 person-rem in 1998 to 8.6 person-rem in 1999. Activities at ETTP in 1999 include waste handling of legacy, solid, and liquid materials, and uranium hexafluoride cylinder maintenance and operations.*
Rocky Flats		↑ 7%	↑ 17%	↑ 43%	*The collective TEDE at Rocky Flats increased by 7% from 1998 to 1999. Activities in 1999 included repackaging and shipment of low level waste, and the demolition of the Building 779 complex, the largest plutonium facility ever decontaminated and demolished. The increase in dose was primarily due to quantities and radiation levels of the material being processed. The anticipated increase was minimized due to increased use of shielding and the use of administrative controls. An increase in extremity dose was attributed to plutonium salts processing. The collective CEDE increased 32% from 5.0 rem to 6.6 rem from 1998 to 1999 primarily due to an intake of plutonium and americium by a worker from a wound. (See Section 3.3.2.)*
Savannah River		17% ↓	17% ↓	46% ↓	*The collective TEDE at SRS decreased by 17% from 1998 to 1999. This decrease was attributed to an aggressive ALARA program. The collective neutron dose decreased by 31% from 1998 to 1999. The high-level waste and nuclear materials stabilization and storage programs accounted for 75% of the SRS 1999 collective dose. The collective dose for these programs decreased by 20% due to an active decontamination campaign that removed source term using state-of-the-art techniques. Extremity exposures increased from 1998 to 1999 primarily due to increased waste tank sampling, and piping removal and valve installations in the high-level waste operations division. The collective CEDE increased from 2.3 rem in 1998 to 12.8 rem as a result of an event at the FB Line facility where four individuals received internal dose, one of which received a CEDE of 6.7 rem. (See Section 3.3.1.)*

3.6 Transient Individuals

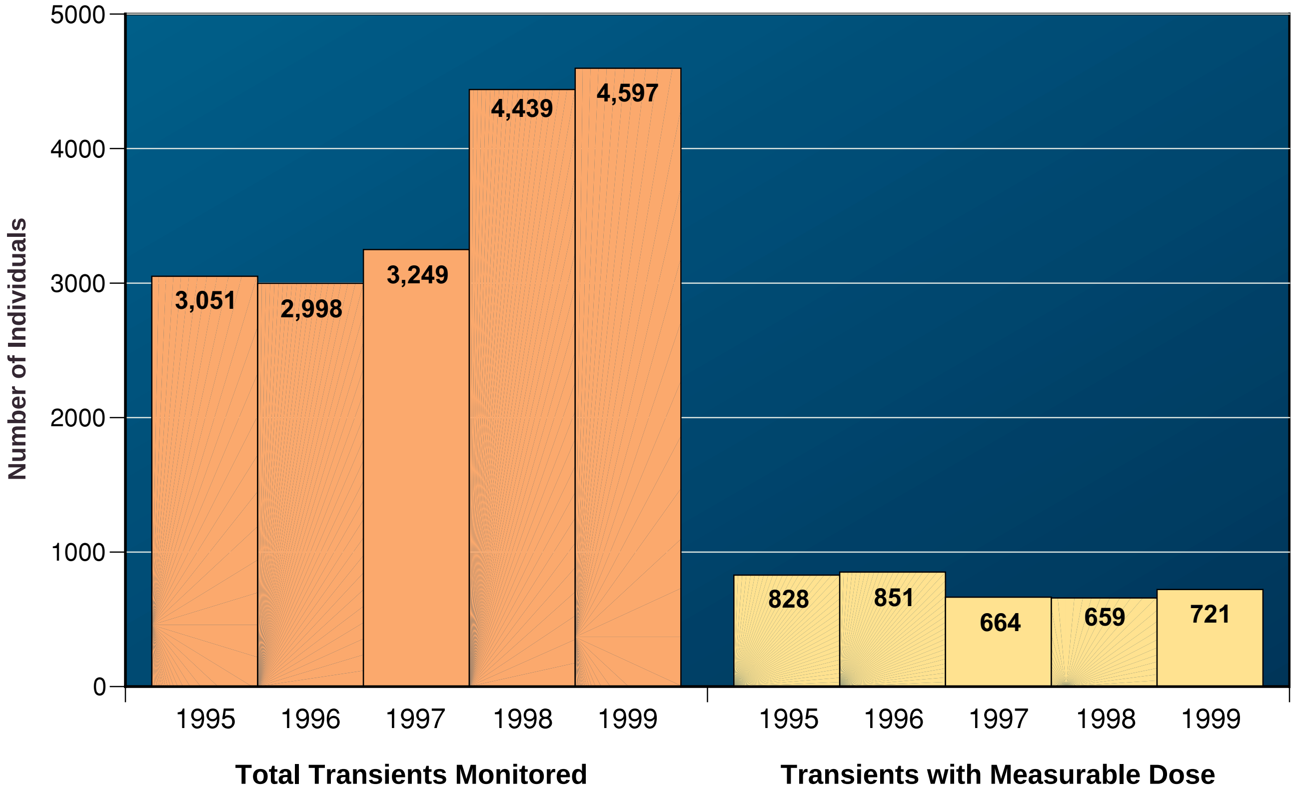
Transient individuals are defined as individuals who are monitored at more than one DOE site during the calendar year. For the purposes of this report, a DOE site is defined as a geographic location. The DOE sites are listed in Appendix A by Operations Office. During the year, some individuals perform work at multiple sites, and therefore have more than one monitoring record reported to the repository. In addition, some individuals transfer from one site to another during the year. This section presents information on transient individual's records to determine the extent to which individuals travel from site to site and examine the dose received by these individuals.

Exhibit 3-31 shows the distribution and total number of transient individuals from 1995 to 1999. Over the past 5 years, transient individuals have accounted for 3% of the total monitored individuals at DOE and received 2.5% of the collective dose. As shown in *Exhibits 3-32* and *3-33* in 1999, the number of transients monitored and the number with measurable dose increased. The collective dose increased by 14% and the average measurable dose increased by 4%. The average measurable TEDE for transients in 1999 was 29% less than the average measurable TEDE for all monitored DOE workers. As shown in *Exhibit 3-34*, the site with the largest collective dose to transient workers from 1995 to 1999 occurred at LANL. LANL has a larger percentage of dose to transients because workers at TA-55 (who generally receive elevated doses) tend to perform temporary work at sites such as Nevada Test Site (NTS), Rocky Flats, and Pantex as part of their routine duties. The collective dose to transient workers at LANL decreased by 55% from 1998 to 1999, which is consistent with the overall decrease in collective dose at LANL.

Exhibit 3-31:
Dose Distribution of Transient Workers, 1995-1999

	Dose Ranges (rem)	1995	1996	1997	1998	1999
Transients	Less than Measurable Dose	2,223	2,147	2,585	3,780	3,876
	Measurable < 0.1	744	764	606	585	638
	0.10 - 0.25	49	57	41	49	50
	0.25 - 0.5	20	21	14	14	21
	0.5 - 0.75	5	4	2	8	6
	0.75 - 1.0	3	3		2	6
	1.0 - 2.0	7	2	1	1	
	Total Monitored	3,051	2,998	3,249	4,439	4,597
	Number with Measurable Dose	828	851	664	659	721
	% with Measurable Dose	27%	28%	20%	15%	16%
	Collective TEDE (person rem)	45.155	41.392	27.426	34.742	39.521
	Average Measurable TEDE (rem)	0.055	0.049	0.041	0.053	0.055
All DOE	Total Monitored	127,276	123,324	107,181	108,508	113,061
	Number with Meas. Dose	23,613	22,725	18,689	17,544	16,668
	% of Total Monitored who are Transient	2.4%	2.4%	3.0%	4.1%	4.1%
	% of the Number with Measurable Dose Who are Transient	3.5%	3.7%	3.6%	3.8%	4.3%

Exhibit 3-32:
Individuals Monitored at More Than One Site (Transients) During the Year, 1995-1999



One group of individuals that routinely travel from site to site is DOE employees from Headquarters or the Field Offices who visit or inspect multiple sites during the year. For 1999, this group accounts for 11% of the monitored transient individuals and 3% of the collective dose to transients.

Over the past 5 years, only 12% of the transient individuals were monitored at three or more sites. DOE Headquarters and Field Office personnel make up a large percentage of these individuals. From 1995 to 1999, 27% of the individuals monitored at three or more sites were DOE Headquarters or Field Office employees and 39% of the individuals monitored at four or more facilities were DOE Headquarters or Field Office employees. The maximum number of sites visited by one monitored individual during 1998 was seven.

Exhibit 3-33:
Collective and Average Measurable Dose to Transient Individuals, 1995-1999

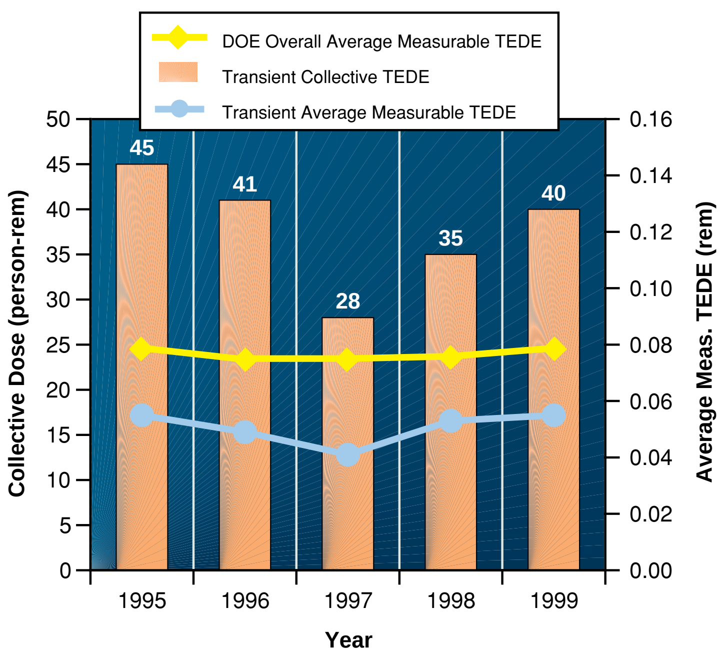
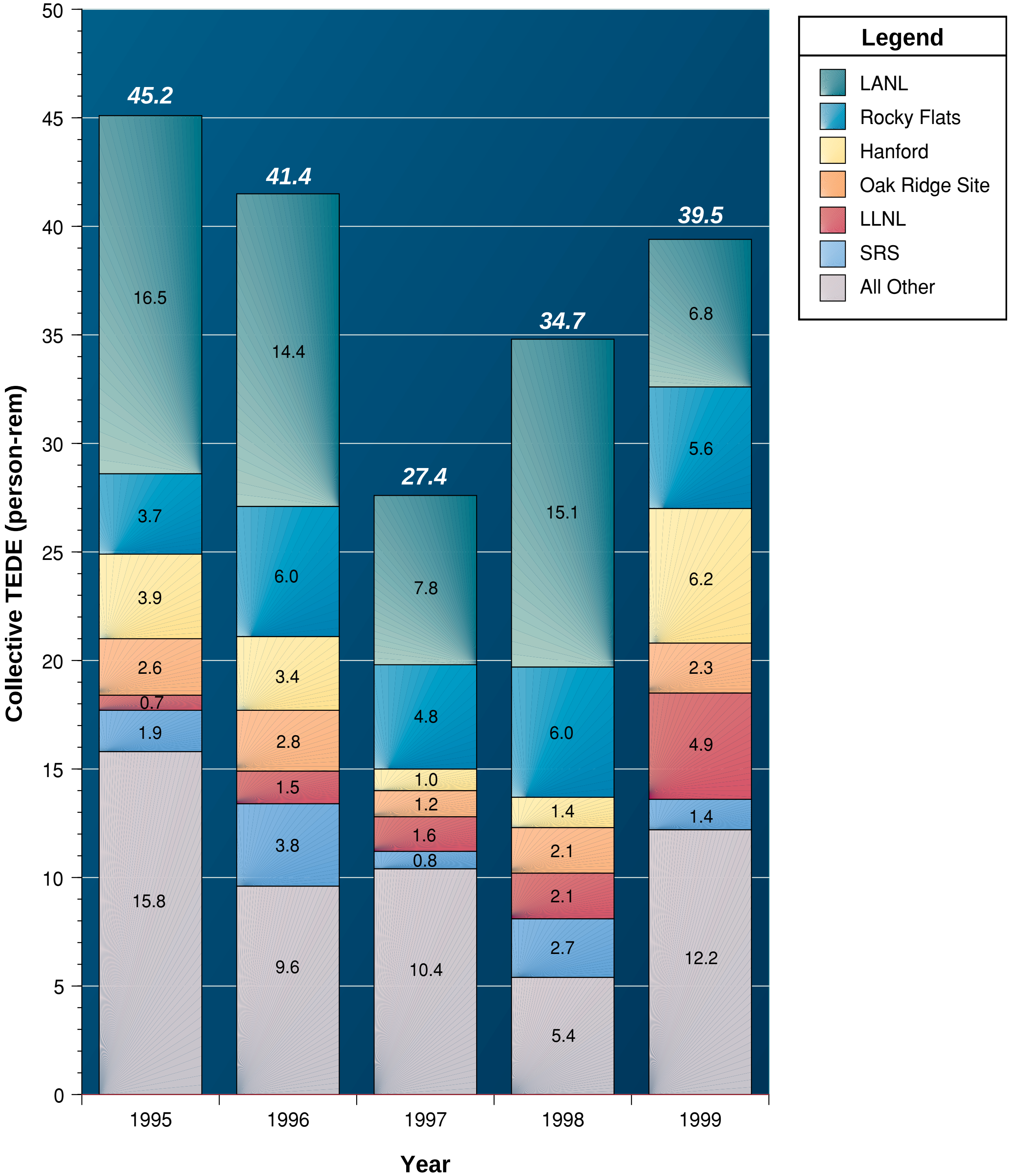


Exhibit 3-34:
Collective TEDE to Transient Workers by Site, 1995-1999



LANL has a larger percentage of dose to transients due to the fact that workers at TA-55 (which generally receive elevated doses) tend to perform temporary work at sites such as NTS, Rocky Flats, and Pantex as part of their routine duties.

ALARA Activities at DOE

This section on ALARA activities is a vehicle to document successes and to point all DOE sites to those programs whose managers have struggled with radiation protection issues and have used innovative techniques to solve problems common to most DOE sites. DOE program and site offices and contractors who are interested in benchmarks of success and continuous improvement in the context of Integrated Safety Management and quality are encouraged to provide input to be included in the future reports.

4.1 Rolling Shields Cut Dose by More than Half at Rocky Flats Environmental Technology Site

With the termination of Nuclear Production Operations in 1989, Building 371's mission has been changed to provide stabilization and storage for plutonium and uranium metals, oxides, and residues, in support of the decontamination & decommissioning (D&D) of Rocky Flats. In addition, to facilitate the rapid D&D of other buildings in the Protected Area, all of the plutonium residues that were scheduled for stabilization in other facilities are being moved into Building 371. As a result, at any particular time, there are approximately 2600 drums of highly radioactive materials in Building 371. Futhermore, the on-going stabilization activities result in the interim staging of many drums in the work areas, elevating ambient radiation dose rates.

Clearly, the optimum solution to this problem would be to move the drums to a non-occupied facility, but when the Building Radiological Engineers exhausted all avenues to move the drums out of the work areas, they turned to the use of shielding. Not wanting to erect any permanent shielding in a facility scheduled to come down in a few years, the engineers designed a rolling shield to reduce the dose from the drums. *Exhibit 4-1* shows the shield in use in Building 371. While there are many shielding designs possible, the Building Radiological Engineers chose a system that was calculated to reduce the maximum dose from the Rocky Flats materials, while still being cost-effective and portable. The shields are stationed in high worker occupancy areas, and situated to separate workers from legacy drums being staged for repackaging, thereby establishing low-dose work zones.

The shielding as shown in *Exhibit 4-1* consists of 1/16-inch stainless steel canning plate on the outside, pop riveted or tack welded to allow venting of any built-up internal pressure. Within the canning plate are two slabs of 1-inch thick high-density polyethylene sandwiching a 1/8-inch layer of lead. The shield is mounted on a wide, heavy-duty steel base with industrial-quality, lockable wheels. The shields vary from 6 to 8 feet long, and are between 40 and 48 inches tall. They weigh between 700-850 pounds. High-density polyethylene was used to attenuate the neutron dose component, of particular importance with plutonium fluoride and oxide residues. The cost for a 4´ x 8´ shield was about $7,000.00

Exhibit 4-1: Rolling Shield.

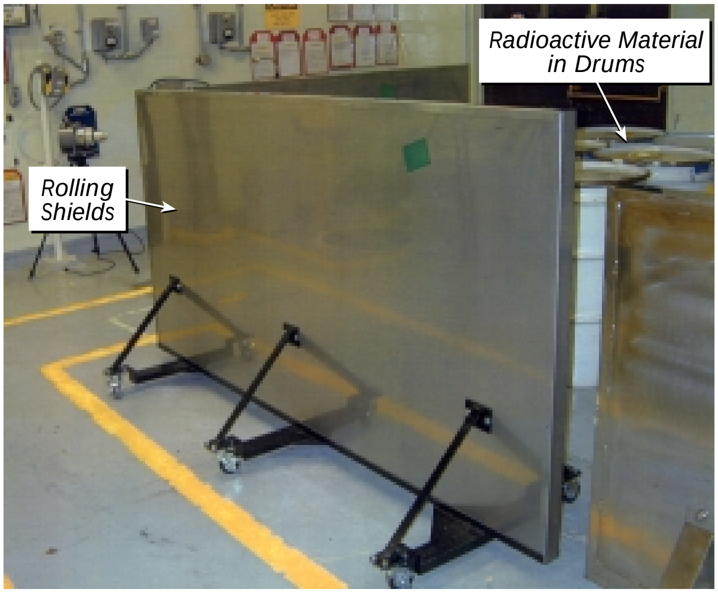


Photo Courtesy of RFETS

The dose rate reduction from the shields was noticeable shortly after their introduction. Ambient dose in the work areas has been cut in half, as recorded by the workers' dosimetry. With the shield, the measured dose rate from a typical drum is cut by about 50% for neutrons, and over 1000% for gammas which has resulted in an estimated reduction of 10 person-rem per year. They are easy to move, allowing quick shielding as storage locations change, and they will be reducing dose for the workers at Rocky Flats for years, until the last of the plutonium residues has been shipped.

For more information about this project, contact Building 371/374 Complex Radiological Engineer Mr. Gwynn Aldrich (303) 966-7175.

4.2 Stabilizing the Chernobyl Unit 3/4 Ventilation Stack

In the April 1986 accident that destroyed the Unit 4 reactor at Chernobyl, the ventilation stack, a structure common to Units 3 and 4, sustained significant structural damage to its external bracing and foundation (see *Exhibit 4-2*). In its weakened condition, a collapse of the stack was postulated to be the most significant initiating event of a major accident involving either the Unit 4 Shelter or the operating Unit 3 reactor. Limited U.S. analysis confirmed that stack repairs were an urgent safety concern. Repair of the ventilation stack was an emergency priority.

Ukrainian structural experts devised a repair plan to restore the stack to its original structural integrity by replacing broken or dented sections of the support structure. The initial collective dose estimate for this repair program was over 4,800 person-rem at a cost of $3.6M.

An ALARA workshop was conducted to identify how worker radiation doses could be reduced. The ALARA workshop involved shelter, engineering design, construction, and U.S. personnel. Pacific Northwest National Laboratory* (PNNL) at Hanford provided health physics, ALARA, project management, and contracting expertise. Significant dose savings were realized by changing the original material handling route to avoid high radiation areas around the Unit 4 Shelter. Selective shielding and decontamination, including the removal of some nuclear debris deposited in the April 1986 accident, were also successful in reducing localized dose rates.

The repair program was successfully completed with a 443 person-rem collective dose, a maximum individual dose of 1.8 rem and cost under $2.3M. Lessons-learned from this project will be valuable in planning future stabilization and remediation efforts at Chernobyl.

For more information, contact Brenda Pangborn, Richland Operations Office Radiological Control Manager at (509) 372-3841.

Exhibit 4-2:
Photo Showing Damage to Stack Supports.

Photo Courtesy of PNNL

* Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle under Contract DE-AC06-76RLO 1830.

4.3 Decommissioning of 233-S Presents a Significant Challenge for Maintaining Internal Radiation Exposure ALARA at Hanford

The 233-S Plutonium Concentration Facility was built in 1953 and concentrated fissile material from the 202-S Reduction-Oxidation Plant at Hanford. In 1963, a fire in the process areas contaminated the facility, which resulted in constructing the 233-SA Exhaust Filter Building for continued operation. The facility has been inactive for more than 25 years, is significantly radioactively contaminated, and has undergone severe structural deterioration due to exposure to extreme weather conditions. Contamination levels as high as 25,000,000 dpm/100 cm^2 alpha, were found. Bechtel Hanford, Inc. (BHI), has been performing decommissioning activities at the facility. This included removal of process pipe located in the pipe trench between the 233-S Facility and the 202-S Building, removal of the old supply duct system from the roof, and demolition of the loadout hood inside the facility. Current focus is on gross decontamination of the Process Hood and removal of out-of-service exhaust duct from the roof.

This project has represented significant challenges for maintaining internal radiation exposures ALARA. Disturbing the high levels of contamination during D&D activities has resulted in airborne radioactivity levels as high as 17,000 DAC. BHI, with the support of Hanford's ALARA Center of Technology, developed and implemented engineering controls to minimize the generation of airborne radioactivity and spread of contamination. Fixatives were applied to reduce the removable contamination levels as shown in *Exhibit 4-3*. To improve the effectiveness of the HEPA filtered ventilation system for the decommissioning efforts, BHI installed portable exhausters to help scrub the air free of airborne contaminants as seen in *Exhibit 4-4*. The portable ventilation system includes temporary ducting to provide localized exhaust in the work area to control airborne radioactivity at the source of

Exhibit 4-3:
Application of Fixative to Reduce Contamination Levels.

Photo Courtesy of Hanford

Exhibit 4-4:
Portable Exhauster Unit for Facility Ventilation.

Photo Courtesy of Hanford

generation. As a result of the improved airborne radioactivity control, the level of respiratory protection required was reduced from Ska-Pak airline respirators to Powered Air Purifying Respirators or air fed hood. In addition, special containments were designed and installed to reduce airborne radioactivity generation and spread of contamination during the decommissioning of the pipe trench and loadout hood as shown in *Exhibit 4-5*.

The use of these engineered controls contributed significantly to the improvement of worker safety.

For more information, contact Brenda Pangborn, Richland Operations Office Radiological Control Manager at (509) 372-3841.

Exhibit 4-5:
Installation of the Cold Pipe Trench Containment.

Photo Courtesy of Hanford

4.4 Ultra High Pressure System Used in Airlock Reduces Dose Rates by Thirty-Five Percent at Hanford

The Waste Technology Engineering Facility (324 Facility), was designed to conduct engineering studies using radioactive materials in a series of four cells known as the Radiochemical Engineering Cells (REC) at Hanford. These cells are accessed through a common air lock that is roughly 484 square feet in area and 34 feet high. B cell is the largest of the four cells, approximately 550 square feet in area and nearly 30 feet high. Vitrification of highly radioactive materials was performed in B cell. Spillage of the base materials being vitrified resulted in very high loose surface contamination and airborne radioactivity levels in B cell. Highly contaminated equipment from B cell is being removed for disposal. Removal consists of remotely cutting up previously used process tanks, support structures, and process equipment, placing the material in inner containers, transferring those inner containers from the cell into the airlock with the use of remotely operated cranes, where shipping casks are staged for loading. Once loaded within the shielded containers, they are brought into the cask handling area for inspection and survey.

Due to the high levels of contamination that has spread to the airlock, dose rates in the airlock where personnel entry is required were an average of 89.4 mrem/hr. Fluor Hanford, Inc., used an Ultra High Pressure System (UHPS) to wash down the interior of the airlock to reduce dose rates to the workers. Water from the wash flowed from the airlock drains, back into the B-cell where it evaporated, creating no liquid waste that required disposal. After completion of the UHPS wash, dose rates were an average of 57.9 mrem/hr, a reduction of 35 percent. The projected dose savings for clean-up activities at the 324 Facility REC during the year following the UHPS wash is 9.78 person-rem. The UHPS will continue to be used as needed to maintain doses to workers ALARA.

For more information, contact Brenda Pangborn, Richland Operations Office Radiological Control Manager at (509) 372-3841.

4.5 Techniques Used to Reduce Doses at Solid Waste Management Facility (SWMF) at Savannah River

In 1999, several projects had the potential to increase the radiation exposure to workers at SRS's Solid Waste Management Facility. By using good ALARA techniques, the resulting exposure was greatly reduced below expected levels. These projects included retrieval of Transuranic (TRU) waste from in-ground burial, venting after retrieval, and receipt of high radiation shipments.

The retrieval process was undertaken due to the approaching end of the life expectancy of TRU waste drums. These drums, placed on a concrete pad and buried under several feet of soil, were unearthed using heavy equipment. Once the majority of the soil was removed, a remote drum handler attached to a forklift was used to relocate the drums for surveying. Once surveying was complete, the drums were placed on a pallet for transportation to the venting facility. The use of these remote handling methods reduced the dose from these drums, some of which exceeded 100 mrem/hr @ 30 cms whole body dose rate.

The majority of the venting process was also handled remotely. Once the drums arrived from the TRU waste storage pads, they were removed from the pallet using another drum handler. The drum was then placed in an explosion proof cabinet and the drum lid was pierced remotely. The head space gas was sampled for hydrogen and volatile organic compounds and purged with nitrogen if necessary. A filtered vent was then installed to prevent a buildup of gas while the drum was in storage. Once removed from the cabinet, the drums were re-palletized for transportation to a covered above-ground storage pad.

Several on-site and off-site shipments (GTS Duratek at Knolls Atomic Laboratory) were received that had whole body dose rates greater than 100 mrem/hr @ 30 cms. Some of these had whole body dose rates greater than 1000 mrem/hr @ 30 cms. Utilizing effective job pre-planning and remote rigging techniques where possible, the maximum exposure received was less than 25 mrem on any of these shipments.

In summary, by employing simple planning and remote handling techniques, we reduced the risk to our workers from radiation exposure.

For additional information about this project contact: Athena D. Freeman, Site ALARA Coordinator, (803) 952-9938, e-mail: athena.freeman@srs.gov

4.6 Shielding Used to Reduce Exposures at the High-Level Waste Tank Farm at Savannah River

Loop Piping removal and Back Flush Valve installation activities were necessary to support startup testing and eventual radioactive material processing in Westinghouse Savannah River Company's High-Level Waste H-Tank Farm. These activities included removing C-2 riser plugs and removal of loop piping that had been installed by hand when the tanks were initially constructed. After the initial remote method to loosen the piping connectors failed, an alternative remote wrench was designed and developed by SRS personnel. The work was tedious and time consuming.

The maximum exposure rate associated with loop piping removal activities was 25 rem/hr at and around the edge of the open riser. It was necessary for personnel to stand at the edge of the open riser in order to perform the required activities. A shielded cylinder (diving bell) was placed over and around the open riser after the riser plug had been removed. This shielded cylinder (lead sandwiched between carbon steel) allowed personnel to work through lead-lined glove ports and observe some work activities through shielded glass windows. The shielded cylinder reduced the whole body dose rate from 25 rem/hr to 40 mrem/hr based on distance and shielding. The shielded cylinder greatly diminished the dose rate and acted as a physical barrier to prevent workers from accessing the high dose rate areas. Additionally, cameras/video monitors were deployed to aid personnel in Loop Piping removal activities.

After the Loop Piping was removed, the Back Flush Valves were installed using the same ALARA methods mentioned above. The shielded cylinder was successful in maintaining whole body doses at ALARA levels. All work was performed in a certified containment hut with HEPA filtered ventilation system. Containment sleeving was used for removing items from the tank.

For additional information about this project contact: Athena D. Freeman, Site ALARA Coordinator, (803) 952-9938, e-mail: athena.freeman@srs.gov

4.7 Submitting ALARA Success Stories for Future Annual Reports

Individual success stories should be submitted in writing to the DOE Office of Worker Protection Policy and Programs. The submittal should describe the process in sufficient detail to provide a basic understanding of the project, the radiological concerns, and the activities initiated to reduce dose.

The submittal should address the following:

- mission statement,
- project description,
- radiological concerns,
- information on how the process implemented ALARA techniques in an innovative or unique manner,
- estimated dose avoided,
- project staff involved,
- approximate cost of the ALARA effort,
- impact on work processes, in person-hours if possible (may be negative or positive), and
- point-of-contact for follow-up by interested professionals.

4.8 Lessons Learned Process Improvement Team

In March 1994, the Deputy Assistant Secretary for Field Management established a DOE Lessons Learned Process Improvement Team (LLPIT). The purpose of the LLPIT is to develop a complex-wide program to standardize and facilitate identification, documentation, sharing, and use of lessons learned from actual operating experiences throughout the DOE complex. This information sharing and utilization is commonly termed "Lessons Learned" within the DOE community. The LLPIT has now transitioned into the DOE Society for Effective Lessons Learned Sharing.

The collected information is currently located on an Internet World Wide Web (Web) site as part of the Environmental Safety & Health (ES&H) Information Portal. This system allows for shared access to lessons learned across the DOE complex. The information available on the system complements existing reporting systems presently used within DOE. DOE is taking this approach to enhance those existing systems by providing a method to quickly share information among the field elements. Also, this approach goes beyond the typical occurrence reporting to identify good lessons learned. DOE uses the Web site to openly disseminate such information so that not only DOE but other entities will have a source of information to improve the health and safety aspects of operations at and within their facilities. Additional benefits include enhancing the work place environment and reducing the number of accidents and injuries.

The Web site contains several items that are related to health physics. Items range from off-normal occurrences to procedural and training issues. Documentation of occurrences includes the description of events, root-cause analysis, and corrective measures. Several of the larger sites have systems that are connected through this system. DOE organizations are encouraged to participate in this valuable effort.

The Web site address for DOE Lessons Learned is:

http://www.eh.doe.gov/ll

The specific Web site address may be subject to change. ES&H information services can be accessed through the main ES&H Information Portal at:

http://www.eh.doe.gov/portal

Section Five

Conclusions

5

Conclusions

5.1 Conclusions

The collective dose at DOE facilities has experienced a dramatic (84%) decrease since 1986. The main reasons for this large decrease were the shutdown of facilities within the weapons complex and the end of the Cold War era, which shifted the DOE mission from weapons production to shutdown, stabilization, and D&D activities. The DOE weapons production sites have continued to contribute the majority of the collective dose over these years. Sites reporting under the category of weapons fabrication and testing account for the highest collective dose. Even though these sites are now primarily involved in nuclear materials stabilization and waste management, they still report under this facility type. As facilities are shut down and undergo transition from operation to stabilization or D&D, there are significant changes in the opportunities for individuals to be exposed. More modest reductions in collective dose have occurred during the past 5 years at some facilities that have continued to transition to shutdown and stabilization.

The collective TEDE decreased 1% from 1998 to 1999 due to decreases in the collective dose at three of the six highest dose sites. These six sites accounted for 83% of the collective dose at DOE. Reports submitted by three of the sites that experienced decreases in the collective dose (Savannah River, Los Alamos, and Idaho) indicate that decreases in the collective dose were due to: aggressive ALARA programs, a decontamination campaign at SRS to reduce source term, increased management awareness, improved work practices, and a delay in several projects at Idaho due to an accident in 1998 which resulted in corrective actions that affected the work control system. Statistical analysis reveals that, although the collective dose decreased by 1%, the logarithmic mean dose increased slightly from 0.028 rem in 1998 to 0.029 rem in 1999. This suggests that the drop in the collective dose reflects fewer workers exposed to radiation, rather than lower doses to individual workers. This is supported by the decrease in number of workers receiving measurable dose from 1998 to 1999.

The collective internal dose (CEDE) increased by 82% from 1998 to 1999 to a value of 152.9 person-rem (1,529 person mSv) for 1999. The increase in collective internal dose was primarily due to a 260% increase in uranium doses at the Oak Ridge Y-12 site, where a large number of individuals were reported with relatively small individual internal doses from uranium. The increased internal dose at the Y-12 site is due to the exposure of Enriched Uranium Operations (EUO) personnel to insoluble uranium and the use of more conservative internal dosimetry modeling parameters associated with uranium solubility. Apart from the large increase in internal dose from uranium at Y-12 and the single plutonium CEDE of 6.719 rem (67.19 mSv) at Savannah River, internal doses for the rest of DOE decreased from 1998 to 1999. Due to several factors such as changes in internal dosimetry practices, monitoring and reporting procedures, changes in the dosimetry equipment, and the relatively small number of internal doses, care should be taken in examining trends in internal dose.

An analysis was performed on the transient workforce at DOE. A transient worker is defined as an individual monitored at more than one DOE site in a year. The results of this analysis show that the number of transient workers monitored has increased by 51% over the past 5 years. From 1998 to 1999, the number of transients monitored increased by 4%, while the collective dose for these transients increased by 14%, resulting in a 4% increase in the average measurable dose to transients. However, the average measurable dose to transient workers has been less than the value for the overall DOE workforce for the past 5 years.

The detailed nature of the data available has made it possible to investigate distribution and trends in data and to identify and correlate parameters having an effect on occupational radiation exposure at DOE sites. This also revealed the limitations of available data, and identified additional data needed to correlate more definitively trends in occupational exposure to past and present activities at DOE sites. A summary of the findings for 1999 is shown in *Exhibit 5-1*.

Exhibit 5-1:
1999 Radiation Exposure Fact Sheet.

- The collective TEDE decreased by 1% from 1998 to 1999. Statistical analysis indicates that the drop in the collective dose reflects fewer workers exposed to radiation, rather than lower doses to individual workers. This is supported by the decrease in number of workers receiving measurable dose from 1998 to 1999.

- The six highest dose sites (Rocky Flats, Oak Ridge, Hanford, Savannah River, Los Alamos, and Idaho) accounted for 83% of the collective dose at DOE in 1999.

- Decreases at three of the top six sites (Idaho, Los Alamos, and Savannah River) were due to: aggressive ALARA programs, a decontamination campaign at SRS to reduce source term, increased management awareness, improved work practices, and a delay in several projects at Idaho due to an accident in 1998 which resulted in corrective actions that affected the work control system.

- The collective internal dose increased by 82% from 1998 to 1999 primarily due to an increase in dose from uranium operations and a change in internal dosimetry modeling parameters at the Y-12 facility in Oak Ridge. In addition, one individual at Savannah River received a dose of 6.719 rem (67.19 mSv) CEDE , in excess of the 5 rem (50 mSv) standard from plutonium.

- The number of transient workers monitored at DOE has increased by 51% over the past 5 years, but the average measurable dose to these transients has been less than the value for the overall DOE workforce.

Glossary

Administrative Control Level (ACL)
A dose level that is established below the DOE dose limit in order to administratively control exposures. ACLs are multi-tiered, with increasing levels of authority required to approve a higher level of exposure.

ALARA
Acronym for "As Low As Reasonably Achievable," which is the approach to radiation protection to manage and control exposures (both individual and collective) to the workforce and the general public to as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but a process with the objective of attaining doses as far below the applicable limits as is reasonably achievable.

Annual Effective Dose Equivalent (AEDE)
The summation for all tissues and organs of the products of the dose equivalent calculated to be received by each tissue or organ during the specified year from all internal depositions multiplied by the appropriate weighting factor. Annual effective dose equivalent is expressed in units of rem.

Average Measurable Dose
Dose obtained by dividing the collective dose by the number of individuals who received a measurable dose. This is the average most commonly used in this and other reports when examining trends and comparing doses received by workers because it reflects the exclusion of those individuals receiving a less than measurable dose. Average measurable dose is calculated for TEDE, DDE, neutron dose, extremity dose, and other types of doses.

Collective Dose
The sum of the total annual effective dose equivalent or total effective dose equivalent values for all individuals in a specified population. Collective dose is expressed in units of person–rem.

Committed Dose Equivalent (CDE) (H_T,50)
The dose equivalent calculated to be received by a tissue or organ over a 50–year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem.

Committed Effective Dose Equivalent (CEDE) (H_E,50)
The sum of the committed dose equivalents to various tissues in the body (H_T,50), each multiplied by the appropriate weighting factor (w_T)—i.e., $H_E,50 = \Sigma w_T H_T,50$. Committed effective dose equivalent is expressed in units of rem.

CR
CR is defined by the United Nations Scientific Committee on the Effects of Atomic Radiation as the ratio of the annual collective dose delivered at individual doses exceeding 1.5 rem to the collective dose.

Deep Dose Equivalent (DDE)
The dose equivalent derived from external radiation at a depth of 1 cm in tissue.

DOE Site

A geographic location operated under the authority of the Department of Energy. The DOE sites considered in this report are listed in Appendix A by Operations Office.

Effective Dose Equivalent (H_E)

The summation of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factor (w_T)—i.e., $H_E = \Sigma w_T H_T$. It includes the dose from radiation sources internal and/or external to the body. The effective dose equivalent is expressed in units of rem.

Kruskall-Wallis Test

Uses a test statistic based on rank sums to determine whether two populations are significantly different.

Lens of the Eye Dose Equivalent (LDE)

The radiation exposure for the lens of the eye is taken as the external equivalent at a tissue depth of 0.3 cm.

Logarithmic Mean

The mean calculated from log-transformed values.

Minimum Detectable Activity (MDA)

The smallest quantity of radioactive material or level of radiation that can be distinguished from background with a specified degree of confidence. Often used synonymously with minimum detection level (MDL) or lower limit of detection (LLD).

Non-parametric Procedures

Statistical tests that do not depend on a specific parent distribution.

Normal Log-transformed Data

Data that fits a normal distribution after it is transformed to logarithms.

Number of Individuals with Measurable Exposure

The subset of all monitored individuals who receive a measurable exposure (greater than limit of detection for the monitoring system). Many personnel are monitored as a matter of prudence and may not receive a measurable exposure. For this reason, the number of individuals with measurable exposure is presented in this report as a more accurate indicator of the exposed workforce. The number of individuals represents the number of exposure records reported. Some individuals may be counted more than once if multiple exposure records are reported for the individual during the year.

Occupational Exposure

An individual's exposure to ionizing radiation (external and internal) as a result of that individual's work assignment. Occupational exposure does not include planned special exposures, exposure received as a medical patient, background radiation, or voluntary participation in medical research programs.

Pairwise T-tests

This test compares all possible pairs of means and uses a T-test to determine whether differences are significant.

Shallow Dose Equivalent (SDE)

The dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

Statistical Normal Distribution

A distribution that is symmetric and can be described completely by the mean and variance. This property is required for many statistical tests.

Total Effective Dose Equivalent (TEDE)

The sum of the effective dose equivalent for external exposures and the committed effective dose equivalent for internal exposures. Deep dose equivalent to the whole body is typically used as effective dose equivalent for external exposures. The internal dose component of TEDE changed from the Annual Effective Dose Equivalent (AEDE) to the Committed Effective Dose Equivalent (CEDE) in 1993.

Total Monitored Individuals

All individuals who are monitored and reported to the DOE Headquarters database system. This includes DOE employees, contractors, visitors, and members of the public monitored during a visit to a DOE site. The number of individuals represents the number of exposure records reported. Some individuals may be counted more than once if multiple exposure records are reported for the individual during the year.

Transient Individual

An individual who is monitored at more than one DOE site during the calendar year.

T-test

A statistical test for comparing means from two populations based on the value of t, where

$t = \dfrac{\overline{y}_1 - \overline{y}_2}{S_{\overline{y}_1 - \overline{y}_2}}$ and $\overline{y}_1$ = sample mean, population 1

$\overline{y}_2$ = sample mean, population 2

$S_{\overline{y}_1 - \overline{y}_2}$ = standard deviation appropriate to the difference between the two means.

This page intentionally left blank.

References

1. EPA (U.S. Environmental Protection Agency), 1987. "Radiation Protection Guidance to Federal Agencies for Occupational Exposure," *Federal Register* 52, No. 17, 2822; with corrections published in the *Federal Registers* of Friday, January 30, and Wednesday, February 4, 1987.

2. ICRP (International Commission on Radiological Protection), 1977. "Recommendations of the International Commission on Radiological Protection," ICRP Publication 26, Annals of the ICRP, Vol. 1, No. 3 (Pergamon Press, New York).

3. NCRP (National Council on Radiation Protection and Measurements), 1987. "Recommendations on Limits for Exposure to Ionizing Radiation," NCRP 91; superceded by NCRP Report No. 116.

4. DOE (U.S. Department of Energy), December 21, 1998, Order 5480.11, Radiation Protection for Occupational Workers, Change 3, June 17, 1992.

5. DOE 1994. *Radiological Control Manual.* Revision 1, DOE/EH-0256T, Assistant Secretary for Environment, Safety and Health, April.

6. 10CFR Part 835. "Occupational Radiation Protection." Final Rule; DOE *Federal Register*, November 4, 1998.

7. DOE-STD-1098-99, "Radiological Control Standard," July 1999.

8. The Price-Anderson Amendments Act of 1988, Public Law 100-408, August 20, 1988.

9. 10CFR 820. "Procedural Rules for DOE Nuclear Activities." August 17, 1993.

10. DOE Notice 441.1, "Radiological Protection for DOE Activities," September 29, 1995.

11. DOE Order 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements," February 24, 1981, Change 7, October 17, 1990.

12. DOE M231.1-1, "Environment, Safety and Health Reporting," September 10, 1995.

13. Munson, L.H. et al., 1988. *Health Physics Manual of Good Practices for Reducing Radiation Exposures to Levels that are As Low As Reasonably Achievable (ALARA)*, PNL-6577, Pacific Northwest Lab.

14. United Nations, *Report of the Scientific Committee on the Effects of Atomic Radiation*, General Assembly of Official Records, United Nations, New York, 1993.

This page intentionally left blank.

Appendix A

A

DOE Reporting Sites and Reporting Codes

DOE Reporting Sites and Reporting Codes

A.1 Labor Categories and Occupation Codes

The following is a list of the Occupation Codes that are reported with each individual's dose record to the DOE Radiation Exposure Monitoring System (REMS) in accordance with DOE Manual 231.1-1 [12]. Occupation Codes are grouped into Labor Categories for the purposes of analysis and summary in this report. The occupation codes are listed in DOE M 231.1-1, Appendix G, Table 2 and represent a subset of the occupations listed in the Department of Commerce's Standard Occupational Classification (SOC) Manual (1980).

Exhibit A-1.
Labor Categories and Occupation Codes.

Labor Category	Occupation Code	Occupation Name
Agriculture	*0562*	*Groundskeepers*
	0570	*Forest Workers*
	0580	*Misc. Agriculture*
Construction	*0610*	*Mechanics/Repairers*
	0641	*Masons*
	0642	*Carpenters*
	0643	*Electricians*
	0644	*Painters*
	0645	*Pipe Fitter*
	0650	*Miners/Drillers*
	0660	*Misc. Repair/Construction*
Laborers	*0850*	*Handlers/Laborers/Helpers*
Management	*0110*	*Manager - Administrator*
	0400	*Sales*
	0450	*Admin. Support and Clerical*
Misc.	*0910*	*Military*
	0990	*Miscellaneous*
Production	*0681*	*Machinists*
	0682	*Sheet Metal Workers*
	0690	*Operators, Plant/ System/Utility*
	0710	*Machine Setup/Operators*
	0771	*Welders and Solderers*
	0780	*Misc. Precision/Production*
Scientists	*0160*	*Engineer*
	0170	*Scientist*
	0184	*Health Physicist*
	0200	*Misc. Professional*
	0260	*Doctors and Nurses*
Service	*0512*	*Firefighters*
	0513	*Security Guards*
	0521	*Food Service Employees*
	0524	*Janitors*
	0525	*Misc. Service*
Technicians	*0350*	*Technicians*
	0360	*Health Technicians*
	0370	*Engineering Technicians*
	0380	*Science Technicians*
	0383	*Radiation Monitors/Techs.*
	0390	*Misc. Technicians*
Transport	*0820*	*Truck Drivers*
	0821	*Bus Drivers*
	0825	*Pilots*
	0830	*Equipment Operators*
	0840	*Misc. Transport*
Unknown	*0001*	*Unknown*

A.2 Organizations Reporting to DOE REMS, 1995-1999

The following is a listing of all organizations reporting to the DOE REMS from 1995 to 1999. The Operations Office and Site groupings used in this report are shown in addition to the organization reporting code and name.

Exhibit A-2.
Organizations Reporting to DOE REMS, 1995-1999.

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'95	'96	'97	'98	'99
Albuquerque	Ops. and Other Facilities	0501001	Albuquerque Field Office	●	●	●	●	●
		0501006	Albuquerque Office Subs.	●	●			
		0502009	Albuquerque Transportation Division	●	●	●	●	●
		0530001	Kansas City Area Office	●	●	●	●	●
		0531002	Honeywell Federal Manufacturing Tech.	●	●	●	●	●
		0553002	Martin Marietta Specialty Components Inc.	●	●	●		
		0590001	Waste Isolation Pilot Project (WIPP)	●	●	●	●	●
		0593001	Carlsbad Area Office			●		
		0593004	Carlsbad Area Miscellaneous Contractors	●	●	●	●	●
		2806003	National Renewable Energy Lab (NREL) - GO	●	●	●	●	●
	Grand Junction	0560605	MACTEC - ERS				●	●
		0560704	WASTREN					●
	Los Alamos National Lab. (LANL)	0540001	Los Alamos Area Office	●	●	●	●	●
		0544003	Los Alamos National Laboratory	●	●	●	●	●
		0544809	Protection Technologies Los Alamos	●	●	●	●	●
		0544904	Johnson Controls, Inc.	●	●	●	●	●
	Pantex Plant (PP)	0510001	Amarillo Area Office	●	●	●	●	●
		0514004	Battelle - Pantex	●	●	●	●	●
		0515002	Mason & Hanger - Amarillo	●	●	●	●	●
		0515009	M&H - Amarillo - Security Forces	●			●	●
	Sandia National Lab. (SNL)	0570001	Kirtland Area Office	●	●	●	●	
		0575003	Inhalation Toxicology Research	●	●			
		0577004	Ross Aviation, Inc.	●				
		0578003	Sandia National Laboratory	●	●	●	●	●
	Uranium Mill Tailings Remedial Action (UMTRA) Project	0582004	MK-Ferguson Subs - UMTRA	●	●	●		
		0582005	MK-Ferguson Co. - UMTRA	●	●	●		
Chicago	Ops. and Other Facilities	1000503	Ames Laboratory (Iowa State)	●	●	●	●	●
		1000903	Battelle Memorial Institute - Columbus (Old)	●	●			
		1001501	Chicago Field Office	●	●	●	●	●
		1001606	Chicago Office Subs	●				●
		1002001	Environmental Meas. Lab. - Research	●	●	●	●	●
		1004031	New Brunswick Laboratory - Research	●	●	●	●	●
		1005003	Princeton Plasma Physics Laboratory	●	●	●	●	●
	Argonne Nat'l Lab. - East (ANL-E)	1000703	Argonne National Laboratory - East	●	●	●	●	●
	Argonne Nat'l Lab. - West (ANL-W)	1000713	Argonne National Laboratory - West	●	●	●	●	●
	Brookhaven Nat'l Lab. (BNL)	1001003	Brookhaven National Laboratory	●	●	●	●	●
	Fermi Nat'l. Accelerator Lab.(FERMI)	1002503	Fermilab	●	●	●	●	●
DOE HQ	DOE Headquarters	1504001	DOE Headquarters	●	●	●	●	●
	N. Korea Project	8009001	DOE North Korea Project		●	●	●	
		8009104	CenTech 21 - North Korea		●	●		
		8009204	Nuclear Assurance Corp. (NAC)		●	●		
		8009304	Pacific Northwest Lab. - Korea		●	●		
		8009401	U.S. Dept. of State - North Korea		●	●		
	Kazakhstan	8010001	DOE Kazakhstan Project					●

Exhibit A-2.
Organizations Reporting to DOE REMS, 1995-1999 (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'95	'96	'97	'98	'99
Idaho	Idaho Site	3000504	Chem-Nuclear Geotech	●	●			
		3003402	Babcock & Wilcox Idaho, Inc.		●	●	●	
		3004001	Idaho Field Office	●	●	●	●	●
		3004004	Idaho Office Subs	●	●	●		
		3005004	Bechtel BWXT Idaho, LLC - Services	●	●	●	●	●
		3005005	Lockheed Martin Idaho Tech. Co. - Construction		●	●		
		3005016	Bechtel BWXT Idaho, LLC Subs - Construction			●	●	●
		3005024	LMITCO Subcontractor - Coleman			●	●	
		3005034	LMITCO Subcontractor - Parsons			●	●	
		3005505	MK-Ferguson Company - ID			●		
Nevada	Nevada Test Site (NTS)	3500000	Nevada Operations			●	●	●
		3501104	Bechtel Nevada - Amador Valley				●	
		3501304	Bechtel Nevada - Los Alamos				●	
		3501405	Bechtel Nevada - NTS			●	●	●
		3501416	Bechtel Nevada - NTS Subcontractors			●	●	●
		3501503	Bechtel Nevada - Special Technologies Labs				●	●
		3501604	Bechtel Nevada - Washington Aerial Meas.				●	
		3502004	Computer Sciences Corporation			●	●	
		3502504	EG&G Kirtland			●		
		3502804	EG&G Special Technologies Laboratories	●	●	●		
		3502904	EG&G Washington D.C.	●				
		3503004	EG&G Las Vegas	●	●			
		3503504	EG&G Los Alamos	●				
		3504504	EG&G Santa Barbara	●	●	●	●	
		3506004	Raytheon Services - Nevada	●	●		●	
		3506024	Raytheon Services Subcontractors	●	●			
		3507501	Nevada Field Office	●	●	●	●	●
		3507514	Nevada Miscellaneous Contractors	●	●	●	●	●
		3507521	Air Resources Laboratory				●	
		3507531	Defense Nuclear Agency - Kirtland AFB	●	●	●	●	●
		3507551	Environmental Protection Agency (NERC)	●	●	●	●	
		3508004	Nye County Sheriff			●	●	●
		3508504	Bechtel Nevada Services	●	●	●		
		3508505	Bechtel Nevada - NTS	●	●	●	●	
		3508703	Science Applications Int'l. Corp. - NV	●	●	●	●	●
		3509009	Wackenhut Services, Inc. - NV	●	●	●	●	●
		3509504	Westinghouse Electric Corp. - NV	●	●	●	●	
Oak Ridge	Ops. and Other Facilities	4004203	Oak Ridge Inst. for Science & Educ. (ORISE)	●	●	●	●	●
		4004501	Oak Ridge Field Office	●	●	●	●	●
		4004704	Bechtel National, Inc. - (FUSRAP)	●	●	●		
		4009006	Morrison-Knudsen (WSSRAP)	●	●	●	●	●
		4009503	Thomas Jefferson National Accel. Facility	●	●	●	●	●
		4542005	RMI Company	●	●	●	●	●
	Oak Ridge Site	4005105	Lockheed Martin/MK-Ferguson Co.	●	●			
		4005505	LMES/MK - Ferguson Subcontractors			●	●	●
		4006002	Bechtel-Jacobs Co., LLC – ETTP	●	●	●	●	●
		4006007	Decontam. & Recovery Services (DRS) (K-25)				●	

Exhibit A-2.
Organizations Reporting to DOE REMS, 1995-1999 (continued).

Operations/ Field Office		Organization Code	Organization Name	Year Reported*				
				'95	'96	'97	'98	'99
Oak Ridge	Oak Ridge Site	4006302	British Nuclear Fuels Limited (BNFL) (ETTP)				●	●
		4006406	Decontamination & Recovery Services-ETTP					●
		4006503	Lockheed Martin Energy Research Corp. (ORNL)	●	●	●	●	●
		4008002	Lockheed Martin Energy Systems (Y-12)	●	●	●	●	●
	Paducah Gas. Diff. Plant (PGDP)	4007002	Bechtel-Jacobs Co., LLC – Paducah	●	●	●	●	●
	Portsmouth Gaseous Diff. Plant (PORTS)	4002501	LMES Portsmouth		●			
		4002502	Bechtel-Jacobs (Portsmouth)	●	●		●	●
		4002504	M.M. Portsmouth Subcontractors	●				
		4002506	M.M. Portsmouth Subcontractors	●				
Oakland	Ops. and Other Facilities	8001003	Boeing, Rocketdyne - ETEC	●	●	●	●	●
		8006103	U. of Cal./Davis, Radiobiology Lab. - LEHR	●	●	●	●	●
		8006303	U. of Cal./SF - Lab of Radiobiology	●	●			
	Lawrence Berkeley Nat'l. Lab. (LBNL)	8003003	Lawrence Berkeley National Laboratory	●	●	●	●	●
	Lawrence Livermore Nat'l. Lab. (LLNL)	8004003	Lawrence Livermore National Laboratory	●	●	●	●	●
		8004004	LLNL Subcontractors	●		●	●	
		8004009	LLNL Security	●	●	●	●	
		8004024	LLNL Plant Services	●	●	●		
		8005003	Lawrence Livermore Nat'l Lab. - Nevada	●				
	Stanford Linear Acc. Center (SLAC)	8008003	Stanford Linear Accelerator Center	●	●	●	●	●
Ohio	Ops. and Other Facilities	4500001	Ohio Field Office	●	●	●	●	●
		4510001	Miamisburg Area Office	●	●	●	●	●
		4510006	Miamisburg Office Subs		●	●	●	●
		4517003	Battelle Memorial Institute - Columbus		●	●	●	●
	Fernald Environmental	4521001	Fernald Area Office	●	●	●	●	●
		4521004	Fernald Office Service Subcontractors	●		●	●	●
		4523702	Fernald Envir. Rest. Mgmt. Corp (FERMCO)	●	●	●	●	●
		4523704	FERMCO Service Vendors					●
		4523706	FERMCO Subcontractors	●	●	●	●	●
	Mound Plant	4516002	BWX Technologies, Inc.	●	●	●	●	●
		4516004	BWX Technologies, Inc. - Subcontractors	●	●	●	●	●
		4516009	BWX Technologies, Inc. - Security Forces	●	●	●	●	●
	West Valley Project	4530001	West Valley Area Office		●			
		4539004	West Valley Nuclear Services, Inc. (WVNS)	●	●	●	●	●
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	7700001	Rocky Flats Office	●	●	●	●	●
		7700007	Rocky Flats Office Subs	●	●	●	●	
		7707002	Rocky Flats Prime Contractors	●	●	●	●	●
		7707004	Rocky Flats Subcontractors	●	●	●	●	●
		7711004	Kaiser-Hill RFETS	●				
Richland	Hanford Site	7500503	Battelle Memorial Institute (PNL)	●	●	●	●	●
		7500705	Bechtel Power Co.	●	●	●	●	●
		7501004	Boeing Computer Services		●			
		7502504	Hanford Environmental Health Foundation	●	●	●	●	●
		7503005	Kaiser Engineers Hanford - Cost Const.	●	●	●		●
		7505004	Fluor Daniel - Hanford		●	●	●	●
		7505005	Fluor Daniel Northwest		●	●	●	●
		7505006	Fluor Daniel Northwest Services		●	●	●	●
		7505012	Babcock Wilcox Hanford		●	●	●	●

Exhibit A-2.
Organizations Reporting to DOE REMS, 1995-1999 (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'95	'96	'97	'98	'99
Richland	Hanford Site	7505013	Babcock Wilcox Protection, Inc.		●	●	●	●
		7505024	Rust Services Hanford		●	●	●	●
		7505025	Rust Services Northwest		●	●	●	●
		7505034	Duke Engineering Services Hanford		●	●	●	●
		7505035	Duke Engineering & Services Northwest, Inc.		●	●	●	●
		7505044	NUMATEC Hanford		●	●	●	●
		7505054	Lockheed Martin Hanford		●	●	●	●
		7505055	Lockheed Martin Services, Inc.		●	●	●	●
		7505064	Dyncorp Hanford		●	●	●	●
		7505075	SGN Eurisys Services Corp.		●	●		●
		7505099	Hanford Security					●
		7506001	Richland Field Office		●	●		●
		7508805	US Corps of Engineers - RL		●	●		
		7509004	Westinghouse Hanford Services		●	●		
		7509104	Westinghouse Hanford Service Subs	●	●	●	●	●
Savannah River	Savannah River Site (SRS)	8500505	Bechtel Construction - SR	●	●	●	●	●
		8501002	Westinghouse Savannah River Co.	●	●	●	●	●
		8501004	Service America	●	●	●		
		8501014	Westinghouse S.R. Subcontractors	●	●	●	●	●
		8501024	Diversco	●	●			
		8503001	S.R. Army Corps of Engineers	●	●	●	●	
		8505001	S.R. Forest Station	●	●			
		8505501	Savannah River Field Office	●	●	●	●	●
		8507004	Miscellaneous DOE Contractors - SR	●	●	●	●	●
		8507504	Southern Bell Tel. & Tel.	●	●	●		
		8509003	Univ. of Georgia Ecology Laboratories	●	●	●	●	●
		8509509	Wackenhut Services, Inc. - SR	●	●	●	●	●

Not included in this report (see Appendix D)

Pittsburgh Naval Reactor Office	Pittsburgh Naval Reactor Office	6007001	Pittsburgh N.R. Office					
		6007504	Westinghouse Plant Apparatus Division					
		6008003	Westinghouse Electric (BAPL)					
		6009003	Westinghouse Electric (NRF)					
Schenectady Naval Reactor Office	Schenectady Naval Reactor Office	6009014	Newport News Reactor Services					
		9004003	LM-KAPL - Kesselring					
		9004005	Gen. Dynam. - Kesselring - Electric Boat					
		9005003	LM-KAPL - Knolls					
		9005004	LM-KAPL - Knolls Subs					
		9007003	LM-KAPL - Windsor					
		9007005	LM-KAPL - Windsor - Electric Boat					
		9009001	Schenectady N.R. Office					

* Those organizations no longer reporting radiation exposure information have either ceased operations requiring the monitoring and reporting of radiation records, are no longer under contract or subcontract at the DOE facility, or have changed organization codes or the name of the organization.

A.3 Facility Type Codes

The following is the list of facility type codes reported to REMS in accordance with DOE Manual 231.1-1 [12]. A facility type code is reported with each individual's dose record indicating the facility type where the majority of the individual's dose was accrued during the monitoring year.

Exhibit A-3. Facility Type Codes.

Facility Type Code	Description
10	Accelerator
21	Fuel/Uranium Enrichment
22	Fuel Fabrication
23	Fuel Processing
40	Maintenance and Support (Site Wide)
50	Reactor
61	Research, General
62	Research, Fusion
70	Waste Processing/Mgmt.
80	Weapons Fab. and Testing
99	Other

See complete Facility Type descriptions shown in Appendix C.

This page intentionally left blank.

Appendix B

Additional Data

B-1a: Operations Office/Site Dose Data (1997)

		1997							
Operations/ Field Office	Site	Collective TEDE (person-rem)	Percent Change from 1996	Number with Meas. Dose	Percent Change from 1996	Avg. Meas. TEDE (rem)	Percent Change from 1996	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 1996
Albuquerque	Ops. and Other Facilities	0.5	-86% ▼	25	-32% ▼	0.020	-80% ▼	0%	-28% ▼
	Los Alamos National Lab. (LANL)	192.2	4% ▲	2,333	18% ▲	0.082	-11% ▼	44%	
	Pantex Plant (PP)	11.1	-61% ▼	213	-35% ▼	0.052	-39% ▼	0%	-13% ▼
	Sandia National Lab. (SNL)	9.7	-42% ▼	196	-60% ▼	0.049	44% ▲	35%	11% ▲
	Uranium Mill Tailings Remedial Action (UMTRA) Project	0.3	-31% ▼	36	38% ▲	0.008	-50% ▼	0%	
Chicago	Ops. and Other Facilities	3.4	75% ▲	105	42% ▲	0.032	-55% ▼	0%	-4% ▼
	Argonne National Lab. - East (ANL-E)	19.0	3% ▲	238	18% ▲	0.080	-13% ▼	21%	-11% ▼
	Argonne National Lab. - West (ANL-W)	18.9	-57% ▼	249	-25% ▼	0.076	-42% ▼	3%	-15% ▼
	Brookhaven National Lab. (BNL)	68.9	-41% ▼	1,463	1% ▲	0.047	-42% ▼	14%	-26% ▼
	Fermi Nat'l. Accelerator Lab. (FERMI)	25.0	54% ▲	859	60% ▲	0.029	-4% ▼	5%	1% ▲
DOE HQ	DOE Headquarters (includes DNFSB)	0.2	-23% ▼	5	-17% ▼	0.041	-8% ▼	0%	
	North Korea Project	8.3	-38% ▼	24	-33% ▼	0.344	-7% ▼	71%	-7% ▼
Idaho	Idaho Site	115.3	-30% ▼	1,141	-12% ▼	0.101	-20% ▼	24%	-28% ▼
Nevada	Nevada Test Site (NTS)	1.3	32% ▲	25	32% ▲	0.054	0%	0%	
Oakland	Ops. and Other Facilities	1.4	7,806% ▲	50	733% ▲	0.028	849% ▲	0%	
	Lawrence Berkeley National Lab. (LBNL)	5.2	13% ▲	128	28% ▲	0.041	-12% ▼	0%	
	Lawrence Livermore National Lab. (LLNL)	22.1	48% ▲	190	2% ▲	0.116	45% ▲	49%	25% ▲
	Stanford Linear Accelerator Center (SLAC)	14.2	-26% ▼	117	-63% ▼	0.121	95% ▲	17%	13% ▲
Oak Ridge	Ops. and Other Facilities	6.6	-45% ▼	135	-33% ▼	0.049	-18% ▼	25%	-8% ▼
	Oak Ridge Site	77.7	-12% ▼	1,614	2% ▲	0.048	-14% ▼	14%	-7% ▼
	Paducah Gaseous Diff. Plant (PGDP)	2.5	-87% ▼	36	-88% ▼	0.069	7% ▲	0%	
	Portsmouth Gaseous Diff. Plant (PORTS)	0.2	-99% ▼	3	-100% ▼	0.079	100% ▲	0%	-12% ▼
Ohio	Ops. and Other Facilities	1.2	3,263% ▲	31	520% ▲	0.038	442% ▲	0%	
	Fernald Environmental Mgmt. Project	18.4	-33% ▼	520	-35% ▼	0.035	4% ▲	3%	-3% ▼
	Mound Plant	5.8	-71% ▼	197	-51% ▼	0.029	-41% ▼	0%	-41% ▼
	West Valley Project	6.9	-38% ▼	174	-25% ▼	0.040	-18% ▼	8%	2% ▲
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	323.2	21% ▲	3,187	-7% ▼	0.101	30% ▲	14%	6% ▲
Richland	Hanford Site	235.4	-11% ▼	2,058	-25% ▼	0.114	19% ▲	37%	19% ▲
Savannah River	Savannah River Site (SRS)	165.3	-34% ▼	3,327	-30% ▼	0.050	-7% ▼	12%	-9% ▼
Totals		**1,360.1**	**-18%** ▼	**18,679**	**-18%** ▼	**0.073**	**0%**	**23%**	**-2%** ▼

Note: Boxed values indicate the greatest value in each column.

B-1b: Operations Office/Site Dose Data (1998)

		1998							
Operations/ Field Office	Site	Collective TEDE (person-rem)	Percent Change from 1997	Number with Meas. Dose	Percent Change from 1997	Avg. Meas. TEDE (rem)	Percent Change from 1997	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 1997
Albuquerque	Ops. and Other Facilities	0.2	-57% ▼	11	-56% ▼	0.019	-3% ▼	0%	
	Los Alamos National Lab. (LANL)	161.6	-16% ▼	1,916	-18% ▼	0.084	2% ▲	39%	-5% ▼
	Pantex Plant (PP)	17.2	56% ▲	312	46% ▲	0.055	6% ▲	8%	8% ▲
	Sandia National Lab. (SNL)	9.5	-2% ▼	181	-8% ▼	0.053	6% ▲	42%	6% ▲
	Uranium Mill Tailings Remedial Action (UMTRA) Project*								
	Grand Junction	38.9		295		0.132		17%	17% ▲
Chicago	Ops. and Other Facilities	1.2	-64% ▼	44	-58% ▼	0.028	-14% ▼	0%	
	Argonne National Lab. - East (ANL-E)	17.7	-7% ▼	182	-24% ▼	0.097	22% ▲	22%	1% ▲
	Argonne National Lab. - West (ANL-W)	21.7	15% ▲	236	-5% ▼	0.092	21% ▲	5%	2% ▲
	Brookhaven National Lab. (BNL)	63.0	-9% ▼	1,055	-28% ▼	0.060	27% ▲	20%	6% ▲
	Fermi Nat'l. Accelerator Lab. (FERMI)	12.8	-49% ▼	441	-49% ▼	0.029	0% ▼	0%	-5% ▼
DOE HQ	DOE Headquarters (includes DNFSB)	0.0	-86% ▼	2	-60% ▼	0.014	-66% ▼	0%	
	North Korea Project	5.4	-34% ▼	14	-42% ▼	$\boxed{0.388}$	13% ▲	64%	-7% ▼
	Kazakhstan	0.4		13		0.031		0%	
Idaho	Idaho Site	64.9	-44% ▼	743	-35% ▼	0.087	-14% ▼	12%	-13% ▼
Nevada	Nevada Test Site (NTS)	1.0	-26% ▼	13	-48% ▼	0.077	43% ▲	0%	
Oakland	Ops. and Other Facilities	1.0	-28% ▼	45	-10% ▼	0.023	-20% ▼	0%	
	Lawrence Berkeley National Lab. (LBNL)	2.9	-45% ▼	76	-41% ▼	0.038	-7% ▼	0%	
	Lawrence Livermore National Lab. (LLNL)	6.9	-69% ▼	107	-44% ▼	0.065	-44% ▼	36%	-13% ▼
	Stanford Linear Accelerator Center (SLAC)	13.1	-7% ▼	157	34% ▲	0.084	-31% ▼	0%	-17% ▼
Oak Ridge	Ops. and Other Facilities	3.8	-42% ▼	195	44% ▲	0.020	-60% ▼	0%	-25% ▼
	Oak Ridge Site	102.7	32% ▲	2,187	36% ▲	0.047	-2% ▼	28%	14% ▲
	Paducah Gaseous Diff. Plant (PGDP)	5.3	113% ▲	68	89% ▲	0.078	13% ▲	0%	
	Portsmouth Gaseous Diff. Plant (PORTS)	0.2	2% ▲	15	$\boxed{400\%}$ ▲	0.016	-80% ▼	0%	
Ohio	Ops. and Other Facilities	24.1	$\boxed{1,951\%}$ ▲	78	152% ▲	0.310	$\boxed{715\%}$ ▲	$\boxed{68\%}$	$\boxed{68\%}$ ▲
	Fernald Environmental Mgmt. Project	13.3	-27% ▼	559	8% ▲	0.024	-33% ▼	0%	-3% ▼
	Mound Plant	1.3	-78% ▼	106	-46% ▼	0.012	-59% ▼	0%	
	West Valley Project	18.2	162% ▲	260	49% ▲	0.070	76% ▲	4%	-4% ▼
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	$\boxed{348.1}$	8% ▲	$\boxed{3,298}$	3% ▲	0.106	4% ▲	20%	6% ▲
Richland	Hanford Site	180.9	-23% ▼	1,772	-14% ▼	0.102	-11% ▼	18%	-19% ▼
Savannah River	Savannah River Site (SRS)	165.5	0% ▲	3,163	-5% ▼	0.052	5% ▲	13%	1% ▲
Totals		**1,303.1**	**-4%** ▼	**17,544**	**-6%** ▼	**0.074**	**2%** ▲	**21%**	**-2%** ▼

* Ceased operations requiring monitoring as of 1/1/98.
Note: Boxed values indicate the greatest value in each column.

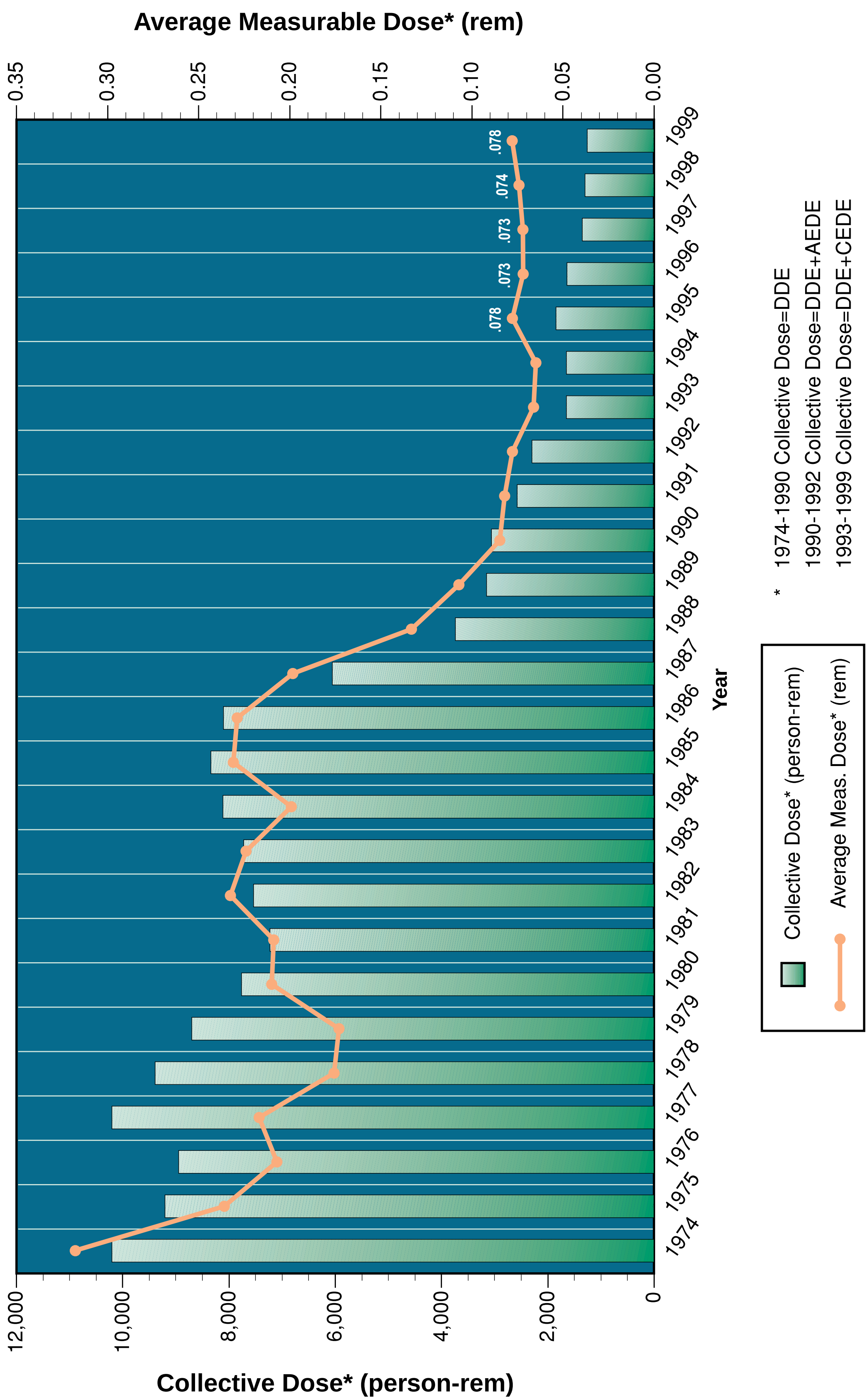
B-1c: Operations Office/Site Dose Data (1999)

Operations/ Field Office	Site	1999 Collective TEDE (person-rem)	Percent Change from 1998	Number with Meas. Dose	Percent Change from 1998	Avg. Meas. TEDE (rem)	Percent Change from 1998	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 1998
Albuquerque	Ops. and Other Facilities	0.4	97% ▲	26	136% ▲	0.016	-17% ▼	0%	0%
	Los Alamos National Lab. (LANL)	131.0	-19% ▼	1,479	-23% ▼	0.089	5% ▲	39%	0%
	Pantex Plant (PP)	29.3	70% ▲	353	13% ▲	0.083	50% ▲	11%	3% ▲
	Sandia National Lab. (SNL)	6.4	-33% ▼	120	-34% ▼	0.053	1% ▲	18%	-23% ▼
	Uranium Mill Tailings Remedial Action (UMTRA) Project *								
	Grand Junction	2.5	-94% ▼	48	-84% ▼	0.052	-60% ▼	0%	-17% ▼
Chicago	Ops. and Other Facilities	1.5	20% ▲	82	86% ▲	0.018	-35% ▼	0%	0%
	Argonne National Lab. - East (ANL-E)	24.6	39% ▲	187	3% ▲	0.131	35% ▲	42%	20% ▲
	Argonne National Lab. - West (ANL-W)	26.7	23% ▲	299	27% ▲	0.089	-3% ▼	3%	-3% ▼
	Brookhaven National Lab. (BNL)	23.4	-63% ▼	521	-51% ▼	0.045	-25% ▼	6%	-14% ▼
	Fermi Nat'l. Accelerator Lab. (FERMI)	8.7	-32% ▼	227	-49% ▼	0.039	33% ▲	14%	14% ▲
DOE HQ	DOE Headquarters (includes DNFSB)	0.0	-18% ▼	4	100% ▲	0.006	-59% ▼	0%	0%
	North Korea Project		-100% ▼					0%	0%
	Kazakhstan	0.1	-78% ▼	3	-77% ▼	0.030	-4% ▼	0%	0%
Idaho	Idaho Site	48.3	-26% ▼	729	-2% ▼	0.066	-24% ▼	5%	-7% ▼
Nevada	Nevada Test Site (NTS)	0.4	-55% ▼	6	-54% ▼	0.075	-3% ▼	0%	0%
Oakland	Ops. and Other Facilities	1.0	-1% ▼	85	89% ▲	0.012	-47% ▼	0%	0%
	Lawrence Berkeley National Lab. (LBNL)	1.8	-37% ▼	46	-39% ▼	0.040	3% ▲	0%	0%
	Lawrence Livermore National Lab. (LLNL)	14.9	116% ▲	137	28% ▲	0.109	69% ▲	36%	0%
	Stanford Linear Accelerator Center (SLAC)	10.2	-22% ▼	104	-34% ▼	0.098	17% ▲	11%	11% ▲
Oak Ridge	Ops. and Other Facilities	2.4	-37% ▼	109	-44% ▼	0.022	12% ▲	0%	0%
	Oak Ridge Site	202.2	97% ▲	2,493	14% ▲	0.081	73% ▲	38%	10% ▲
	Paducah Gaseous Diff. Plant (PGDP)	4.3	-18% ▼	58	-15% ▼	0.075	-4% ▼	0%	0%
	Portsmouth Gaseous Diff. Plant (PORTS)	0.5	113% ▲	25	67% ▲	0.021	28% ▲	0%	0%
Ohio	Ops. and Other Facilities	31.6	31% ▲	104	33% ▲	0.304	-2% ▼	72%	4% ▲
	Fernald Environmental Mgmt. Project	15.1	13% ▲	458	-18% ▼	0.033	38% ▲	0%	0%
	Mound Plant	2.7	115% ▲	197	86% ▲	0.014	16% ▲	0%	0%
	West Valley Project	12.5	-31% ▼	243	-7% ▼	0.052	-26% ▼	0%	-4% ▼
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	373.9	7% ▲	3,517	7% ▲	0.106	1% ▲	28%	8% ▲
Richland	Hanford Site	182.0	1% ▲	2,013	14% ▲	0.090	-11% ▼	35%	17% ▲
Savannah River	Savannah River Site (SRS)	136.5	-18% ▼	2,995	-5% ▼	0.046	-13% ▼	10%	-3% ▼
Totals		**1,295.2**	**-1% ▼**	**16,668**	**-5% ▼**	**0.078**	**5% ▲**	**26%**	**5% ▲**

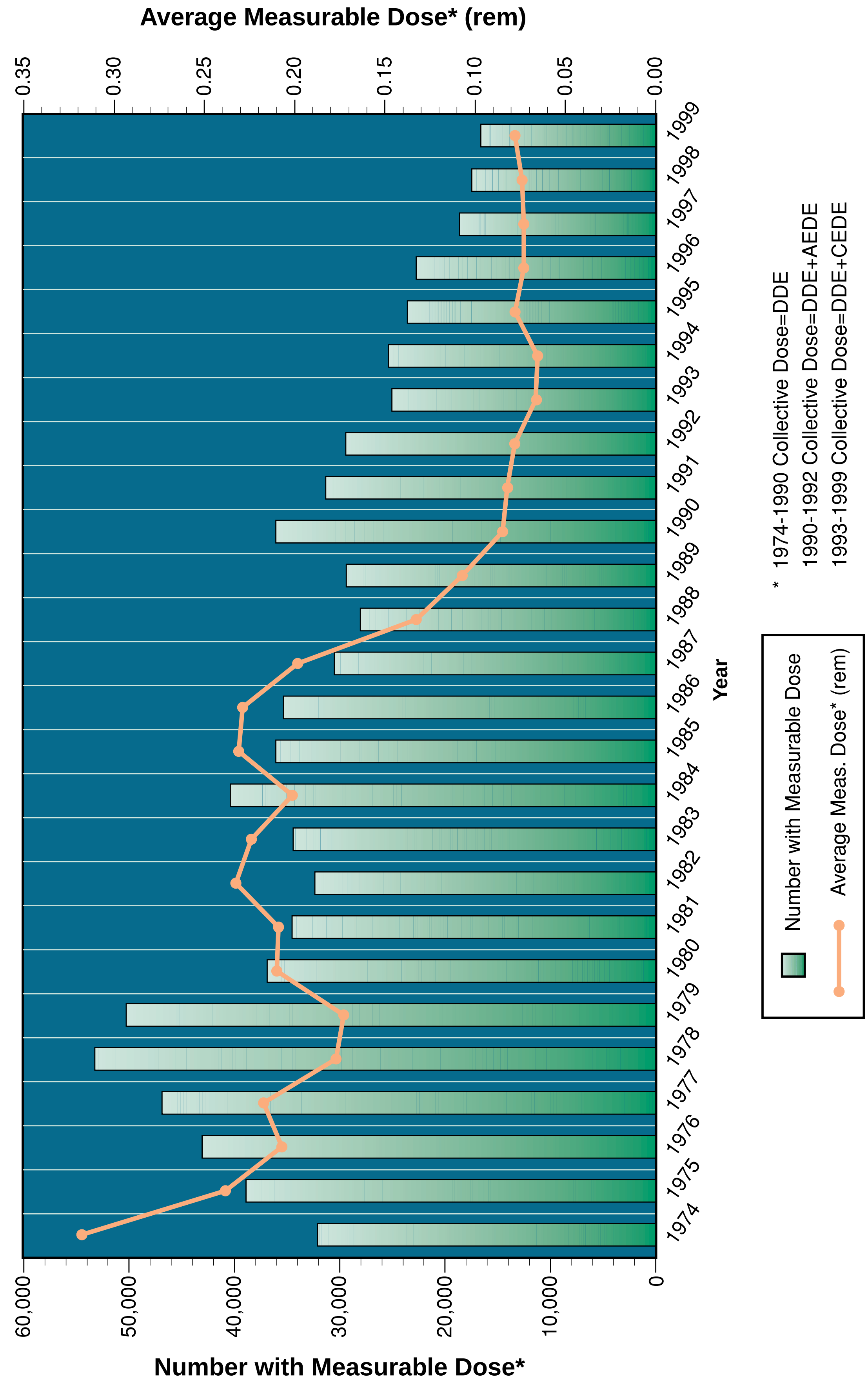
* Ceased operations requiring monitoring as of 1/1/98.
Note: Boxed values indicate the greatest value in each column.

Sixty percent of the sites reported decreases in collective TEDE for 1999.

B-2a: Collective TEDE and Average Measurable Dose 1974-1999



B-2b: Number with Measurable Dose and Average Measurable Dose 1974-1999



B-3: Distribution of Deep Dose Equivalent (DDE) and Total Effective Dose Equivalent (TEDE), 1974-1999

Deep Dose Equivalent (DDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Year	Less than Meas.	Meas.-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12	Total Monitored	No. with Meas. DDE	Coll. DDE (person-rem)	Avg. Meas. DDE
1974	37,060	29,735	1,531	652	149	40	4								69,171	32,111	**10,202** ◄	**0.318** ◄
1975	41,390	36,795	1,437	541	122	28				1					80,314	38,924	9,202	0.236
1976	38,408	41,321	1,296	387	70	6	1								81,489	43,081	8,938	0.207
1977	41,572	44,730	1,499	540	103	23			1	2				2	88,472	46,900	10,199	0.217
1978	43,317	51,444	1,311	439	53	11									96,575	**53,258** ◄	9,390	0.176
1979	48,529	48,553	1,281	416	33	10	1							2	98,825	50,296	8,691	0.173
1980	43,663	35,385	1,113	387	16										80,564	36,901	7,760	0.210
1981	43,775	33,251	967	263	29	5									78,290	34,515	7,223	0.209
1982	47,420	30,988	990	313	56	28									79,795	32,375	7,538	0.233
1983	48,340	32,842	1,225	294	49	31									82,781	34,441	7,720	0.224
1984	46,056	38,821	1,223	312	31	11									86,454	40,398	8,113	0.201
1985	54,582	34,317	1,362	356	51	8				1					90,677	36,095	8,340	0.231
1986	53,586	33,671	1,279	349	35	1		1					1		88,923	35,337	8,095	0.229
1987	45,241	28,995	1,210	283	36										75,765	30,524	6,056	0.198
1988	48,704	27,492	502	34											76,732	28,028	3,735	0.133
1989	56,363	28,925	428	21											85,737	29,374	3,151	0.107
1990	76,798	31,110	140	17											108,065	31,267	2,230	0.071
1991	92,526	27,149	95												119,770	27,244	1,762	0.065
1992	98,900	24,769	42												123,711	24,811	1,504	0.061
1993	103,905	23,050	86			1									127,042	23,137	1,534	0.066
1994	92,245	24,189	77												116,511	24,266	1,600	0.066
1995	104,793	22,330	153												**127,276** ◄	22,483	1,809	0.080
1996	101,529	21,720	74	1											123,324	21,795	1,598	0.073
1997	89,805	17,331	45												107,181	17,376	1,285	0.074
1998	92,790	15,656	36												108,482	15,692	1,218	0.078
1999	98,122	14,877	62												113,061	14,939	1,142	0.076

Total Effective Dose Equivalent (TEDE)*

Year	Less than Meas.	Meas.-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12	Total Monitored	No. with Meas. TEDE	Coll. TEDE (person-rem)	Avg. Meas. TEDE
1990	71,991	35,780	226	47	8	8	1	2		1				1	108,065	**36,074** ◄	**3,052** ◄	**0.085** ◄
1991	88,444	31,086	193	25	9	8		2		1				2	119,770	31,326	2,574	0.082
1992	94,297	29,240	132	22	9	6		2	1		1			1	123,711	29,414	2,295	0.078
1993	101,947	25,002	87			2				1	1			2	127,042	25,095	1,644	0.066
1994	91,121	25,310	79		1										116,511	25,390	1,643	0.065
1995	103,663	23,454	157		1	1									**127,276** ◄	23,613	1,845	0.078
1996	100,599	22,641	80	2	1								1		123,324	22,725	1,652	0.073
1997	88,502	18,627	48	1	2	1									107,181	18,675	1,356	0.073
1998	90,951	17,489	41	1											108,482	17,531	1,303	0.074
1999	96,393	16,585	80	1	1			1							113,061	16,668	1,295	0.078

* 1990-1992 TEDE=DDE+AEDE 1993-1999 TEDE=DDE+CEDE Note: Arrowed values indicate the greatest value in each column.

B-4: Internal Dose by Operations/Site, 1997 - 1999

Operations/ Field Office	Site	No. of Individuals with New Intakes*			Collective CEDE Dose from Intake (person-rem)			Average CEDE (rem)		
		1997	1998	1999	1997	1998	1999	1997	1998	1999
Albuquerque	Ops. and Facilities	6			0.085			0.014		
	LANL	76	80	65	10.481	2.781	3.06	0.138	0.035	0.047
	Pantex	3	4	1	0.003	0.004	0.025	0.001	0.001	0.025
	Sandia National Lab			11			0.036			0.003
	Grand Junction		280	39		33.840	2.147		0.121	0.055
Chicago	Ops. and Other Facilities	51	20	12	0.126	0.240	0.017	0.002	0.012	0.001
	ANL-E	12	43	26	0.322	1.150	0.368	0.027	0.027	0.014
	ANL-W	1	1		0.070	0.070		0.070	0.070	
	BNL	66	58	36	2.282	0.623	0.524	0.035	0.011	0.015
Idaho	Idaho Site	276	1	1	**27.928** ◀	0.016	0.016	0.101	0.016	0.016
Nevada	NTS	4	8		0.473	0.383		0.118	0.048	
Oakland	LBNL	9	6	7	0.238	0.310	0.154	0.026	0.052	0.022
	LLNL	14	6	1	4.055	0.041	0.010	**0.290** ◀	0.007	0.010
Oak Ridge	Ops. and Other Facilities	47	33	35	4.185	0.301	0.519	0.089	0.009	0.015
	Oak Ridge Site	**700** ◀	**1,281** ◀	**1,622** ◀	8.234	**35.263** ◀	**125.418** ◀	0.012	0.028	0.077
	Paducah	1	1		0.023	0.012		0.023	0.012	
	Portsmouth	2			0.003			0.002		
Ohio	OH	1	29	35	0.004	0.062	0.129	0.004	0.002	0.004
	Fernald	24	18	35	0.231	0.083	0.191	0.010	0.005	0.005
	Mound Plant	103	97	100	0.543	0.965	0.602	0.005	0.010	0.006
	WVNS	1			0.049			0.049		
Rocky Flats	Rocky Flats	43	31	61	2.748	3.986	6.626	0.064	0.129	**0.109** ◀
Richland	Hanford Site	7	11	19	0.446	1.792	0.226	0.064	**0.163** ◀	0.012
Savannah River	Savannah River Site	467	457	357	2.826	2.285	12.794	0.006	0.005	0.036
Totals		**1,914**	**2,465**	**2,463**	**65.355**	**84.207**	**152.868**	**0.034**	**0.034**	**0.062**

Facilities with no new intakes reported during the past 3 years: UMTRA, Fermi Lab, DOE-HQ, Oakland Ops., SLAC.

* *Only includes intakes that occurred during the monitoring year. Individuals may be counted more than once.*

Note: Arrowed values indicate the greatest value in each column.

The number of individuals with intakes and the collective CEDE continues to increase for the third year in a row for the Oak Ridge Site. The increase in 1999 is due to uranium intakes at the Y-12 plant that increased because of increased operations and a change in monitoring processes.

B-5: Neutron Dose Distribution by Operations/Site, 1999

Operations	Site	No Meas. Dose	Meas. <0.1	0.1-0.25	0.25-0.5	0.5-0.75	0.75-1.0	1-2	>2	Total Monitored*	No. of Individuals with Meas. Dose	% of Individuals with Meas. Dose	Collective Neutron Dose (person-rem)	Average Meas. Neutron Dose (rem)
Albuquerque	Albuquerque	702	4							706	4	0%	0.054	0.016
	Grand Junction	277	3							280	3	1%	0.112	0.037
	Los Alamos National Lab. (LANL)	9,977	972	123	49	17	5	6		11,149	**1,172**	**11%**	**79.619**	0.068
	Pantex Plant (PP)	6,232	103	6						6,341	109	2%	4.603	0.042
	Sandia National Lab. (SNL)	3,263	8							3,271	8	0%	0.103	0.013
Chicago	Chicago Operations	684	1							685		0%	0.007	0.007
	Argonne Nat'l. Lab. - East (ANL-E)	2,822	57	9						2,888	66	2%	2.770	0.042
	Argonne Nat'l. Lab. - West (ANL-W)	1,555	10							1,565	10	1%	0.348	0.035
	Brookhaven Nat'l. Lab. (BNL)	5,556	96	1						5,653	97	2%	1.659	0.017
	Fermi Nat'l. Accelerator Lab. (FERMI)	1,051								1,051		0%		
DOE HQ	DOE Headquarters	171	1							172	1	1%	0.007	0.007
	Kazakhstan	53								53		0%		
Idaho	Idaho Site	8,831	53	1						8,885	54	1%	1.852	0.034
Nevada	Nevada Test Site (NTS)	4,371								4,371		0%		
Oakland	Oakland Operations	230								230		0%		
	Lawrence Berkeley National Lab. (LBNL)	1,764	15	2						1,781	17	1%	0.666	0.039
	Lawrence Livermore National Lab. (LLNL)	8,969	34	7	3					9,013	44	0%	2.907	0.066
	Stanford Linear Accelerator Center (SLAC)	2,490	2	1						2,493	3	0%	0.128	0.043
Oak Ridge	Oak Ridge Operations	2,341	1							2,342	1	0%	0.078	0.078
	Oak Ridge Site	14,217	80	16	8	1				**14,322**	105	1%	8.544	0.081
	Paducah Gaseous Diff. Plant (PGDP)	443	32	8						483	40	8%	2.233	0.056
	Portsmouth Gaseous Diff. Plant (PORTS)	195	9							204	9	4%	0.125	0.014
Ohio	Ohio Field Office	376								376		0%		
	Fernald Environmental Mgmt. Project	4,210								4,210		0%		
	Mound Plant	985	16							1,001	16	2%	0.125	0.008
	West Valley	1,064								1,064		0%		
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	5,772	642	278	54	6	1			6,753	981	15%	92.879	**0.095**
Richland	Hanford Site	10,700	540	53	13	3	1			11,310	610	5%	26.833	0.044
Savannah	Savannah River Site (SRS)	9,703	650	54	2					10,409	706	7%	30.423	0.043
	Totals	**109,004**	**3,329**	**559**	**129**	**27**	**7**	**6**	**0**	**113,061**	**4,057**	**4%**	**256.075**	**0.063**

* Represents the total number of monitoring records. The number of individuals specifically monitored for neutron radiation cannot be determined.

Los Alamos accounts for the largest percentage of the collective neutron dose due to their continued handling of plutonium, which results in neutron exposure.

B-6a: Distribution of TEDE by Facility Type - 1997

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Facility Type	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Accelerator	8,927	2,282	178	77	19	6						11,489	22%	2,562	114.379	0.045
Fuel/Uran. Enrich.	2,958	130	16	2	1							3,107	5%	149	6.178	0.041
Fuel Fabrication	2,405	501	35	8	1							2,950	18%	545	18.839	0.035
Fuel Processing	2,948	1,098	128	17	11	4	3					4,209	30%	1,261	67.426	0.053
Maint. and Support	12,599	1,779	195	120	53	23	6			1		14,776	15%	2,177	179.989	0.083
Other	17,468	2,006	236	87	50	23	20		1			19,891	12%	2,423	191.274	0.079
Reactor	1,461	622	63	37	4	3						2,190	**33%** ◄	729	42.313	0.058
Research, General	16,842	2,119	350	138	35	25	12	1	1			19,523	14%	2,681	225.950	0.084
Research, Fusion	554	111	11	2	6	2						686	19%	132	10.548	0.080
Waste Proc./Mgmt.	5,949	1,363	181	54	6	4	1					7,558	21%	1,609	94.498	0.059
Weapons Fab. & Test	16,391	3,252	749	314	79	11	6					**20,802** ◄	21%	**4,411** ◄	**408.697** ◄	**0.093** ◄
Totals	**88,502**	**15,263**	**2,142**	**856**	**265**	**101**	**48**	**1**	**2**	**1**	**0**	**107,181**	**17%**	**18,679**	**1,360.091**	**0.073**

Note: Arrowed values indicate the greatest value in each column.

B-6b: Distribution of TEDE by Facility Type - 1998

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Facility Type	Less than Meas.	Meas. 0-10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Accelerator	9,786	1,384	133	76	17	6	2					11,404	14%	1,618	94.744	0.059
Fuel/Uran. Enrich.	3,474	225	23	8								3,730	7%	256	9.883	0.039
Fuel Fabrication	4,037	562	31									4,630	13%	593	14.252	0.024
Fuel Processing	2,889	1,045	98	27	1	1						4,061	29%	1,172	52.546	0.045
Maint. and Support	11,272	1,344	224	100	46	9	5					13,000	13%	1,728	147.316	0.085
Other	19,244	1,859	285	100	37	8	8					21,541	11%	2,297	161.024	0.070
Reactor	1,434	543	49	16	7	4						2,053	**30%** ◄	619	31.410	0.051
Research, General	16,098	1,917	308	126	29	15	15					18,508	13%	2,410	196.596	0.082
Research, Fusion	482	67	3	1	4							557	13%	75	5.243	0.070
Waste Proc./Mgmt.	5,575	1,179	229	90	12	2						7,087	21%	1,512	111.354	0.074
Weapons Fab. & Test	16,673	3,941	870	297	115	29	11	1				**21,937** ◄	24%	**5,264** ◄	**474.498** ◄	**0.090** ◄
Totals	**90,964**	**14,066**	**2,253**	**841**	**268**	**74**	**41**	**1**	**0**	**0**	**0**	**108,508**	**16%**	**17,544**	**1,298.866**	**0.074**

Note: Arrowed values indicate the greatest value in each column.

B-6c: Distribution of TEDE by Facility Type - 1999

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Facility Type	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Accelerator	9,866	797	86	19	4	1						10,773	8%	907	44.024	0.049
Fuel/Uran. Enrich.	3,463	382	27	6	1							3,879	11%	416	13.626	0.033
Fuel Fabrication	3,760	420	26	13								4,219	11%	459	15.081	0.033
Fuel Processing	3,865	1,019	74	14								4,972	22%	1,107	41.187	0.037
Maint. and Support	17,123	1,665	239	89	54	23	13					19,206	11%	2,083	179.522	0.086
Other	18,795	1,358	91	45	20	12	7					**20,328** ◄	8%	1,533	97.156	0.063
Reactor	2,121	554	45	22	7	1						2,750	23%	629	30.958	0.049
Research, General	17,257	1,759	312	108	24	10	11					19,481	11%	2,224	170.016	0.076
Research, Fusion	618	40	3	3	1	2	1					668	7%	50	6.000	**0.120** ◄
Waste Proc./Mgmt.	5,664	1,223	175	40	17	8	12					7,139	21%	1,475	106.617	0.072
Weapons Fab. & Test	13,861	4,344	820	411	110	62	35	1	1		1	19,646	**29%** ◄	**5,785** ◄	**590.993** ◄	0.102
Totals	**96,393**	**13,561**	**1,898**	**770**	**238**	**118**	**80**	**1**	**1**	**0**	**1**	**113,061**	**15%**	**16,668**	**1,295.180**	**0.078**

Note: Arrowed values indicate the greatest value in each column.

Weapons Fabrication and Testing remains the facility type with the highest collective dose and number of individuals with measurable dose. It should be noted that Rocky Flats and Savannah River account for the majority of the dose reported under this facility type even though these sites are no longer actively involved in this activity.

B-7a: Collective TEDE by Facility Type, 1997

DOE Operations	Site	Accelerator	Fuel/Uranium Enrichment	Fuel Fabrication	Fuel Processing	Maintenance and Support	Reactor	Research, General	Research, Fusion	Waste Processing/ Management	Weapons Fab. and Testing	Other	Totals
Albuquerque	Ops. and Other Facilities									0.1	0.3	0.1	**0.5**
	Los Alamos National Lab. (LANL)	17.3				59.0	0.2	**96.5**	0.3	1.8	0.0	17.0	**192.1**
	Pantex Plant (PP)										11.1	-	**11.1**
	Sandia National Lab. (SNL)	0.7				0.3	4.9	2.4	0.0	0.3	0.3	0.8	**9.7**
	UMTRA											0.3	**0.3**
Chicago	Ops. and Other Facilities					1.1		0.4	2.9			0.0	**4.4**
	Argonne Nat'l. Lab. - East (ANL-E)	9.3				2.4		6.1		1.0		0.2	**19.0**
	Argonne Nat'l. Lab. - West (ANL-W)			0.2		0.5	0.7	17.5				0.0	**18.9**
	Brookhaven Nat'l. Lab. (BNL)	**44.7**				4.9	7.0	8.6		0.8		3.0	**69.0**
	Fermi Nat'l. Accelerator Lab. (FERMI)	25.0											**25.0**
DOE HQ	DOE Headquarters											0.2	**0.2**
	North Korea											8.3	**8.3**
Idaho	Idaho Site				31.8	5.4	**16.7**	4.3		3.4		53.8	**115.4**
Nevada	Nevada Test Site (NTS)										1.3		**1.3**
Oakland	Ops. and Other Facilities							1.4					**1.4**
	Lawrence Berkeley National Lab. (LBNL)	1.7						3.6					**5.3**
	Lawrence Livermore National Lab. (LLNL)	0.1	2.0			1.9		1.8	**7.2**		1.3	7.8	**22.1**
	Stanford Linear Accelerator Center (SLAC)	14.2											**14.2**
Oak Ridge	Ops. and Other Facilities	1.4			0.0			0.4		4.1		0.7	**6.6**
	Oak Ridge Site		1.4					54.1			10.7	11.5	**77.7**
	Paducah Gaseous Diff. Plant (PGDP)		**2.5**										**2.5**
	Portsmouth Gaseous Diff. Plant (PORTS)		0.2										**0.2**
Ohio	Ops. and Other Facilities											0.1	**0.1**
	Fernald Environmental Mgmt. Project			**18.4**									**18.4**
	Mound Plant					0.2					0.1	5.4	**5.7**
	West Valley											6.9	**6.9**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**322.1**	1.1	**323.2**
Richland	Hanford Site			0.1	2.5	**88.1**	6.6	14.0		**50.0**		**73.9**	**235.2**
Savannah River	Savannah River Site (SRS)			0.2	**33.2**	16.0	6.3	15.1		33.0	61.5	0.1	**165.4**
	Totals	**114.4**	**6.1**	**18.9**	**67.5**	**179.8**	**42.4**	**226.2**	**10.4**	**94.5**	**408.7**	**191.2**	**1,360.2**

Note: Arrowed values indicate the greatest value in each column.

B-7b: Collective TEDE by Facility Type, 1998

DOE Operations	Site	Accelerator	Fuel/Uranium Enrichment	Fuel Fabrication	Fuel Processing	Maintenance and Support	Reactor	Research, General	Research, Fusion	Waste Processing/ Management	Weapons Fab. and Testing	Other	Totals
Albuquerque	*Ops. and Other Facilities*									*0.1*	*0.1*	*0.0*	**0.2**
	Los Alamos National Lab. (LANL)	*15.3*				*48.8*	*0.3*	**71.2** ◄	*0.8*	*2.1*	*0.1*	*23.2*	**161.6**
	Pantex Plant (PP)										*17.2*	-	**17.2**
	Sandia National Lab. (SNL)	*0.1*				*0.2*	*4.6*	*2.8*		*0.2*	*0.4*	*1.2*	**9.5**
	Grand Junction											*38.9*	**38.9**
Chicago	*Ops. and Other Facilities*		*0.1*					*0.1*	*1.1*			*0.0*	**1.2**
	Argonne Nat'l. Lab. - East (ANL-E)	*5.4*				*0.2*		*8.3*		*3.7*		*0.1*	**17.7**
	Argonne Nat'l. Lab. - West (ANL-W)			*0.2*		*0.5*	*0.7*	*20.2*				*0.1*	**21.7**
	Brookhaven Nat'l. Lab. (BNL)	**45.9** ◄				*4.8*	*2.7*	*7.6*		*0.8*		*1.2*	**63.0**
	Fermi Nat'l. Accelerator Lab. (FERMI)	*12.8*											**12.8**
DOE HQ	*DOE Headquarters*					*0.0*		*0.0*					**0.0**
	North Korea											*5.4*	**5.4**
	Kazakhstan											*0.4*	**0.4**
Idaho	*Idaho Site*				*22.0*	*4.3*	**14.3** ◄	*4.0*		*7.2*		*13.1*	**64.9**
Nevada	*Nevada Test Site (NTS)*										*1.0*	*0.0*	**1.0**
Oakland	*Ops. and Other Facilities*							*1.0*					**1.0**
	Lawrence Berkeley National Lab. (LBNL)	*1.1*						*1.8*					**2.9**
	Lawrence Livermore National Lab. (LLNL)	*0.0*	*0.5*			*0.4*		*0.8*	**3.4** ◄		*0.6*	*1.2*	**6.9**
	Stanford Linear Accelerator Center (SLAC)	*13.1*											**13.1**
Oak Ridge	*Ops. and Other Facilities*	*1.0*			*0.1*			*0.0*		*2.1*		*0.6*	**3.8**
	Oak Ridge Site		*3.9*					*53.0*			*41.2*	*4.6*	**102.7**
	Paducah Gaseous Diff. Plant (PGDP)		**5.3** ◄										**5.3**
	Portsmouth Gaseous Diff. Plant (PORTS)		*0.2*										**0.2**
Ohio	*Ops. and Other Facilities*					*24.1*						*0.0*	**24.1**
	Fernald Environmental Mgmt. Project			**13.3** ◄									**13.3**
	Mound Plant					*0.1*					*0.0*	*1.2*	**1.3**
	West Valley											*18.2*	**18.2**
Rocky Flats	*Rocky Flats Env. Tech. Site (RFETS)*										**346.5** ◄	*1.5*	**348.1** ◄
Richland	*Hanford Site*			*0.1*	*1.5*	**55.2** ◄	*5.2*	*13.8*		**51.7** ◄		**53.4** ◄	**180.9**
Savannah River	*Savannah River Site (SRS)*			*0.6*	**29.0** ◄	*8.7*	*3.7*	*11.8*		*43.5*	*67.9*	*0.4*	**165.5**
	Totals	**94.7**	**10.0**	**14.3**	**52.6**	**147.3**	**31.4**	**196.6**	**5.2**	**111.4**	**475.0**	**164.6**	**1,303.1**

Note: Arrowed values indicate the greatest value in each column.

B-7c: Collective TEDE by Facility Type, 1999

DOE Operations	Site	Accelerator	Fuel/Uranium Enrichment	Fuel Fabrication	Fuel Processing	Maintenance and Support	Reactor	Research, General	Research, Fusion	Waste Processing/ Management	Weapons Fab. and Testing	Other	Totals
Albuquerque	Ops. and Other Facilities									0.3	0.1	0.1	**0.4**
	Los Alamos National Lab. (LANL)	4.8				42.5	0.0	**51.9**	0.1	1.8	0.0	**30.0**	**131.0**
	Pantex Plant (PP)										29.3	-	**29.3**
	Sandia National Lab. (SNL)	0.2				0.2	3.1	1.9		0.5	0.2	0.3	**6.4**
	Grand Junction											2.5	**2.5**
Chicago	Ops. and Other Facilities							0.6	0.8			0.0	**1.5**
	Argonne Nat'l. Lab. - East (ANL-E)	4.9				0.3		10.0		2.2		7.2	**24.6**
	Argonne Nat'l. Lab. - West (ANL-W)				0.5	0.0	0.2	26.0		0.1			**26.7**
	Brookhaven Nat'l. Lab. (BNL)	**13.0**				1.5	1.3	3.6		3.5		0.4	**23.4**
	Fermi Nat'l. Accelerator Lab. (FERMI)	8.7											**8.7**
DOE HQ	DOE Headquarters							0.0				0.0	**0.0**
	North Korea												
	Kazakhstan											0.1	**0.1**
Idaho	Idaho Site				13.4	3.6	**18.3**	4.3		7.6		1.1	**48.3**
Nevada	Nevada Test Site (NTS)					0.4							**0.4**
Oakland	Ops. and Other Facilities							1.0					**1.0**
	Lawrence Berkeley National Lab. (LBNL)	0.8						1.1					**1.8**
	Lawrence Livermore National Lab. (LLNL)	0.1	0.1			0.5		1.4	**5.1**		3.9	3.8	**14.9**
	Stanford Linear Accelerator Center (SLAC)	10.2											**10.2**
Oak Ridge	Ops. and Other Facilities	1.4						0.0		0.3		0.7	**2.4**
	Oak Ridge Site		**8.6**					43.7			127.6	22.2	**202.2**
	Paducah Gaseous Diff. Plant (PGDP)		4.3										**4.3**
	Portsmouth Gaseous Diff. Plant (PORTS)		0.5										**0.5**
Ohio	Ops. and Other Facilities					31.6							**31.6**
	Fernald Environmental Mgmt. Project			**15.1**									**15.1**
	Mound Plant					2.1				0.0	0.6	0.0	**2.7**
	West Valley											12.5	**12.5**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**372.7**	1.2	**373.9**
Richland	Hanford Site			0.0	1.2	**86.8**	4.6	10.8		**64.3**		14.5	**182.0**
Savannah River	Savannah River Site (SRS)				**26.2**	9.9	3.5	13.5		26.1	56.7	0.6	**136.5**
	Totals	**44.0**	**13.6**	**15.1**	**41.2**	**179.5**	**31.0**	**170.0**	**6.0**	**106.6**	**591.0**	**97.2**	**1,295.2**

Note: Arrowed values indicate the greatest value in each column.

A decrease in the collective TEDE at Brookhaven for Accelerators resulted in a 54% decrease in this facility category from 1998 to 1999.

B-8: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Accelerator Facilities, 1999

ACCELERATORS	Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)													
Ops. Office	**Site/Contractor**	**Less than Meas.**	**Meas. 0-0.1**	**0.10-0.25**	**0.25-0.50**	**0.50-0.75**	**0.75-1.00**	**1.00-2.00**	**>2**	**Total Monitored**	**Percent of Monitored with Meas. TEDE**	**No. with Meas. TEDE**	**Collective TEDE (person-rem)**	**Avg. Meas. TEDE (rem)**	**Percent of TEDE above 0.5 rem**
OAK	Stanford Linear Accelerator Center	2,389	78	17	7	2				2,493	4%	104	10.192	0.098 ◄	11%
CH	Argonne National Laboratory - East	580	58	16		1				655	11%	75	4.910	0.065	13% ◄
OAK	Lawrence Berkeley National Laboratory	475	11	3						489	3%	14	0.762	0.054	0%
CH	Brookhaven National Laboratory	3,022	249	28	6	1				3,306 ◄	9%	284 ◄	13.003 ◄	0.046	6%
CH	Fermilab	824	211	13	2			1		1,051	22%	227	8.740	0.039	14%
AL	Los Alamos National Laboratory	603	134	7	4					748	19%	145	4.757	0.033	0%
OR	Thomas Jefferson Nat'l. Accel. Facil.	1,409	43	2						1,454	3%	45	1.370	0.030	0%
OAK	Lawrence Berkeley National Laboratory	297	4							301	1%	4	0.104	0.026	0%
AL	Sandia National Laboratory	259	7							266	3%	7	0.164	0.023	0%
AL	Johnson Controls, Inc.	2	1							3	33% ◄	1	0.012	0.012	0%
OR	Oak Ridge Field Office	4	1							5	20%	1	0.010	0.010	0%
RL	Battelle Memorial Institute (PNNL)	2								2	0%				0%
	Totals	**9,866**	**797**	**86**	**19**	**4**	**0**	**1**	**0**	**10,773**	**8%**	**907**	**44.024**	**0.049**	**9%**

Note: Arrowed values indicate the greatest value in each column.

The collective TEDE has dropped 54% in 1999 primarily due to the decrease at BNL.

B-9: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 1999

FUEL FACILITIES

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
ENRICHMENT															
OR	Bechtel-Jacobs Co., LLC – Paducah	425	41	16	1					483	12%	58	4.335	**0.075** ◄	0%
OR	Bechtel-Jacobs Co., LLC – ETTP	1,608	123	11	5	1				**1,748** ◄	8%	**140** ◄	**7.943** ◄	0.057	**6%** ◄
OAK	Lawrence Livermore National Lab.	581	6							587	1%	6	0.134	0.022	0%
OR	Bechtel-Jacobs Co., LLC – Portsmouth	179	25							204	12%	25	0.513	0.021	0%
OR	British Nuclear Fuels Limited (BNFL)-ETTP	609	118							727	16%	118	0.502	0.004	0%
OR	Decontamination & Recovery Services-ETTP	61	69							130	**53%** ◄	69	0.199	0.003	0%
	Totals	**3,463**	**382**	**27**	**6**	**1**	**0**	**0**	**0**	**3,879**	**11%**	**416**	**13.626**	**0.033**	**4%**
FABRICATION															
OH	FERMCO	2,786	322	25	12					**3,145** ◄	11%	**359** ◄	**13.336** ◄	**0.037** ◄	0%
OH	FERMCO Subcontractors	876	96	1	1					974	10%	98	1.734	0.018	0%
OH	Fernald Area Office	52	1							53	2%	1	0.006	0.006	0%
RL	Fluor Daniel – Hanford	4	1							5	**20%** ◄	1	0.005	0.005	0%
OH	FERMCO Service Vendors	13								13	0%				0%
OH	Fernald Office Services Subcontractors	25								25	0%				0%
RL	Duke Engineering Services Hanford	1								1	0%				0%
RL	Lockheed Martin Hanford	3								3	0%				0%
	Totals	**3,760**	**420**	**26**	**13**	**0**	**0**	**0**	**0**	**4,219**	**11%**	**459**	**15.081**	**0.033**	**0%**

Note: Arrowed values indicate the greatest value in each column.

The collective TEDE for Fuel Enrichment increased by 120% from 1998 to 1999 primarily from increases at Paducah and ETTP, while the average measurable dose decreased by 20%. The collective TEDE for Fuel Fabrication decreased by 20% due to decreased dose at FERMCO, and the average measurable dose decreased by 3%.

B-9: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 1999 (Continued)

FUEL FACILITIES

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
PROCESSING															
RL	Lockheed Martin Hanford	1		1						2	**50%** ◄	1	0.117	**0.117** ◄	0%
RL	Fluor Daniel - Hanford	9	6	1	2					18	**50%** ◄	9	1.048	0.116	0%
ID	Bechtel BWXT Idaho, LLC Subs – Constr.	810	12	6	3					831	3%	21	2.195	0.105	0%
CH	Argonne National Laboratory – West	57	6	2						65	12%	8	0.454	0.057	0%
ID	Bechtel BWXT Idaho, LLC. – Services	1,259	182	19	6					1,466	14%	207	11.168	0.054	0%
SR	Bechtel Construction – SR	181	106	8						295	39%	114	3.555	0.031	0%
SR	Westinghouse Savannah River Co.	1,379	670	37	3					**2,089** ◄	34%	**710** ◄	**21.908** ◄	0.031	0%
SR	Wackenhut Services, Inc., – SR	76	28							104	27%	28	0.658	0.024	0%
SR	Savannah River Field Office	26	3							29	10%	3	0.031	0.010	0%
SR	Westinghouse S.R. Subcontractors	58	6							64	9%	6	0.053	0.009	0%
RL	Duke Engineering Services Hanford	9								9	0%				0%
	Totals	**3,865**	**1,019**	**74**	**14**	**0**	**0**	**0**	**0**	**4,972**	**22%**	**1,107**	**41.187**	**0.037**	**0%**

Note: Arrowed values indicate the greatest value in each column.

Bechtel BWXT (Idaho) and Westinghouse (Savannah River) continue to have the majority of people involved in fuel processing activities (71%) and collective TEDE (80%). The average dose per person has decreased 18% and the number of people exposed to more than 0.5 rem has decreased to 0 in 1999.

B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 1999

MAINTENANCE AND SUPPORT

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less Than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
OH	Battelle Memorial Institute - Columbus	212	44	8	18	26	8					316	33%	104	31.619	**0.304**	**72%**
NV	Bechtel Nevada - NTS Subcontractors	832		2								834	0%	2	0.283	0.142	0%
AL	Los Alamos National Laboratory	1,030	165	29	19	9	2	4				1,258	18%	228	27.404	0.120	45%
RL	Fluor Daniel - Hanford	1,291	480	104	33	16	12	9				1,945	34%	**654**	**72.637**	0.111	41%
RL	Babcock Wilcox Hanford	121	20	2	3		1					147	18%	26	2.751	0.106	29%
AL	Johnson Controls, Inc.	1,230	114	39	7	3						1,393	12%	163	14.281	0.088	13%
CH	Argonne National Laboratory - East	340	3		1							344	1%	4	0.312	0.078	0%
ID	Bechtel BWXT Idaho, LLC Subs - Construction	623	5		1							629	1%	6	0.451	0.075	0%
RL	Fluor Daniel Northwest Services	96	59	9	5							169	43%	73	4.917	0.067	0%
RL	Duke Engineering Services Hanford	137	10	2								149	8%	12	0.667	0.056	0%
RL	Lockheed Martin Services, Inc.	42	2									44	5%	2	0.111	0.056	0%
SR	Westinghouse Savannah River Co.	371	170	21								562	34%	191	8.426	0.044	0%
ID	Bechtel BWXT Idaho, LLC - Services	745	64	6	2							817	9%	72	3.171	0.044	0%
NV	Bechtel Nevada - NTS	1,920	4									1,924	0%	4	0.165	0.041	0%
AL	Sandia National Laboratory	508	5									513	1%	5	0.197	0.039	0%
SR	Bechtel Construction - SR	115	31	5								151	24%	36	1.293	0.036	0%
OAK	Lawrence Livermore National Laboratory	2,740	14									**2,754**	1%	14	0.485	0.035	0%
RL	Hanford Security	74	9	1								84	12%	10	0.346	0.035	0%
RL	Battelle Memorial Institute (PNL)	15	3	1								19	21%	4	0.133	0.033	0%
RL	Lockheed Martin Hanford	427	133	6								566	25%	139	4.344	0.031	0%
CH	Brookhaven National Laboratory	930	60	3								993	6%	63	1.543	0.024	0%
SR	Savannah River Field Office	3	3									6	**50%**	3	0.070	0.023	0%
RL	Rust Federal Services Northwest	24	8									32	25%	8	0.161	0.020	0%
RL	Fluor Daniel Northwest	133	26									159	16%	26	0.494	0.019	0%
OH	BWX Technologies, Inc. - Security Forces	23	4									27	15%	4	0.072	0.018	0%
SR	Westinghouse S.R. Subcontractors	34	8									42	19%	8	0.142	0.018	0%
RL	SGN Eurisys Services Corp.	17	1									18	6%	1	0.017	0.017	0%
RL	Rust Services Hanford	145	10									155	6%	10	0.162	0.016	0%

Note: Arrowed values indicate the greatest value in each column.

B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 1999 (Continued)

MAINTENANCE AND SUPPORT

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
CH	Argonne National Laboratory - West	190	3									193	2%	3	0.044	0.015	0%
AL	Protection Technologies Los Alamos	355	54									409	13%	54	0.764	0.014	0%
AL	Los Alamos Area Office	29	2									31	6%	2	0.028	0.014	0%
OH	BWX Technologies, Inc.	326	114	1								441	26%	115	1.598	0.014	0%
OH	BWX Technologies, Inc.–Subcontractors	262	34									296	11%	34	0.415	0.012	0%
RL	DynCorp Hanford	88	2									90	2%	2	0.013	0.007	0%
SR	Wackenhut Services, Inc. - SR	16	1									17	6%	1	0.006	0.006	0%
DOE	DOE Headquarters	1										1	0%				0%
NV	Bechtel Nevada - Special Tech. Lab.	1										1	0%				0%
NV	Defense Nuclear Agency - Kirtland AFB	102										102	0%				0%
NV	Nevada Field Office	256										256	0%				0%
NV	Nevada Miscellaneous Contractors	837										837	0%				0%
NV	Nevada Operations	140										140	0%				0%
NV	Nye County Sheriff	5										5	0%				0%
NV	Science Applications Int'l. Corp. - NV	13										13	0%				0%
NV	Wackenhut Services, Inc. – NV	193										193	0%				0%
OH	Miamisburg Area Office	20										20	0%				0%
OH	Miamisburg Office Subs	8										8	0%				0%
OH	Ohio Field Office	15										15	0%				0%
OH	West Valley Nuclear Services, Inc.	1										1	0%				0%
RL	Babcock Wilcox Protection, Inc.	5										5	0%				0%
RL	Bechtel Power Company	21										21	0%				0%
RL	Duke Eng. & Services Northwest, Inc.	3										3	0%				0%
RL	NUMATEC Hanford	32										32	0%				0%
RL	Richland Field Office	13										13	0%				0%
RL	Westinghouse Hanford Service Subs	4										4	0%				0%
SR	Miscellaneous DOE Contractors-SR	1										1	0%				0%
SR	Univ. of Georgia Ecology Lab.	8										8	0%				0%
	Totals	**17,123**	**1,665**	**239**	**89**	**54**	**23**	**13**	**0**	**0**	**0**	**19,206**	**11%**	**2,083**	**179.522**	**0.086**	**37%**

Note: Arrowed values indicate the greatest value in each column.

Collective dose for maintenance and support increased by 22% in 1999 and total personnel with measurable dose increased by 21%. The average dose per person increased 1.2% over 1998. Fluor-Daniel Hanford, Battelle Memorial, and Los Alamos are primary contributors to this category.

B-11: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Reactor Facilities, 1999

REACTOR FACILITIES

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
RL	Babcock Wilcox Hanford	16	3	1			1			21	24%	5	1.178	**0.236**	**79%**
AL	Sandia National Laboratory	39	10	3	3	2				57	32%	18	3.087	0.172	38%
ID	Bechtel BWXT Idaho, LLC Subs-Construction	522	12	4	4	1				543	4%	21	3.191	0.152	17%
ID	Bechtel BWXT Idaho, LLC - Services	425	126	24	14	3				592	28%	167	**15.120**	0.091	11%
CH	Argonne National Laboratory – West	27	1	1						29	7%	2	0.166	0.083	0%
RL	Fluor Daniel – Hanford	114	35	8	1	1				159	28%	45	2.943	0.065	17%
RL	Hanford Security	9	1							10	10%	1	0.065	0.065	0%
RL	Lockheed Martin Hanford	24	7							31	23%	7	0.254	0.036	0%
RL	Duke Engineering Services Hanford	30	4							34	12%	4	0.145	0.036	0%
AL	Los Alamos National Laboratory	5	1							6	17%	1	0.034	0.034	0%
CH	Brookhaven National Laboratory	183	36	4						223	18%	40	1.286	0.032	0%
SR	Savannah River Field Office	27	5							32	16%	5	0.090	0.018	0%
SR	Wackenhut Services, Inc. – SR	79	52							131	**40%**	52	0.912	0.018	0%
SR	Bechtel Construction - SR	92	35							127	28%	35	0.515	0.015	0%
RL	Fluor Daniel Northwest	7	1							8	13%	1	0.012	0.012	0%
SR	Westinghouse Savannah River Co.	457	218							**675**	32%	**218**	1.909	0.009	0%
SR	Westinghouse S.R. Subcontractors	28	7							35	20%	7	0.051	0.007	0%
RL	Babcock Wilcox Protection, Inc.	3								3	0%				0%
RL	Battelle Memorial Institute (PNL)	1								1	0%				0%
RL	Bechtel Power Co.	1								1	0%				0%
RL	DynCorp Hanford	6								6	0%				0%
RL	Lockheed Martin Services, Inc.	1								1	0%				0%
RL	NUMATEC Hanford	5								5	0%				0%
RL	Richland Field Office	1								1	0%				0%
RL	Rust Federal Services Northwest	2								2	0%				0%
RL	Rust Services Hanford	9								9	0%				0%
RL	SGN Eurisys Services Corp.	7								7	0%				0%
SR	University of Georgia Ecology Lab.	1								1	0%				0%
	Totals	**2,121**	**554**	**45**	**22**	**7**	**1**	**0**	**0**	**2,750**	**23%**	**629**	**30.958**	**0.049**	**16%**

Note: Arrowed values indicate the greatest value in each column.

Collective doses were reduced in 1999 with Bechtel BWXT Idaho, LLC Idaho contributing the majority.

B-12: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 1999

RESEARCH, GENERAL

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
CH	Argonne National Laboratory - East	1,735	43	7	10	2		2				1,799	4%	64	9.983	**0.156** ◄	38%
RL	Duke Engineering Services Hanford	10	1	1								12	17%	2	0.246	0.123	0%
AL	Los Alamos National Laboratory	1,492	331	65	31	10	8	7				1,944	23%	452	**51.861** ◄	0.115	**43%** ◄
OAK	Lawrence Livermore National Lab	704	12	1	1	1						719	2%	15	1.443	0.096	35%
CH	Argonne National Laboratory - West	942	198	63	22	1						1,226	23%	284	26.024	0.092	3%
OR	Lockheed Martin Energy Res. Corp. (ORNL)	5,653	376	89	28	9	2	2				**6,159** ◄	8%	**506** ◄	43.740	0.086	21%
CH	Ames Laboratory (Iowa State)	106	1	2								109	3%	3	0.230	0.077	0%
RL	Battelle Memorial Institute (PNL)	587	124	23	8	1						743	21%	156	10.512	0.067	5%
SR	Wackenhut Services, Inc. - SR	24	2	2								28	14%	4	0.257	0.064	0%
ID	Bechtel BWXT Idaho, LLC - Services	1,071	63	9	3							1,146	7%	75	4.210	0.056	0%
CH	Brookhaven National Laboratory	767	64	12								843	9%	76	3.615	0.048	0%
AL	Sandia National Laboratory	1,280	41	4	1							1,326	3%	46	1.922	0.042	0%
SR	Bechtel Construction - SR	43	39	4								86	50%	43	1.700	0.040	0%
SR	Westinghouse Savannah River Co.	786	256	25	4							1,071	27%	285	10.988	0.039	0%
AL	Johnson Controls, Inc.	7	2									9	22%	2	0.067	0.034	0%
OAK	Lawrence Berkeley National Lab	1,260	30	2								1,292	2%	32	1.060	0.033	0%
CH	New Brunswick Laboratory - Research	27	5									32	16%	5	0.145	0.029	0%
SR	Univ. of Georgia Ecology Laboratory	23	1									24	4%	1	0.026	0.026	0%

Note: Arrowed values indicate the greatest value in each column.

B-12: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 1999 (Continued)

RESEARCH, GENERAL

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
SR	Westinghouse S.R. Subcontractors	32	12									44	27%	12	0.250	0.021	0%
ID	Bechtel BWXT Idaho, LLC Subs - Constr.	460	4									464	1%	4	0.081	0.020	0%
SR	Savannah River Field Office	51	21									72	29%	21	0.293	0.014	0%
RL	SGN Eurisys Services Corp.	8	1									9	11%	1	0.013	0.013	0%
OAK	Boeing, Rocketdyne -ETEC	91	82	3								176	48%	85	1.022	0.012	0%
AL	Los Alamos Area Office	1	1									2	50%	1	0.008	0.008	0%
DOE	DOE Headquarters		1									1	**100%** ◄	1	0.007	0.007	0%
CH	Chicago Office Subs	7	39									46	85%	39	0.265	0.007	0%
SR	Miscellaneous DOE Contractors - SR	1	1									2	50%	1	0.006	0.006	0%
OR	Oak Ridge Inst. for Sci. & Educ. (ORISE)	40	8									48	17%	8	0.042	0.005	0%
AL	Nat'l. Renewable Energy Lab (NREL)-GO	11										11	0%				0%
AL	Protection Technologies Los Alamos	9										9	0%				0%
RL	Babcock Wilcox Hanford	3										3	0%				0%
RL	Fluor Daniel - Hanford	11										11	0%				0%
RL	Fluor Daniel Northwest	8										8	0%				0%
RL	Lockheed Martin Hanford	3										3	0%				0%
RL	NUMATEC Hanford	3										3	0%				0%
RL	Rust Services Hanford	1										1	0%				0%
	Totals	**17,257**	**1,759**	**312**	**108**	**24**	**10**	**11**	**0**	**0**	**0**	**19,481**	**11%**	**2,224**	**170.016**	**0.076**	**22%**

Note: Arrowed values indicate the greatest value in each column.

LANL had the highest collective exposure for 1999. ORNL had the highest number of persons monitored and number with measurable dose. Overall, the number of persons monitored increased 5%, the number with measurable dose dropped 8%, and collective TEDE dropped 14% from 1998 to 1999.

B-13: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, Fusion, 1999

RESEARCH, FUSION

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
OAK	Lawrence Livermore National Laboratory	176	2	2	3	1	2	1		187	6%	11	5.124 ◄	0.466 ◄	68% ◄
CH	Princeton Plasma Physics Laboratory	372	33	1						406 ◄	8%	34 ◄	0.817	0.024	0%
AL	Los Alamos National Laboratory	50	5							55	9% ◄	5	0.059	0.012	0%
AL	Sandia National Laboratory	20								20	0%				0%
	Totals	**618**	**40**	**3**	**3**	**1**	**2**	**1**	**0**	**668**	**7%**	**50**	**6.000**	**0.120**	**58%**

Note: Arrowed values indicate the greatest value in each column.

Fusion research only accounted for 0.5% of the total collective TEDE in 1999. LLNL and Princeton Plasma Physics Laboratory had the greatest contribution in 1999. Overall collective TEDE increased by 14% during 1999 and the average exposure increased by 71% in 1999. Variations in these values are to be expected in this category from year to year as there are few sites and few individuals in this category.

B-14: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 1999

WASTE PROCESSING		Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)													
Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
RL	Babcock Wilcox Hanford	58	13	7	4	2	2			86	33%	28	5.417	**0.193**	**52%**
RL	Fluor Daniel - Hanford	568	251	54	29	13	6	12		933	39%	365	**54.390**	0.149	50%
RL	SGN Eurisys Services Corp.	23	1	1						25	8%	2	0.231	0.116	0%
AL	Los Alamos National Laboratory	108	15	5	2					130	17%	22	1.808	0.082	0%
CH	Brookhaven National Laboratory	92	32	10	1	1				136	32%	44	3.479	0.079	20%
RL	Hanford Security	1	1							2	**50%**	1	0.074	0.074	0%
CH	Argonne National Laboratory - East	46	21	8	1					76	39%	30	2.175	0.073	0%
ID	Bechtel BWXT Idaho, LLC - Services	377	84	27	2					490	23%	113	7.608	0.067	0%
RL	NUMATEC Hanford	42	4	2						48	13%	6	0.395	0.066	0%
RL	Fluor Daniel Northwest Services	4	2	1						7	43%	3	0.184	0.061	0%
OR	Morrison-Knudsen (WSSRAP)	349	4	1						354	1%	5	0.293	0.059	0%
RL	Lockheed Martin Hanford	267	52	6	1	1				327	18%	60	3.167	0.053	18%
RL	Rust Services Hanford	82	4	1						87	6%	5	0.238	0.048	0%
SR	Westinghouse Savannah River Co.	2,187	565	47						**2,799**	22%	**612**	22.042	0.036	0%
SR	Bechtel Construction - SR	189	101	5						295	36%	106	3.747	0.035	0%
ID	Bechtel BWXT Idaho, LLC Subs - Constr.	237	1							238	0%	1	0.032	0.032	0%
AL	Sandia National Laboratory	142	19							161	12%	19	0.522	0.027	0%
CH	Argonne National Laboratory - West	34	2							36	6%	2	0.052	0.026	0%

Note: Arrowed values indicate the greatest value in each column.

B-14: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 1999 (Continued)

WASTE PROCESSING

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
RL	Dyncorp Hanford	19	2							21	10%	2	0.045	0.023	0%
RL	Rust Federal Services Northwest	3	2							5	40%	2	0.039	0.020	0%
RL	Duke Engineering Services Hanford	26	1							27	4%	1	0.017	0.017	0%
AL	Carlsbad Area Misc. Contractors	373	19							392	5%	19	0.317	0.017	0%
RL	Fluor Daniel Northwest	16	3							19	16%	3	0.049	0.016	0%
SR	Westinghouse S.R. Subcontractors	194	19							213	9%	19	0.259	0.014	0%
RL	Bechtel Power Co.	8	1							9	11%	1	0.012	0.012	0%
OH	BWX Technologies, Inc.	4	1							5	20%	1	0.007	0.007	0%
SR	Miscellaneous DOE Contractors - SR	1	1							2	**50%** ◄	1	0.006	0.006	0%
SR	Savannah River Field Office	54	2							56	4%	2	0.012	0.006	0%
AL	Los Alamos Area Office	1	-							1	0%				0%
AL	Waste Isolation Pilot Project (WIPP)	12	-							12	0%				0%
OAK	Lawrence Livermore National Lab	71	-							71	0%				0%
OH	BWX Technologies, Inc. - Subcontractors	2	-							2	0%				0%
OH	West Valley Nuclear Services, Inc.	68	-							68	0%				0%
RL	Richland Field Office	2	-							2	0%				0%
SR	Wackenhut Services, Inc. - SR	4	-							4	0%				0%
	Totals	**5,664**	**1,223**	**175**	**40**	**17**	**8**	**12**	**0**	**7,139**	**21%**	**1,475**	**106.617**	**0.072**	**30%**

Note: Arrowed values indicate the greatest value in each column.

Fluor-Daniel Hanford again had the highest collective dose showing an increase of 24% in 1999 with Westinghouse Savannah River having the second greatest collective dose showing a 37% decrease during 1999. Overall the number monitored increased by 1%, the number with measurable dose was 2% less, the collective dose decreased 4% and the average dose decreased 3% during 1999.

B-15: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Weapons Fabrication, 1999

WEAPONS FABRICATION

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	>3	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
SR	Westinghouse Savannah River Co.	263	161	68	47		2	2		1	544	52%	281	45.160	**0.161** ◄	27%
RF	Rocky Flats Prime Contractors	646	1,465	441	232	71	33	21		1	2,910	**78%** ◄	**2,264** ◄	**310.721** ◄	0.137	32%
OAK	Lawrence Livermore National Lab	1,045	27	3	5	1					1,081	3%	36	3.851	0.107	16%
SR	Wackenhut Services, Inc. - SR	46	73	23					1		143	68%	97	9.208	0.095	22%
AL	Mason & Hanger - Amarillo	5,344	257	50	27	4	1				**5,683** ◄	6%	339	28.623	0.084	11%
OR	Lockheed Martin Energy Systems (Y-12)	3,450	1,159	141	69	29	25	12			4,885	29%	1,435	127.599	0.089	**43%** ◄
AL	M&H - Amarillo - Security Forces	545	10	1							556	2%	11	0.628	0.057	0%
RF	Rocky Flats Subcontractors	1,531	927	81	30	5	1				2,575	41%	1,044	54.325	0.052	6%
RF	Rocky Flats Office	69	155	8	1						233	70%	164	7.637	0.047	0%
SR	Bechtel Construction - SR	25	45	4							74	66%	49	2.202	0.045	0%
AL	Sandia National Laboratory	444	8								452	2%	8	0.210	0.026	0%
AL	Amarillo Area Office	90	3								93	3%	3	0.049	0.016	0%
SR	Westinghouse S.R. Subcontractors	6	3								9	33%	3	0.049	0.016	0%
OH	BWX Technologies, Inc.-Subcontractors	56	13								69	19%	13	0.200	0.015	0%
OH	BWX Technologies, Inc.	57	27								84	32%	27	0.411	0.015	0%
AL	Albuquerque Operations Office	193	4								197	2%	4	0.053	0.013	0%
SR	Savannah River Field Office	20	5								25	20%	5	0.055	0.011	0%
AL	Los Alamos National Laboratory	7	2								9	22%	2	0.012	0.006	0%
AL	Albuquerque Transportation Div.	1									1	0%				0%
AL	Battelle - Pantex	9									9	0%				0%
OH	Miamisburg Area Office	9									9	0%				0%
OH	Miamisburg Office Subs	3									3	0%				0%
OH	Ohio Field Office	2									2	0%				0%
	Totals	**13,861**	**4,344**	**820**	**411**	**110**	**62**	**35**	**1**	**2**	**19,646**	**29%**	**5,785**	**590.993**	**0.102**	**30%**

Note: Arrowed values indicate the greatest value in each column.

Rocky Flats Prime Contractors had the highest collective dose posting an increase of 20% in 1999 while Westinghouse Savannah River Co. had the highest average dose.

B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 1999

OTHER

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
CH	Argonne National Laboratory - East		1	3	2	5	3			14	100% ◄	14	7.203	0.515 ◄	80% ◄
OR	LMES/MK-Ferguson Subcontractors	359	180	16	12	10	3	3		583	38%	224	22.230	0.099	57%
ID	Bechtel BWXT Idaho, LLC Subs - Constr.	93	2	1						96	3%	3	0.260	0.087	0%
AL	Los Alamos Area Office	18	1							19	5%	1	0.085	0.085	0%
AL	Johnson Controls, Inc.	65	13	2	1					81	20%	16	1.308	0.082	0%
AL	Los Alamos National Laboratory	4,572	328	16	12	5	5	4		4,942 ◄	7%	370 ◄	28.189 ◄	0.076	52%
OAK	Lawrence Livermore National Lab	3,262	41	6	3		1			3,313	2%	51	3.777	0.074	22%
RL	Fluor Daniel - Hanford	519	26	4	3					552	6%	33	2.218	0.067	0%
RL	Battelle Memorial Institute (PNL)	768	63	6	7					844	9%	76	4.924	0.065	0%
RL	Fluor Daniel Northwest Services	112	40	5	2					159	30%	47	2.658	0.057	0%
OH	West Valley Nuclear Services, Inc.	752	220	20	3					995	24%	243	12.537	0.052	0%
AL	MACTEC - ERS	232	43	5						280	17%	48	2.495	0.052	0%
RL	Lockheed Martin Hanford	64	6	1						71	10%	7	0.347	0.050	0%
RL	Babcock Wilcox Hanford	349	11	1						361	3%	12	0.438	0.037	0%
CH	Brookhaven National Laboratory	138	12	2						152	9%	14	0.445	0.032	0%
RL	Hanford Security	24	6							30	20%	6	0.188	0.031	0%
RL	Kaiser Engineers Hanford - Cost Const.		1							1	100% ◄	1	0.030	0.030	0%
DOE	DOE Kazakhstan Project	50	3							53	6%	3	0.089	0.030	0%
RF	Rocky Flats Office	990	43	2						1,035	4%	45	1.207	0.027	0%
AL	Protection Technologies Los Alamos	86	14							100	14%	14	0.370	0.026	0%

Note: Arrowed values indicate the greatest value in each column.

B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 1999 (Continued)

OTHER

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
RL	Bechtel Power Co.	877	76	1						954	8%	77	2.010	0.026	0%
RL	Westinghouse Hanford Service Subs	34	1							35	3%	1	0.026	0.026	0%
RL	SGN Eurisys Services Corp.	55	8							63	13%	8	0.207	0.026	0%
RL	Richland Field Office	1,093	35							1,128	3%	35	0.787	0.022	0%
RL	Rust Federal Services Northwest	46	2							48	4%	2	0.044	0.022	0%
ID	Bechtel BWXT Idaho, LLC - Services	1,503	39							1,542	3%	39	0.849	0.022	0%
RL	Duke Engineering Services Hanford	168	7							175	4%	7	0.152	0.022	0%
RL	Fluor Daniel Northwest	230	14							244	6%	14	0.292	0.021	0%
SR	Savannah River Field Office	9	3							12	25%	3	0.057	0.019	0%
RL	Rust Services Hanford	153	7							160	4%	7	0.124	0.018	0%
AL	Honeywell, Federal Mfg. & Techno.	85	3							88	3%	3	0.050	0.017	0%
AL	Sandia National Laboratory	459	17							476	4%	17	0.281	0.017	0%
SR	Bechtel Construction - SR	24	10							34	29%	10	0.164	0.016	0%
SR	Westinghouse Savannah River Co.	429	20							449	4%	20	0.322	0.016	0%
OH	BWX Technologies, Inc. - Subcontractors	20	3							23	13%	3	0.042	0.014	0%
OR	RMI Company	431	50							481	10%	50	0.681	0.014	0%
SR	Westinghouse S.R. Subcontractors	41	3							44	7%	3	0.035	0.012	0%
CH	Environmental Meas. Lab. - Research	12	1							13	8%	1	0.010	0.010	0%
RL	Babcock Wilcox Protection, Inc.	11	1							12	8%	1	0.006	0.006	0%

Note: Arrowed values indicate the greatest value in each column.

B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 1999 (Continued)

OTHER	Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)														
Ops. Office	Site/Contractor	Less than Meas.	Meas. 0-0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	>2	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)	Percent of TEDE above 0.5 rem
DOE	DOE Headquarters	167	3							170	2%	3	0.016	0.005	0%
OR	Lockheed Martin Energy Systems (Y-12)	86	1							87	1%	1	0.003	0.003	0%
AL	Kansas City Area Office	5								5	0%				0%
CH	Argonne National Laboratory - West	16								16	0%				0%
ID	Idaho Field Office	31								31	0%				0%
NV	Bechtel Nevada - NTS	66								66	0%				0%
OAK	U. of Cal./Davis, Radiobiology Lab-LEHR	54								54	0%				0%
OH	BWX Technologies, Inc.	54								54	0%				0%
OH	Miamisburg Office Subs	2								2	0%				0%
OH	Ohio Field Office	1								1	0%				0%
OR	Bechtel Jacobs - ETTP	3								3	0%				0%
RL	Duke Eng. & Services Northwest, Inc.	2								2	0%				0%
RL	Dyncorp Hanford	4								4	0%				0%
RL	Hanford Environmental Health Found.	36								36	0%				0%
RL	Lockheed Martin Services, Inc.	15								15	0%				0%
RL	NUMATEC Hanford	31								31	0%				0%
SR	Miscellaneous DOE Contractors - SR	9								9	0%				0%
SR	Univ. of Georgia Ecology Laboratory	1								1	0%				0%
	Totals	**18,795**	**1,358**	**91**	**45**	**20**	**12**	**7**	**0**	**20,328**	**8%**	**1,533**	**97.156**	**0.063**	**35%**

Note: Arrowed values indicate the greatest value in each column.

The total monitored, number with measurable, and collective dose for the "other" category decreased in 1999 for the second year.

B-17: Internal Dose by Facility Type and Nuclide, 1997-1999

Facility Type	Nuclide*	No. of Individuals with New Intakes**			Collective CEDE (person-rem)			Average CEDE (rem)		
		1997	1998	1999	1997	1998	1999	1997	1998	1999
Accelerator	*Hydrogen-3*	16	6	5	0.322	0.078	0.091	0.020	0.013	0.018
	Uranium	1	2	1	0.001	0.010	0.007	0.001	0.005	0.007
	Total	**17**	**8**	**6**	**0.323**	**0.088**	**0.098**	**0.019**	**0.011**	**0.016**
Fuel Fabrication	*Hydrogen-3*		6			0.012			0.002	
	Plutonium	3			0.048			0.016		
	Thorium	8	9	5	0.132	0.057	0.060		0.006	0.012
	Uranium	13	9	30	0.051	0.026	0.131	0.004	0.002	0.004
	Total	**24**	**24**	**35**	**0.231**	**0.095**	**0.191**	**0.010**	**0.004**	**0.005**
Fuel Processing	*Hydrogen-3*	123	115	123	0.264	0.234	0.222	0.002	0.002	0.002
	Plutonium	3	1	2	0.344	0.322	0.042	0.115	**0.322** ◄	0.021
	Uranium				0.016			0.016		
	Total	**127**	**116**	**125**	**0.624**	**0.556**	**0.264**	**0.005**	**0.005**	**0.002**
Fuel/Uranium Enrichment	*Americium*		1			0.055			0.055	
	Hydrogen-3		2			0.003			0.002	
	Other									
	Technetium	8	2		0.009	0.006		0.001	0.003	
	Thorium	1			0.001			0.001		
	Uranium	34	86	177	0.157	0.321	0.560	0.005	0.004	0.003
	Total	**43**	**91**	**177**	**0.167**	**0.385**	**0.560**	**0.004**	**0.004**	**0.003**
Maintenance and Support	*Americium*		3	4		0.039	0.015	0.003	0.013	0.004
	Hydrogen-3	94	78	81	0.522	0.238	0.399	0.006	0.003	0.005
	Mixed and Other	1	16	18	0.069	0.039	0.203	0.069	0.002	0.011
	Plutonium	5	15	25	3.203	1.680	0.293	0.641	0.112	0.012
	Thorium	5	2	4	0.020	0.089	0.091	0.004	0.045	0.023
	Uranium	11	10	16	0.035	0.038	0.055	0.003	0.004	0.003
	Total	**116**	**124**	**148**	**3.849**	**2.123**	**1.056**	**0.033**	**0.017**	**0.007**
Other	*Americium*		4	2		0.297	0.055		0.074	0.028
	Hydrogen-3	78	80	45	0.499	0.313	0.195	0.006	0.004	0.004
	Mixed and Other	6	1	1	4.038	0.300	0.007	**0.673** ◄	0.300	0.007
	Plutonium	3	5	5	0.177	0.378	0.360	0.059	0.076	0.072
	Radon-222	270	280	39	**27.834** ◄	**33.840** ◄	2.147	0.103	0.121	0.055
	Thorium		2			0.111			0.056	
	Uranium	260	141	190	1.641	0.601	13.726	0.006	0.004	0.072
	Total	**617**	**513**	**282**	**34.189**	**35.84**	**16.490**	**0.049**	**0.070**	**0.058**
Reactor	*Hydrogen-3*	304	287	212	3.305	1.433	0.949	0.011	0.005	0.004
	Mixed & Other	3			0.022			0.007		
	Total	**307**	**287**	**212**	**3.327**	**1.433**	**0.949**	**0.011**	**0.005**	**0.004**
Research, Fusion	*Hydrogen-3*	53	26	14	0.153	0.309	0.038	0.003	0.012	0.003
	Total	**53**	**26**	**14**	**0.153**	**0.309**	**0.038**	**0.003**	**0.012**	**0.003**
Research, General	*Americium*	3	8	3	0.059	0.828	0.111	0.020	0.104	0.037
	Hydrogen-3	36	44	31	0.177	0.500	0.336	0.005	0.011	0.011
	Mixed & Other	11	46	49	0.255	0.390	0.185	0.023	0.008	0.004
	Plutonium	14	11	4	7.232	1.391	1.465	0.517	0.126	0.366
	Thorium			1			0.685			**0.685** ◄
	Uranium	20	17	19	0.136	0.083	0.088	0.007	0.005	0.005
	Total	**84**	**126**	**107**	**7.859**	**3.192**	**2.870**	**0.094**	**0.025**	**0.027**
Waste Processing	*Americium*	1		2	0.004		0.013	0.004		0.007
	Hydrogen-3	8	15	20	0.015	0.028	0.058	0.002	0.002	0.003
	Mixed & Other	2		3	0.221		0.006	0.111		0.002
	Plutonium		22	1		0.957	0.002		0.044	0.002
	Thorium	3			0.669			0.223		
	Uranium	16	5	10	3.858	0.157	0.786	0.241	0.031	0.079
	Total	**30**	**42**	**36**	**4.767**	**1.142**	**0.865**	**0.158**	**0.027**	**0.024**
Weapons Fab. and Testing	*Americium*	5		5	0.501		1.487	0.100		0.297
	Hydrogen-3	22	14	23		0.051	0.150	0.009	0.004	0.007
	Mixed and Other			1	0.193		0.025			0.025
	Plutonium	38	38	64	2.045	4.825	17.015	0.053	0.127	0.266
	Uranium	**431** ◄	**1,056** ◄	**1,228** ◄	7.127	34.168	**110.810** ◄	0.016	0.032	0.090
	Total	**496**	**1,108**	**1,321**	**9.866**	**39.044**	**129.487**	**0.019**	**0.035**	**0.098**
	Totals	**1,914**	**2,465**	**2,463**	**65.355**	**84.207**	**152.868**	**0.034**	**0.034**	**0.062**

* Intakes grouped by nuclide. Intakes involving multiple nuclides were grouped into "mixed".
Nuclides where fewer than 10 individuals had intakes were grouped as "other".
** Individuals may be counted more than once.
Note: Arrowed values indicate the greatest value in each column.

The large increase in internal dose from uranium intakes in 1999 is due to increased weapons fabrication and testing activities and a change in monitoring practices at the Oak Ridge Y-12 plant.

B-18a: Distribution of TEDE by Labor Category, 1997

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Labor Category	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	>4	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Agriculture	41	3										44	16%	8	1.072	0.134
Construction	5,018	1,383	184	85	27	15	2					6,714	25%	1,695	125.741	0.074
Laborers	742	331	84	39	28	17	10					1,251	**41%** ◄	509	81.893	**0.161** ◄
Management	10,558	1,224	135	34	7	2						11,960	12%	1,402	75.409	0.053
Misc.	10,451	1,822	224	45	2							12,544	17%	2,093	98.201	0.047
Production	2,854	1,405	251	103	27	6	4					4,650	39%	1,794	144.308	0.080
Scientists	23,221	2,732	242	58	9	9	2					26,273	12%	3,052	136.118	0.044
Service	3,419	579	33	16	5	1						4,053	16%	634	35.025	0.055
Technicians	5,630	1,821	598	292	87	19	8		1			8,456	33%	2,826	**339.469** ◄	0.120
Transport	1,278	155	18	4	1	1						1,457	12%	177	8.364	0.047
Unknown	25,290	3,808	373	180	72	31	22	1	1	1		**29,779** ◄	15%	**4,489** ◄	314.491	0.070
Totals	**88,502**	**15,263**	**2,142**	**856**	**265**	**101**	**48**	**1**	**2**	**1**	**0**	**107,181**	**17%**	**18,679**	**1,360.091**	**0.073**

Note: Arrowed values indicate the greatest value in each column.

B-18b: Distribution of TEDE by Labor Category, 1998

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Labor Category	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	>4	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Agriculture	35											35	0%			
Construction	4,549	1,422	173	47	18	4						6,213	27%	1,664	90.422	0.054
Laborers	658	353	78	37	14	6	4					1,150	**43%** ◄	492	53.594	0.109
Management	10,612	1,215	122	43	9	4	2					12,007	12%	1,395	80.521	0.058
Misc.	10,499	1,947	254	57	12	2						12,771	18%	2,272	120.281	0.053
Production	2,717	1,351	266	117	36	10	3					4,500	40%	1,783	155.513	0.087
Scientists	24,359	2,512	200	53	11	6	2					27,143	10%	2,784	120.005	0.043
Service	3,468	531	116	13	3	2						4,133	16%	665	43.872	0.066
Technicians	5,994	1,877	607	308	104	14	9					8,913	33%	2,919	**356.160** ◄	**0.122** ◄
Transport	1,315	122	13	8	3							1,461	10%	146	9.521	0.065
Unknown	26,758	2,736	424	158	58	26	21	1				**30,182** ◄	11%	**3,424** ◄	273.187	0.080
Totals	**90,964**	**14,066**	**2,253**	**841**	**268**	**74**	**41**	**1**	**0**	**0**	**0**	**108,508**	**16%**	**17,544**	**1,303.076**	**0.074**

Note: Arrowed values indicate the greatest value in each column.

B-18c: Distribution of TEDE by Labor Category, 1999

Total Effective Dose Equivalent (TEDE)

Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)

Labor Category	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	>4	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Agriculture	58	1										59	2%	1	0.020	0.020
Construction	5,008	1,255	141	57	16	3	8					6,488	23%	1,480	92.392	0.062
Laborers	781	222	38	17	4	3	1					1,066	25%	285	25.243	0.089
Management	10,954	1,574	129	31	10	6	5					12,709	14%	1,755	86.947	0.050
Misc.	8,477	1,613	223	107	30	17	10		1			10,478	19%	2,001	168.940	0.084
Production	2,827	1,592	343	186	67	48	26				1	5,090	**44%** ◄	2,263	**291.609** ◄	**0.129** ◄
Scientists	22,969	2,352	187	58	15	2	3					25,586	10%	2,617	120.966	0.046
Service	3,745	760	57	9	2			1				4,574	18%	829	36.828	0.044
Technicians	5,415	1,886	507	206	58	23	10					8,105	33%	**2,690** ◄	282.647	0.105
Transport	1,094	109	13									1,216	10%	122	4.408	0.036
Unknown	35,065	2,197	260	99	36	16	17					**37,690** ◄	7%	2,625	185.180	0.071
Totals	**96,393**	**13,561**	**1,898**	**770**	**238**	**118**	**80**	**1**	**1**	**0**	**1**	**113,061**	**15%**	**16,668**	**1,295.180**	**0.078**

Note: Arrowed values indicate the greatest value in each column.

Subcontracting and outsourcing has increased the number monitored in the Unknown category 24% during 1999, comprising 33% of the labor force. Production and Technicians remain the categories with the highest collective TEDE with Production staff receiving the highest percentage of personnel receiving measurable dose and the highest average measurable dose.

B-19: Internal Dose by Labor Category, 1997 - 1999

Labor Category	Number of Individuals with New Intakes*			Collective CEDE (person-rem)			Average CEDE (rem)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
Construction	278	**488** ◄	537	5.580	7.808	22.710	0.020	0.016	0.042
Laborers	91	66	34	9.687	9.305	8.888	0.106	0.141	**0.261** ◄
Management	100	173	239	1.779	7.053	14.917	0.018	0.041	0.062
Misc.	283	253	70	2.214	4.829	5.408	0.007	0.019	0.077
Production	320	412	**563** ◄	4.224	15.942	**63.049** ◄	0.013	0.039	0.112
Scientists	214	297	276	4.137	1.974	5.003	0.019	0.007	0.018
Service	42	80	73	0.214	0.925	3.071	0.005	0.012	0.042
Technicians	221	287	265	8.960	7.113	13.769	0.041	0.025	0.052
Transport	2	8	3	0.312	1.882	0.008	**0.156** ◄	**0.235** ◄	0.003
Unknown	**363** ◄	401	403	**28.248** ◄	**27.376** ◄	16.047	0.078	0.068	0.040
Totals	**1,914**	**2,465**	**2,463**	**65.355**	**84.207**	**152.868**	**0.034**	**0.034**	**0.062**

* Only included intakes that occurred during the monitoring year. Individuals may be counted more than once.

Note: Arrowed values indicate the greatest value in each column.

In 1999, laborers received the highest average CEDE. The majority of these were laborers at Y-12 that received increased internal dose from uranium due to Enriched Uranium Operations personnel exposure to insoluble uranium and the use of more conservative internal dosimetry modeling parameters associated with uranium solubility.

B-20: Dose Distribution by Labor Category and Occupation, 1999

Labor Category	Occupation	Less Than Meas.	Meas. <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1-2	2-3	3-4	4-5	>5	Total Monitored	Percent with Meas.	No. with Meas.	Collective TEDE	Average Meas. TEDE
Agriculture	Groundskeepers	37	1										38	3%	1	0.020	0.020
	Misc. Agriculture	21											21	0%	-	-	-
Construction	Carpenters	229	64	2	1								296	23%	67	2.626	0.039
	Electricians	1,018	273	36	11	1		5					1,344	24%	326	23.636	0.073
	Masons	10											10	0%	-	-	-
	Mechanics/Repairers	1,362	305	32	9								1,708	20%	346	14.728	0.043
	Miners/Drillers	59	6										65	9%	6	0.087	0.015
	Misc. Repair/Construction	1,805	446	44	27	13	3	3					2,341	23%	536	38.373	0.072
	Painters	137	30	2									169	19%	32	1.139	0.036
	Pipe Fitter	388	131	25	9	2							555	30%	167	11.803	0.071
Laborers	Handlers/Laborers/Helpers	781	222	38	17	4	3	1					1,066	27%	285	25.243	0.089
Management	Admin. Support and Clerical	4,357	743	52	2	1	1						5,156	15%	799	29.574	0.037
	Manager - Administrator	6,544	829	77	29	9	5	5					7,498	13%	954	57.339	0.060
	Sales	53	2										55	4%	2	0.034	0.017
Misc.	Military	29	4										33	12%	4	0.108	-
	Miscellaneous	8,448	1,609	223	107	30	17	10		1			10,445	19%	1,997	168.832	0.085
Production	Machine Setup/Operators	127	148	50	24	9	12	3					373	66%	246	41.138	0.167
	Machinists	302	52	15	5		1						375	19%	73	6.408	0.088
	Misc. Precision/Production	339	199	64	50	38	20	13					723	53%	384	92.416	0.241
	Operators, Plant/ System/Util.	1,859	1,148	208	106	20	15	10				1	3,367	45%	1,508	148.801	0.099
	Sheet Metal Workers	107	26	3	1								137	22%	30	1.561	0.052
	Welders and Solderers	93	19	3									115	19%	22	1.285	0.058
Scientists	Doctors and Nurses	148	6	2									156	5%	8	0.393	0.049
	Engineer	8,627	1,086	70	15	6	1						9,805	12%	1,178	45.473	0.039
	Health Physicist	522	109	6	2	1							640	18%	118	5.087	0.043
	Misc. Professional	5,313	628	55	23	4	1	1					6,025	12%	712	36.755	0.052
	Scientist	8,359	523	54	18	4		2					8,960	7%	601	33.258	0.055
Service	Firefighters	575	72										647	11%	72	1.476	0.021
	Food Service Employees	42	3	1									46	9%	4	0.223	0.056
	Janitors	578	55	8	4	1							646	11%	68	4.913	0.072
	Misc. Service	664	84	11	2								761	13%	97	4.394	0.045
	Security Guards	1,886	546	37	3	1			1				2,474	24%	588	25.822	0.044
Technicians	Engineering Technicians	899	175	33	16	4	5						1,132	21%	233	22.541	0.097
	Health Technicians	213	54	18	10	3	3	1					302	29%	89	13.706	0.154
	Misc. Technicians	2,079	354	57	19	18	7						2,534	18%	455	43.134	0.095
	Radiation Monitors/Techs.	1,021	806	278	136	24	3	3					2,271	55%	1,250	142.598	0.114
	Science Technicians	322	113	31	10	2	3	3					483	34%	162	19.238	0.119
	Technicians	882	384	90	15	7	2	3					1,383	36%	501	41.430	0.083
Transport	Bus Drivers	39											39	0%	-	-	-
	Equipment Operators	198	69	12									279	29%	81	3.442	0.042
	Misc. Transport	304	13	1									318	4%	14	0.415	0.030
	Pilots	1											1	0%	-	-	-
	Truck Drivers	552	27										579	5%	27	0.551	0.020
Unknown	Unknown	35,065	2,197	260	99	36	16	17					37,690	7%	2,625	185.180	0.071
Totals		**96,393**	**13,561**	**1,898**	**770**	**238**	**118**	**80**	**1**	**1**	**0**	**1**	**113,061**	**15%**	**16,668**	**1,295.180**	**0.078**

Note: Arrowed values indicate the greatest value in each column.

The Miscellaneous and Unknown occupation categories have the largest numbers with measurable dose and collective dose. These individuals tend to be contract workers where less information is available and recorded regarding occupation. The highest collective TEDE for a known occupational category was received by plant operators, with radiation technicians a close second.

B-21: Internal Dose Distribution by Site and Nuclide, 1999

Operations/ Field Office	Site	Nuclide	Number of Individuals Receiving Doses in Each Dose Range											Total Individuals with Meas. CEDE	Collective CEDE (person-rem)	Average CEDE (rem)
			Meas. -0.02	0.02-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	>5.0			
Albuquerque	Los Alamos National Lab (LANL)	Hydrogen-3	38	3										41	0.320	0.008
		Other		1										1	0.030	0.030
		Plutonium	1	1		1			1					4	1.450	0.363
		Thorium					1							1	0.685	0.685
		Uranium	16	1		1								18	0.581	0.032
	Pantex Plant (PP)	Mixed		1										1	0.025	0.025
	Sandia National Laboratory	Hydrogen-3	1											1	0.013	0.013
		Uranium	10											10	0.023	0.002
	Grand Junction	Radon 222		34	5									39	2.147	0.055
Chicago	Ops. and Other Facilities	Hydrogen-3	12											12	0.017	0.001
	Argonne National Lab - East (ANL-E)	Americium	4	2										6	0.131	0.022
		Hydrogen-3	14	1										15	0.092	0.006
		Other	3											3	0.019	0.006
		Plutonium		2										2	0.126	0.063
	Brookhaven National Lab (BNL)	Hydrogen-3	27	9										36	0.524	0.015
Idaho	Idaho Site	Plutonium	1											1	0.016	0.016
Oakland	Lawrence Berkeley National Lab. (LBNL)	Hydrogen-3	6		1									7	0.154	0.022
	Lawrence Livermore National Lab. (LLNL)	Hydrogen-3	1											1	0.010	0.010
Oak Ridge	Ops. and Other Facilities	Uranium	28	6	1									35	0.519	0.015
	Oak Ridge Site	Americium	1	1										2	0.055	0.028
		Hydrogen-3	1											1	0.001	0.001
		Other	45	1										46	0.138	0.003
		Plutonium		3	1									4	0.343	0.086
		Technetium	1											1	0.007	0.007
		Uranium	958	350	116	73	31	25	15					1,568 ◄	124.874 ◄	0.080
Ohio	Ops. and Other Facilities	Americium	3											3	0.008	0.003
		Mixed	13											13	0.056	0.004
		Plutonium	19											19	0.065	0.003
	Fernald Environmental Mgmt. Project	Thorium	4	1										5	0.060	0.012
		Uranium	29	1										30	0.131	0.004
	Mound Plant	Hydrogen-3	79	2	1									82	0.398	0.005
		Plutonium	2	2										4	0.078	0.020
		Thorium	1	3										4	0.091	0.023
		Uranium	10											10	0.035	0.004
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	Americium			1									1	0.160	0.160
		Plutonium	34	14	8	3					1			60	6.466	0.108
Richland	Hanford Site	Hydrogen-3	10											10	0.017	0.002
		Mixed	4	2										6	0.142	0.024
		Other	1											1	0.009	0.009
		Plutonium	1	1										2	0.058	0.029
Savannah River	Savannah River Site (SRS)	Americium			3			1						4	1.327	0.332
		Hydrogen-3	348											348	0.892	0.003
		Plutonium		1					3				1	5	10.575	2.644 ◄
Totals			**1,726**	**443**	**137**	**78**	**32**	**26**	**19**	**0**	**1**	**0**	**1**	**2,463**	**152.868**	**0.062**

The collective CEDE from uranium intakes increased by 258% from 1998 at the Oak Ridge Y-12 plant due to increased activities and changes in uranium intake monitoring procedures.

B-22: Extremity Dose Distribution by Operations/Site, 1999

Operations	Site	No Meas. Dose	Meas. −0.1	0.1-1	1-5	5-10	10-20	20-30	30-40	>40	Total Monitored*	No. with Meas.	No. Above Monitoring Threshold. (5 rem) **	Collective Extremity Dose (person-rem)	Average Meas. Extremity Dose (rem)
Albuquerque	Albuquerque	677	27	2							706	29		1.281	0.044
	Grand Junction	280	0								280	0		0	0.000
	Los Alamos National Lab. (LANL)	10,665	153	235	85	11					11,149	484	11	340.483	0.703
	Pantex Plant (PP)	6,172	38	89	42						6,341	169		99.590	0.589
	Sandia National Lab. (SNL)	3,235	12	17	6	1					3,271	36	1	24.447	0.679
Chicago	Chicago Operations	658	22	4	1						685	27		3.210	0.119
	Argonne Nat'l. Lab. - East (ANL-E)	2,687	145	46	8	2					2,888	201	2	48.205	0.240
	Argonne Nat'l. Lab. - West (ANL-W)	1,255	188	111	10	1					1,565	310	1	68.135	0.220
	Brookhaven National Lab. (BNL)	5,179	400	72	2						5,653	474		30.740	0.065
	Fermi Nat'l. Accelerator Lab. (FERMI)	1,048		2	1						1,051	3		2.520	**0.840** ◄
DOE HQ	DOE Headquarters	172									172				
	Kazakhstan	53									53				
Idaho	Idaho Site	8,068	623	190	4						8,885	817		75.183	0.092
Nevada	Nevada Test Site (NTS)	4,352	11	5	3						4,371	19		4.961	0.261
Oakland	Oakland Operations	140	87	3							230	90		1.154	0.013
	Lawrence Berkeley National Lab. (LBNL)	1,732	27	19	1	2					1,781	49	2	22.130	0.452
	Lawrence Livermore Nat'l. Lab. (LLNL)	8,853	83	62	15						9,013	160		58.223	0.364
	Stanford Linear Accelerator Center (SLAC)	2,493									2,493				
Ohio	Ohio Field Office	269	41	32	34						376	107		60.990	0.570
	Fernald Environmental Mgmt. Project	4,196	14								4,210	14		0.545	0.039
	Mound Plant	1,001									1,001				
	West Valley	817	209	38							1,064	247		15.424	0.062
Oak Ridge	Oak Ridge Operations	2,342									2,342				
	Oak Ridge Site	14,080	60	146	34	2					**14,322** ◄	242	2	138.946	0.574
	Paducah Gaseous Diff. Plant (PGDP)	483									483				
	Portsmouth Gaseous Diff. Plant (PORTS)	204									204				
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	3,190	2,514	765	229	43	12				6,753	**3,563** ◄	**55** ◄	**1,282.854** ◄	0.360
Richland	Hanford Site	8,296	2,195	636	138	29	14	2			11,310	3,014	45	1,006.848	0.334
Savannah River	Savannah River Site (SRS)	7,179	1,910	1,175	137	4	4				10,409	3,230	8	702.681	0.218
	Totals	**99,776**	**8,759**	**3,649**	**750**	**95**	**30**	**2**	**0**	**0**	**113,061**	**13,285**	**127**	**3,988.550**	**0.300**

* Represents the total number of monitoring records. The number of individuals provided extremity monitoring cannot be determined.

** All extremity doses above 5 rem were for the upper extremities (hands and forearms). DOE annual limit for extremities is 50 rem. 10 CFR 835.402(a)(1)(ii) requires extremity monitoring for a shallow dose equivalent to the skin or extremity of 5 rem or more in a year.

Fernald had the greatest number of people receiving an extremity dose and Rocky Flats had the greatest collective extremity dose. Rocky Flats also recorded the greatest number of people above the extremity monitoring requirement threshold. Plutonium cleanup and packaging and analytical laboratory operations accounted for most of Rocky Flats extremity exposures.

Facility Type Code Descriptions

DOE M 231.1-1 [12] requires contractors to indicate for each reported individual the facility contributing the predominant portion of that individual's effective dose equivalent. In cases when this cannot be distinguished, the facility type indicated should represent the facility type wherein the greatest portion of work service was performed.

The facility type indicated must be one of 11 general facility categories shown in *Exhibit C-1*. Because it is not always a straightforward procedure to determine the appropriate facility type for each individual, the assignment of an individual to a particular facility type is a judgement by each contractor.

The facility descriptions that follow indicate the types of facilities included in each category. Also included are the types of work performed at the facilities and the sources of the majority of the radiation exposures.

Accelerator

The DOE administers approximately a dozen laboratories that perform significant accelerator-based research. The accelerators range in size from small single-room electrostatic devices to a 4-mile circumference synchrotron, and their energies range from keV to TeV.

The differences in accelerator types, sizes, and energies result in differences in the radiation types and dose rates associated with the accelerator facilities. In general, radiation doses to employees at the facilities are attributable to neutrons and X-rays, as well as muons at some larger facilities. Dose rates inside the primary shielding can range up to 0.2 rem/hr as a result of X-ray production near some machine components. Outside the shielding, however, X-ray exposure rates are very low, and neutron dose rates are generally less than 0.005 rem/hr. Regarding internal exposures, tritium and short-lived airborne activation products exist at some accelerator facilities.

Fuel/Uranium Enrichment

The DOE involvement in the nuclear fuel cycle generally begins with uranium enrichment operations and facilities. The current method of enrichment is isotopic separation using the gaseous diffusion process, which involves diffusing uranium through a porous membrane and using the different atomic weights of the uranium isotopes to achieve separation.

Although current facility designs and physical controls result in low doses from internally deposited uranium, the primary radiological hazard is the potential for inhalation of airborne uranium and transuranics from recycled uranium. Because of the low specific activity of uranium, external dose rates are usually a few millirem per hour or less. Most of the external doses that are received are attributable to gamma exposures, although neutron exposures can occur, especially when work is performed near highly enriched uranium.

Exhibit C-1:
Facility Type Codes

Facility Type Code	Description
10	Accelerator
21	Fuel/Uranium Enrichment
22	Fuel Fabrication
23	Fuel Processing
40	Maintenance and Support (Site Wide)
50	Reactor
61	Research, General
62	Research, Fusion
70	Waste Processing/Mgmt.
80	Weapons Fab. and Testing
99	Other

Fuel Fabrication

Activities at fuel fabrication facilities involve the physical conversion of uranium compounds to usable forms, usually rod-shaped metal. Radiation exposures to personnel at these facilities are attributable almost entirely to gamma and beta radiation. However, beta radiation is considered the primary external radiation hazard because of high beta dose rates (up to several hundred mrad per hour) at the surface of uranium rods. For example, physical modification of uranium metal by various metalworking operations, such as machining and lathing operations, requires protection against beta radiation exposures to the skin, eyes, and extremities.

Fuel Processing

The DOE administers several facilities that reprocess spent reactor fuel. These facilities separate the plutonium produced in reactors. They also separate the fission products and uranium; the fission products are normally designated as radioactive waste products, while the uranium can be refabricated for further use as fuel.

Penetrating doses are attributable primarily to gamma photons, although some neutron exposures do occur. Skin and extremity doses can result from handling samples. Strict controls are in place at fuel reprocessing facilities to prevent internal depositions; however, several measurable intakes typically occur per year. Plutonium isotopes represent the majority of the internal depositions.

Maintenance and Support

Most DOE sites have facilities dedicated to maintaining and supporting the site. In addition, some employees may be classified under this facility type if their main function is to provide site maintenance and support, even though they may not be located at a single facility dedicated to that purpose.

The sources of ionizing radiation exposure are primarily gamma photons. However, variations in the types of work performed and work locations result in exposures of all types, including exposures to beta particles, x-rays, neutrons, and airborne radioactivity.

Reactor

The DOE and its predecessors have built and operated dozens of nuclear reactors since the mid-1940s. These facilities have included plutonium and tritium production reactors, prototype reactors for energy production, research reactors, reactors designed for special purposes such as production of medical radioisotopes, and reactors designed for the propulsion of naval vessels.

By 1992, many of the DOE reactors were not operating. As a result, personnel exposures at DOE reactor facilities were attributable primarily to gamma photons and beta particles from contaminated equipment and plant areas, spent reactor fuel, activated reactor components, and other areas containing fission or activation products encountered during plant maintenance and decommissioning operations. Neutron exposures do occur at operating reactors, although the resulting doses are a very small fraction of the collective penetrating doses. Gamma dose rates in some plant areas can be very high (up to several rems per hour), requiring extensive protective measures.

Research, General

The DOE contractors perform research at many DOE facilities, including all of the national laboratories. Research is performed in general areas including biology, biochemistry, health physics, materials science, environmental science, epidemiology, and many others. Research is also performed in more specific areas such as global warming, hazardous waste disposal, energy conservation, and energy production.

The spectrum of research involving ionizing radiation or radioactive materials being performed at DOE facilities results in a wide variety of radiological conditions. Depending on the research performed, personnel may be exposed to virtually any type of external radiation, including beta particles, gamma photons, x-rays, and neutrons. In addition, there is the potential for inhalation of radioactive material. Area dose rates and individual annual doses are highly variable.

Research, Fusion

DOE currently operates both major and small facilities that participate in research on fusion energy. In general, both penetrating and shallow radiation doses are minimal at these facilities because the dose rates near the equipment are both low and intermittent. The external doses that do occur are attributable primarily to x-rays from energized equipment.

Waste Processing/Management

Most DOE sites have facilities dedicated to the processing and disposal of radioactive waste. In general, the dose rates to employees when handling waste are very low because of the low specific activities or the effectiveness of shielding materials. As a result, very few employees at these facilities receive annual doses greater than 0.1 rem. At two DOE sites, however, large-scale waste processing facilities exist to properly dispose of radioactive waste products generated during the nuclear fuel cycle. At these facilities, radiation doses to some employees can be elevated, sometimes exceeding 1 rem/year. Penetrating doses at waste processing facilities are attributable primarily to gamma photons; however, neutron exposures also occur at the large-scale facilities.

Weapons Fabrication and Testing

The primary function of a facility in this category is to fabricate weapons-grade material for the production or testing of nuclear weapons. At these facilities, workers can receive neutron radiation dose when processing plutonium isotopes as well as penetrating dose from gamma photons and plutonium x-rays, and skin and extremity dose from plutonium x-rays. An additional pathway for radiation exposure at these facilities is the inhalation of plutonium, where the inhalation of material can result in some of the highest individual doses based on the calculation of the 50-year committed effective dose equivalent. To prevent plutonium intakes, strict controls are in place including process containment, contamination control procedures, and air monitoring and bioassay programs.

There are no DOE facilities currently involved in weapons testing. Several of the sites reporting under this category are no longer actively involved in weapons fabrication and testing, but are in the process of stabilization and waste management.

Other

Individuals included in this facility type can be generally classified under three categories: (1) those who worked in a facility that did not match one of the ten facility types described above; (2) those who did not work for any appreciable time at any specific facility, such as transient workers; or (3) those for whom facility type was not indicated on the report forms. Examples of a facility type not included in the ten described above include construction and irradiation facilities. Although exposures to gamma photons are predominant, some individuals may be exposed to beta particles, x-rays, neutrons, or airborne radioactive material.

Appendix D

Limitations of Data

D

Limitations of Data

The following is a description of the limitations of the data currently available in the DOE Radiation Exposure Monitoring System (REMS). While these limitations have been taken into consideration in the analysis presented in this report, readers should be alert to these limitations and consider their implications when drawing conclusions from these data.

Individual Dose Records vs Dose Distribution

Prior to 1987, exposure data were reported from each facility in terms of a statistical dose distribution wherein the number of individuals receiving a dose within specific dose ranges was reported. The collective dose was then calculated from the distribution by multiplying the number of individuals in each dose range by the midpoint value of the dose range. Starting in 1987, reports of individual exposures were collected that recorded the specific dose for each monitored individual. The collective dose can be accurately determined by summing the total dose for each individual. The dose distribution reporting method prior to 1987 resulted in up to a 20% overestimation of collective dose. The reason is that the distribution of doses within a range is usually skewed toward the lower end of the range. If the midpoint of the range is multiplied by the number of people in the range, the product overestimates the collective dose. This overestimation only affects the data prior to 1987 presented in Appendix B-4, B-5, and B-6.

The dose distributions presented in this report are based on the individual dose records reported to REMS. Individuals may be counted more than once as some sites report multiple dose records for an individual that visits the site more than once, or the individual may visit more than one site during the year. (See Section 3.6).

Monitoring Practices

Radiation monitoring practices vary from site to site and are based on the radiation hazards and work practices at each site. Sites use different dosimeters and have different policies to determine which workers are monitored. All sites have achieved compliance with the DOE Laboratory Accreditation Program (DOELAP), which standardizes the quality of dosimetry measurements. The number of monitored individuals can significantly impact the site's collective dose. Some sites supply dosimeters to virtually all workers. While this tends to increase the number of monitored workers with no dose, it also can add an increased number of very low dose workers to the total number of workers with measurable dose, thereby lowering the site's average measurable dose. Even at low doses, these workers increase the site's collective dose. In contrast, other sites only monitor workers who exceed the monitoring requirement threshold (as specified in 10 CFR 835.402). This tends to reduce the number of monitored workers and reports only those workers receiving doses above the monitoring threshold. This can decrease the site's collective dose while increasing the average measurable dose.

AEDE vs CEDE

Prior to 1989, intakes of radionuclides into the body were not reported as dose, but as body burden in units of activity of systemic burden. The implementation of DOE Order 5480.11 in 1989 specified that the intakes of radionuclides be converted to internal dose and reported using the Annual Effective Dose Equivalent (AEDE) methodology. The AEDE methodology requires the calculation of the summation of dose for all tissues and organs multiplied by the appropriate weighting factor for a specified year. In addition to the calculation of AEDE, the DOE required the reporting of the Total Effective Dose Equivalent (TEDE) which is the summation of the external whole body dose and the AEDE from 1989 through 1992.

With the implementation of the RadCon Manual in 1993, the required methodology used to calculate and report internal dose was changed from the AEDE to the 50-year CEDE. The CEDE represents the dose equivalent delivered to all organs and tissues over the next 50 years and the 50 year CEDE is reported to REMS and assigned to the individual in the year of intake. The change was made to provide consistency with scientific recommendations, facilitate the transfer of workers between DOE and NRC regulated facilities, and simplify record keeping by recording all dose in the year of intake. The CEDE methodology is now codified in 10 CFR 835. From 1993 to the present, the TEDE is defined as the summation of the Deep Dose Equivalent (DDE) to the whole body and the CEDE.

This report primarily analyzes dose information for the past 5 years, from 1995 to 1999. During these years, the CEDE methodology was used to calculate internal dose; therefore, the change in methodology from AEDE to CEDE between 1992 and 1993 does not affect the analysis contained in this report. Readers should keep in mind the change in methodology if analyzing TEDE data prior to 1993 in Exhibit B-4 through Exhibit B-6.

Occupation Codes

Each individual's dose record includes the occupation code for the individual while he worked at the DOE site during the monitoring year. Occupational codes typically represent the occupation the individual held at the end of the calendar year and may not represent the occupation where the majority of dose was received if the individual held multiple occupations during the year. The occupation codes are very broad categorizations and are grouped into nine general categories. Each year a percentage (up to 20%) of the occupations is listed as unknown, or as miscellaneous. The definitions of each of the labor categories are subject to interpretation by the reporting organization and/or the individual's employer.

Facility Type

The facility type is also recorded with each dose record for the monitoring year. It is intended to reflect the type of facility where the individual received most of their occupational radiation exposure during the monitoring year. While the facility types are clearly defined (see Appendices A and C), the reporting organizations often have difficulty tracking which facility type contributed to the majority of the individual's exposure. Certain individuals tend to work in the proximity of several different facility types throughout the monitoring year and are often included in the "Maintenance and Support (Site-wide)" facility type. The facility type for temporary contract workers and visitors is often not reported and is defaulted to "unknown."

In addition to these uncertainties, the phase of operation of the facility types is not currently reported. A facility type of "accelerator" may be reported when in fact, the accelerator has not been in operation for a considerable time and may be in the process of stabilization, decommissioning, or decontamination. In addition, several sites have commented that they have difficulty assigning the facility type, because many of the facilities are no longer operational. For example, some sites commented that a reactor that is being decommissioned is no longer considered a "reactor" facility type. Other sites continue to categorize a facility based on the original intent or design of the facility, regardless of its current status.

DOE Headquarters will be reviewing the Facility Type codification scheme and modifying the reporting requirements to standardize the use of facility type classifications and improve the quality of the data and the data analysis. DOE will also pursue the usefulness of collecting data on the operational phase of facilities with end-users of this report.

Organization Code

Facilities report data to the central repository based on an "organization code." This code identifies the Operations or Field Office, the reporting facility, and the contractor or subcontractor that is reporting the exposure information. The organization code changes over time as DOE Offices are reorganized. In some cases, new Operations or Field Offices are created, in other cases a Field Office may change organizations and begin reporting with another Field Office. An example of this change is that the Mound Plant and West Valley Project changed Operations Office during the past 3 years and are now shown under the Ohio Field Office. Footnotes indicate the change in Operations Offices.

Occurrence Reports

Occurrence reports involving radiation exposure and personnel contamination events are additional indicators of the effectiveness of radiation protection efforts at DOE. These events will continue to be analyzed and presented in this report.

Additional Data Requirements

To provide analysis of the activities at DOE sites with respect to radiation exposure (see Section 3.5), it is necessary to augment the information reported to the REMS database. For the past 5 years, DOE Headquarters has requested additional information from the six sites with the highest collective dose. This information includes a summary of activities, project descriptions, and ALARA planning documentation. DOE Headquarters will continue to request this information in subsequent years. It is recommended that sites submit this information with their annual records.

Naval Reactor Facilities

The exposure information for the Schenectady and Pittsburgh Naval Reactor facilities is not included in this report. Readers should note that the dose information for the overall DOE complex presented in this report may differ from other reports or sources of information because of the exclusion of these data.

Exposure information for Naval Reactor programs can be found in the most recent version of the following series of reports (where XX represents the report year):

- NT-XX-2 – "Occupational Radiation Exposure from U.S. Naval Nuclear Plants and Their Support Facilities",
- NT-XX-3 – "Occupational Radiation Exposure from U.S. Naval Reactors' Department of Energy Facilities".

Appendix E

Access to Radiation Exposure Information

Radiation Exposure Monitoring System

The data used to compile this report were obtained from the DOE Radiation Exposure Monitoring System (REMS), which serves as the central repository of radiation exposure information for DOE Headquarters. The database consists of individual monitoring records of occupational exposure for DOE workers from 1987 to the present. In 1995, REMS underwent an extensive redesign effort in combination with the efforts involved in revising the annual report. One of the main goals of the redesign effort is to allow researchers better access to the REMS data. However, there is considerable diversity in the goals and needs of these researchers. For this reason, a multi-faceted approach has been developed to allow researchers flexibility in accessing the REMS data.

A brief summary of the methods of accessing REMS information is shown in *Exhibit E-1*.

Exhibit E-1 lists the various ways of accessing the DOE radiation exposure information contained in REMS. A description is given for each access method as well as requirements for access. To obtain further information, a contact name and phone number are provided.

The data contained in the REMS system are subject to periodic update. Data for the current or previous years may be updated as corrections or additions are submitted by the sites. For this reason, the data presented in published reports may not agree with the current data in the REMS database. These updates typically have a relatively small impact on the data and should not affect the general conclusions and analysis of the data presented in this report.

Comprehensive Epidemiologic Data Resource

Of interest to researchers in radiation exposure are the health effects associated with worker exposure to radiation. While the health effects from occupational exposure are not treated in this report, it has been extensively researched by DOE. The Comprehensive Epidemiologic Data Resource (CEDR) serves as a central resource for radiation health effects studies at the DOE.

Epidemiologic studies on health effects of radiation exposures have been supported by the DOE for more than 30 years. The results of these studies, which initially focused on the evaluation of mortality among workers employed in the nuclear weapons complex, have been published in scientific literature. However, the data collected during the conduct of the studies were not widely shared. CEDR has now been established as a public-use database to broaden independent access and use of these data. At its introduction in 1993, CEDR included primarily occupational studies of the DOE workforce, including demographic, employment, exposure, and mortality follow-up information on more than 420,000 workers. The program's holdings have been expanded to include data from both occupational and historical community health studies, such as those examining the impact of fallout from atmospheric nuclear weapons testing, community dose reconstructions, and data from the decades of follow-up on atomic bomb survivors.

CEDR accomplishes this by a hierarchical structure that accommodates analysis and working files generated during a study, as well as files of documentation that are critical for understanding the data. CEDR provides easy access to its holdings through the Internet or phone and mail interchanges, and provides an extensive catalog of its holdings. CEDR has become a unique resource comprising the majority of data that exist on the health risks of occupational radiation exposure.

For further information about CEDR, access the CEDR internet web page at:

http://cedr.lbl.gov

Or the CEDR Program Manager may be contacted at:

barbara.brooks@eh.doe.gov

Exhibit E-1: Methods of Accessing REMS Information

REMS Information Access Method	Information Available	Eligibility Requirements	Software Requirements	To Get Access
Hardcopy Annual Report	*Analysis and data for annual occupational exposure information, primarily for the past 5 years. Tables and graphs present data and trends for the most commonly asked questions concerning exposure information at DOE facilities.*	***None.***	***None.***	*Contact EH-52* to request that you be added to the Annual Report mailing list.*
Web Page	• *Annual reports from1992 to the most recent report.* • *Information on reporting exposure data to DOE.* • *How to request information from REMS.* • *A query tool for extracting summary data from REMS.* • *DOE Orders and Standards on radiation exposure.* • *Links to other related sites.*	***None.***	*Internet access. Web browser client software.*	*Connect to http://rems.eh.doe.gov*
Access to REMS database	*Individual annualized dose records submitted to REMS from 1987 to the present. In addition, dose records are available for individuals who terminated employment at a DOE facility from 1969 to 1986.*	*Records are subject to the privacy Act of 1974. Records are only available to researchers within DOE or other governmental agency upon approval by the REMS Project Manager in accordance with System of Records #35. Contact the REMS Project Manager* for further information on accessing individual dose records in REMS.*	*Internet access (TCP/IP). Oracle SQLNet and encryption software (provided). Database access tool for querying data that can connect to an Oracle database.*	*Contact EH-52* to request access.*

** EH-52 contact Ms. Nirmala Rao, Radiation Exposure Monitoring System (REMS) Project Manager, U.S. Department of Energy, Office of Worker Protection Policy and Programs (EH-52), Germantown, MD 20874*
Phone: (301) 903-2297, Fax: (301) 903-7773, E-mail: nimi.rao@eh.doe.gov