DOE/EH-0608

DOE Occupational Radiation Exposure

1998 Report

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DOE Occupational Radiation Exposure

1998 Report

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

Foreword

The goal of the U.S. Department of Energy (DOE) is to conduct its radiological operations to ensure the health and safety 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 *1998 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 1998, the collective dose decreased by 4% from the 1997 value due to decreased doses at four of the seven highest-dose DOE sites. These four sites attributed the decrease in collective dose to the shutdown of several facilities, the completion of several key projects, and to ALARA initiatives.

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. A user survey form is included in Appendix F to collect your suggestions to improve this report.

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

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

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10 CFR 835:	Code of Federal Regulations Section 10 on Occupational Radiation Protection, January 13, 1994
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
AGS:	Alternating Gradient Synchrotron
ALAP:	As Low As Practicable
ALARA:	As Low As Reasonably Achievable
AMD:	Average Measurable Dose
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
BNL:	Brookhaven National Laboratory
CD:	Collective Dose
CDE:	Committed Dose Equivalent
CEDE:	Committed Effective Dose Equivalent
CEDR:	Comprehensive Epidemiologic Data Resource
CR:	Distribution Ratio
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 Programs and Hazards Management
ES&H:	Environment, Safety & Health
ETTP:	East Tennessee Technology Park
FERMCO:	Fernald Environmental Research Management Corporation
FERMI:	Enrico Fermi National Accelerator Laboratory
HEPA:	High-Efficiency Particulate Air (Filter)
HFBR:	High-Flux Beam Reactor
HFIR:	High-Flux Isotope Reactor
HLWP:	High Level Waste Program
ICRP:	International Commission on Radiological Protection
INEEL:	Idaho National Engineering & Environmental Laboratory
ISM:	Integrated Safety Management
LANL:	Los Alamos National Laboratory
LANSCE:	Los Alamos Neutron Science Center
LBL:	Lawrence Berkeley Laboratory
LDE:	Lens (of the eye) Dose Equivalent
LEHR:	Laboratory for Energy-Related Health Research
LLNL:	Lawrence Livermore National Laboratory

TABLE OF ACRONYMNS (continued)

MDA:	Minimum Detectable Activity
MSR:	Molten Salt Reactor
mSv:	MilliSievert
NAC:	Nuclear Assurance Corporation
NBD:	Natural Background Dose
NCRP:	National Council on Radiation Protection and Measurements
NREL:	National Renewable Energy Laboratory
NTS:	Nevada Test Site
OD:	Occupational Dose
ORISE:	Oak Ridge Institute for Science & Education
ORNL:	Oak Ridge National Laboratory
PET:	Positron Emission Tomography
PFP:	Plutonium Finishing Plant
PGDP:	Paducah Gaseous Diffusion Plant
PNL:	Battelle Memorial Institute
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
REMS:	Radiation Exposure Monitoring System
RFETS:	Rocky Flats Environmental Technology Site
SDE:	Shallow Dose Equivalent
SDE-ME:	Shallow Dose Equivalent to any Extremity
SDE-WB:	Shallow Dose Equivalent to the skin of the Whole-Body
SLAC:	Stanford Linear Accelerator Center
SNL:	Sandia National Laboratory
SR:	Savannah River
SRS:	Savannah River Site
TEDE:	Total Effective Dose Equivalent
TIS:	Technical Information System
TODE:	Total Organ Dose Equivalent
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 Environment, Safety and Health with support from Environment Safety and Health Technical Information Services publishes the *DOE Occupational Radiation Exposure Report*. This report is intended to be a valuable tool for DOE/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 1997 and 1998, the DOE collective Total Effective Dose Equivalent (TEDE) decreased by 4% due to decreased doses at four of the seven sites with the highest radiation dose. The average dose to workers with measurable dose increased slightly from 0.073 rem (0.73 mSv) in 1997 to 0.074 rem (0.74 mSv) in 1998 as shown in *Exhibit ES-2*. The percentage of monitored individuals receiving measurable dose decreased from 17% in 1997 to 16% in 1998, and there were no exposures over the DOE 5 rem (50 mSv) TEDE limit.

Eighty-three percent of the collective TEDE for the DOE complex was accrued at seven DOE sites in 1998. These seven sites are (in descending order of collective dose) Rocky Flats, Hanford, Savannah River, Los Alamos, Oak Ridge, Idaho, and Brookhaven. 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 received the highest collective dose of any specified labor category.

Exhibit ES-1:
Collective TEDE Dose (person-rem), 1994-1998.

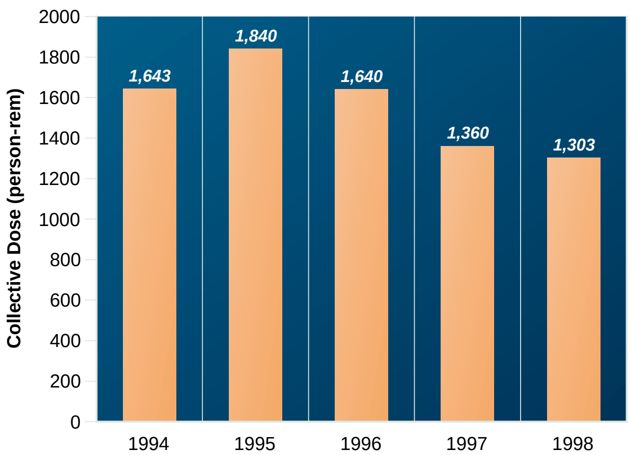
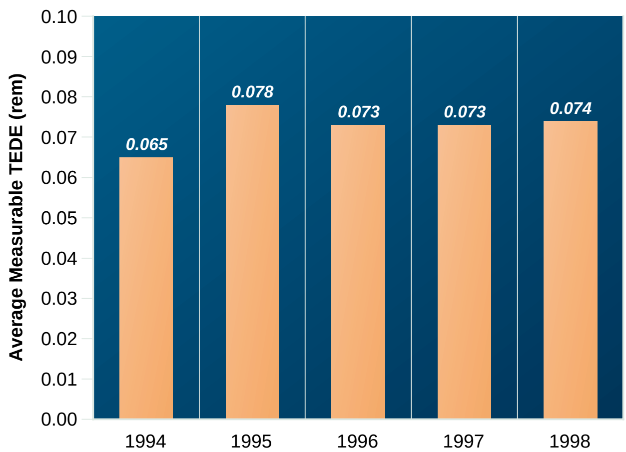


Exhibit ES-2:
Average Measurable TEDE (rem), 1994-1998.



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 four of the sites that experienced decreases in the collective dose (Hanford, Los Alamos, Idaho, and Brookhaven) indicate that decreases in the collective dose were due to the shutdown of several facilities, the completion of several key projects, and to ALARA initiatives.

Statistical analysis reveals that, in addition to the collective dose decreasing by 4%, the logarithmic mean dose decreased slightly from 0.035 rem in 1997 to 0.028 rem in 1998. Because the dose values do not fit a statistically normal distribution, this test used log-transformed data, which were approximately normal. The reasons for the decrease in the 1998 collective dose include a reduction in overall work involving radiation exposure as well as reduction in individuals' doses.

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 and was due to external dose (DDE). No individual received a dose in excess of the 5 rem (50 mSv) TEDE limit in 1997 or 1998. The one individual that was reported to have exceeded 5 rem (50 mSv) TEDE limit in the 1997 annual report was later found not to have exceeded this limit when the final internal dose assessment was completed. The 1996 exposure in excess of 5 rem TEDE was due to an unanticipated intake of plutonium at Savannah River during the removal of a radiological containment hut.

Exhibit ES-3:
Number of Individuals Exceeding 2 rem TEDE, 1994-1998.

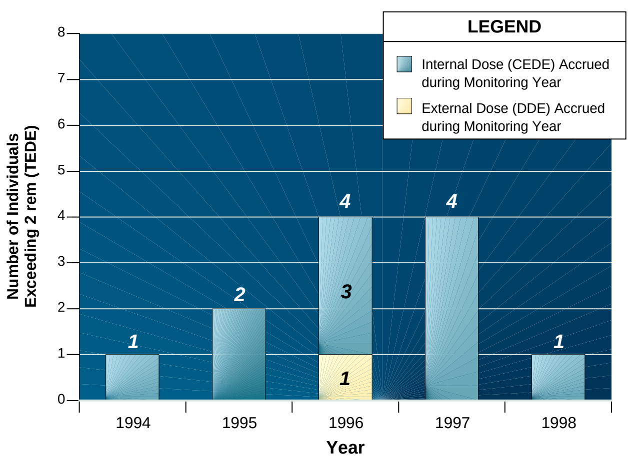
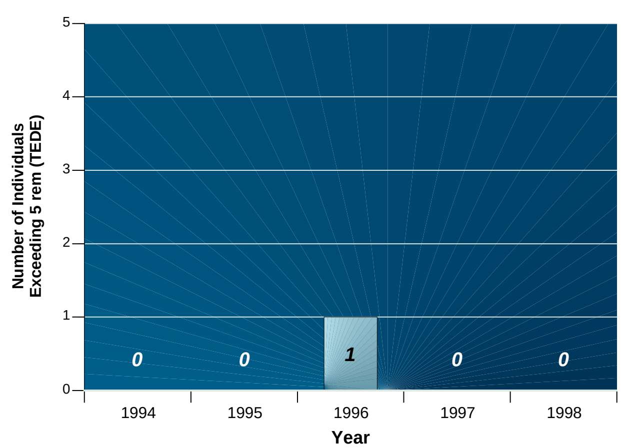


Exhibit ES-4:
Number of Individuals Exceeding 5 rem TEDE, 1994-1998.



The collective internal dose increased by 29% from 1997 to 1998 to a value of 84 person-rem (840 person mSv) for 1998. The increase in collective internal dose was primarily due to an increase in uranium operations at Oak Ridge, where a large number of individuals were reported with relatively small internal doses from uranium. Over 40% of the collective internal dose in 1998 was attributed to radon exposure at Grand Junction which includes the natural background dose from radon as well as the additional occupational dose received from the elevated radon levels.

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 more than tripled over the past 5 years. However, the number of transient workers receiving measurable dose has decreased over the past 4 years. The average measurable dose to transient workers has been less than the value for the overall DOE workforce for the past 5 years.

An analysis of the average age of monitored individuals reveals a steady increase in age of the DOE workforce over the past 12 years, particularly since 1990.

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, 1998* reports occupational radiation exposures incurred by individuals at DOE facilities during the calendar year 1998. This report includes occupational radiation exposure information for all DOE employees, contractors, subcontractors, and visitors. 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 or access to the data files 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 Programs and Hazards Management (EH-52)
Germantown, MD 20874

Or by calling the Environmental Safety & Health (ES&H) InfoCenter at 1-800-473-4375

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 at 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 1998. 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.

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 Programs and Hazards Management 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 1998. 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 Technical Standard (RCS) [7]. The RCS incorporates changes resulting from the amendment to 10 CFR 835 issued in 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 will continue in effect until the amendment issued November 4, 1998 to 10 CFR 835 is completely 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 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 dose (internal or external) 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 dose (internal or external) 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 radionuclides in question, and their chemical form. Follow-up measurements and analysis may take many months to confirm preliminary findings. With the publication of American National Standards Institute (ANSI) N13.30-1996, "Performance Criteria for Radiobioassay," DOE has developed a Radiobioassay Accreditation Program with scheduled implementation starting in November 1998 with the issuance of the amendments to 10 CFR 835.402.d which must be fully implemented by January 1, 2002.

2.2 Radiation Dose Limits

Radiation dose limits are now 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.

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.

ACLs are not specified in 10 CFR 835. However, they are specified under DOE N 441.1. Administrative controls are required to be implemented to keep doses below the dose limits and ALARA. DOE N 441.1 establishes the following administrative control limits: a 2 rem (20 mSv) annual TEDE, a 1 rem (10 mSv) cumulative TEDE per year of age, and requires that a facility-specific ACL be established for each site.

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 permissable 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 1994 to 1998. 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.

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Occupational Radiation Dose at DOE

Section Three

3

Occupational Radiation Dose at DOE

3.1 Analysis of the Data

Analysis and explanation of observed trends in occupational radiation dose data reveals 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. It should be noted that data for 1997 have been updated since the publication of the 1997 annual report due to final internal dose assessments reported by Lawrence Livermore National Laboratory (LLNL).

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. This number represents the sum of all monitored individuals, including all DOE employees, contractors, subcontractors, and visitors. 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.

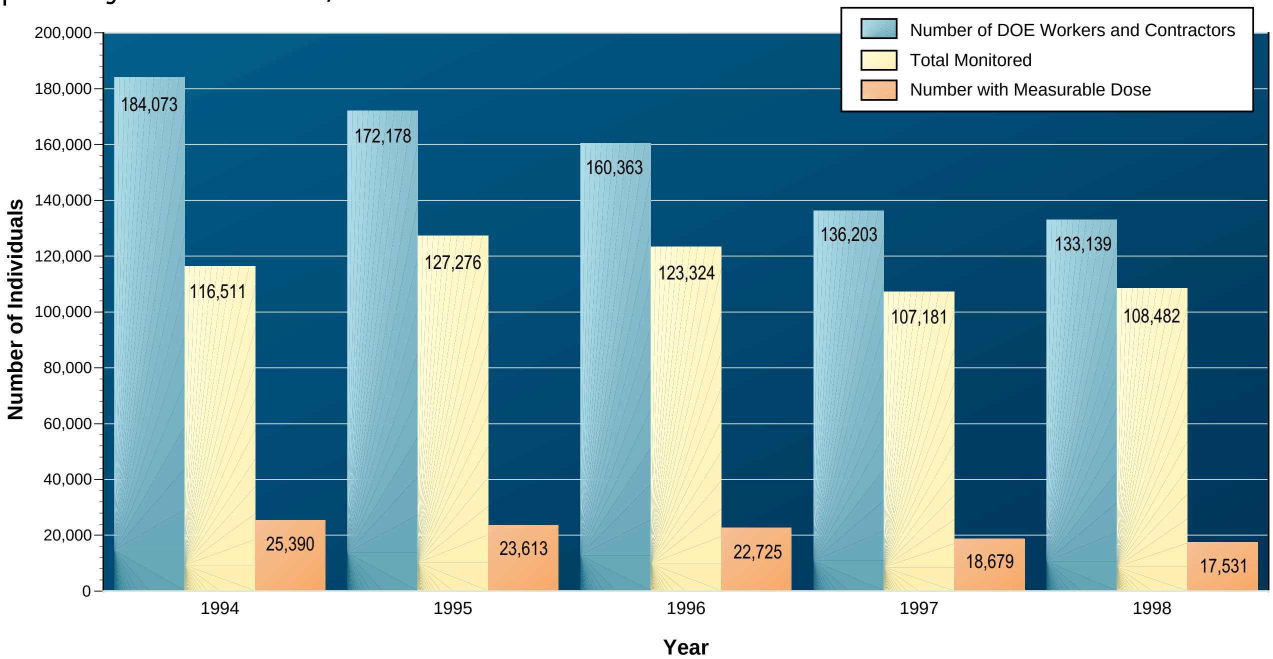
3.2.2 Number of Individuals with Measurable Dose

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 total number of workers at DOE, the total number 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 nearly 7%, the percentage of the DOE workforce monitored for radiation exposure has increased by 18% from 1994 to 1998. However, most (82%) of the monitored individuals over the past 5 years did not receive any measurable radiation dose. An average of 18% of monitored individuals (slightly 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 22% in 1994 to 16% in 1998. The overall DOE workforce has decreased by nearly 27% over the past 5 years

Compared to 1997, more individuals were monitored for radiation exposure during 1998 but fewer workers received measurable radiation exposure.

Exhibit 3-1:
Monitoring of the DOE Workforce, 1994-1998.



with decreases occurring each year. Compared to 1997, a larger percentage of the DOE workforce was monitored for radiation in 1998, while a smaller percentage of monitored individuals received a measurable dose. While the overall workforce size decreased from 1997 to 1998, the number monitored actually increased, indicating that the decrease in the number with measurable dose was not due entirely to workforce reductions.

Nineteen of 30 of the reporting sites experienced decreases in the number of workers with measurable dose from 1997 to 1998, with the largest decreases occurring at Fermi Lab and Idaho. The largest increases in the number of workers receiving measurable dose occurred at Oak Ridge and Rocky Flats primarily due to uranium operations and increases in decontamination and decommissioning (D&D) activities. A discussion of activities at various facilities is included in Section 3.5.

The number of workers with measurable dose decreased from 18,675 in 1997 to 17,531 in 1998.

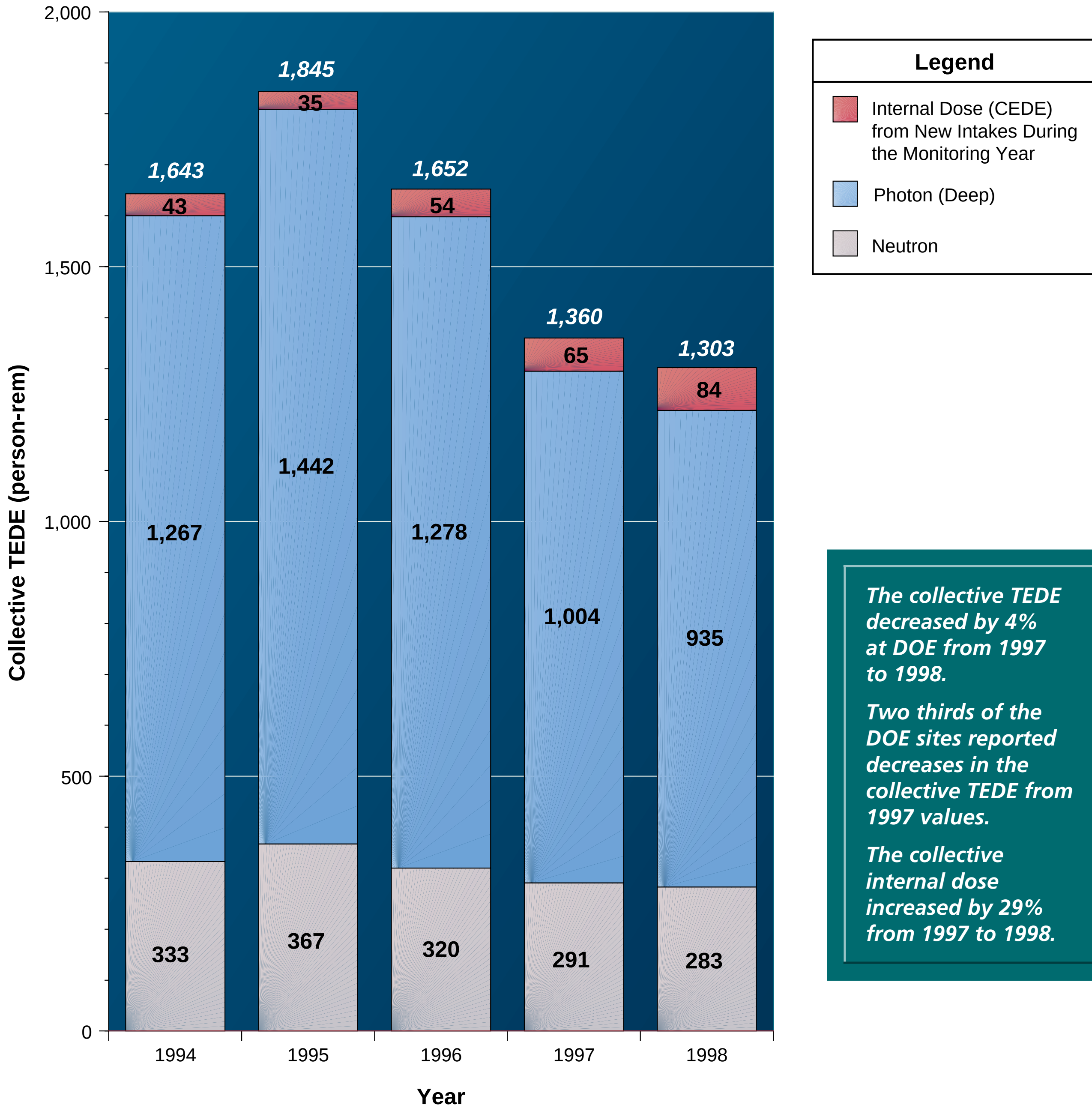
The percentage of monitored workers receiving measurable dose decreased by one percentage point from 17% in 1997 to 16% in 1998.

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 4% from 1997 to 1998. Sixty-three percent of the DOE sites reported decreases in the collective TEDE from the 1997 values. Four out of seven of the highest dose sites reported decreases in the collective TEDE, and one site had an increase of less than 1%. The seven highest dose sites are (in descending order of collective dose) Rocky Flats, Hanford, Savannah River, Los Alamos, Oak Ridge, Idaho, and Brookhaven (BNL). Statistical analysis of the collective TEDE reveals a decrease in the mean TEDE from 1997 to 1998. This finding indicates that the collective dose has decreased due to a combination of the reduction in overall work causing radiation exposure in

Exhibit 3-2:
Components of TEDE, 1994-1998



The collective TEDE decreased by 4% at DOE from 1997 to 1998.

Two thirds of the DOE sites reported decreases in the collective TEDE from 1997 values.

The collective internal dose increased by 29% from 1997 to 1998.

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.

addition to reductions in dose to individuals. Several sites identified improvements in ALARA practices as having contributed to the reduction in the collective TEDE. See 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 noteable 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 photon, neutron, and internal dose components are shown.

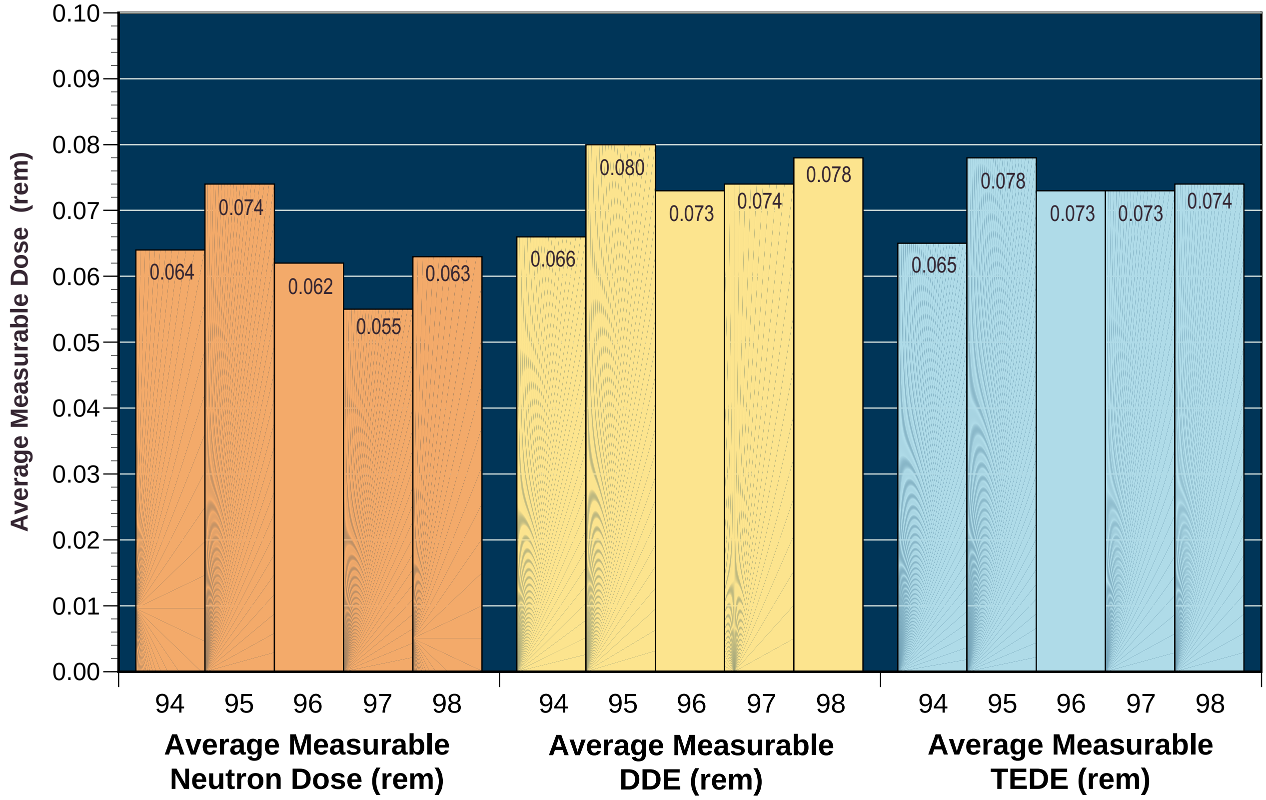
It should be noted that the internal dose shown in *Exhibit 3-2* for 1994 through 1998 is based on the 50-year CEDE methodology. The internal dose component increased by 29% from 1997 to 1998. This increase was largely a result of a number of new, albeit relatively low dose, uranium intakes at Oak Ridge. These doses are accute exposures received by maintenance personnel in support of restart efforts at Y-12.

The collective internal dose can vary from year to year due to the relatively small number of internal doses and the fact that they often involve long-lived radionuclides, which can result in relatively large committed doses. Due to the sporadic nature of these doses, 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 increased by 14% to 1,442 person-rem (14.42 person-Sv) from 1994 to 1995 due to increased activities at several of the highest dose sites. Activities responsible for increased dose at these sites included work on power sources for the National Aeronautics and Space Administration (NASA), increased research at an accelerator facility, nuclear materials stabilization activities, and D&D work. 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 for 1998 decreased to below 1,000 person-rem (10 person-Sv). Sites attributed the reduction in dose to the completion of several projects, and deferral of other projects. A discussion of the activities leading to this decrease is included in Section 3.5.

The neutron component of the TEDE decreased by 15% from 1994 to 1998. This is primarily due to decreases in the neutron dose at Los Alamos National Laboratory (LANL) and Savannah River. LANL contributed 37% of the neutron dose at the DOE during 1998. 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 1998, which resulted in decreased neutron dose from 121.6 person-rem (1.216 person-Sv) in 1996 to 87.8 person-rem (0.878 person-Sv) in 1998. The collective neutron dose at Rocky Flats experienced a 120% increase from 1996 to 1997 and 6% increase between 1997 and 1998. This increase was due to product stabilization activities and D&D activities involving plutonium. The collective neutron dose for 1998 by site is shown in Appendix B-3. External deep dose (DDE) and TEDE for prior years (1974-1998) can be found in Appendix B-4.

Exhibit 3-3:
Average Measurable Neutron, DDE, and TEDE, 1994-1998



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*. All three average measurable doses have increased in 1998. The average measurable neutron dose increased by 15% between 1997 and 1998 after 3 years of decreases, back up to a level just above the 1996 value. Increases in the average measurable neutron dose occurred at LANL, Rocky Flats, and Savannah River, the three top contributors to collective neutron dose. The average measurable DDE increased by 5% in 1998 due to a 10% decrease in the number of individuals with measurable 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. However, statistical analysis indicates that the mean TEDE dose decreased in 1998 indicating 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 1% from 1997 to 1998 while the average measurable DDE increased by 5%.

Exhibit 3-4:
Dose Distributions, 1994-1998

	Dose Ranges (rem)	1994		1995		1996		1997		1998	
		TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE
Number of Individuals in Each Dose Range*	Less than Measurable	91,121	92,245	103,663	104,793	100,599	101,529	88,502	89,805	90,951	92,790
	Measurable < 0.1	21,511	20,469	19,272	18,191	18,759	17,903	15,263	14,098	14,053	12,437
	0.10 - 0.25	2,437	2,389	2,543	2,513	2,441	2,405	2,142	2,046	2,253	2,120
	0.25 - 0.5	934	920	1,134	1,124	1,003	983	856	830	841	790
	0.5 - 0.75	329	317	374	371	339	335	265	258	268	245
	0.75 - 1.0	99	94	131	131	99	94	101	99	74	64
	1 - 2	79	77	157	153	80	74	48	45	41	36
	2 - 3					2	1	1		1	
	3 - 4	1		1		1		2			
	4 - 5			1				1			
	5 - 6										
	6 - 7										
	7 - 8										
	8 - 9										
	9 - 10										
	10 - 11										
	11 - 12					1					
	> 12										
Total Monitored		116,511	116,511	127,276	127,276	123,324	123,324	107,181	107,181	108,482	108,482
Number with Meas. Dose		25,390	24,266	23,613	22,483	22,725	21,795	18,679	17,376	17,531	15,692
Number with Dose >0.1rem		3,879	3,797	4,341	4,292	3,966	3,892	3,416	3,278	3,478	3,255
% of Individuals with Meas. Dose		22%	21%	19%	18%	18%	18%	17%	16%	16%	14%
Collective Dose (person-rem)		1,643	1,600	1,845	1,809	1,652	1,598	1,360	1,285	1,303	1,218
Average Measurable Dose (rem)		0.065	0.066	0.078	0.080	0.073	0.073	0.073	0.074	0.074	0.078

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

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. 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 4 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.

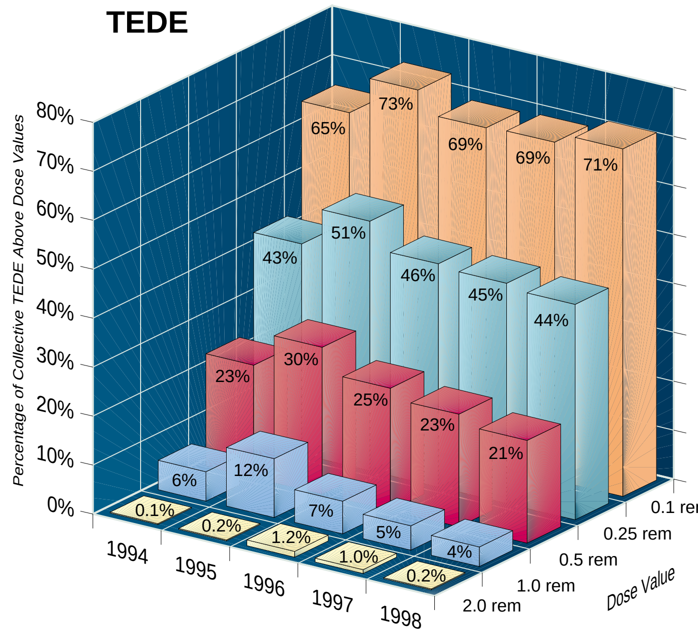
In 1982, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [14] defined distribution ratio "CR" as the fraction of the collective dose delivered above 1.5 rem (15 mSv). UNSCEAR identified this parameter as an indicator of the efforts to reduce high doses. DOE has adapted this approach to allow a quantification and analysis of the dose distribution at DOE. This report uses the percentage rather than the decimal fraction to represent the ratio of the dose delivered above several specified dose values.

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 have decreased or remained the same (DDE 1-2 rem) from 1997 to 1998 for all dose ranges at or above 0.25 rem, and only marginal increases in the 0.1 – 0.25 rem (0.001 mSv) range.

The general trend has been an increase in the percentage of dose above each dose range from 1994 to 1995 and then a decrease from 1995 through 1998. This coincides with the increase in the collective dose reported in 1995 and the increase in activities resulting in radiation exposures at the highest dose sites during 1995. Most of these sites reported decreases in the collective dose and radiological activities in 1997 and 1998 (see Section 3.5), which coincides with the observed decreases in *Exhibit 3-5*.

Exhibit 3-5:
Percentage of Collective Dose above Dose Values During 1994-1998



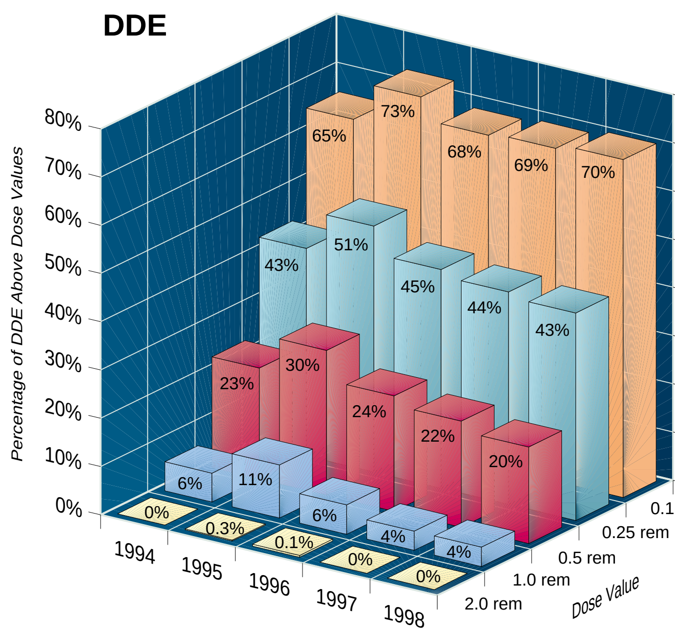


Exhibit 3-6:
Neutron Dose Distribution, 1994-1998

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)
1994	111,391	4,196	662	192	43	14	13	-	116,511	5,120	332.930	0.065
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	103,972	3,680	629	155	34	4	8	-	108,482	4,510	283.078	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 1998, 4,510 individuals (15% fewer than 1997) received measurable neutron dose, which is only 4% of the monitored individuals. The collective neutron dose represents 22% 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 has increased over 4 of the past 5 years, the collective neutron dose has decreased. The average measurable neutron dose increased by 15%. Statistical analysis of the neutron dose (see Section 3.2.6) reveals that the collective neutron dose has experienced a statistically significant decrease from 1994 to 1997, primarily due to decreases at LANL, which is responsible for nearly half the neutron dose at DOE. Decreases at LANL were due to reductions in workload coupled with an aggressive ALARA program. However, the neutron dose increased slightly from 1997 to 1998 primarily due to one-time plutonium processing activites at Rocky Flats. The neutron dose distribution for 1998 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, and 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 to two individuals each year reach extremity dose

Exhibit 3-7:
Extremity Dose Distribution, 1994-1998

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)
1994	96,545	15,903	3,619	418	22	2	2	-	-	116,511	**19,966**	26	2,520.3	0.126
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	95,410	8,347	3,938	722	56	8	1	-	-	108,482	13,072	65	**3,390.1**	**0.259**

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.*

between 30 and 40 rem, and no one has gone above 40 rem in the past 5 years. During 1998, only one individual received more than 20 rem (200 mSv) to the extremities. The number of individuals receiving a measurable extremity dose has increased by 3% from 1997 to 1998. Also, the number of individuals receiving more than 1 rem (10 mSv) has increased 12% over 1997 and the average extremity dose has increased over 1997 by nearly 7%. Much of this increase is a result of processing a greater number of higher activity materials at Rocky Flats during 1998. However, statistical analysis of the logarithmic mean extremity dose (see Section 3.2.6) reveals that the increase in collective extremity dose at DOE in 1998 is not statistically significant. 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,

Exhibit 3-8:
DOE-Wide Summary Results for Statistical Tests, 1994 -1998

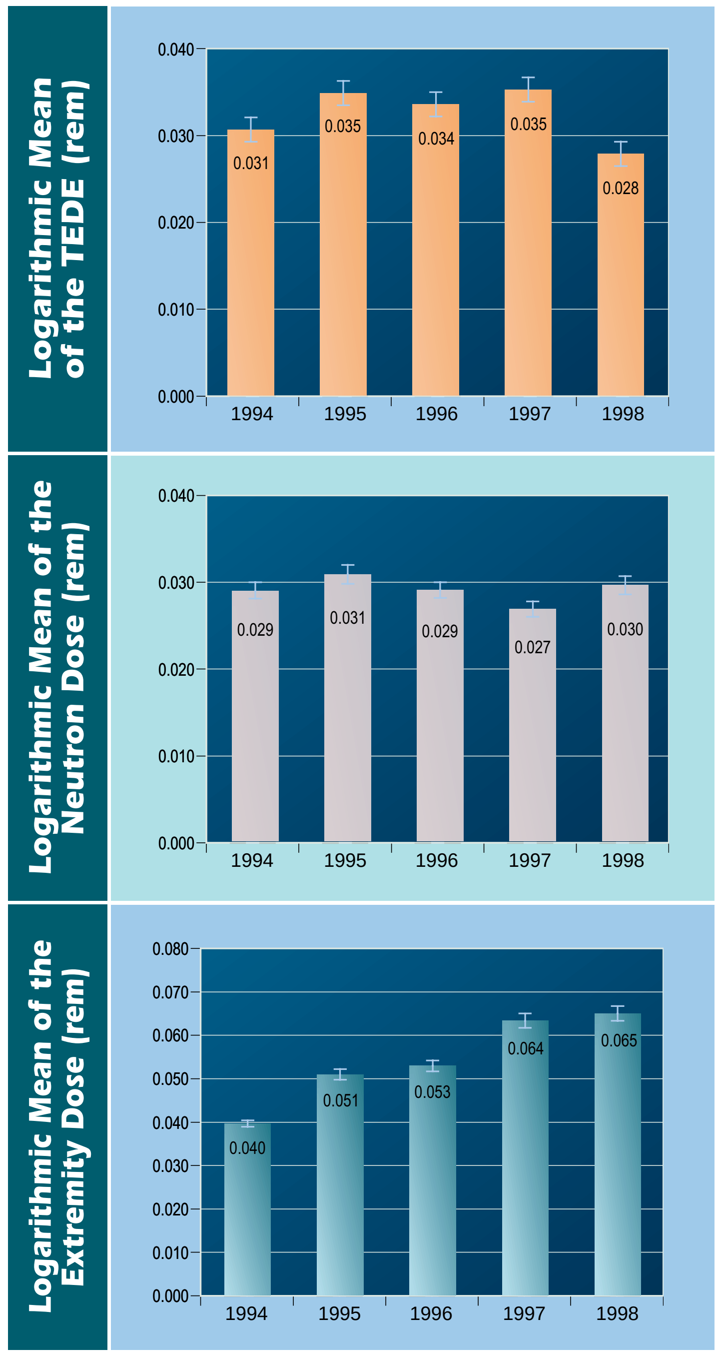
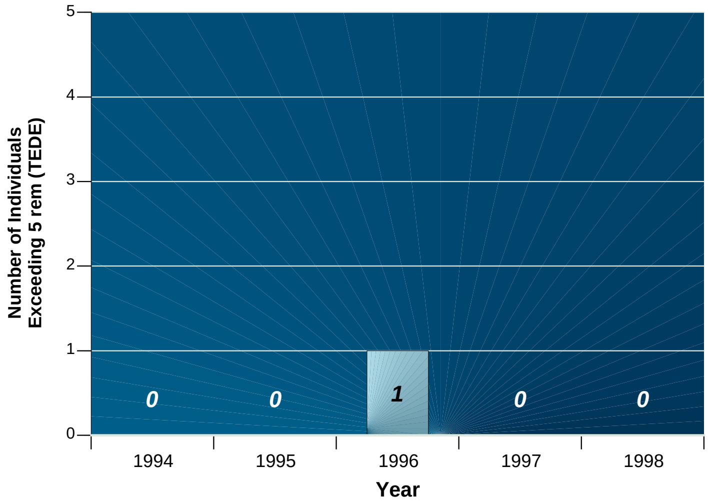


Exhibit 3-9:
Number of Individuals Exceeding 5 rem (TEDE), 1994-1998



and extremity dose DOE-wide. The error bars surrounding each data point represent the 95% confidence levels.

For the collective TEDE, there were small but significant differences in all years with no apparent trends across the 5-year period. The logarithmic mean TEDE per worker decreased by 0.007 rem (.070 mSv) from 1997 to 1998 consistent with the 4% decrease in the collective TEDE. There is also a difference in the dose distribution from 1997 to 1998 resulting from a slight shift of workers into the dose ranges below 0.25 rem (2.5 mSv) range. Because the mean dose to individual workers decreased as well as the collective dose, the change suggests a real reduction in dose to individuals.

Analysis of the neutron dose shows a small but significant increase in measurable dose compared to 1997. The mean neutron dose remained near 0.030 rem (0.300 mSv) for the past 5 years. The upward trend in measurable extremity dose apparently slowed in the last year. Although the logarithmic mean increased for the fourth year since 1994, the increase from 1997 to 1998 was not significant. While no site has reported an extremity dose in excess of the limit in the past 5 years, the increasing trend requires continued observation and may indicate the need for a review of extremity monitoring and protection practices at DOE sites in the future.

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 high dose ranges to thoroughly understand the circumstances leading to high 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 1994 through 1998. Further information concerning the individual dose, radionuclides involved, and site where the dose occurred is shown in *Exhibit 3-10*.

A correction has been made to the number of individuals over 5 rem (50 mSv) TEDE for 1997. Initial internal dose estimates indicated a CEDE of 15 to 30 rem (150 to 300 mSv) due to an unanticipated intake of curium-244 (Cm-244) at the LLNL. Follow-up bioassay and internal dose calculations have determined the individual did not exceed 5 rem (50 mSv) TEDE. For more information on this occurrence, see the Occurrence Report SAN—LLNL-LLNL-1997-0038.

No TEDE greater than 5 rem was reported in 1998.

No individual received a dose in excess of the 5 rem (50 mSv) TEDE limit in 1997 or 1998.

Exhibit 3-10:
Doses in Excess of DOE Limits, 1994-1998

Year	Year Uptake	TEDE (rem)	DDE (rem)	CEDE (rem)	Intake Nuclides	Facility Types	Site
1994					None Reported		
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		

* *Corrected from 1997 report. Final dose assigned at LLNL did not exceed 5 rem TEDE.*

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. It should be noted that doses above the 2 rem (20 mSv) ACL do not pose an undue health risk to the individual.

Although four individuals received doses above the 2 rem (20 mSv) ACL in 1997, as shown in *Exhibit 3-11*, only one individual received a dose above 2 rem during 1998.

On 08/18/98, during D&D activities involving a glovebox at Rocky Flats, a worker realized that his hand had been cut during operations. Per the requirements of the Radiological Work Permit, the worker had been wearing five pair of gloves: one pair of cotton liners, two pair of surgeon's type latex gloves, Level B suit gloves and a pair of leather work gloves. Apparently, the leather glove folded back, exposing his palm and latex gloves for the puncture. A metal splinter on the side of the glovebox floor punctured his palm. The employee was transported to Occupational Medicine for decontamination. Plutonium and americium were detected in the wound. The chelating agent DTPA (diethylenetriaminepentaacetate) was administered, and the wound was excised and cleansed to reduce the level of contamination.

Corrective actions included an investigation of material handling methods, a change in the contamination fixative, improvements in protective gloves, personnel briefings, and a Lessons Learned report. The final dose assigned was 2.400 rem CEDE and 43.000 rem CDE to the bone surfaces. For further information on this occurrence, see the Occurrence Report RFO—KHLL-779OPS-1998-0029.

Exhibit 3-11:
Number of Doses in Excess of the DOE 2 rem ACL, 1994-1998

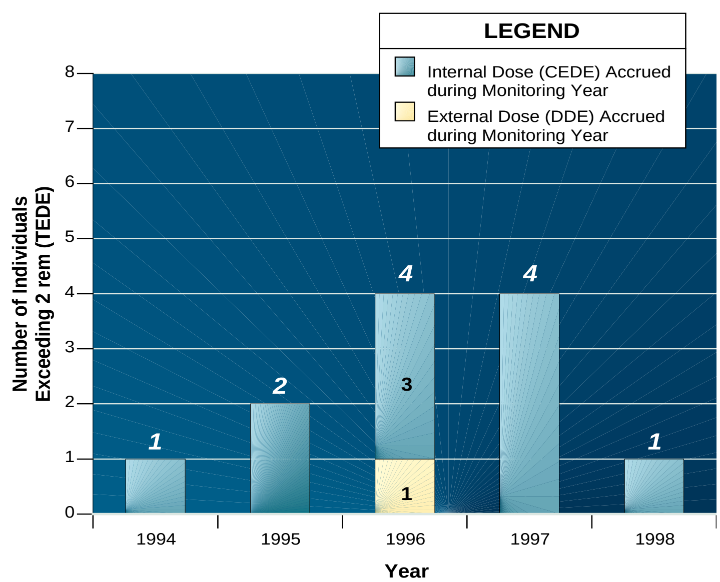
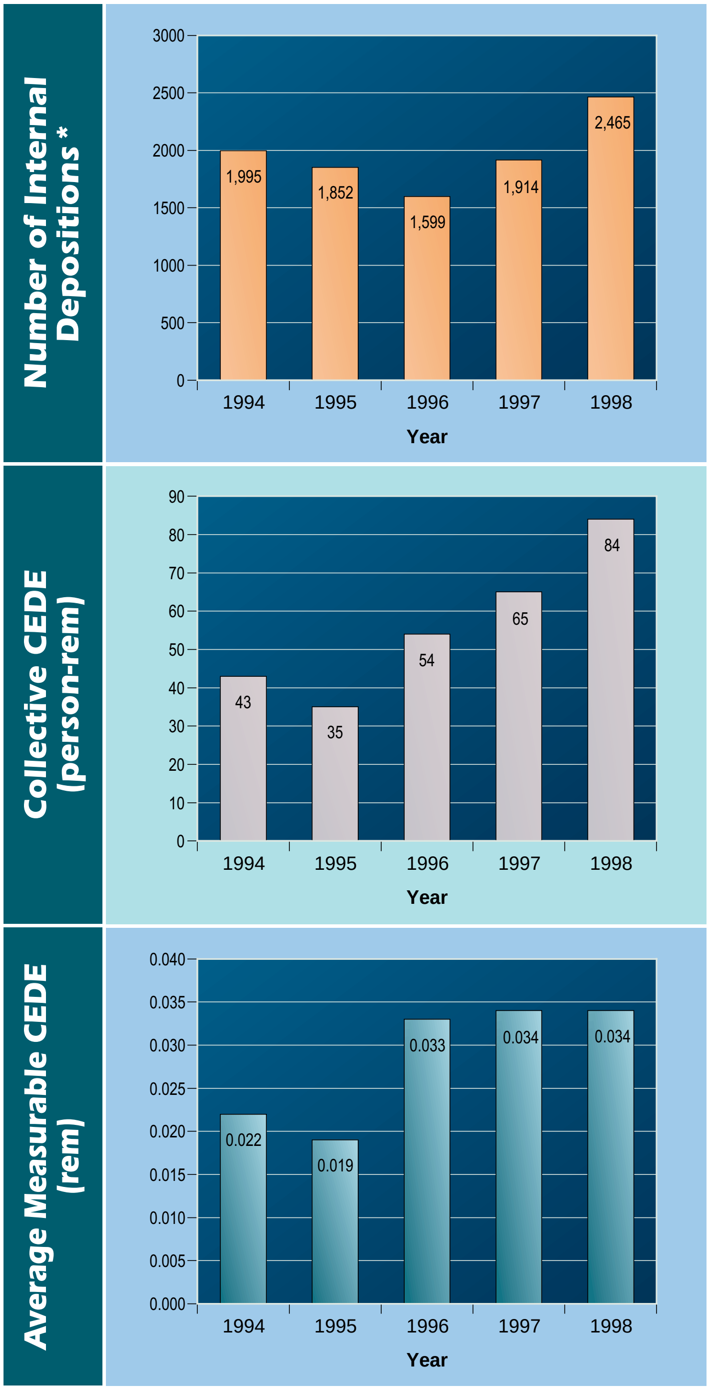


Exhibit 3-12:
Number of Internal Depositions, Collective CEDE, and Average Measurable CEDE, 1994-1998



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

3.3.3 Internal Depositions of Radioactive Material

As discussed in Section 3.3.1, in the past, some of the most significant 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 and the collective CEDE also increased 29% (see Exhibit 3-12).

The number of internal depositions of radioactive material (otherwise known as worker intakes) for 1996-1998 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 number of internal depositions increased by 29% from 1997 to 1998 and the collective CEDE also increased 29%. Although the highest average dose is due to the radon exposures to uranium mill tailings, the highest collective dose is due to uranium exposures, primarily at Oak Ridge. It should be noted that relatively few workers receive significant internal dose and therefore fluctuations in the number of workers and collective CEDE can occur from year to year.

Exhibit 3-13 shows the intakes that occurred during the past 3 years that were reported using the CEDE internal dose calculation methodology. Most intakes of radioactive material during the 3-year period were the result of exposure to tritium or uranium. The average CEDE doses from these intakes are quite low because of the radiological and biological characteristics of these radionuclides and the large number of monitored individuals with low CEDE dose from these radionuclides.

Exhibit 3-13:
Number of Intakes, Collective Internal Dose, and Average Dose by Nuclides, 1996-1998

Nuclide	Number of Internal Depositions*			Collective CEDE (person-rem)			Average CEDE (rem)		
Year	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**
Hydrogen-3 (Tritium)	**797** ◄	734	673	6.353	5.450	3.199	0.008	0.007	0.005
Technetium	2	8	2	0.006	0.009	0.006	0.003	0.001	0.003
Radon-222	-	270	280	-	**27.834** ◄	33.840	-	0.103	**0.121** ◄
Thorium	148	14	13	9.633	0.153	0.257	0.065	0.011	0.020
Uranium	539	**787** ◄	**1,326** ◄	12.380	13.022	**35.404** ◄	0.023	0.017	0.027
Plutonium	66	69	92	**24.297** ◄	13.718	9.553	**0.368** ◄	0.199	0.104
Americium-241	16	9	15	0.572	0.564	1.219	0.036	0.063	0.076
Other	31	18	62	0.283	4.264	0.725	0.009	**0.237** ◄	0.012
Mixed	-	5	1	-	0.341	0.004	-	0.068	0.004
Totals	**1,599**	**1,914**	**2,465**	**53.524**	**65.355**	**84.207**	**0.033**	**0.034**	**0.034**

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.

Both the collective and average doses for plutonium decreased in 1998, however the collective and average dose for americium increased during 1998. The greatest increases in numbers of individuals exposed and collective dose is from uranium intakes primarily due to an increase in uranium operations at Oak Ridge. Uranium operations resumed at the Oak Ridge Y-12 facility in 1997 and activities and the scope of activities increased throughout 1998. Although the receipt, storage, and security surrounding highly-enriched uranium at Y-12 adds little to internal exposure, reactivating the machinery and startup of systems operations after a 4-year stand-down at Y-12 resulted in a large number of individuals receiving a small intake of uranium.

The highest average CEDE dose from 1997 and 1998 was from radon reported from the Grand Junction site. Radon-222 has been reported as a source of occupational exposure since 1997 and it increased nearly 18% during 1998. It should be noted that the radon doses listed here include the natural background dose from radon as well as the additional dose received from the elevated radon levels. The Grand Junction Office is involved in environmental remediation of uranium mill tailings at a former uranium mill site at Monticello, Utah, as well as various Uranium Mill Tailings Remedial Action (UMTRA) sites. The primary radiological exposure pathway at the Monticello mill site is from radon progeny emanating as a gas from the uranium tailings piles. "Tailings" are the soil left over after the uranium ore extraction process. While radon is normally considered an environmental background source of radiation, in this case exposure to radon progeny is considered occupational exposure because the radiation source is greater than normal background, it results from technologically enhanced source of radon (uranium tailings piles), and it exposes workers during their remediation activities.

The collective CEDE from thorium decreased in 1997 because the site reporting most of these intakes, the Portsmouth Gaseous Diffusion Plant, has gone through several operational changes. During 1998, the collective CEDE from thorium increased slightly as a result of legacy "tails" cylinders and some other environmental activities that are not involved in the plant operation but are reported as DOE activities.

Exhibit 3-14:
Internal Dose Distribution from Intakes, 1994 - 1998

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)
1994	1,712	224	29	18	7	2	2		1			1,995	45.600
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

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.

The internal dose records indicate that the majority of the intakes reported are at very low doses. In 1998, 77% of the internal dose records were for doses below 0.020 rem (0.20 mSv) and represent only 8% of the collective internal dose. The other 23% of the internal dose records had doses above 0.020 rem (0.20 mSv) and accounted for 92% of the collective internal dose. Over the 5-year period, internal doses from new intakes accounted for only 4% of the collective TEDE and only 5% of the individuals who received internal dose were above the monitoring threshold specified (100 mrem) in 10 CFR 835.402(c).

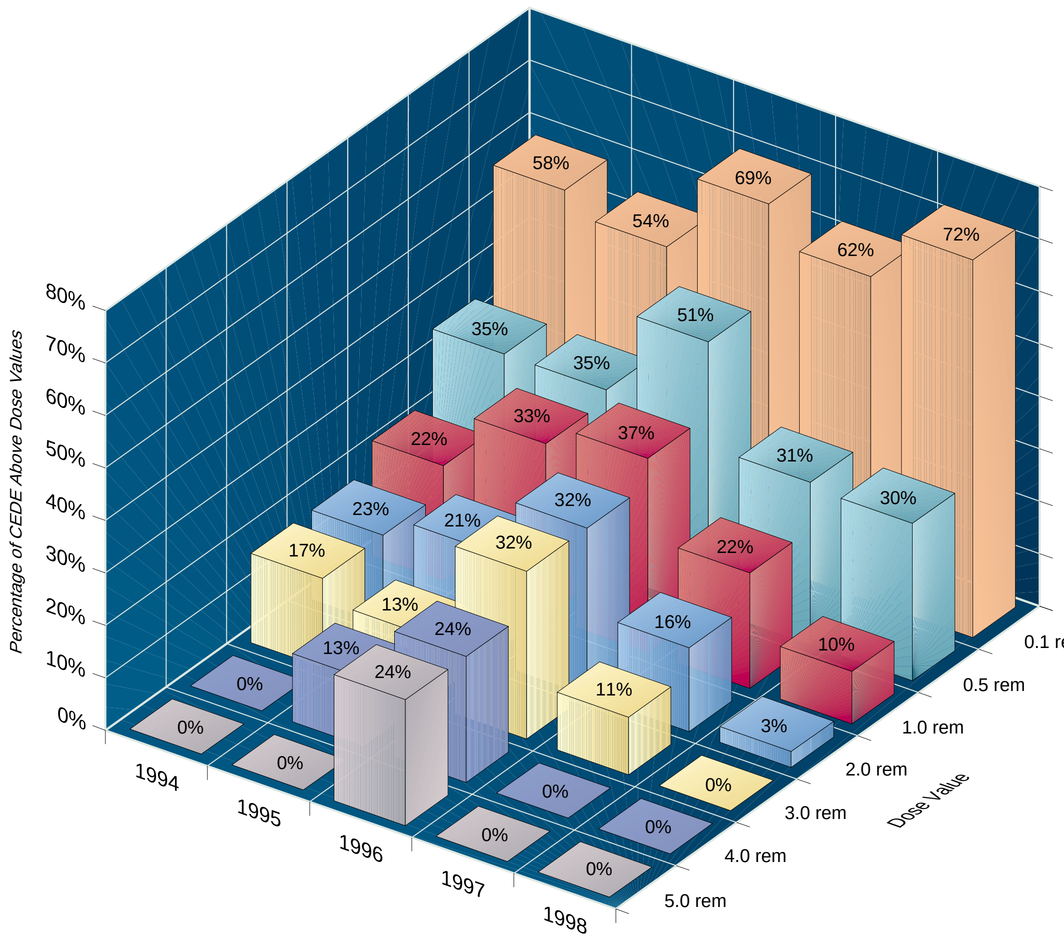
The internal dose records indicate that the majority of the intakes reported are at very low doses.

Over the 5-year period, internal doses accounted for only 4% of the collective TEDE.

Exhibit 3-14 shows the distribution of the internal dose from 1994 to 1998. 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 one of the internal doses were below 2 rem (20 mSv) in 1998.

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 1994 to 1998. While the fluctuations in internal dose prohibit definitive trend analysis, it appears from the graph that internal doses have been shifting from the higher dose ranges to the lower dose ranges since 1996. This confirms that, while the collective internal dose has increased in 1998, the increase was due to a larger number of internal doses received below 0.500 rem. The distribution of internal dose by site and nuclide for 1998 is presented in Appendix B-22.

Exhibit 3-15:
Distribution of Collective CEDE vs. Dose Value, 1994-1998



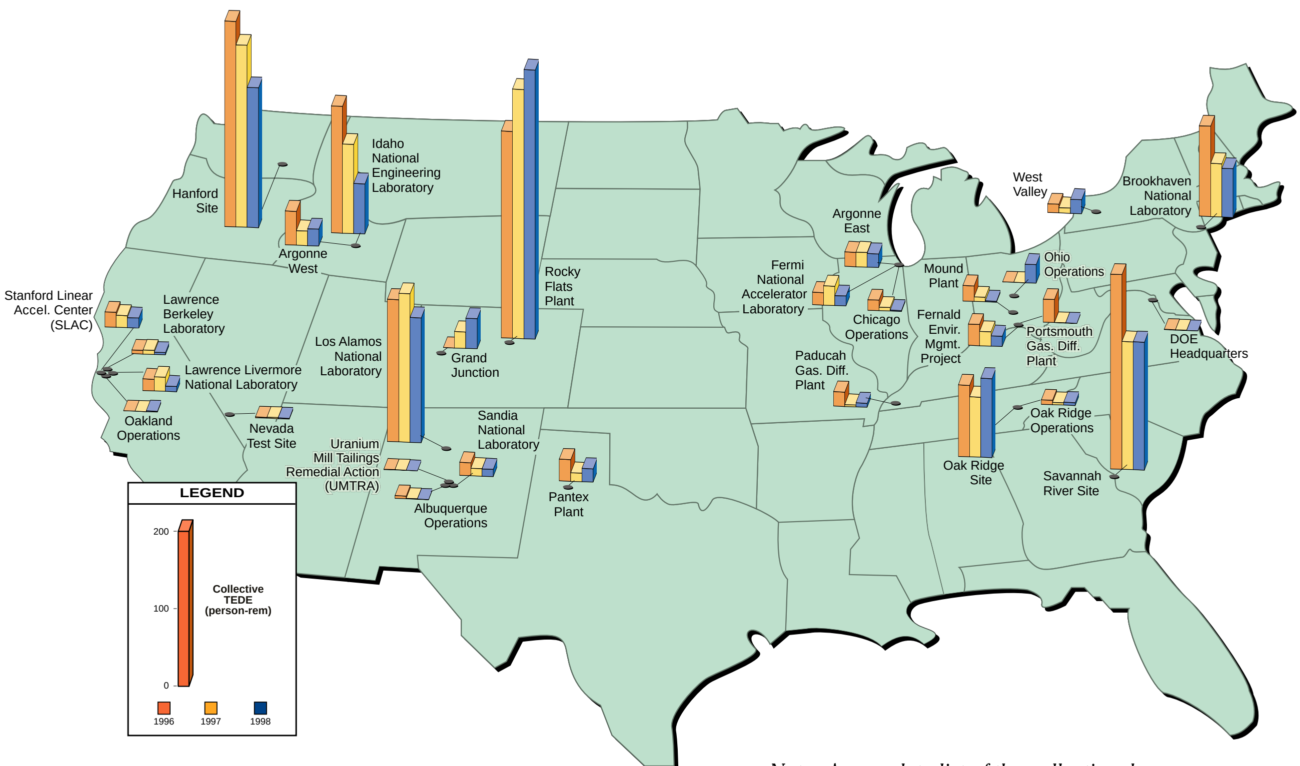
When examining trends involving internal dose, several factors should be considered. Some of the largest changes in the number of reported intakes over the years resulted from changes in internal dosimetry practices. Periodically, sites may change monitoring practices or procedures, which may involve 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 significant statistical variability of the internal dose data from year to year.

3.4 Analysis of Site Data

3.4.1 Collective TEDE by Operations/Field Offices

The relative collective TEDE for 1996-1998 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 Operations/Field Offices and sites is shown in *Exhibit 3-17*. The collective TEDE decreased by 4% between 1997 and 1998, with seven of the highest dose sites (BNL, Savannah River, Oak Ridge, LANL, Rocky Flats, Idaho, and Hanford) contributing 83% of the total DOE collective TEDE.

Exhibit 3-16:
Relative Collective TEDE by Site/Facility for 1996-1998



Note: A complete list of the collective dose, number of individuals with measurable dose, and average measurable dose for each Operations/Field Office can be found in Appendix B.

Exhibit 3-17:
Collective TEDE and Number of Individuals with Measurable TEDE by Site/Facility, 1996-1998

Operations/ Field Office	Site/Facility	1996 Collective TEDE (person-rem)	1996 Number with Meas. TEDE	1997 Collective TEDE (person-rem)	1997 Number with Meas. TEDE	1998 Collective TEDE (person-rem)	1998 Number with Meas. TEDE
Albuquerque	Ops. and Other Facilities	3.6	37	0.5	25	0.2	11
	Los Alamos National Lab. (LANL)	184.1	1,984	192.2	2,333	161.6	1,916
	Pantex Plant (PP)	28.1	327	11.1	213	17.2	312
	Sandia National Lab. (SNL)	16.7	485	9.7	196	9.5	181
	Uranium Mill Tailings Remedial Action (UMTRA) Project	0.4	26	0.3	36	0.0	0
	Grand Junction	0.0	0.0	21.3	169	38.9	295
Chicago	Ops. and Other Facilities	13.5	182	4.5	134	1.2	44
	Argonne Nat'l. Lab. - East (ANL-E)	18.5	202	19.0	238	17.7	182
	Argonne Nat'l. Lab. - West (ANL-W)	43.6	331	18.9	249	21.7	236
	Brookhaven Nat'l. Lab.(BNL)	116.8	1,448	68.9	1,463	63.0	1,055
	Fermi Nat'l. Accelerator Lab.(FERMI)	16.2	538	25.0	859	12.8	441
DOE HQ	DOE Headquarters	0.3	6	0.2	5	0.0	2
	DOE North Korea Project	13.3	36	8.3	24	5.4	14
Idaho	Idaho Site	164.1	1,299	115.3	1,141	64.9	743
Nevada	Nevada Test Site (NTS)	1.0	19	1.3	25	1.0	13
Oakland	Ops. and Other Facilities	0.0	6	1.4	50	1.0	45
	Lawrence Berkeley Lab. (LBL)	4.6	100	5.2	128	2.9	76
	Lawrence Livermore Nat'l. Lab. (LLNL)	14.9	187	22.1	190	6.9	107
	Stanford Linear Accelerator Center (SLAC)	19.3	312	14.2	117	13.1	157
Oak Ridge	Ops. and Other Facilities	11.9	200	6.6	135	3.8	195
	Oak Ridge Site	88.6	1,582	77.7	1,614	102.7	2,187
	Paducah Gaseous Diff. Plant (PGDP)	18.6	290	2.5	36	5.3	68
	Portsmouth Gaseous Diff. Plant (PORTS)	29.9	758	0.2	3	0.2	15
Ohio	Ops. and Other Facilities	0.0	5	0.1	2	24.1	78
	Fernald Environmental Management Project	27.4	804	18.4	520	13.3	559
	Mound Plant	20.1	403	5.8	197	1.3	106
	West Valley	11.2	231	6.9	174	18.2	260
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**267.6** ◄	3,430	**323.2** ◄	3,187	**348.1** ◄	**3,298** ◄
Richland	Hanford Site	265.7	2,761	235.4	2,058	180.9	1,772
Savannah River	Savannah River Site (SRS)	251.8	**4,736** ◄	165.3	**3,327** ◄	165.5	3,163
Totals		**1,651.9**	**22,725**	**1,360.1**	**18,679**	**1,302.7**	**17,531**

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

Exhibit 3-18:
Dose by Labor Category, 1996-1998

Labor Category	Number with Meas. Dose			Collective TEDE* (person-rem)			Average Meas. TEDE (rem)		
	1996	1997	1998	1996	1997	1998	1996	1997	1998
Agriculture	8	8	4	0.4	1.1	0.5	0.047	0.134	**0.123** ◄
Construction	2,588	1,695	1,664	176.8	125.7	90.4	0.068	0.074	0.054
Laborers	542	509	492	49.0	81.9	53.6	0.090	**0.161** ◄	0.109
Management	1,212	1,402	1,395	57.2	75.4	80.5	0.047	0.054	0.058
Misc.	**5,012** ◄	2,093	2,272	259.8	98.2	120.2	0.052	0.047	0.053
Production	2,434	1,794	1,781	267.4	144.3	155.4	0.110	0.080	0.087
Scientists	3,828	3,052	2,784	164.4	136.1	120.0	0.043	0.045	0.043
Service	569	634	665	31.7	35.0	43.9	0.056	0.055	0.066
Technicians	3,576	2,826	2,919	**416.6** ◄	**339.4** ◄	**356.2** ◄	**0.117** ◄	0.120	0.122
Transport	401	177	144	18.8	8.4	9.1	0.047	0.047	0.063
Unknown	2,555	**4,489** ◄	**3,411** ◄	209.9	314.5	272.8	0.082	0.070	0.080
Totals	**22,725**	**18,679**	**17,531**	**1,651.9**	**1,360.1**	**1,302.7**	**0.073**	**0.073**	**0.074**

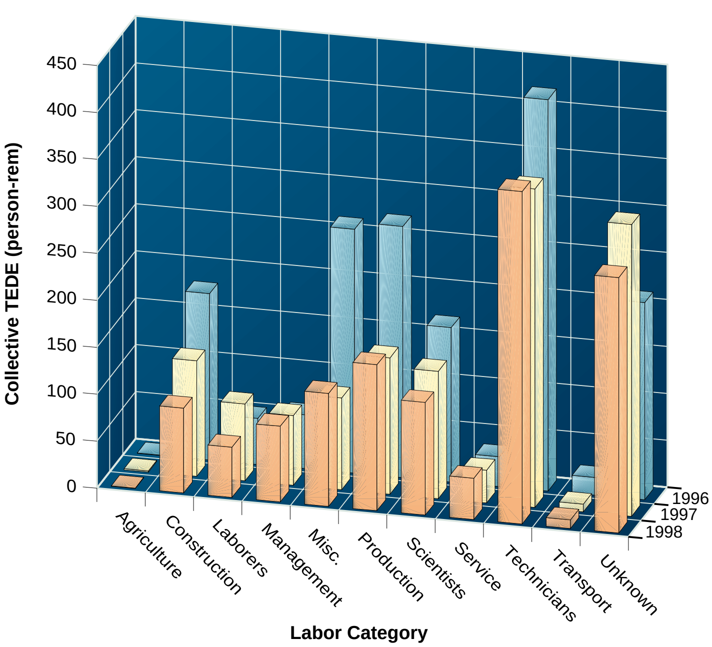
Note: Arrowed values indicate the greatest value in each column.

* *1996-1998 TEDE = CEDE + DDE*

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. 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 1996-1998 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. Forty-two percent of the technician dose is attributed to radiation protection technicians.

Exhibit 3-19:
Graph of Dose by Labor Category, 1996-1998



The collective TEDE is also high for the "unknown" and "miscellaneous" categories. Sixty-three percent of the dose in the "unknown" category 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. LANL is addressing this issue. Other sites also report large numbers of individuals with an occupation code of "unknown". Typically, these workers are subcontractors or temporary workers. Information concerning these workers tends to be limited. Four individuals with measurable dose were reported under the labor category of "agriculture" and had the highest average measurable TEDE in 1998. These individuals worked at the Idaho site. Upon review by Idaho National Engineering and Environmental Laboratory (INEEL), these workers were determined to actually be involved in operations, and were reported with the incorrect occupation code. These records will be corrected in future reports.

An examination of internal dose from intake by labor category from 1996 to 1998 is presented in Appendix B-20. In addition, Appendix B-21 shows the TEDE distribution by labor category and occupation for 1998.

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 1996 to 1998 is presented in Appendix B-18.

The collective TEDE for 1996-1998 was highest at weapons fabrication and testing facilities. Seventy-nine percent of this dose was accrued at Rocky Flats, with 15% from Savannah River. 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 Dose by Facility Type, 1996-1998

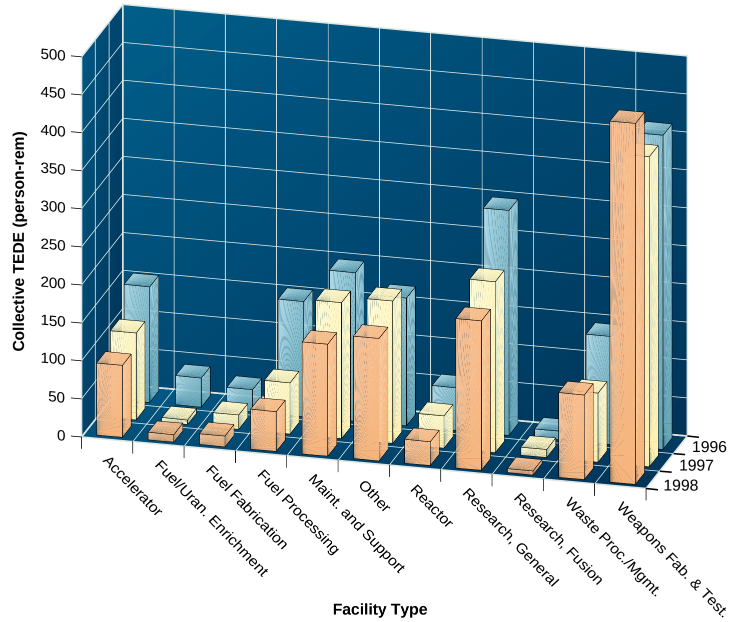


Exhibit 3-21:
Dose by Facility Type, 1996-1998

Facility Type	Number with Meas. Dose			Collective TEDE* (person-rem)			Average Meas. TEDE (rem)		
	1996	1997	1998	1996	1997	1998	1996	1997	1998
Accelerator	2,345	2,562	1,618	152.0	114.4	94.7	0.065	0.045	0.059
Fuel/Uranium Enrichment	908	149	256	38.3	6.2	10.0	0.042	0.041	0.039
Fuel Fabrication	864	545	593	29.0	18.8	14.3	0.034	0.035	0.024
Fuel Processing	1,498	1,261	1,172	151.2	67.4	52.6	**0.101** ◄	0.053	0.045
Maintenance and Support	2,886	2,177	1,728	195.2	180.0	147.3	0.068	0.083	0.085
Other	2,514	2,423	2,284	168.1	191.3	164.2	0.067	0.079	0.072
Reactor	912	729	619	56.1	42.3	31.4	0.062	0.058	0.051
Research, General	3,095	2,681	2,410	295.7	226.0	196.6	0.096	0.084	0.082
Research, Fusion	163	132	75	11.4	10.5	5.2	0.070	0.080	0.070
Waste Processing/Mgmt.	2,422	1,609	1,512	142.1	94.5	111.4	0.059	0.059	0.074
Weapons Fab. and Testing	**5,118** ◄	**4,411** ◄	**5,264** ◄	**412.8** ◄	**408.7** ◄	**475.0** ◄	0.081	**0.093** ◄	**0.090** ◄
Totals	**22,725**	**18,679**	**17,531**	**1,651.9**	**1,360.1**	**1,302.7**	**0.073**	**0.073**	**0.074**

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

** 1996-1998 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 Occurrence Reporting and Processing System (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 are *radiation exposure* occurrences, and Group 4B are *personnel contamination* occurrence reports. 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. Significant 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 significant 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 has decreased by 38% from 1997 to 1998 but is 29% above the 1996 level. Only one *radiation exposure* occurrence was classified as an unusual event, down from three in 1997.

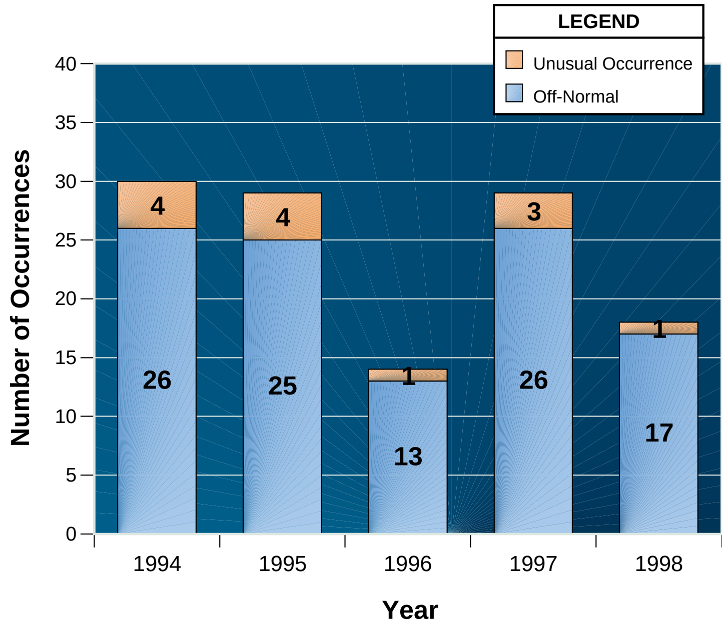
> ***The number of Radiation Exposure occurrences has decreased by 38% from 1997 to 1998.***

The decrease in the number of *radiation exposure* occurrences during 1998 possibly reflects an overall improvement in the radiation protection arena as well as more timely reporting and close-out of events reducing the number of carryovers from previous years. It also reflects the assimilation of the more stringent reporting thresholds instituted during 1996.

For 1998, 17 of the 18 occurrences (94%) shown in *Exhibit 3-23* involved Off-Normal occurrences. Fourteen of the 18 off-normal occurrences (78%) involved internal dose or potential internal dose, while 4 of the 18 off-normal occurrences (22%) involved external dose or the potential to receive an external dose. Of the 18 *radiation exposure* occurrences, only one was categorized as an Unusual Occurrence because it involved the release of a small amount of radioactive materials with the potential for exposure outside of the DOE facility.

Five of the exposures to personnel occurred during 1997 but the analytical results were not reported until 1998. Five other exposures occurred during 1995 and 1996 but were not evaluated or reported until 1998. These resulted from a downward revision of the reporting thresholds. Three of the occurrences reported involved procedural violations and had only a potential for personnel exposure to exceed the reporting threshold of 100 mrem.

Exhibit 3-23:
Number of Radiation Exposure Occurrences, 1994-1998



None of the *radiation exposure* occurrence reports submitted to ORPS from 1994 to 1998 have involved exposure to minors, members of the public, or pregnant workers. *Exhibit 3-24* shows the breakdown of occurrences for *radiation exposure* by site for the 5-year period 1994 to 1998. Seventy-nine percent (79%) of the *radiation exposure* occurrences were reported by six sites: Rocky Flats, Savannah River, Oak Ridge, Hanford, LANL, and Mound.

Exhibit 3-24:
Radiation Exposure Occurrences by Site, 1994-1998

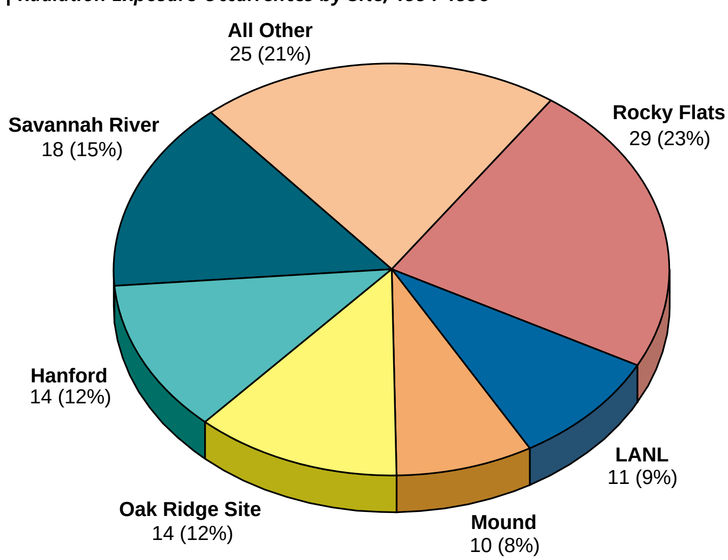
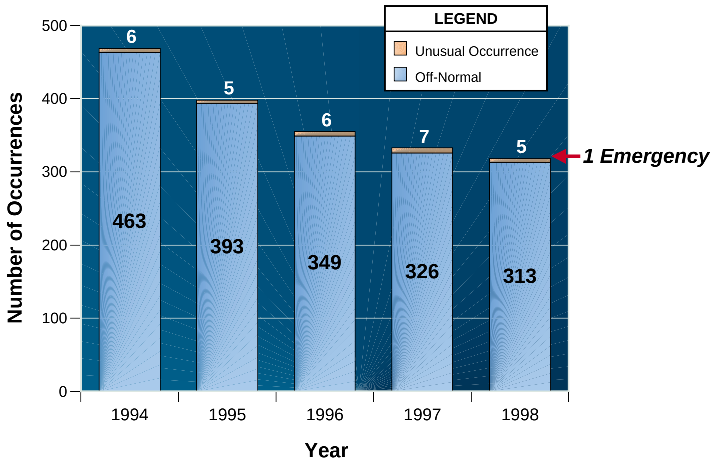


Exhibit 3-25:
Number of Personnel Contamination Occurrences, 1994-1998



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 has decreased by 4% from 1997 to 1998 continuing the downward trend since 1994 (see *Exhibit 3-25*). Five *personnel contamination* occurrences were classed as unusual events, down from 7 in 1997. One *personnel contamination* event was initially classified as an emergency because it involved the potential for an off-site contamination release via radioactively contaminated insects (see Section 4.5).

The number of Personnel Contamination occurrences has decreased by 4% from 1997 to 1998.

Personnel contamination occurrences can involve contamination of the skin, clothing, or shoes. *Exhibit 3-26* shows the breakdown of occurrences by affected area from 1994 through 1998. 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 and therefore may be counted in more than one category. Between 1994 and 1998, contamination occurrences involving the skin continued to decrease. Clothing contamination events increased by 63% from 1997 to 1998, however, all three affected areas (i.e., Skin, Clothing, and Shoe) exhibit a steady decline of contamination occurrences over the past 5 years. Many of these events were attributed to the commercial laundering process wherein radioactive particles from other (i.e., commercial) users of the laundry become loosely attached in the clothing fibers.

Exhibit 3-26:
Personnel Contamination Occurrences by Affected Area, 1994-1998

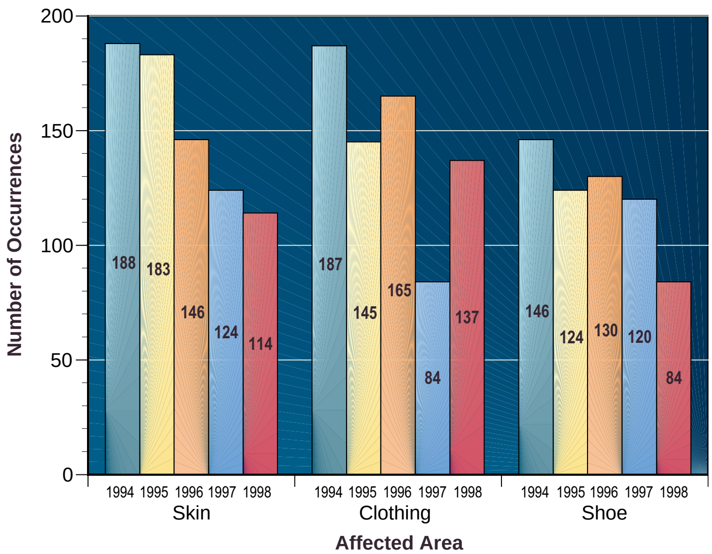


Exhibit 3-27:
Personnel Contamination Occurrences by Site, 1994-1998

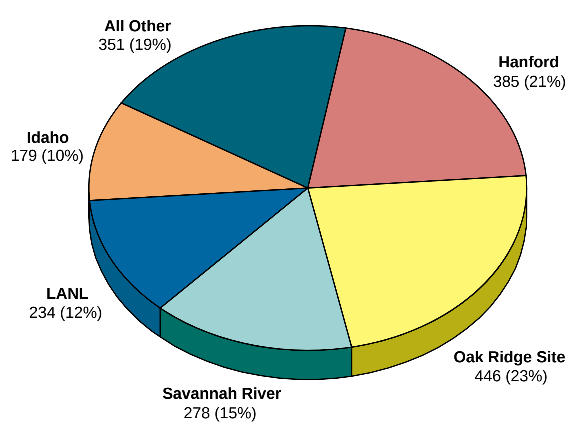


Exhibit 3-27 shows the breakdown of occurrences for *personnel contamination* by site for the 5-year period 1994 to 1998. *Personnel contamination* occurrence reports are distributed among the sites, with Oak Ridge, Hanford, Savannah River, LANL, and Idaho submitting 81% of the reports.

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 30% of the *radiation exposure* and *personnel contamination* occurrences. The most often-cited management problem is inadequate administrative control. Other management problems in 1998 include inadequate policy definition and dissemination, and work organization/planning deficiencies.

The number of *radiation exposure* and *personnel contamination* occurrences attributed to unknown sources of radiation remained approximately the same between 1997 and 1998, but remains the second largest category comprising 30% of these occurrences in 1998. Therefore, continued attention should be given to these occurrences and actions taken in the field to ensure that previously unidentified sources of exposure and contamination are identified and remediated in accordance with DOE Policy 450.4 on integrated safety management (ISM).

The number of personnel errors contributing to *radiation exposure* decreased during 1998. The number of personnel errors leading to *personnel contamination* occurrences increased slightly during 1998; many of these were attributed to *personnel contamination* received during the doffing of personal protective equipment and clothing.

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, 1996-1998

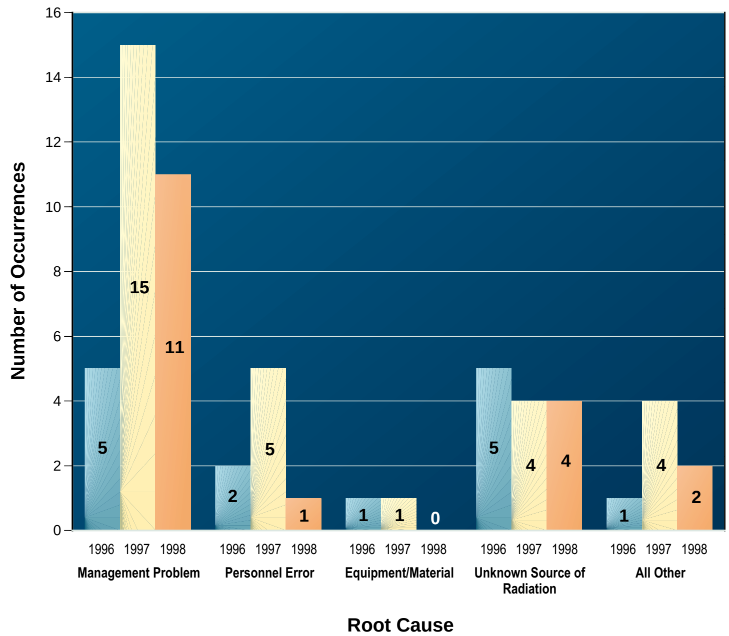
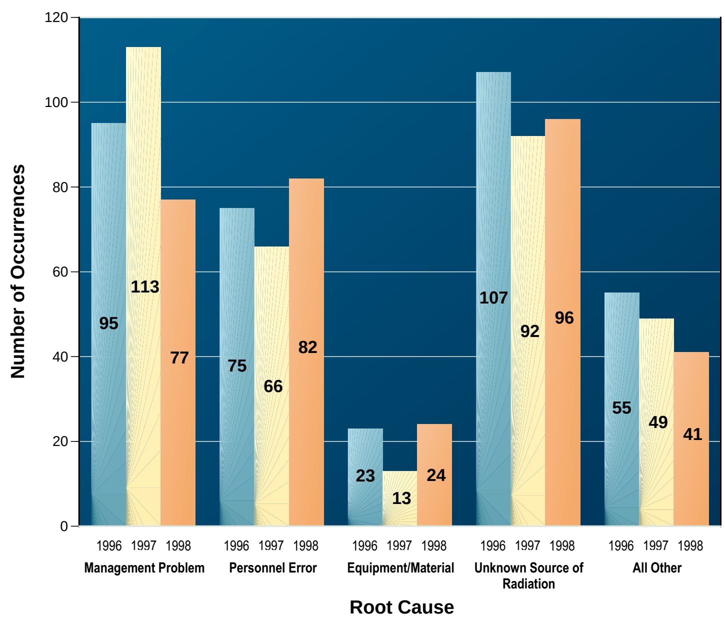


Exhibit 3-29:
Personnel Contamination Occurrences by Root Cause, 1996-1998



3.5 Activities Contributing to Collective Dose in 1998

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 1998. These sites (Rocky Flats, Hanford, Savannah River, LANL, Idaho, BNL, and Oak Ridge) were the top seven sites in their contribution to the collective TEDE for 1998 and comprised 83% of the total DOE dose. Four of the seven sites reported decreases in the collective TEDE, which resulted in a 4% decrease in the DOE collective dose in 1998. The seven sites are shown in *Exhibit 3-30*, including a description of activities that contributed to the collective TEDE for 1998.

Exhibit 3-30:
Activities Contributing to Collective TEDE in 1998 for Seven Sites

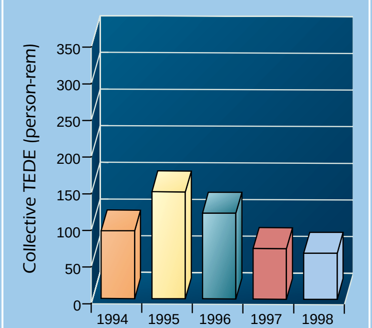
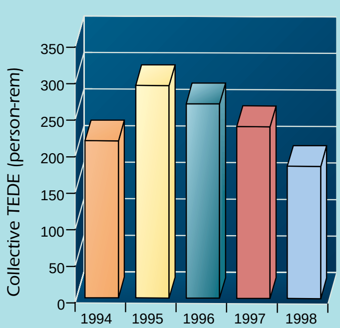
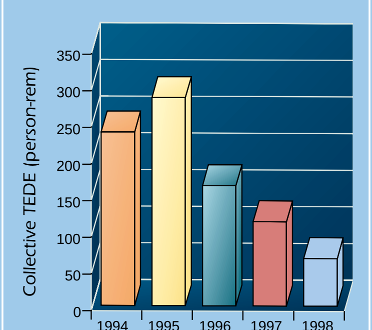
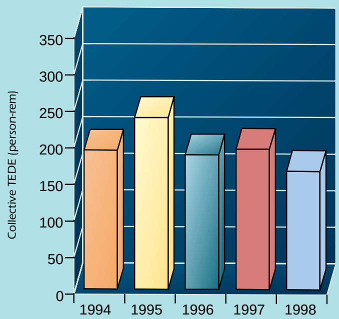
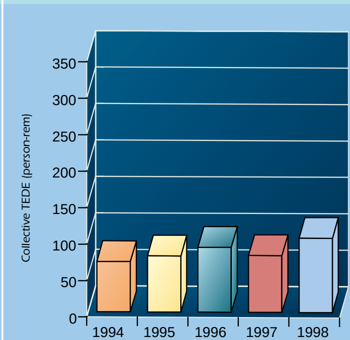
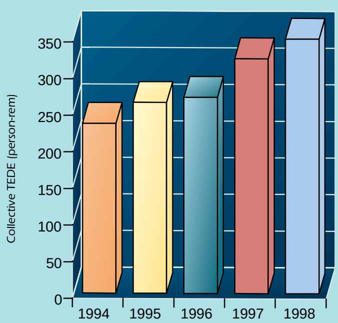
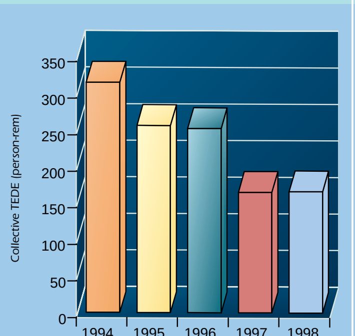
Site	Collective TEDE (person-rem)	Percent Change			Description of Activities at the Site
		97-98 (last yr.)	96-98 (3 yr.)	94-98 (5 yr.)	
Brookhaven National Lab.		9% ▼	46% ▼	32% ▼	The collective dose at BNL dropped by 9% from the 1997 levels due mostly to long-term shutdown of the High-Flux Beam Reactor (HFBR) and implementation of ALARA initiatives. Brookhaven operates the Alternating Gradient Synchrotron (AGS), the National Synchrotron Light Source, the HFBR, the Brookhaven Medical Research Reactor, Positron Emission Tomography, and the Brookhaven Linear Isotope Production. The total radiation exposure for 1998 was 62.8 person-rem, with 73% attributed to accelerator operations, and 70% of that attributed to the AGS. General research was the second most prominent contribution to the collective dose at 12%, maintenance activities was third contributing 8% of the collective dose. Reactor operations only contributed 4% of the collective doses compared with 10% during 1997, this reduction resulting from the shutdown of the HFBR.
Hanford		23% ▼	32% ▼	16% ▼	The site collective TEDE decreased by 23% in 1998. The decrease in dose was attributed to enhanced work planning coupled with new and ongoing ALARA projects. The increase in special nuclear material (SNM) inventory work for plutonium materials at Plutonium Finishing Plant (PFP) contributed to a 57% increase in the neutron dose. The D&D activities at the N-Reactor were the largest dose contributor at 24%, with the baseline inspection of plutonium in the vaults at PFP second at 13%. Other contributions to the dose included tank farms, 12%; Pacific Northwest National Lab (PNNL) facilities, 10%; 222S laboratories, 8%; K-Basins, 6%; and B-Plant closeout at 3%.
Idaho		43% ▼	77% ▼	72% ▼	The site collective CEDE at Idaho National Engineering and Environmental Laboratory (INEEL) dropped 43% from the 1997 levels. The completion of several jobs during 1997 contributed to a significant dose reduction. A maintenance stand-down, continued reductions in the scope of operations at INEEL, and ongoing ALARA initiatives worked to drive down the collective dose during 1998. As in past years, most of the exposure comes from reactor and reprocessing operations.

Exhibit 3-30:
Activities Contributing to Collective TEDE in 1998 for Seven Sites (continued)

Site	Collective TEDE (person-rem)	Percent Change 97-98 (last yr.)	96-98 (3 yr.)	94-98 (5 yr.)	Description of Activities at the Site
Los Alamos National Lab.		16%▼	12%▼	15%▼	The LANL collective TEDE decreased by 16% for 1998. Two-thirds of the laboratory's collective dose results from the handling of nuclear weapons materials, such as plutonium and tritium. Another significant contributor to the dose is the operation of the Los Alamos Neutron Scattering Center accelerator. The overall decrease in dose is due to reductions in workload coupled with an aggressive ALARA program.
Oak Ridge Site		31%▲	15%▲	48%▲	Exposures at the Oak Ridge Site increased 31% from 1997. Exposures at the Y-12 plant increased 287% from 1997 to 1998 as a result of the restart of Enriched Uranium Operations that had been shut down since 1994. Waste packaging, environmental restoration programs, and decommissioning at ETTP continue with little change in total exposures from 1997. The ORNL collective TEDE decreased by 1.9% during 1998 due to the completion of the work on the Melton Valley Line Item and the transfer of Environmental Restoration work to Bechtel Jacobs Corporation in April of 1998. The ORNL neutron exposure increased 7.1% due to the continued work at the Radiochemical Engineering Development Center.
Rocky Flats		8% ▲	30% ▲	50% ▲	At Rocky Flats, the 1998 collective doses increased by 8% over the 1997 collective dose. This increase resulted from a significant ramping up of D&D activities with emphasis on completing product stabilization. Major activities included removal of buried uranium waste; draining of plutonium solution from tanks and piping; processing of plutonium salts, ash, residue and waste for long-term storage; and other plutonium D&D work. Despite processing higher dose materials, the dose per kilogram processed has decreased due to innovative and time-saving techniques. The CEDE increased 46% over 1997 due to a puncture wound to one worker.
Savannah River		<1%▲	34%▼	47%▼	The Savannah River (SR) site collective TEDE increased by less than 1% in 1998, but was about 21% below the ALARA projection for 1998 activities. Nuclear Materials Stabilization and the High Level Waste Programs contributed to nearly 80% of the collective dose. Extensive repackaging of legacy materials and direct metal casting were the primary Nuclear Materials Stabilization activities. Repair and replacement at the F and H tank farms, including construction of a new waste evaporator, jumper replacement, and hot tie-ins at the H Tank Farm, and waste removal projects around and on waste tanks were the prime dose contributors.

3.6 Transient Individuals

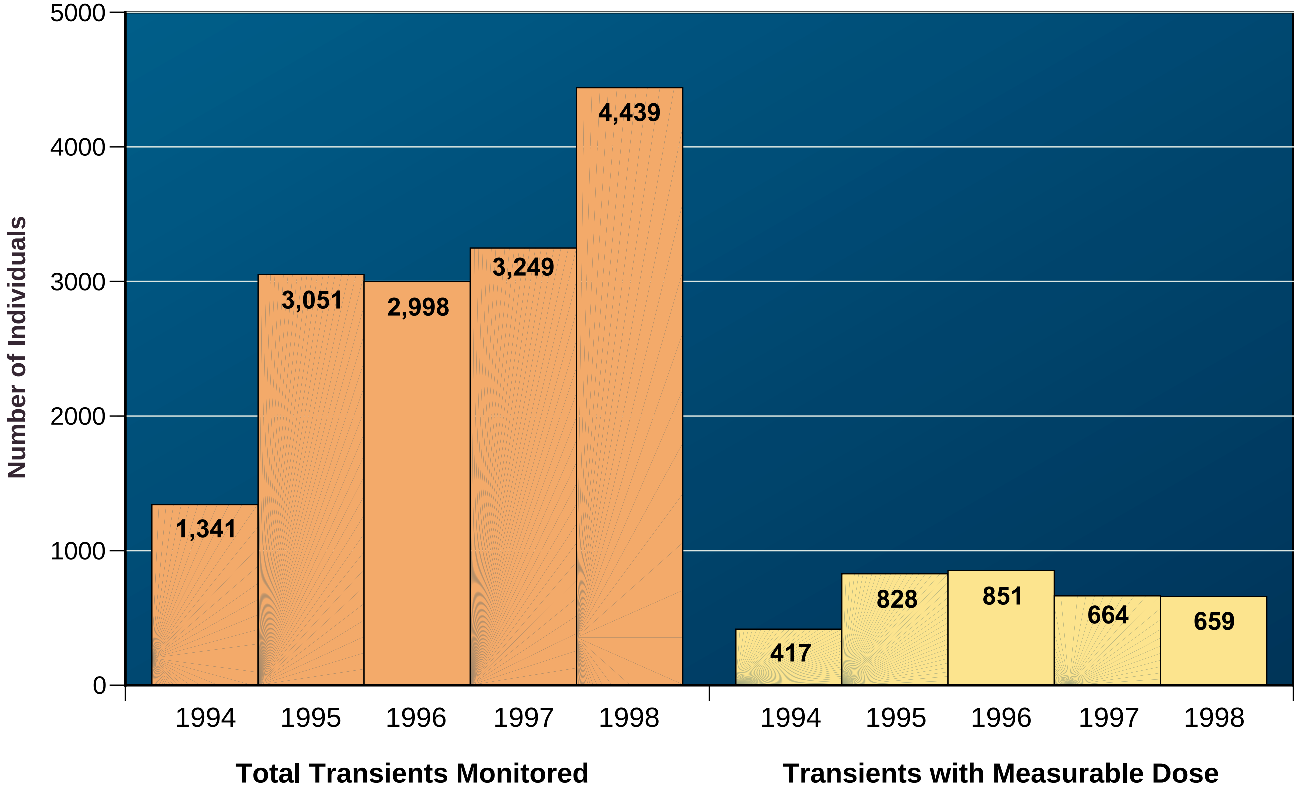
Transient individuals are defined as individuals who are monitored at more than one DOE site during the calendar year. For the purposes of this report, a DOE site is defined as a geographic location. The DOE sites are listed in Appendix A by Operations Office. During the year, some individuals perform 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 1994 to 1998. Over the past 5 years, transient individuals have accounted for 3% of the total monitored individuals at DOE and received 2% of the collective dose. As shown in *Exhibits 3-32* and *3-33*, there was a large increase in the number of transient individuals in 1995 where the number monitored, number with measurable dose, and the collective dose approximately doubled. The largest contribution of the increase in transient collective TEDE from 1994 to 1995 occurred at LANL, West Valley, and Brookhaven. In 1998, the number of transients monitored increased, but the number with measurable dose decreased slightly. The collective dose increased by 27% and the average measurable dose increased by 29%. The average measurable TEDE for transients in 1998 was 28% less than the average measurable TEDE for all monitored DOE workers. The majority of the 1998 increase in dose to transients occurred at LANL. As shown in *Exhibit 3-34,* the largest percentage of transient dose in 1998 occurred at LANL. LANL has a larger percentage of dose to transients due to the fact that workers at TA-55 (which generally receive significant doses) tend to perform temporary work at sites such as Nevada Test Site (NTS), Rocky Flats, and Pantex as part of their routine duties.

Exhibit 3-31:
Dose Distribution of Transient Workers, 1994-1998

	Dose Ranges (rem)	1994	1995	1996	1997	1998
Transients	Less than Measurable Dose	924	2,223	2,147	2,585	3,780
	Measurable < 0.1	376	744	764	606	585
	0.10 - 0.25	29	49	57	41	49
	0.25 - 0.5	9	20	21	14	14
	0.5 - 0.75	2	5	4	2	8
	0.75 - 1.0	1	3	3		2
	1.0 - 2.0		7	2	1	1
	Total Monitored	1,341	3,051	2,998	3,249	4,439
	Number with Measurable Dose	417	828	851	664	659
	% with Measurable Dose	31%	27%	28%	20%	15%
	Collective TEDE (person rem)	18.558	45.155	41.392	27.426	34.742
	Average Measurable TEDE (rem)	0.045	0.055	0.049	0.041	0.053
All DOE	Total Monitored	116,511	127,276	123,324	107,181	108,482
	Number with Meas. Dose	25,390	23,613	22,725	18,689	17,531
	% of Total Monitored who are Transient	1.2%	2.4%	2.4%	3.0%	4.1%
	% of the Number with Measurable Dose Who are Transient	1.6%	3.5%	3.7%	3.6%	3.8%

Exhibit 3-32:
Individuals Monitored at More Than One Site During the Year, 1994-1998



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 1998, this group accounts for 16% of the transient individuals and 6% of the collective dose to transients.

Over the past 5 years, only 10% 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. In 1998, 33% of the individuals monitored at three or more sites were DOE Headquarters or Field Office employees and 47% 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 eight.

Exhibit 3-33:
Collective and Average Measurable Dose to Transient Individuals, 1994-1998

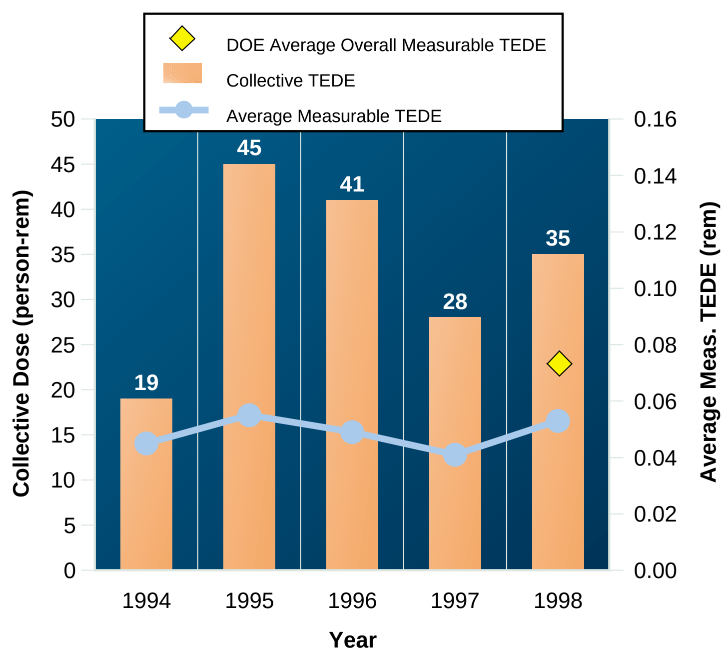
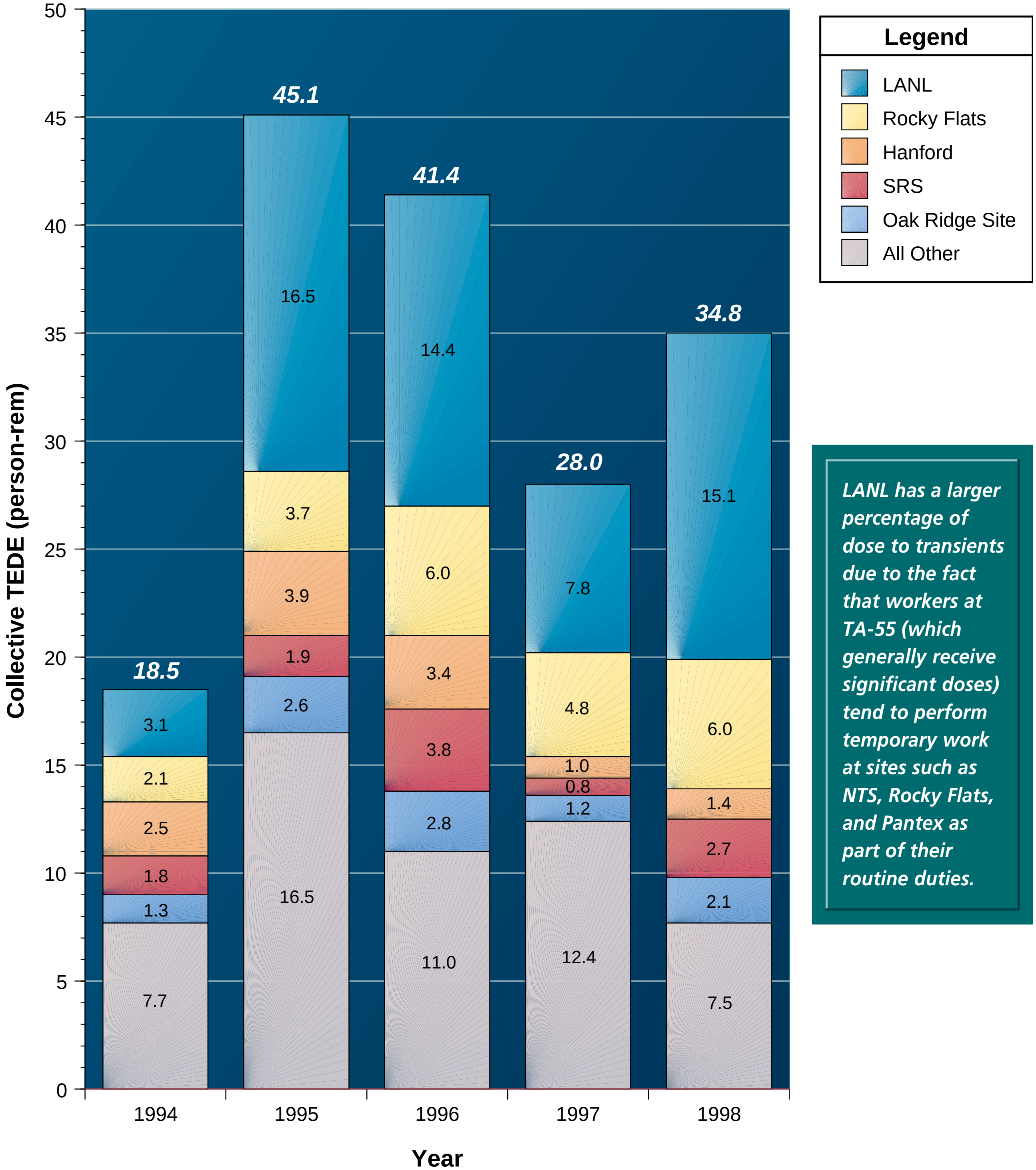


Exhibit 3-34:
Collective TEDE to Transient Workers by Site, 1994-1998



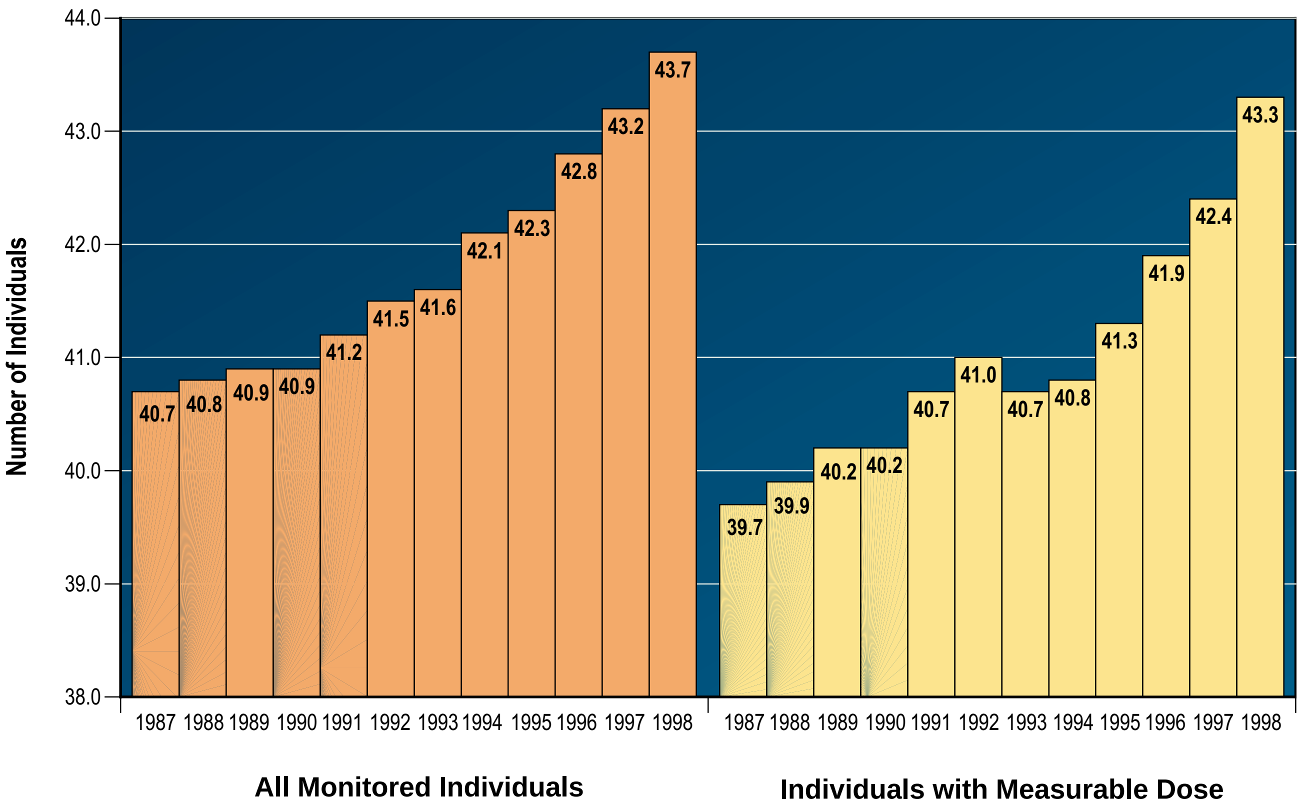
LANL has a larger percentage of dose to transients due to the fact that workers at TA-55 (which generally receive significant doses) tend to perform temporary work at sites such as NTS, Rocky Flats, and Pantex as part of their routine duties.

3.7 Age of Monitored Individuals

DOE is interested in the age of the workforce involved with radioactive materials because this workforce represents one of the special skill sets that is required to achieve DOE mission objectives. A parameter of interest in epidemiologic studies is the age of the individual at the time of the exposure to radiation. As a preliminary analysis of the age of this workforce, the average age of monitored workers was determined for the years 1987 to 1998. The first full year of the annual reporting of each monitored individual was 1987. Only individuals of known age were included in this data set. The average known age of all monitored individuals per year is shown in *Exhibit 3-35*.

The average age of monitored individuals has increased by 3 years from 40.7 to 43.7 over the past 12 years. A statistical analysis of the trend using the least squares method indicates that, if the trend continues, the average age will reach 44.1 years in 2000, and 47.7 by 2010. The increasing trend in average age since 1991 has a statistical correlation with a decrease in the number of workers receiving a measurable dose. Workers receiving a measurable dose tend to represent the number of workers actually involved in activities with radioactive materials. While this analysis is limited, it does support the supposition that the DOE workforce directly involved with radioactive material is indeed increasing in age.

Exhibit 3-35:
Average Age of Monitored Individuals per Year, 1987-1998



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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 Successful ALARA Projects

The following are descriptions of several successful ALARA projects submitted by Rocky Flats, Hanford, and Los Alamos concerning projects that reduced radiation exposure.

4.2 Innovative Shielding at a Plutonium Analytical Laboratory at the Rocky Flats Environmental Technology Center

Building 559 was opened in 1968 to conduct plutonium chemical analysis. With the cessation of production in 1989, Building 559's mission has been changed to provide analytical characterization of samples from various D&D projects at the Rocky Flats Environmental Technology Site. Some of the samples are highly contaminated, and by using careful analysis of the work process, as well as several innovative shielding techniques, the dose to the workers for each sample analyzed has been halved.

The number of samples analyzed by the Building 559 laboratory has been increasing for the past 2 years, so a yardstick was needed to measure the progress of reducing the workers' dose. Where the processes are similar, the measure in use at Rocky Flats is a dose per sample or dose per kilogram processed. This allows a comparison of ALARA techniques applied from one quarter to the next, and comparison of similar jobs from one building to the next. By the end of 1998, the above controls had reduced the Building 559 dose per sample analyzed from 1.3 mrem per sample to 0.93 mrem/sample, despite processing higher activity samples.

During the first quarter 1999, working more effectively with shielding and processing samples more efficiently has reduced the dose per sample to 0.56 mrem. The latest improvements have included flagging the high activity samples with a red self-stick tab as the sample is introduced into the glovebox, thereby alerting the technician to analyze that sample first. The tops of some shielding containers are being used by the workers as shadow shields to further protect the worker while the container is open. The tracking of each workers' daily dose by use of electronic personnel dosimeters has resulted in detecting radioactive debris on the lip of a gloveport, which had caused a spike in one worker's dose.

Some of the gloveboxes were unshielded; these were covered with leaded glass that was scavenged as waste from other D&D projects. Where possible, the 20-mil (0.20 in.) unleaded gloves were replaced with 30-mil leaded gloves with a 0.1 mm lead equivalency. However, many processes required either the dexterity of the thinner glove, or a long-arm extension that was fatiguing if performed with the leaded gloves. Workers cut the hands off of the leaded gloves, and used a portion of the gauntlet of the 30-mil leaded gloves as an inner liner to the thin glovebox glove. This arrangement provided shielding from photons streaming through the area surrounding the arms, thereby reducing the whole body dose as well as the extremity dose.

The building radiological engineer, working with laboratory technicians, designed boxes using a tin alloy to shield the radioactive samples prior to, during, and after their analysis in the glovebox. The tin alloy (92% tin, 7% antimony, 1% copper) is almost four times as effective in attenuating the low energy photons as an equivalent thickness of steel, and does not have the waste issues associated with lead. An example of this type of shielding box is shown in *Exhibit 4-1*.

For more information about this project contact Scott Staley, Building 559 Radiological Engineer at (303) 966-3349.

4.3 Fluor-Daniel Hanford Remote Radiation Mapping System Saves Time and Dose

A remote radiation mapping system using the Gammacam™ (AIL Systems Inc. Trademark) with real-time response was used in deactivating the B Plant at Hanford to produce digitized images showing actual radiation fields and dose rates. Deployment of this technology has significantly reduced labor requirements, decreased personnel exposure, and increased the accuracy of the measurements. Personnel entries into the high

Exhibit 4-1:
Easily formed tin-alloy shielding and lead-shielded inner gloves used in the Building 559 Laboratory at Rocky Flats have reduced the dose per sample handled by more than 50%.

Photo Courtesy of RFETS

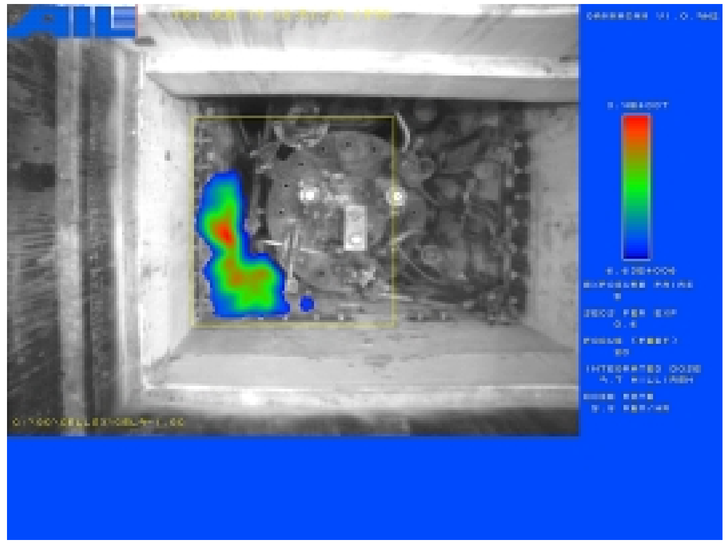
radiation/contamination areas were minimized for a dose savings of 30 person-rem (.3 person-Seivert) and a cost savings of $640K. In addition, the data gathered was utilized along with historical information to estimate the amount of remaining hazardous waste in the process cells.

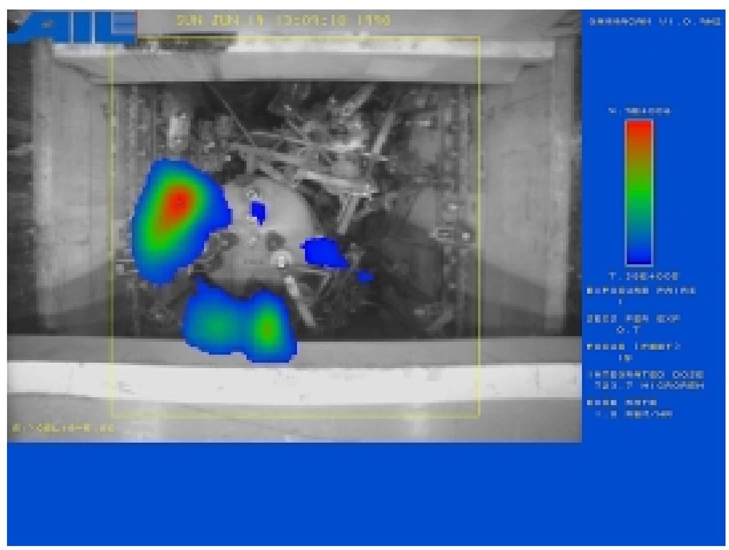
The B Plant facility is a canyon facility containing 40 process cells that were used to separate cesium and strontium from high level waste. The cells and vessels are contaminated with chemicals used in the separation and purification processes. Most of the contaminants have been removed but the residual contamination from spills in the cells and heels in the tanks contribute to the localized high radioactivity. The radiation fields are so high people can't be in close proximity to the cells.

The Gammacam™ system consists of a high-density terbium-activated scintillating glass detector coupled with a digitized video camera. Composite images generated by the system are presented in pseudo color over a black and white image as shown in *Exhibit 4-2*. Exposure times can be set from 10 milliseconds to 1 hour depending on the field intensity. The camera is enclosed in an airtight container making it retrievable. This information coupled with process knowledge is then used to document the hazardous waste remaining in each cell. Additional uses for this radiation mapping system would be in support of facilities stabilization and deactivation activities at Hanford or other DOE sites.The system is currently scheduled for installation and mapping of the U Plant in 1999. This system is unique due to its portability and its suitability for use in high dose rate areas.

For additional information about this project contact Fen M.Simmons via e-mail at Fen_M_Simmons@rl.gov.

Exhibit 4-2:
"Gammacam" Pictures Showing Areas of High Dose Rate.





4.4 Canyon Bubble Containment Unit Eliminates Exposure for Workers and Visitors at Hanford

A bubble containment unit was constructed inside of the airborne radioactivity area of the U-Plant that allows personnel to enter the canyon without wearing personal protective equipment and clothing. The bubble is a "clean" space within a highly contaminated environment that allows managers and planners safe quick access to the low radioactivity areas of the canyon. In addition to eliminating the potential for radiation exposure, cost of donning and doffing personal protective equipment, and decontamination and radioactive waste disposal, it allowed regulators, stakeholders and tribal nations to see first-hand the areas to be decommissioned and helped to expedite final decommissioning decisions.

For additional information about this project contact Brenda Panghorn, Richland Operations Office Radiological Control Manager at (509) 372-3841.

4.5 Contamination Spread by Flying Insects at Hanford

In Section 4.5 of the *1997 DOE Occupational Radiation Exposure Report*, an ALARA project was included that has since been determined to have contributed to the spread of contamination by flying insects at Hanford. As a result of using a sugar-based encapsulant to control the release of contamination from the concrete walls of a diversion pit, insects (fruit flies) were attracted to and bred in a radioactively contaminated media. Later when the flies hatched, contamination was carried from the diversion pit to other occupied areas at the Hanford site. The coating was applied in an effort to prevent contamination on the walls of the diversion pit from becoming airborne causing contamination spread and potential exposure to workers in the area. The sugar-based coating was used because it did not cause a mixed waste disposal problem. While the encapsulation technique was successful in removing airborne contamination, the sugar-based fixative led to the insect contamination. The technique continues to be used, but with a different type of fixative.

For additional information about this incident go to http://www.hanford.gov/safety/conspread/index.html.

4.6 Remote Removal of Spallation Target Water System at Los Alamos Saves Worker Dose

The Los Alamos Neutron Science Center (LANSCE) recently upgraded the short-pulse spallation source target at the Manuel Lujan, Jr. Neutron Scattering Center. During the upgrade, workers encountered a highly radioactive (160R/h) air separator unit located in an unshielded area on a water system that was not designed for remote handling (see *Exhibit 4-3*). This device would have caused unacceptable radiation doses to personnel maintaining the water system and was already causing chronic elevated doses to personnel working in the service area.

The target itself is located inside a shielded crypt and the service connections are located inside a hot cell that is on top of the crypt. The target water lines run outside the hot cell into a service area. Although the pumps and heat exchangers are located behind a shield wall, the air separator and piping run overhead and were unshielded. There are other, non-radioactive, systems located in the service area.

The air separator unit combined the functions of a dirt catcher, air separator, and air eliminator. It was located near the ceiling, at the highest point in the system, because of its air eliminator function. Functioning as a dirt catcher, the unit collected highly activated corrosion products from the tungsten targets. The target water return lines were also coated with activated corrosion products and were reading 350 to 700 mR/h.

The group responsible for remote handling and targeting (LANSCE-7) devised a plan to remove the device using a specialized remote handling operation. They used television cameras to observe the operations and two forklifts with long booms that cut the water lines and lowered the unit into a cask. They rehearsed the operation using mock ups of the activated components and performed dry runs in the target service area. Before attempting the removal operation, workers installed a local steel shield around the lower part of the unit. This reduced the contact dose rate from 160R/h to 4R/h. Workers used a portable HEPA-filtered air handling unit to control contamination during the removal operation. Workers separated the functions of the original unit by installing dirt catchers and air eliminators inside the target hot cell as shown in *Exhibit 4-4*. They placed an air eliminator at the old location near the roof of the service area. The new air eliminator now reads 13mR/h after irradiating the target.

For more information, contact J. Donahue at (505) 667-2856.

Exhibit 4-3: Old Air Separator Unit Before Removal.

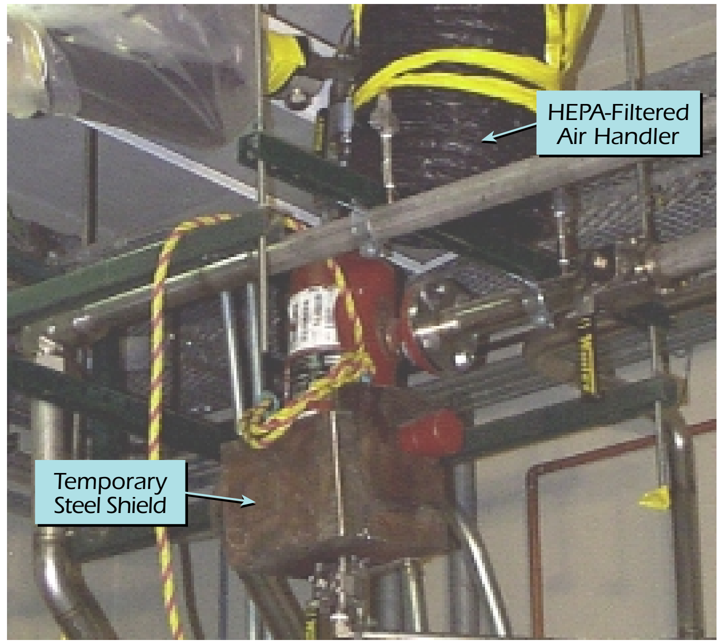


Photo Courtesy of LANL

4.7 Reduction in Neutron Dose at Brookhaven National Laboratory

Brookhaven National Laboratory continues to pursue ALARA goals through dose tracking and through selective improvements in operations. Dose tracking on specific Radiation Work Permits (RWPs) improved during 1998 such that 34% of the total 43.8 person-rem direct exposure was tracked compared to 23% of the dose in 1997.

The direct neutron dose to the staff of the Alternating Gradient Synchrotron (AGS) was reduced from 25% in 1997 to 5% in 1998 by changing the access across the switchyard shield top during Slow Extracted Beam running and reducing proton losses in the switchyard area. The use of new software that alarms if ALARA thresholds are exceeded during proton beam tuning and designating appropriate operator responses have helped reduce the direct radiation to the AGS staff. This control of losses also improves the beam efficiency as well as reducing the direct exposure.

For more information about this project, contact Steve Layendecker at (516) 344-7921.

Exhibit 4-4: New Air Separator and Dirt Catchers Inside Hot Cell.

Photo Courtesy of LANL

4.8 Submitting ALARA Success Stories for Future Annual Reports

Individual success stories should be submitted in writing to the DOE Office of Worker Protection Programs and Hazards Management. 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.

4.9 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

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 4% from 1997 to 1998 due to decreases in the collective dose at four of the seven highest dose sites. These seven sites accounted for 83% of the collective dose at DOE. Reports submitted by four of the sites that experienced decreases in the collective dose (Hanford, Los Alamos, Idaho, and Brookhaven) indicate that decreases in the collective dose were due to the shutdown of several facilities, the completion of several key projects, and to ALARA initiatives. Statistical analysis reveals that, in addition to the collective dose decreasing by 4%, the logarithmic mean dose decreased slightly from 1997 to 1998. This finding indicates that the collective dose has decreased due to a reduction in overall work involving radiation exposure as well as a reduction in dose to individuals.

The collective internal dose increased by 29% from 1997 to 1998. The increase in collective internal dose was primarily due to an increase in uranium operations at Oak Ridge, where a large number of individuals were reported with relatively small internal doses from uranium. 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. The results of this analysis show that the number of transients monitored has more than tripled over the past 5 years. However, the number of transients receiving measurable dose decreased over the past 4 years. The average measurable dose to transients has been less than the value for the overall DOE workforce for the past 5 years. Due to the significant increase in the number of these transient workers, tracking of this group will continue in subsequent years.

An analysis of the average age of monitored individuals was performed that reveals a steady increase in age of the DOE workforce over the past 12 years, particularly since 1990. The average age of individuals receiving measurable dose has increased 2.5 years since 1994.

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 1998 is shown in *Exhibit 5-1*.

Exhibit 5-1:
1998 Radiation Exposure Fact Sheet.

- The collective TEDE decreased by 4% from 1997 to 1998 due to decreases in the collective dose at four of the seven highest dose sites.
- The seven highest dose sites accounted for 83% of the collective dose at DOE in 1998.
- Decreases at four of the top seven sites were due to the shutdown of several facilities, the completion of several key projects, and to ALARA initiatives.
- Statistical analysis indicates the collective dose has decreased due to a reduction in overall work involving radiation exposure as well as a reduction in dose to individuals.
- The collective internal dose increased by 29% from 1997 to 1998 primarily due to an increase in uranium operations in Oak Ridge in support of the restart at Y-12.
- The number of transient workers monitored at DOE has more than tripled over the past 5 years, but the average measurable dose to these transients has been less than the value for the overall DOE workforce.
- The average age of monitored workers exhibits an increasing trend, and has increased by 3 years over the past 12 years.

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.

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 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, and visitors.

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

$t = \frac{\overline{y}_1 - \overline{y}_2}{S_{\overline{y}_1 - \overline{y}_2}}$ 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.

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Appendix 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.

Exhibit A-1.
Labor Categories and Occupation Codes.

Labor Category	Occupation Code (5484.1)	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, 1994-1998

The following is a listing of all organizations reporting to the DOE REMS from 1994 to 1998. 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, 1994-1998.

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'94	'95	'96	'97	'98
Albuquerque	Ops. and Other Facilities	0501001	Albuquerque Field Office	●	●	●	●	●
		0501006	Albuquerque Office Subs.		●	●		
		0502009	Albuquerque Transportation Division	●	●	●	●	●
		0530001	Kansas City Area Office		●	●	●	●
		0531002	Allied-Signal, Inc.	●	●	●	●	●
		0553002	Martin Marietta Specialty Components Inc.	●	●	●	●	
		0590001	WIPP Project Integration Office	●	●	●	●	●
		0593001	Carlsbad Area Office				●	
		0593004	Carlsbad Area Miscellaneous Contractors	●	●	●	●	●
		2806003	National Renewable Energy Lab (NREL)-GO	●	●	●	●	●
	Grand Junction	0560605	MACTEC - ERS					●
	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	●	●	●	●	●
		0515006	M&H - Amarillo - Subcontractors	●				
		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.	●	●	●	●	●
		1004031	New Brunswick Laboratory	●	●	●	●	●
		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	●	●	●	●	●
		1504506	DOE Office Subs	●				
	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			●	●	

Exhibit A-2.
Organizations Reporting to DOE REMS, 1994-1998 (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'94	'95	'96	'97	'98
Idaho	Idaho Site	3000209	Protection Technology - INEL	●				
		3000504	Chem-Nuclear Geotech	●	●	●		
		3003003	EG&G Idaho, Inc.	●				
		3003402	Babcock & Wilcox Idaho, Inc.	●		●	●	●
		3003502	Westinghouse Idaho Nuclear Co.	●				
		3004001	Idaho Field Office	●	●	●	●	●
		3004004	Idaho Office Subs	●	●	●	●	
		3005004	Lockheed Martin Idaho Tech. Co.-Services		●	●	●	●
		3005005	Lockheed Martin Idaho Tech. Co.-Construction			●	●	
		3005016	LMITCO Subcontractors - Construction				●	●
		3005024	LMITCO Subcontractor - Coleman				●	●
		3005034	LMITCO Subcontractor - Parsons				●	●
		3005505	MK-Ferguson Company - ID	●			●	
		3005506	MK-Ferguson Subcontractors - 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)	●	●	●	●	
		4005002	RMI Company	●	●	●	●	●
		4009006	Morrison-Knudsen (WSSRAP)	●	●	●	●	●
		4009503	Thomas Jefferson National Accel. Facility	●	●	●	●	●
	Oak Ridge Site	4005105	Lockheed Martin/MK-Ferguson Co.	●	●	●		
		4005505	MK-Ferguson, Oak Ridge				●	●
		4006002	Bechtel-Jacobs Co., LLC – ETTP	●	●	●	●	●
		4006007	Decontam. & Recovery Services (DRS) (K-25)					●

Exhibit A-2.
Organizations Reporting to DOE REMS, 1994-1998 (continued).

Operations/ Field Office		Organization Code	Organization Name	Year Reported *				
				'94	'95	'96	'97	'98
Oak Ridge	Oak Ridge Site	4006302	British Nuclear Fuels Limited (BNFL) (ETTP)					●
		4006503	Lockheed Martin Energy Systems (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	Rockwell International, Rocketdyne - ETEC	●	●	●	●	●
		8006103	U. of Cal./Davis, Radiobiology Lab. - LEHR	●	●	●	●	●
		8006303	U. of Cal./SF - Lab of Radiobiology	●	●	●		
	Lawrence Berkeley Lab. (LBL)	8003003	Lawrence Berkeley 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)	●	●	●	●	●
		4523706	FERMCO Subcontractors		●	●	●	●
	Mound Plant	4516002	BWX Technologies	●	●	●	●	●
		4516004	BWX Technologies - Subcontractors	●	●	●	●	●
		4516009	BWX Technologies - Security Forces	●	●	●	●	●
	West Valley Project	4530001	West Valley Area Office			●		
		4539004	West Valley Nuclear Services, Inc.	●	●	●	●	●
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	7700001	Rocky Flats Office	●	●	●	●	●
		7700006	Rocky Flats Office Subs	●				
		7700007	Rocky Flats Office Subs	●	●	●	●	●
		7707002	Rocky Flats Prime Contractors	●	●	●	●	●
		7707004	Rocky Flats Subcontractors	●	●	●	●	●
		7707005	J.A. Jones – Rocky Flats	●				
		7707006	EG&G Rocky Flats Subcontractors	●				
		7707009	EG&G Rocky Flats Security Forces	●				
		7709009	Wackenhut Services – Rocky Flats	●				
		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			●	●	●
		7505013	Babcock Wilcox Protection, Inc.			●	●	●
		7505024	Waste Mgmt. Federal Services of Hanford			●	●	●

Exhibit A-2.
Organizations Reporting to DOE REMS, 1994-1998 (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'94	'95	'96	'97	'98
Richland	Hanford Site	7505025	Waste Mgmt. Federal Svcs., Inc., 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.			●	●	
		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.

A.4 Phase of Operation

In addition to the Facility Type listing that has been reported in the past, the DOE Office of Environment, Safety and Health is interested in obtaining information on the operational status of these facilities. This information will be codified in terms of a Phase of Operation to describe the operating status of a facility. The listing that follows covers each of the phases of operation from construction to the final stage of surveillance and maintenance once a site has undergone environmental restoration.

The phase of operation will be recorded for the calendar year for which the phase of operation is most appropriate. For facilities that transition between phases during a year, the phase that is appropriate for the majority of the calendar year should be recorded. The Phase of Operation will be recorded and submitted along with the Facility Type as part of the monitored individual's dose record. Reporting format and specifications will be included in subsequent revisions to DOE M231.1-1 [12].

Each DOE facility falls into one of the Phase of Operations shown in *Exhibit A-4*. In general, each phase follows in sequential order, although a facility may forgo one or more phases or may not follow the order listed here.

This is the proposed table for the phases of operation of DOE facilities. Please submit comments, additions, or revisions to this table, to EH-52 (see Appendix E for address). If end users feel this additional supporting information will be useful to them, then DOE M231.1-1 [12] will be so modified.

Exhibit A-4.
Phase of Operation - Lifecycle for a DOE Facility.

	Code	Phase of Operation	Definition
	A	Construction (includes Major Renovation)	New facilities that are brought on line to replace or augment existing facilities. This phase includes major renovations for existing facilities but does not include environmental restoration construction.
	B	Operation/ Maintenance	Includes the operations and maintenance of the reported Facility Type.
	C	Stabilization	Facilities that have been declared to be surplus (assigned to the environment restoration program). This includes facilities where all operations have been suspended but environmental restoration activities have not begun. This may include periods of surveillance and maintenance prior to environmental restoration activities.
Environmental Restoration Phases	**D**	Remediation	Period during which corrective actions that are necessary to bring the facility into regulatory compliance are being performed.
Environmental Restoration Phases	**E**	Decontamination and Decommissioning	Decontamination is the act of removing a chemical, biological, or radiologic contaminant from, or neutralizing its potential effect on, a person, object or environment by washing, chemical action, mechanical cleaning, or other techniques. Decommissioning is the process of closing and securing a facility.
	F	Waste Management	This phase includes the management of wastes generated during the environment restoration process. (D,E)
	G	Surveillance and Maintenance	This phase includes those activities that provide for the safety and protection of a facility after the environmental restoration phase.
	Z	Other	All DOE facilities should fit into one of the above categories. "Other" should be used only in highly unusual circumstance.

Additional Data

Page

B-1a: Operations Office/Site Dose Data (1996)

Operations/ Field Office	Site	1996							
		Collective TEDE (person-rem)	Percent Change from 1995	Number with Meas. Dose	Percent Change from 1995	Avg. Meas. TEDE (rem)	Percent Change from 1995	Percentage of Collective TEDE above 0.500 rem	Percent Change from 1995
Albuquerque	Ops. and Other Facilities	3.6	126% ▲	37	-8% ▼	0.098	144% ▲	28%	28% ▲
	Los Alamos Nat'l. Lab. (LANL)	184.1	-22% ▼	1,984	-23% ▼	0.093	2% ▲	44%	-5% ▲
	Pantex Plant (PP)	28.1	-24% ▼	327	-1% ▼	0.086	-23% ▼	13%	-11% ▼
	Sandia Nat'l. Lab. (SNL)	16.7	51% ▲	485	41% ▲	0.034	7% ▲	25%	25% ▲
	Uranium Mill Tailings Remedial Action (UMTRA) Project	0.4	-67% ▼	26	-55% ▼	0.016	-27% ▼	0%	-
Chicago	Ops. and Other Facilities	13.5	106% ▲	182	35% ▲	0.074	53% ▲	4%	4% ▲
	Argonne Nat'l. Lab. - East (ANL-E)	18.5	-50% ▼	202	-32% ▼	0.092	-27% ▼	31%	-5% ▼
	Argonne Nat'l. Lab. - West (ANL-W)	43.6	16% ▲	331	-1% ▼	0.132	17% ▲	18%	8% ▲
	Brookhaven Nat'l. Lab. (BNL)	116.8	-20% ▼	1,448	49% ▲	0.081	-46% ▼	40%	7% ▼
	Fermi Nat'l. Accelerator Lab. (FERMI)	16.2	21% ▲	538	14% ▲	0.030	6% ▲	4%	4% ▲
DOE HQ	DOE Headquarters (includes DNFSB)	0.3	180% ▲	6	-25% ▼	0.044	**273%** ▲	0%	-
	North Korea Project	13.3	-	36	-	**0.370**	-	**78%**	-
Idaho	Idaho Site	164.1	-42% ▼	1,299	-13% ▼	0.126	-33% ▼	52%	-10% ▼
Nevada	Nevada Test Site (NTS)	1.0	120% ▲	19	111% ▲	0.054	4% ▲	0%	-
Oakland	Ops. and Other Facilities	0.0	-99% ▼	6	-70% ▼	0.003	-95% ▼	0%	-
	Lawrence Berkeley Lab. (LBL)	4.6	3% ▲	100	32% ▲	0.046	-21% ▼	0%	-89% ▼
	Lawrence Livermore Nat'l. Lab. (LLNL)	14.9	15% ▲	187	18% ▲	0.080	-2% ▼	24%	-47% ▼
	Stanford Linear Accelerator Center (SLAC)	19.3	-4% ▼	312	32% ▲	0.062	-28% ▼	3%	1% ▼
Oak Ridge	Ops. and Other Facilities	11.9	93% ▲	200	20% ▲	0.060	61% ▲	33%	**33%** ▲
	Oak Ridge Site	88.6	15% ▲	1,582	-12% ▼	0.056	31% ▲	21%	-114% ▲
	Paducah Gaseous Diff. Plant (PGDP)	18.6	106% ▲	290	29% ▲	0.064	60% ▲	0%	-
	Portsmouth Gaseous Diff. Plant (PORTS)	29.9	9% ▲	758	-53% ▼	0.039	133% ▲	12%	8% ▲
Ohio	Ops. and Other Facilities	0.0	0%	5	0%	0.007	0%	0%	-
	Fernald Environmental Mgmt. Project	27.4	-10% ▼	804	-16% ▼	0.034	7% ▲	6%	6% ▲
	Mound Plant	20.1	**216%** ▲	403	**130%** ▲	0.050	37% ▲	41%	-4% ▲
	West Valley Project	11.2	-59% ▼	231	-26% ▼	0.048	-44% ▼	6%	-22% ▼
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**267.6**	3% ▲	3,430	0%	0.078	3% ▲	8%	-295% ▲
Richland	Hanford Site	265.7	-9% ▼	2,761	10% ▲	0.096	-17% ▼	18%	-44% ▼
Savannah River	Savannah River Site (SRS)	251.8	-1% ▼	**4,736**	-2% ▼	0.053	1% ▲	21%	-19% ▲
Totals		**1,652.0**	**-10%** ▼	**22,725**	**-4%** ▼	**0.073**	**-7%** ▼	**25%**	**-5%** ▼

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

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

Operations/ Field Office	Site	1997 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 Nat'l. 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 Nat'l. 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 Nat'l. Lab. - East (ANL-E)	19.0	3% ▲	238	18% ▲	0.080	-13% ▼	21%	-11% ▼
	Argonne Nat'l. Lab. - West (ANL-W)	18.9	-57% ▼	249	-25% ▼	0.076	-42% ▼	3%	-15% ▼
	Brookhaven Nat'l. 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 Lab. (LBL)	5.2	13% ▲	128	28% ▲	0.041	-12% ▼	0%	-
	Lawrence Livermore Nat'l. 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-1c: Operations Office/Site Dose Data (1998)

Operations/ Field Office	Site	1998 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 Nat'l. 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 Nat'l. 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 Nat'l. Lab. - East (ANL-E)	17.7	-7% ▼	182	-24% ▼	0.097	22% ▲	22%	1% ▲
	Argonne Nat'l. Lab. - West (ANL-W)	21.7	15% ▲	236	-5% ▼	0.092	21% ▲	5%	2% ▲
	Brookhaven Nat'l. 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% ▼	**0.388**	13% ▲	64%	-7% ▼
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 Lab. (LBL)	2.9	-45% ▼	76	-41% ▼	0.038	-7% ▼	0%	-
	Lawrence Livermore Nat'l. 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	**400%** ▲	0.016	-80% ▼	0%	-
Ohio	Ops. and Other Facilities	24.1	**1,951%** ▲	78	152% ▲	0.310	**715%** ▲	**68%**	**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)	**348.1**	8% ▲	**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		**1,302.7**	**-4%** ▼	**17,531**	**-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-2: Internal Dose by Operations/Site, 1996 - 1998

Operations/ Field Office	Site	No. of Individuals with New Intakes*			Collective CEDE Dose from Intake (person-rem)			Average CEDE (rem)		
		1996	1997	1998	1996	1997	1998	1996	1997	1998
Albuquerque	Ops. and Facilities	9	6	-	0.085	0.085	-	0.009	0.014	-
	LANL	90	76	80	5.287	10.481	2.781	0.059	0.138	0.035
	Pantex	7	3	4	0.016	0.003	0.004	0.002	0.001	0.001
	Grand Junction	-	-	280	-	-	33.840	-	-	0.121
Chicago	Ops. and Other Facilities	91	51	20	0.474	0.126	0.240	0.005	0.002	0.012
	ANL-E	13	12	43	0.301	0.322	1.150	0.023	0.027	0.027
	ANL-W	-	1	1	-	0.070	0.070	-	0.070	0.070
	BNL	72	66	58	2.962	2.282	0.623	0.041	0.035	0.011
Idaho	Idaho Site	17	276	1	3.729	**27.928** ◀	0.016	0.219	0.101	0.016
Nevada	NTS	-	4	8	-	0.473	0.383	-	0.118	0.048
Oakland	LBL	2	9	6	0.112	0.238	0.310	0.056	0.026	0.052
	LLNL	6	14	6	0.013	4.055	0.041	0.002	**0.290** ◀	0.007
Oak Ridge	Ops. and Other Facilities	27	47	33	6.802	4.185	0.301	**0.252** ◀	0.089	0.009
	Oak Ridge Site	399	**700** ◀	**1,281** ◀	4.661	8.234	**35.263** ◀	0.012	0.012	0.028
	Paducah	40	1	1	0.651	0.023	0.012	0.016	0.023	0.012
	Portsmouth	112	2	-	8.628	0.003	-	0.077	0.002	-
Ohio	OH		1	29	-	0.004	0.062	-	0.004	0.002
	Fernald	65	24	18	1.050	0.231	0.083	0.016	0.010	0.005
	Mound Plant	72	103	97	0.355	0.543	0.965	0.005	0.005	0.010
	WVNS	-	1	-	-	0.049	-	-	0.049	-
Rocky Flats	Rocky Flats	27	43	31	1.736	2.748	3.986	0.064	0.064	0.129
Richland	Hanford Site	22	7	11	0.822	0.446	1.792	0.037	0.064	**0.163** ◀
Savannah River	Savannah River Site	**528** ◀	467	457	**15.840** ◀	2.826	2.285	0.030	0.006	0.005
Totals		**1,599**	**1,914**	**2,465**	**53.524**	**65.355**	**84.207**	**0.033**	**0.034**	**0.034**

Facilities with no new intakes reported during the past 3 years: Sandia, 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.

In 1998 Grand Junction reported internal dose as an individual facility – in 1997 they reported through Idaho. The Idaho internal dose dropped in 1998 as a result.

B-3: Neutron Dose Distribution by Operations/Site, 1998

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	714	3	-	-	-	-	-	-	717	3	0%	0.080	0.027
	Grand Junction	304	3	-	-	-	-	-	-	307	3	1%	0.186	0.062
	Los Alamos National Lab. (LANL)	9,548	1,388	139	60	16	2	6	-	11,159	**1,611** ◀	14%	87.818	0.055
	Pantex Plant (PP)	5,764	70	5	-	-	-	-	-	5,839	75	1%	2.994	0.040
	Sandia National Lab. (SNL)	3,453	9	-	-	-	-	-	-	3,462	9	0%	0.147	0.016
Chicago	Chicago Operations	520	-	-	-	-	-	-	-	520	-	0%	-	-
	Argonne Nat'l. Lab. - East (ANL-E)	2,876	51	11	-	-	-	-	-	2,938	62	2%	2.805	0.045
	Argonne Nat'l. Lab. - West (ANL-W)	855	7	3	-	-	-	-	-	865	10	1%	0.657	0.066
	Brookhaven Nat'l. Lab. (BNL)	5,167	417	10	2	-	-	-	-	5,596	429	8%	7.373	0.017
	Fermi Nat'l. Accelerator Lab. (FERMI)	2,066	-	-	-	-	-	-	-	2,066	-	0%	-	-
DOE HQ	DOE Headquarters	2	2	-	-	-	-	-	-	4	2	**50%** ◀	0.028	0.014
	North Korea Project	24	-	-	-	-	-	-	-	24	-	0%	-	-
Idaho	Idaho Site	5,030	44	1	-	-	-	-	-	5,075	45	1%	1.739	0.039
Nevada	Nevada Test Site (NTS)	4,891	2	-	-	-	-	-	-	4,893	2	0%	0.055	0.028
Oakland	Oakland Operations	282	-	-	-	-	-	-	-	282	-	0%	-	-
	Lawrence Berkeley Lab.(LBL)	1,954	38	-	-	-	-	-	-	1,992	38	2%	1.194	0.031
	Lawrence Livermore Nat'l. Lab. (LLNL)	7,682	32	4	-	-	-	-	-	7,718	36	0%	1.648	0.046
	Stanford Linear Accelerator Center (SLAC)	2,282	-	1	-	-	-	-	-	2,283	1	0%	0.122	**0.122** ◀
Oak Ridge	Oak Ridge Operations	2,559	-	-	-	-	-	-	-	2,559	-	0%	-	-
	Oak Ridge Site	14,768	84	25	7	7	-	2	-	**14,893** ◀	125	1%	15.080	0.121
	Paducah Gaseous Diff. Plant (PGDP)	508	16	6	-	-	-	-	-	530	22	4%	1.691	0.077
	Portsmouth Gaseous Diff. Plant (PORTS)	176	-	-	-	-	-	-	-	176	-	0%	-	-
Ohio	Ohio Field Office	468	-	-	-	-	-	-	-	468	-	0%	-	-
	Fernald Environmental Mgmt. Project	4,338	-	-	-	-	-	-	-	4,338	-	0%	-	-
	Mound Plant	925	3	-	-	-	-	-	-	928	3	0%	0.043	0.014
	West Valley	1,115	-	-	-	-	-	-	-	1,115	-	0%	-	-
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	5,212	767	266	64	9	-	-	-	6,318	1,106	18%	**99.631** ◀	0.090
Richland	Hanford Site	10,192	210	30	5	2	2	-	-	10,441	249	2%	15.646	0.063
Savannah	Savannah River Site (SRS)	10,297	534	128	17	-	-	-	-	10,976	679	6%	44.141	0.065
	Totals	**103,972**	**3,680**	**629**	**155**	**34**	**4**	**8**	**0**	**108,482**	**4,510**	**4%**	**283.078**	**0.063**

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

Plutonium packaging and processing at Rocky Flats accounted for the largest collective neutron dose in 1998.

B-4: Distribution of Deep Dose Equivalent (DDE) and Total Effective Dose Equivalent (TEDE), 1974-1998

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

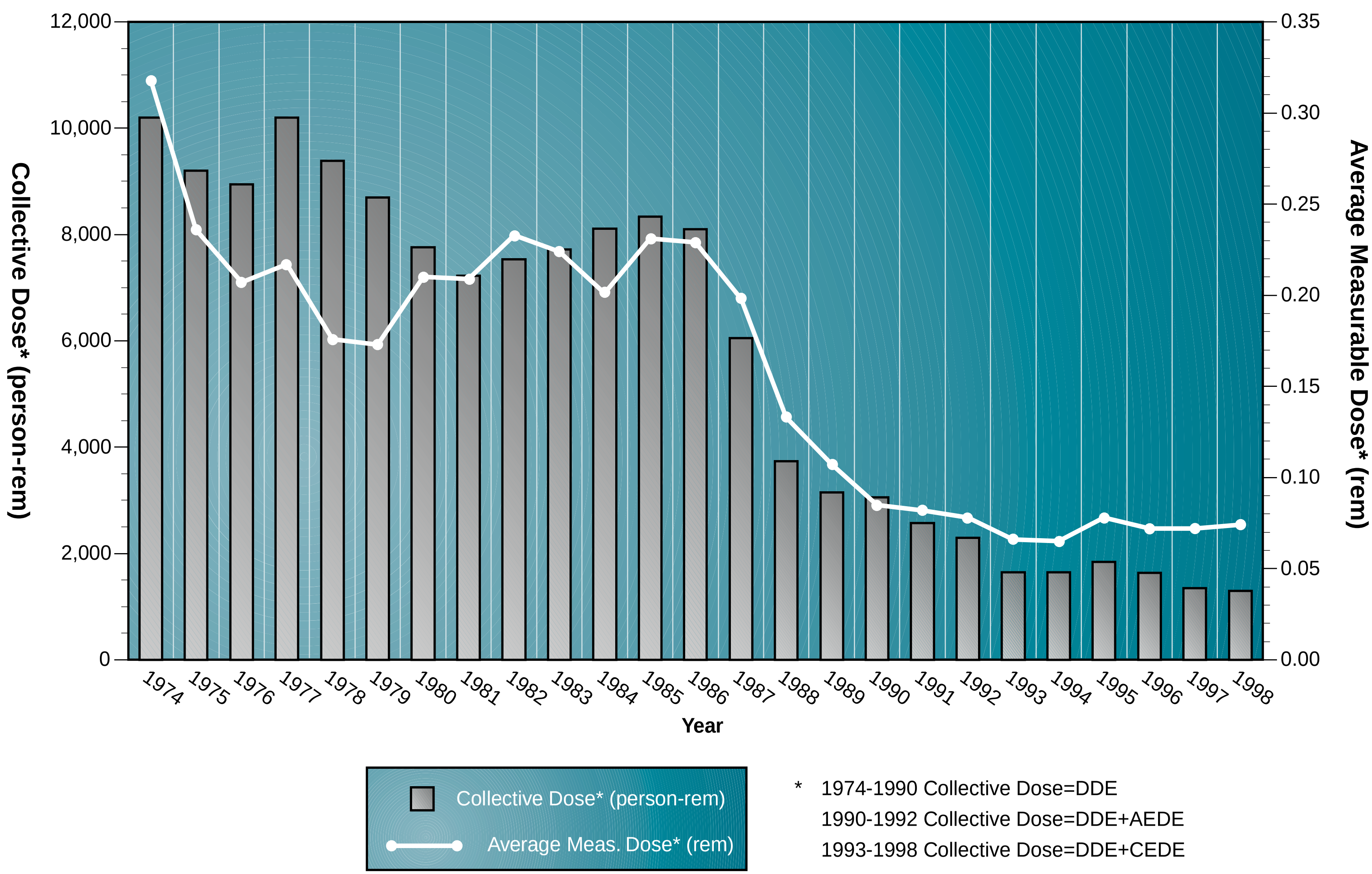
Total Effective Dose Equivalent (TEDE)*

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

* 1990-1992 TEDE=DDE+AEDE 1993-1998 TEDE=DDE+CEDE Note: Arrowed values indicate the greatest value in each column.

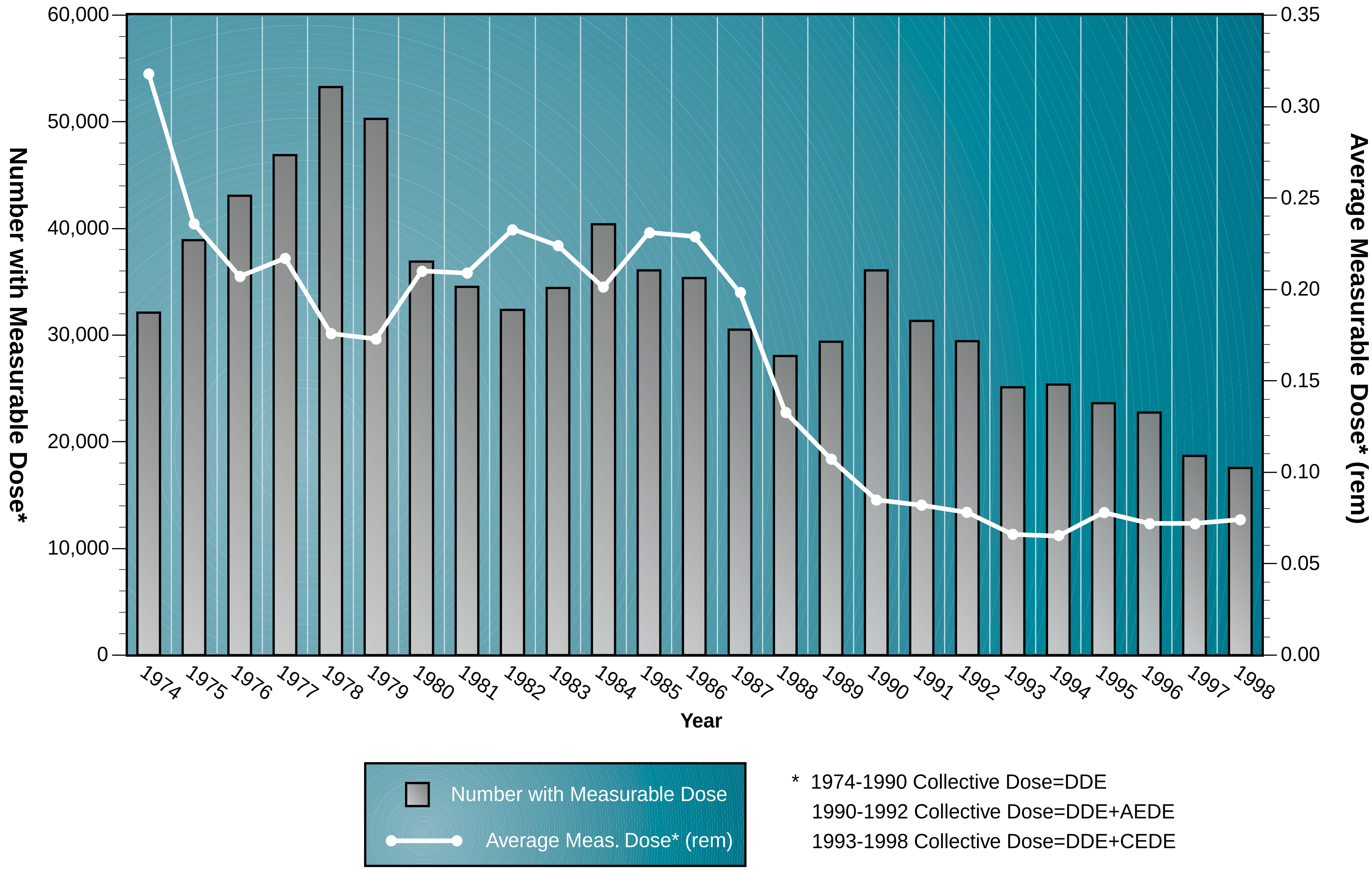
During 1998 only one person received a TEDE greater than 2 rem. It was the result of internal plutonium at Rocky Flats.

B-5: Collective TEDE and Average Measurable Dose 1974-1998



* 1974-1990 Collective Dose=DDE
1990-1992 Collective Dose=DDE+AEDE
1993-1998 Collective Dose=DDE+CEDE

B-6: Number with Measurable Dose and Average Measurable Dose 1974-1998



* 1974-1990 Collective Dose=DDE
1990-1992 Collective Dose=DDE+AEDE
1993-1998 Collective Dose=DDE+CEDE

B-7a: Distribution of TEDE by Facility Type - 1996

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	8,948	1,998	217	65	40	20	5					11,293	21%	2,345	152.025	0.065
Fuel/Uran. Enrich.	8,400	817	67	20	1	2	1					9,308	10%	908	38.301	0.042
Fuel Fabrication	2,300	815	32	14	3							3,164	27%	864	28.970	0.034
Fuel Processing	2,634	1,163	177	96	36	13	12				1	4,132	36%	1,498	151.224	**0.101◄**
Maint. and Support	14,226	2,388	304	148	30	7	9					17,112	17%	2,886	195.230	0.068
Other	21,665	2,173	179	82	49	13	17	1				**24,179◄**	10%	2,514	168.074	0.067
Reactor	1,437	768	85	47	10	2						2,349	**39%◄**	912	56.119	0.062
Research, General	17,866	2,390	382	199	73	20	29	1	1			20,961	15%	3,095	295.711	0.096
Research, Fusion	656	133	19	7	2	2						819	20%	163	11.366	0.070
Waste Proc./Mgmt.	7,016	2,031	278	96	14	2	1					9,438	26%	2,422	142.080	0.059
Weapons Fab. & Test	15,451	4,083	701	229	81	18	6					20,569	25%	**5,118◄**	**412.830◄**	0.081
Totals	**100,599**	**18,759**	**2,441**	**1,003**	**339**	**99**	**80**	**2**	**1**	**0**	**1**	**123,324**	**18%**	**22,725**	**1,651.930**	**0.073**

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

B-7b: 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-7c: 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. 0-0.10	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	9.953	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	52.585	0.045
Maint. and Support	11,272	1,344	224	100	46	9	5					13,000	13%	1,728	147.316	0.085
Other	19,231	1,846	285	100	37	8	8					21,515	11%	2,284	164.209	0.072
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** ◄	**474.990** ◄	**0.090** ◄
Totals	**90,951**	**14,053**	**2,253**	**841**	**268**	**74**	**41**	**1**	**0**	**0**	**0**	**108,482**	**16%**	**17,531**	**1,302.652**	**0.074**

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

Weapons Fabrication and Testing remains the facility type with the highest collective dose, highest average dose, and number of individuals with measurable dose. This year they were also the highest average measurable TEDE; up slightly from last year. 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-8a: Collective TEDE by Facility Type, 1996

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	0.5	3.1	**3.7**
	Los Alamos National Lab. (LANL)	15.9				55.7	0.1	**100.4◄**	0.3	2.4	0.0	9.3	**184.1**
	Pantex Plant (PP)										28.1	0.0	**28.1**
	Sandia National Lab. (SNL)	0.7				0.6	5.4	4.5	0.1	0.6	4.2	0.6	**16.7**
	UMTRA											0.4	**0.4**
Chicago	Ops. and Other Facilities					7.1		0.3	**6.0◄**			0.1	**13.5**
	Argonne Nat'l. Lab. - East (ANL-E)	7.5				0.4		8.4		1.5		0.7	**18.5**
	Argonne Nat'l. Lab. - West (ANL-W)			0.5		1.0	5.7	36.3				0.0	**43.5**
	Brookhaven Nat'l. Lab. (BNL)	**87.0◄**				6.0	9.8	7.2		1.3		5.5	**116.8**
	Fermi Nat'l. Accelerator Lab. (FERMI)	16.2											**16.2**
DOE HQ	DOE Headquarters					0.0						0.3	**0.3**
	North Korea											13.3	**13.3**
Idaho	Idaho Site				**78.6◄**	6.1	**15.5◄**	9.0		6.0		**49.0◄**	**164.2**
Nevada	Nevada Test Site (NTS)										1.0		**1.0**
Oakland	Ops. and Other Facilities											0.0	**0.0**
	Lawrence Berkeley Lab.(LBL)	2.4						2.2					**4.6**
	Lawrence Livermore Nat'l. Lab. (LLNL)	0.0	2.3			1.6		1.2	4.9	0.0	1.9	3.0	**14.9**
	Stanford Linear Accelerator Center (SLAC)	19.3											**19.3**
Oak Ridge	Ops. and Other Facilities	2.9						0.4		7.8		0.9	**12.0**
	Oak Ridge Site		1.1					60.1			10.9	16.5	**88.6**
	Paducah Gaseous Diff. Plant (PGDP)		5.0									13.5	**18.5**
	Portsmouth Gaseous Diff. Plant (PORTS)		**29.9◄**										**29.9**
Ohio	Ops. and Other Facilities					0.0							**0.0**
	Fernald Environmental Mgmt. Project			**27.4◄**									**27.4**
	Mound Plant					6.7					11.7	1.7	**20.1**
	West Valley											11.2	**11.2**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**265.7◄**	2.0	**267.7◄**
Richland	Hanford Site			0.3	5.5	**94.0◄**	13.0	45.0		**74.6◄**		33.4	**265.8**
Savannah River	Savannah River Site (SRS)			0.8	67.1	15.7	6.9	20.8		47.8	89.0	3.7	**251.8**
	Totals	**151.9**	**38.3**	**29.0**	**151.2**	**194.9**	**56.4**	**295.8**	**11.3**	**142.1**	**413.0◄**	**168.2**	**1,651.9**

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

B-8b: 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 Lab.(LBL)	1.7						3.6					**5.3**
	Lawrence Livermore Nat'l. 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-8c: 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	**161.8**
	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	**1.3**
	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**
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 Lab. (LBL)	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	**348.0◄**
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	**165.6**
	Totals	**94.7**	**10.0**	**14.2**	**52.6**	**147.3**	**31.5**	**196.4**	**5.3**	**111.4**	**475.0**	**164.3**	**1,302.7**

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

Because of increasing clean up activities collective TEDE increased at Rocky Flats in the weapons category. Weapons dismantling at Pantex and restart of high-enriched activities at Oak Ridge also caused increases in weapons activities exposure. Other facilities conducting weapons activities experienced decreases in doses.

B-9: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Accelerator Facilities, 1998

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
AL	Los Alamos National Laboratory	530	139	14	15	3	2	2	-	705	25%	175	15.209	**0.087◄**	**36%◄**
OAK	Stanford Linear Accelerator Center	2,126	126	19	12	-	-	-	-	2,283	7%	157	13.137	0.084	0%
CH	Argonne National Laboratory - East	547	55	18	3	-	-	-	-	623	12%	76	5.415	0.071	0%
CH	Brookhaven National Laboratory	2,427	569	66	41	14	4	-	-	**3,121◄**	22%	**694◄**	**45.860◄**	0.066	26%
OAK	Lawrence Berkeley Laboratory	496	25	-	-	-	-	-	-	521	5%	25	1.110	0.044	0%
AL	Sandia National Laboratory	280	4	-	-	-	-	-	-	284	1%	4	0.123	0.031	0%
CH	Fermilab	1,625	421	15	5	-	-	-	-	2,066	21%	441	12.790	0.029	0%
OR	Thomas Jefferson Nat'l. Accel. Facil.	1,464	42	1	-	-	-	-	-	1,507	3%	43	1.039	0.024	0%
AL	Johnson Controls, Inc.	2	2	-	-	-	-	-	-	4	**50%◄**	2	0.048	0.024	0%
OAK	Lawrence Livermore National Lab.	239	1	-	-	-	-	-	-	240	0%	1	0.013	0.013	0%
NV	Bechtel Nevada–NTS Subcontractors	2	-	-	-	-	-	-	-	2	0%	-	-	-	0%
NV	Bechtel Nevada–Amador Valley	8	-	-	-	-	-	-	-	8	0%	-	-	–	0%
NV	Bechtel Nevada–Special Tech. Lab.	29	-	-	-	-	-	-	-	29	0%	-	-	-	0%
NV	Defense Nuclear Agency-Kirtland AFB	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
NV	EG&G Santa Barbara	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
OR	Oak Ridge Field Office	6	-	-	-	-	-	-	-	6	0%	-	-	-	0%
RL	Battelle Memorial Institute (PNL)	3	-	-	-	-	-	-	-	3	0%	-	-	-	0%
	Totals	**9,786**	**1,384**	**133**	**76**	**17**	**6**	**2**	**0**	**11,404**	**14%**	**1,618**	**94.744**	**0.059**	**18%**

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

The collective TEDE has dropped 17% from 1997 with each individual reporting site, except for BNL, showing a collective reduction in TEDE. Overall, fewer people were exposed comprising a lower percentage of the workforce, however, the average dose per person increased by 23% over 1997.

B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 1998

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	462	49	12	7	-	-	-	-	530	**13% ◄**	68	**5.272 ◄**	**0.078 ◄**	0%
OAK	Lawrence Livermore National Lab.	654	6	2	-	-	-	-	-	662	1%	8	0.475	0.059	0%
OR	Bechtel-Jacobs Co., LLC – ETTP	1,660	110	9	1	-	-	-	-	**1,780 ◄**	7%	**120 ◄**	3.668	0.031	0%
OR	Bechtel-Jacobs Co., LLC – Portsmouth	161	15	-	-	-	-	-	-	176	9%	15	0.241	0.016	0%
CH	Chicago Field Office	77	4	-	-	-	-	-	-	81	5%	4	0.052	0.013	0%
OR	British Nuclear Fuels Limited (BNFL) (ETTP)	460	41	-	-	-	-	-	-	501	8%	41	0.245	0.006	0%
	Totals	**3,474**	**225**	**23**	**8**	**0**	**0**	**0**	**0**	**3,730**	**7%**	**256**	**9.953**	**0.039**	**0%**
FABRICATION															
SR	Westinghouse S.R. Subcontractors	17	5	1	-	-	-	-	-	23	26%	6	0.282	**0.047 ◄**	0%
RL	Fluor Daniel – Hanford	-	3	-	-	-	-	-	-	3	**100% ◄**	3	0.134	0.045	0%
CH	Argonne National Laboratory – West	24	5	-	-	-	-	-	-	29	17%	5	0.201	0.040	0%
OH	FERMCO	2,940	398	28	-	-	-	-	-	**3,366 ◄**	13%	**426 ◄**	**11.033 ◄**	0.026	0%
OH	FERMCO Subcontractors	772	130	1	-	-	-	-	-	903	15%	131	2.287	0.017	0%
SR	Westinghouse Savannah River Co.	205	17	1	-	-	-	-	-	223	8%	18	0.281	0.016	0%
RL	Babcock Wilcox Hanford	1	1	-	-	-	-	-	-	2	50%	1	0.013	0.013	0%
OH	Fernald Office Service Subcontractors	16	1	-	-	-	-	-	-	17	6%	1	0.009	0.009	0%
OH	Fernald Area Office	51	1	-	-	-	-	-	-	52	2%	1	0.007	0.007	0%
SR	Savannah River Field Office	2	1	-	-	-	-	-	-	3	33%	1	0.005	0.005	0%
RL	Duke Engineering Services Hanford	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	DynCorp Hanford	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	Lockheed Martin Hanford	2	-	-	-	-	-	-	-	2	0%	-	-	-	0%
SR	Bechtel Construction – SR	5	-	-	-	-	-	-	-	5	0%	-	-	-	0%
	Totals	**4,037**	**562**	**31**	**0**	**0**	**0**	**0**	**0**	**4,630**	**13%**	**593**	**14.252**	**0.024**	**0%**

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

During 1998 a greater number of DOE employees reported doses in the uranium enrichment category primarily because of the D&D operations by BNFL at Oak Ridge. The average TEDE per person was reduced. Most of the doses reported are related to environmental remediation of D&D activities by BNFL at ETTP. Fuel fabrication activities continue to be dominated by Fernald activities which although the number of people has increased by 38% over 1997, their collective dose was reduced by 27.5% in 1998.

B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 1998 (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	Fluor Daniel – Hanford	3	3	6	1	-	-	-	-	13	**77%◄**	10	1.449	**0.145◄**	0%
ID	LMITCO – Services	1,065	191	40	21	-	1	-	-	1,318	19%	253	21.787	0.086	**4%◄**
ID	LMITCO Subcontractors – Construction	27	2	1	-	-	-	-	-	30	10%	3	0.228	0.076	0%
SR	Bechtel Construction – SR	153	87	10	2	-	-	-	-	252	39%	99	4.401	0.044	0%
SR	Wackenhut Services, Inc., – SR	100	18	-	-	-	-	-	-	118	15%	18	0.572	0.032	0%
SR	Westinghouse Savannah River Co.	1,341	705	41	3	1	-	-	-	**2,091◄**	36%	**750◄**	**23.703◄**	0.032	3%
RL	Duke Engineering Services Hanford	8	1	-	-	-	-	-	-	9	11%	1	0.026	0.026	0%
OR	RMI Company	16	3	-	-	-	-	-	-	19	16%	3	0.062	0.021	0%
SR	Westinghouse S.R. Subcontractors	83	25	-	-	-	-	-	-	108	23%	25	0.288	0.012	0%
SR	Savannah River Field Office	34	9	-	-	-	-	-	-	43	21%	9	0.067	0.007	0%
SR	Miscellaneous DOE Contractors – SR	6	1	-	-	-	-	-	-	7	14%	1	0.002	0.002	0%
ID	Idaho Field Office	16	-	-	-	-	-	-	-	16	0%	-	-	-	0%
ID	LMITCO Subcontractor – Coleman	36	-	-	-	-	-	-	-	36	0%	-	-	-	0%
RL	Babcock Wilcox Hanford	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
	Totals	**2,889**	**1,045**	**98**	**27**	**1**	**1**	**0**	**0**	**4,061**	**29%**	**1,172**	**52.585**	**0.045**	**3%**

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

Although the total number (-3.5%) and the collective dose (-22%) dropped during 1998, Lockheed Martin (Idaho) and Westinghouse (Savannah River) continue to have the majority of people involved in fuel processing activities (84%) and collective TEDE (87%). The average dose per person has decreased (-15%) and the number of people exposed to more than 0.5 rem has decreased 17% from 1997 to 1998 almost all of which was from Lockheed Martin Idaho.

B-11: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 1998

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	316	23	11	14	28	-	-	-	-	-	392	19%	76	24.122	**0.317 ◄**	**68% ◄**
AL	Los Alamos National Laboratory	939	242	33	20	9	6	5	-	-	-	1,254	25%	315	35.816	0.114	51%
RL	Fluor Daniel - Hanford	897	249	91	44	4	2	-	-	-	-	1,287	30%	**390 ◄**	**42.767 ◄**	0.110	9%
OH	BWX Technologies, Inc.	15	1	-	-	-	-	-	-	-	-	16	6%	1	0.089	0.089	0%
OAK	LLNL Security	231	1	-	-	-	-	-	-	-	-	232	0%	1	0.080	0.080	0%
RL	Fluor Daniel Northwest Services	132	79	19	7	-	-	-	-	-	-	237	44%	105	7.946	0.076	0%
AL	Johnson Controls, Inc.	1,077	147	40	6	2	-	-	-	-	-	1,272	15%	195	12.669	0.065	9%
CH	Argonne National Laboratory - East	352	3	-	-	-	-	-	-	-	-	355	1%	3	0.185	0.062	0%
RL	Babcock Wilcox Hanford	209	29	1	1	-	1	-	-	-	-	241	13%	32	1.829	0.057	44%
RL	Babcock Wilcox Protection, Inc.	73	5	-	1	-	-	-	-	-	-	79	8%	6	0.342	0.057	0%
SR	Savannah River Field Office	8	1	-	-	-	-	-	-	-	-	9	11%	1	0.051	0.051	0%
RL	Lockheed Martin Services, Inc.	47	3	-	-	-	-	-	-	-	-	50	6%	3	0.149	0.050	0%
CH	Brookhaven National Laboratory	899	89	6	4	1	-	-	-	-	-	999	10%	100	4.846	0.048	11%
CH	Argonne National Laboratory - West	28	11	-	-	-	-	-	-	-	-	39	28%	11	0.478	0.043	0%
ID	LMITCO - Services	760	98	5	-	2	-	-	-	-	-	865	12%	105	4.297	0.041	28%
OAK	Lawrence Livermore National Lab.	1,646	7	-	-	-	-	-	-	-	-	**1,653 ◄**	0%	7	0.286	0.041	0%
SR	Bechtel Construction - SR	171	44	2	2	-	-	-	-	-	-	219	22%	48	1.823	0.038	0%
RL	SGN Eurisys Services Corp.	14	2	-	-	-	-	-	-	-	-	16	13%	2	0.072	0.036	0%
SR	Westinghouse Savannah River Co.	649	162	15	1	-	-	-	-	-	-	827	22%	178	6.260	0.035	0%
RL	Lockheed Martin Hanford	192	13	-	-	-	-	-	-	-	-	205	6%	13	0.446	0.034	0%
SR	Miscellaneous DOE Contractors-SR	7	3	-	-	-	-	-	-	-	-	10	30%	3	0.099	0.033	0%
RL	Waste Mgmt. Federal Services of Hanford, Inc.	248	13	-	-	-	-	-	-	-	-	261	5%	13	0.402	0.031	0%
RL	Duke Engineering Services Hanford	117	10	-	-	-	-	-	-	-	-	127	8%	10	0.289	0.029	0%
RL	Waste Mgmt. Federal Services, Inc., Northwest	26	8	-	-	-	-	-	-	-	-	34	24%	8	0.208	0.026	0%
RL	NUMATEC Hanford	32	2	-	-	-	-	-	-	-	-	34	6%	2	0.050	0.025	0%
SR	Westinghouse S.R. Subcontractors	113	14	1	-	-	-	-	-	-	-	128	12%	15	0.372	0.025	0%

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

B-11: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 1998 (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
AL	Sandia National Laboratory	520	9	-	-	-	-	-	-	-	-	529	2%	9	0.221	0.025	0%
RL	DynCorp Hanford	94	4	-	-	-	-	-	-	-	-	98	4%	4	0.080	0.020	0%
RL	Bechtel Power Company	22	1	-	-	-	-	-	-	-	-	23	4%	1	0.018	0.018	0%
RL	Fluor Daniel Northwest	178	36	-	-	-	-	-	-	-	-	214	17%	36	0.612	0.017	0%
AL	Los Alamos Area Office	25	3	-	-	-	-	-	-	-	-	28	11%	3	0.049	0.016	0%
SR	Wackenhut Services, Inc. - SR	15	3	-	-	-	-	-	-	-	-	18	17%	3	0.046	0.015	0%
OAK	LLNL Subcontractors	461	2	-	-	-	-	-	-	-	-	463	0%	2	0.029	0.015	0%
ID	LMITCO Subcontractor - Coleman	26	1	-	-	-	-	-	-	-	-	27	4%	1	0.013	0.013	0%
RL	Richland Field Office	18	1	-	-	-	-	-	-	-	-	19	5%	1	0.012	0.012	0%
AL	Protection Technologies Los Alamos	331	21	-	-	-	-	-	-	-	-	352	6%	21	0.238	0.011	0%
ID	Idaho Field Office	12	1	-	-	-	-	-	-	-	-	13	8%	1	0.010	0.010	0%
DOE	DOE Headquarters	-	1	-	-	-	-	-	-	-	-	1	**100%◄**	1	0.007	0.007	0%
SR	Univ. of Georgia Ecology Lab.	7	1	-	-	-	-	-	-	-	-	8	13%	1	0.006	0.006	0%
OH	BWX Technologies, Inc.–Subcontractors	20	1	-	-	-	-	-	-	-	-	21	5%	1	0.002	0.002	0%
NV	Computer Sciences Corp.	15	-	-	-	-	-	-	-	-	-	15	0%	-	-		0%
NV	Nevada Miscellaneous Contractors	4	-	-	-	-	-	-	-	-	-	4	0%	-	-	-	0%
NV	Nye County Sheriff	6	-	-	-	-	-	-	-	-	-	6	0%	-	-	-	0%
NV	Wackenhut Services, Inc. – NV	280	-	-	-	-	-	-	-	-	-	280	0%	-	-	-	0%
OH	Miamisburg Area Office	4	-	-	-	-	-	-	-	-	-	4	0%	-	-	-	0%
OH	Miamisburg Office Subs	3	-	-	-	-	-	-	-	-	-	3	0%	-	-	-	0%
OH	Ohio Field Office	1	-	-	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	Battelle Memorial Institute (PNL)	19	-	-	-	-	-	-	-	-	-	19	0%	-	-	-	0%
RL	Duke Eng. & Serv. Northwest, Inc.	6	-	-	-	-	-	-	-	-	-	6	0%	-	-	-	0%
RL	Westinghouse Hanford Service Subs	6	-	-	-	-	-	-	-	-	-	6	0%	-	-	-	0%
	Totals	**11,271**	**1,344**	**224**	**100**	**46**	**9**	**5**	**0**	**0**	**0**	**12,999**	**13%**	**1,728**	**147.316**	**0.085**	**28%**

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

Collective dose was reduced 18% in 1998 and total personnel exposed was reduced by 12%. The average dose per person increased 2.3% over 1997. Fluor-Daniel Hanford and Los Alamos are primary contributors to this category. In D&D activities Battelle Columbus has increased the number of personnel measured by 162%, their collective dose by over 2000%, and their average dose by 734%.

B-12: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Reactor Facilities, 1998

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
AL	Sandia National Laboratory	44	22	2	1	1	3	-	-	73	40%	29	4.606	**0.159** ◀	72%
AL	Los Alamos National Laboratory	4	1	-	1	-	-	-	-	6	33%	2	0.277	0.139	0%
ID	LMITCO - Services	182	72	26	10	6	-	-	-	296	39%	114	**14.307** ◀	0.126	23%
RL	Fluor Daniel – Hanford	58	16	11	4	-	-	-	-	89	35%	31	3.573	0.115	0%
RL	Babcock Wilcox Hanford	79	11	-	-	-	1	-	-	91	13%	12	1.274	0.106	**77%** ◀
CH	Argonne National Laboratory – West	98	12	2	-	-	-	-	-	112	13%	14	0.678	0.048	0%
SR	Miscellaneous DOE Contractors – SR	4	1	-	-	-	-	-	-	5	20%	1	0.046	0.046	0%
CH	Brookhaven National Laboratory	152	57	7	-	-	-	-	-	216	30%	64	2.673	0.042	0%
RL	Lockheed Martin Services, Inc.	-	1	-	-	-	-	-	-	1	**100%** ◀	1	0.034	0.034	0%
RL	Lockheed Martin Hanford	25	3	-	-	-	-	-	-	28	11%	3	0.093	0.031	0%
RL	Duke Engineering Services Hanford	40	7	-	-	-	-	-	-	47	15%	7	0.167	0.024	0%
RL	SGN Eurisys Services Corp.	7	1	-	-	-	-	-	-	8	13%	1	0.016	0.016	0%
SR	Bechtel Construction - SR	88	36	-	-	-	-	-	-	124	29%	36	0.460	0.013	0%
SR	Westinghouse S.R. Subcontractors	41	6	-	-	-	-	-	-	47	13%	6	0.067	0.011	0%
SR	Wackenhut Services, Inc. – SR	65	35	-	-	-	-	-	-	100	35%	35	0.381	0.011	0%
SR	Westinghouse Savannah River Co.	440	261	1	-	-	-	-	-	**702** ◀	37%	**262** ◀	2.748	0.010	0%
SR	Savannah River Field Office	25	1	-	-	-	-	-	-	26	4%	1	0.010	0.010	0%
ID	Idaho Field Office	10	-	-	-	-	-	-	-	10	0%	-	-	-	0%
ID	LMITCO Subcontractor-Coleman	4	-	-	-	-	-	-	-	4	0%	-	-	-	0%
ID	LMITCO Subcontractor-Parsons	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
ID	LMITCO Subcontractor-Construction	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	Babcock Wilcox Protection, Inc.	10	-	-	-	-	-	-	-	10	0%	-	-	-	0%
RL	Battelle Memorial Institute (PNL)	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	Bechtel Power Co.	3	-	-	-	-	-	-	-	3	0%	-	-	-	0%
RL	DynCorp Hanford	8	-	-	-	-	-	-	-	8	0%	-	-	-	0%
RL	Fluor Daniel Northwest	11	-	-	-	-	-	-	-	11	0%	-	-	-	0%
RL	NUMATEC Hanford	5	-	-	-	-	-	-	-	5	0%	-	-	-	0%
RL	Richland Field Office	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	Waste Mgmt. Federal Svcs., Inc., Northwest	2	-	-	-	-	-	-	-	2	0%	-	-	-	0%
RL	Waste Mgmt. Federal Services of Hanford	25	-	-	-	-	-	-	-	25	0%	-	-	-	0%
	Totals	**1,434**	**543**	**49**	**16**	**7**	**4**	**0**	**0**	**2,053**	**30%**	**619**	**31.410**	**0.051**	**24%**

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

Collective doses were reduced in 1998 with Lockheed-Martin Idaho and Sandia Laboratory contributing the majority. The highest number of people exposed to >0.5 rem remained Fluor-Daniel Hanford where both the number of people exposed and average dose increased in 1998.

B-13: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 1998

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	1,798	52	6	7	1	2	1	-	-	-	1,867	4%	69	8.342	**0.121◄**	**46%◄**
AL	Los Alamos National Laboratory	1,424	499	82	39	13	10	11	-	-	-	2,078	31%	**654◄**	**70.947◄**	0.108	44%
OR	Lockheed Martin Energy Research (ORNL)	5,861	389	79	43	10	3	3	-	-	-	**6,388◄**	8%	527	53.005	0.101	23%
CH	Argonne National Laboratory – West	479	134	50	18	2	-	-	-	-	-	683	30%	204	20.240	0.099	5%
RL	Battelle Memorial Institute (PNL)	650	141	33	9	3	-	-	-	-	-	836	22%	186	13.734	0.074	14%
AL	Johnson Controls, Inc.	6	2	1	-	-	-	-	-	-	-	9	33%	3	0.211	0.070	0%
ID	LMITCO - Services	335	46	11	2	-	-	-	-	-	-	394	15%	59	4.017	0.068	0%
OAK	Lawrence Livermore National Lab.	706	10	3	-	-	-	-	-	-	-	719	2%	13	0.831	0.064	0%
CH	Brookhaven National Laboratory	605	105	20	5	-	-	-	-	-	-	735	18%	130	7.625	0.059	0%
SR	Wackenhut Services, Inc. – SR	17	6	-	-	-	-	-	-	-	-	23	26%	6	0.234	0.039	0%
OAK	Lawrence Berkeley Laboratory	1,420	50	1	-	-	-	-	-	-	-	1,471	3%	51	1.802	0.035	0%
SR	Westinghouse Savannah River Co.	793	279	17	2	-	-	-	-	-	-	1,091	27%	298	10.203	0.034	0%
CH	New Brunswick Laboratory	34	2	-	-	-	-	-	-	-	-	36	6%	2	0.065	0.033	0%
AL	Sandia National Laboratory	1,296	81	5	1	-	-	-	-	-	-	1,383	6%	87	2.772	0.032	0%
SR	Westinghouse S.R. Subcontractors	37	16	-	-	-	-	-	-	-	-	53	30%	16	0.441	0.028	0%
SR	Miscellaneous DOE Contractors – SR	5	4	-	-	-	-	-	-	-	-	9	44%	4	0.099	0.025	0%
RL	Duke Engineering Services Hanford	16	2	-	-	-	-	-	-	-	-	18	11%	2	0.047	0.024	0%
RL	SGN Eurisys Services Corp.	9	1	-	-	-	-	-	-	-	-	10	10%	1	0.023	0.023	0%
OAK	Rockwell International, Rocketdyne ETEC	190	45	-	-	-	-	-	-	-	-	235	19%	45	1.030	0.023	0%
SR	Bechtel Construction - SR	46	23	-	-	-	-	-	-	-	-	69	33%	23	0.516	0.022	0%
DOE	DOE Headquarters	-	1	-	-	-	-	-	-	-	-	1	**100%◄**	1	0.021	0.021	0%

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

B-13: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 1998 (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
OR	Oak Ridge Inst. for Sci. & Educ. (ORISE)	53	1	-	-	-	-	-	-	-	-	54	2%	1	0.020	0.020	0%
AL	Los Alamos Area Office	1	1	-	-	-	-	-	-	-	-	2	50%	1	0.017	0.017	0%
SR	Savannah River Field Office	62	16	-	-	-	-	-	-	-	-	78	21%	16	0.245	0.015	0%
RL	Fluor Daniel Northwest	9	2	-	-	-	-	-	-	-	-	11	18%	2	0.022	0.011	0%
RL	DynCorp Hanford	1	1	-	-	-	-	-	-	-	-	2	50%	1	0.011	0.011	0%
CH	Ames Laboratory (Iowa State)	111	2	-	-	-	-	-	-	-	-	113	2%	2	0.020	0.010	0%
SR	Univ. of Georgia Ecology Laboratory	13	6	-	-	-	-	-	-	-	-	19	32%	6	0.056	0.009	0%
AL	Nat. Renewable Energy Lab (NREL) - GO	13	-	-	-	-	-	-	-	-	-	13	0%	-	-	-	0%
AL	Protection Technologies Los Alamos	9	-	-	-	-	-	-	-	-	-	9	0%	-	-	-	0%
ID	Idaho Field Office	6	-	-	-	-	-	-	-	-	-	6	0%	-	-	-	0%
ID	LMITCO Subcontractor - Coleman	1	-	-	-	-	-	-	-	-	-	1	0%	-	-	-	0%
ID	LMITCO Subcontractor - Parsons	5	-	-	-	-	-	-	-	-	-	5	0%	-	-	-	0%
NV	Defense Nuclear Agency-Kirtland AFB	2	-	-	-	-	-	-	-	-	-	2	0%	-	-	-	0%
NV	Nevada Miscellaneous Contractors	63	-	-	-	-	-	-	-	-	-	63	0%	-	-	-	0%
RL	Babcock Wilcox Hanford	8	-	-	-	-	-	-	-	-	-	8	0%	-	-	-	0%
RL	Fluor Daniel – Hanford	3	-	-	-	-	-	-	-	-	-	3	0%	-	-	-	0%
RL	Lockheed Martin Hanford	2	-	-	-	-	-	-	-	-	-	2	0%	-	-	-	0%
RL	NUMATEC Hanford	5	-	-	-	-	-	-	-	-	-	5	0%	-	-	-	0%
RL	Waste Mgmt. Federal Services of Hanford	2	-	-	-	-	-	-	-	-	-	2	0%	-	-	-	0%
SR	SR Army Corps of Engineers	2	-	-	-	-	-	-	-	-	-	2	0%	-	-	-	0%
	Totals	**16,098**	**1,917**	**308**	**126**	**29**	**15**	**15**	**0**	**0**	**0**	**18,508**	**13%**	**2,410**	**196.596**	**0.082**	**26%**

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

LANL had the greatest number of people exposed as well as the highest collective exposure. ORNL had the highest number of persons monitored and nearly 27% of the collective exposure. Overall the number of persons monitored dropped 5.2%, the number with measurable dose dropped 10.1%, and collective TEDE dropped 13% in 1998.

B-14: *Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, Fusion, 1998*

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	188	20	1	-	4	-	-	-	213	12%	25	**3.387** ◄	**0.135** ◄	**74%** ◄
AL	Los Alamos National Laboratory	42	14	-	1	-	-	-	-	57	**26%** ◄	15	0.776	0.052	0%
CH	Princeton Plasma Physics Laboratory	240	33	2	-	-	-	-	-	**275** ◄	13%	**35** ◄	1.080	0.031	0%
AL	Sandia National Laboratory	12	-	-	-	-	-	-	-	12	0%	-	-	-	0%
	Totals	**482**	**67**	**3**	**1**	**4**	**0**	**0**	**0**	**557**	**13%**	**75**	**5.243**	**0.070**	**48%**

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

Fusion research only accounted for 2.6% of the total collective TEDE in 1998, down from 4.7% in 1997. Once again LLNL and Princeton Plasma Physics Laboratory had the greatest contribution in 1998. Overall collective TEDE dropped by over 50% during 1998 and the average exposure dropped by 14% in 1998.

B-15: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 1998

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	Fluor Daniel – Hanford	437	165	69	57	10	-	-	-	738	41%	301	**43.874** ◀	**0.146** ◀	13%
RL	Fluor Daniel Northwest Services	4	3	1	2	-	-	-	-	10	60%	6	0.868	0.145	0%
CH	Argonne National Laboratory – East	59	15	16	1	-	-	-	-	91	35%	32	3.703	0.116	0%
ID	LMITCO - Services	186	32	34	1	-	-	-	-	253	26%	67	7.140	0.107	0%
RL	Babcock Wilcox Hanford	230	48	6	-	1	2	-	-	287	20%	57	4.767	0.084	**47%** ◀
SR	Westinghouse Savannah River Co.	2,075	489	71	29	-	-	-	-	**2,664** ◀	22%	**589** ◀	35.055	0.060	0%
RL	NUMATEC Hanford	43	4	1	-	-	-	-	-	48	10%	5	0.286	0.057	0%
RL	SGN Eurisys Services Corp.	22	4	1	-	-	-	-	-	27	19%	5	0.277	0.055	0%
RL	Bechtel Power Co.	8	1	-	-	-	-	-	-	9	11%	1	0.049	0.049	0%
RL	Waste Mgmt. Federal Svcs., Inc., Northwest	6	1	-	–	-	-	-	-	7	14%	1	0.048	0.048	0%
RL	Lockheed Martin Hanford	186	10	1	-	-	-	-	-	197	6%	11	0.509	0.046	0%
AL	Los Alamos National Laboratory	106	41	4	-	1	-	-	-	152	30%	46	2.081	0.045	31%
SR	Bechtel Construction - SR	190	144	17	-	-	-	-	-	351	46%	161	6.374	0.040	0%
RL	Waste Mgmt. Federal Services of Hanford	159	21	2	-	-	-	-	-	182	13%	23	0.864	0.038	0%
SR	Westinghouse S.R. Subcontractors	278	50	6	-	-	-	-	-	334	17%	56	2.018	0.036	0%
CH	Brookhaven National Laboratory	92	22	-	-	-	-	-	-	114	19%	22	0.768	0.035	0%
RL	DynCorp Hanford	26	2	-	-	-	-	-	-	28	7%	2	0.046	0.023	0%
RL	Babcock Wilcox Protection, Inc.	1	2	-	-	-	-	-	-	3	**67%** ◀	2	0.045	0.023	0%
OR	Morrison-Knudsen (WSSRAP)	404	98	-	-	-	-	-	-	502	20%	98	2.137	0.022	0%
RL	Duke Engineering Services Hanford	41	3	-	-	-	-	-	-	44	7%	3	0.063	0.021	0%
AL	Sandia National Laboratory	155	12	-	-	-	-	-	-	167	7%	12	0.231	0.019	0%

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

B-15: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 1998 (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	Fluor Daniel Northwest	22	2	-	-	-	-	-	-	24	8%	2	0.032	0.016	0%
ID	LMITCO Subcontractor - Parsons	2	1	-	-	-	-	-	-	3	33%	1	0.014	0.014	0%
AL	Carlsbad Area Misc. Contractors	383	7	-	-	-	-	-	-	390	2%	7	0.094	0.013	0%
SR	Savannah River Field Office	64	2	-	-	-	-	-	-	66	3%	2	0.011	0.006	0%
AL	Los Alamos Area Office	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
AL	WIPP Project Integration Office	9	-	-	-	-	-	-	-	9	0%	-	-	-	0%
ID	Idaho Field Office	7	-	-	-	-	-	-	-	7	0%	-	-	-	0%
ID	LMITCO Subcontractor - Coleman	6	-	-	-	-	-	-	-	6	0%	-	-	-	0%
NV	Nevada Field Office	8	-	-	-	-	-	-	-	8	0%	-	-	-	0%
NV	Nevada Miscellaneous Contractors	154	-	-	-	-	-	-	-	154	0%	-	-	-	0%
NV	Raytheon Services - Nevada	35	-	-	-	-	-	-	-	35	0%	-	-	-	0%
NV	Bechtel Nevada - NTS	11	-	-	-	-	-	-	-	11	0%	-	-	-	0%
NV	Science Applications Int'l. Corp.-NV	19	-	-	-	-	-	-	-	19	0%	-	-	-	0%
OAK	Lawrence Livermore National Lab.	67	-	-	-	-	-	-	-	67	0%	-	-	-	0%
OH	West Valley Nuclear Services, Inc.	70	-	-	-	-	-	-	-	70	0%	-	-	-	0%
RL	Battelle Memorial Institute (PNL)	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	Duke Eng. & Services Northwest, Inc.	2	-	-	-	-	-	-	-	2	0%	-	-	-	0%
RL	Richland Field Office	2	-	-	-	-	-	-	-	2	0%	-	-	-	0%
SR	Miscellaneous DOE Contractors – SR	1	-	-	-	-	-	-	-	1	0%	-	–	-	0%
SR	Wackenhut Services, Inc. – SR	3	-	-	-	-	-	-	-	3	0%	-	-	-	0%
	Totals	**5,575**	**1,179**	**229**	**90**	**12**	**2**	**0**	**0**	**7,087**	**21%**	**1,512**	**111.354**	**0.074**	**8%**

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

Fluor-Daniel Hanford again had the highest collective dose showing an increase of 18.4% in 1998 with Westinghouse Savannah River having the second greatest collective dose showing a 43.5% increase during 1998. Overall the number monitored was 6.2% less, the number with measurable dose was 6% less but the collective dose increased 17.9% and the average dose increased 25% during 1998.

B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Weapons Fabrication, 1998

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.	258	149	59	46	22	8	1	-	-	543	52%	285	52.538	**0.184◄**	**40%◄**
SR	Wackenhut Services, Inc. – SR	45	31	67	1	-	-	-	-	-	144	69%	99	12.340	0.125	0%
RFO	Rocky Flats Prime Contractors	603	1,355	456	181	69	16	6	1	-	2,687	78%	**2,084◄**	**259.289◄**	0.124	24%
NV	B.N. – NTS Subcontractors	595	4	3	-	-	-	-	-	-	602	1%	7	0.789	0.113	0%
RFO	Rocky Flats Subcontractors	1,454	766	193	41	10	-	-	-	-	2,464	41%	1,010	78.766	0.078	8%
AL	M&H-Amarillo-Security Forces	529	4	3	-	-	-	-	-	-	536	1%	7	0.464	0.066	0%
AL	Mason & Hanger - Amarillo	4,668	243	43	6	2	-	-	-	-	4,962	6%	294	16.565	0.056	8%
SR	Bechtel Construction – SR	33	42	9	-	-	-	-	-	-	84	61%	51	2.814	0.055	0%
RFO	Rocky Flats Office	117	166	5	-	-	-	-	-	-	288	59%	171	8.469	0.050	0%
OAK	Lawrence Livermore National Lab.	802	10	2	-	-	-	-	-	-	814	1%	12	0.585	0.049	0%
AL	Albuquerque Field Office	197	3	-	-	-	-	-	-	-	200	2%	3	0.109	0.036	0%
NV	Bechtel Nevada – NTS	2,532	5	-	-	-	-	-	-	-	2,537	0%	5	0.178	0.036	0%
OR	Lockheed Martin Energy Systems (Y-12)	3,887	1,117	30	22	12	5	4	-	-	**5,077◄**	23%	1,190	41.241	0.035	**40%◄**
AL	Sandia National Laboratory	476	15	-	-	-	-	-	-	-	491	3%	15	0.366	0.024	0%
AL	Battelle – Pantex	172	11	-	-	-	-	-	-	-	183	6%	11	0.196	0.018	0%
AL	Los Alamos National Laboratory	4	6	-	-	-	-	-	-	-	10	60%	6	0.096	0.016	0%
SR	Westinghouse S.R. Subcontractors	15	6	-	-	-	-	-	-	-	21	29%	6	0.095	0.016	0%
SR	Savannah River Field Office	15	7	-	-	-	-	-	-	-	22	32%	7	0.086	0.012	0%
OH	BWX Technologies, Inc.–Subcontractors	-	1	-	-	-	-	-	-	-	1	**100%◄**	1	0.004	0.004	0%
AL	Albuquerque Transportation Division	1	-	-	-	-	-	-	-	-	1	0%	0	-	-	0%
AL	Amarillo Area Office	105	-	-	-	-	-	-	-	-	105	0%	0	-	-	0%
AL	Kirtland Area Office	33	-	-	-	-	-	-	-	-	33	0%	0	-	-	0%
NV	Defense Nuclear Agency-Kirtland AFB	55	-	-	-	-	-	-	-	-	55	0%	0	-	-	0%
NV	Environmental Prot. Agency (NERC)	11	-	-	-	-	-	-	-	-	11	0%	0	-	-	0%
NV	Nevada Miscellaneous Contractors	45	-	-	-	-	-	-	-	-	45	0%	0	-	-	0%
NV	Westinghouse Electric Corp. - NV	5	-	-	-	-	-	-	-	-	5	0%	0	-	-	0%
OH	BWX Technologies, Inc.	2	-	-	-	-	-	-	-	-	2	0%	0	-	-	0%
RFO	Rocky Flats Office Subs	14	-	-	-	-	-	-	-	-	14	0%	0	-	-	0%
	Totals	**16,673**	**3,941**	**870**	**297**	**115**	**29**	**11**	**1**	**0**	**21,937**	**24%**	**5,264**	**474.990**	**0.090**	**23%**

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

Rocky Flats Prime Contractors had the highest collective dose posting an increase of 1.2% in 1998 while Westinghouse Savannah River Co. had the highest average dose although their average dropped nearly 11% from 1997. Although the overall number of persons monitored increased 5.2% in 1998, the number who received dose increased 16.2%, the collective TEDE increased 14%, and the average exposure dropped 3.3% in 1998.

B-17: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 1998

OTHER

Ops. Office	Site/Contractor	Number of Individuals Receiving Radiation Doses in Each Dose Range (rem): 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 North Korea Project	10	2	5	3	2	-	2	-	24	58%	14	5.430	**0.388**◄	**64%**◄
RL	Bechtel Power Co.	898	147	44	35	17	4	3	-	1,148	22%	250	**42.156**◄	0.169	39%
ID	LMITCO Subcontractors - Construction	123	49	15	14	4	-	-	-	205	40%	82	11.402	0.139	20%
AL	MACTEC - ERS	12	159	103	23	7	2	1	-	307	96%	295	38.865	0.132	17%
AL	Johnson Controls, Inc.	89	13	3	2	-	-	-	-	107	17%	18	1.639	0.091	0%
ID	Idaho Field Office	144	3	1	-	-	-	-	-	148	3%	4	0.336	0.084	0%
OH	West Valley Nuclear Services, Inc.	785	203	51	5	1	-	-	-	1,045	25%	260	18.176	0.070	4%
RL	Fluor Daniel Northwest Services	66	33	5	3	-	-	-	-	107	38%	41	2.657	0.065	0%
RL	Babcock Wilcox Protection, Inc.	41	4	2	-	-	-	-	-	47	13%	6	0.370	0.062	0%
RL	Fluor Daniel - Hanford	282	14	5	-	-	-	-	-	301	6%	19	1.171	0.062	0%
RL	Battelle Memorial Institute (PNL)	781	64	10	2	1	-	-	-	858	9%	77	4.555	0.059	14%
RL	Lockheed Martin Hanford	37	2	1	-	-	-	-	-	40	8%	3	0.174	0.058	0%
RL	Babcock Wilcox Hanford	388	7	1	-	-	-	-	-	396	2%	8	0.406	0.051	0%
AL	Sandia National Laboratory	465	24	-	-	1	-	-	-	490	5%	25	1.208	0.048	54%
AL	Los Alamos National Laboratory	4,538	407	21	11	4	2	2	-	**4,985**◄	9%	**447**◄	21.332	0.048	31%
RFO	Rocky Flats Office	832	30	1	2	-	-	-	-	865	4%	33	1.530	0.046	0%
CH	Argonne National Laboratory - West	-	2	-	-	-	-	-	-	2	**100%**◄	2	0.076	0.038	0%
AL	Los Alamos Area Office	16	3	1	-	-	-	-	-	20	20%	4	0.150	0.038	0%
RL	Richland Field Office	1,004	33	2	-	-	-	-	-	1,039	3%	35	1.267	0.036	0%
SR	Westinghouse S.R. Subcontractors	17	3	-	-	-	-	-	-	20	15%	3	0.106	0.035	0%
CH	Argonne National Laboratory - East	-	2	-	-	-	-	-	-	2	**100%**◄	2	0.070	0.035	0%
OAK	Lawrence Livermore National Lab.	2,488	34	1	-	-	-	-	-	2,523	1%	35	1.155	0.033	0%
NV	Nevada Miscellaneous Contractors	199	1	-	-	-	-	-	-	200	1%	1	0.029	0.029	0%
RL	Fluor Daniel Northwest	226	8	-	-	-	-	-	-	234	3%	8	0.216	0.027	0%

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

B-17: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 1998 (Continued)

OTHER

Ops. Office	Site/Contractor	Number of Individuals Receiving Radiation Doses in Each Dose Range (rem): 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	Brookhaven National Laboratory	366	43	2	-	-	-	-	-	411	11%	45	1.193	0.027	0%
ID	Lockheed Martin Idaho Tech. Co.-Services	1,352	49	2	-	-	-	-	-	1,403	4%	51	1.351	0.026	0%
RL	SGN Eurisys Services Corp.	36	8	-	-	-	-	-	-	44	18%	8	0.201	0.025	0%
RL	Hanford Environmental Health Foun.	32	1	-	-	-	-	-	-	33	3%	1	0.022	0.022	0%
OAK	LLNL Subcontractors	126	3	-	-	-	-	-	-	129	2%	3	0.065	0.022	0%
RL	Duke Engineering Services Hanford	104	4	-	-	-	-	-	-	108	4%	4	0.084	0.021	0%
RL	Waste Mgmt. Federal Services of Hanford	164	3	-	-	-	-	-	-	167	2%	3	0.056	0.019	0%
SR	Savannah River Field Office	26	5	-	-	-	-	-	-	31	16%	5	0.085	0.017	0%
SR	Westinghouse Savannah River Co.	224	12	-	-	-	-	-	-	236	5%	12	0.198	0.017	0%
SR	Bechtel Construction - SR	10	1	-	-	-	-	-	-	11	9%	1	0.016	0.016	0%
RL	Westinghouse Hanford Service Subs	29	1	-	-	-	-	-	-	30	3%	1	0.015	0.015	0%
OR	MK Ferguson Oak Ridge	628	297	7	-	-	-	-	-	932	33%	304	4.539	0.015	0%
OH	BWX Technologies, Inc.	463	83	2	-	-	-	-	-	548	16%	85	1.040	0.012	0%
OR	RMI Company	420	50	-	-	-	-	-	-	470	11%	50	0.565	0.011	0%
OH	BWX Technologies, Inc. – Security Forces	29	1	-	-	-	-	-	-	30	3%	1	0.011	0.011	0%
OH	Ohio Field Office	13	1	-	-	-	-	-	-	14	7%	1	0.011	0.011	0%
RL	Waste Mgmt. Federal Svcs., Inc., Northwest	16	1	-	-	-	-	-	-	17	6%	1	0.011	0.011	0%
ID	LMITCO Subcontractor - Parsons	11	2	-	-	-	-	-	-	13	15%	2	0.020	0.010	0%
AL	Allied-Signal, Inc.	96	1	-	-	-	-	-	-	97	1%	1	0.010	0.010	0%
OH	Miamisburg Area Office	25	1	-	-	-	-	-	-	26	4%	1	0.010	0.010	0%
AL	Protection Technologies Los Alamos	99	9	-	-	-	-	-	-	108	8%	9	0.072	0.008	0%
OH	BWX Technologies, Inc. – Subcontractors	293	17	-	-	-	-	-	-	310	5%	17	0.132	0.008	0%
OR	Lockheed Martin Energy Systems (Y-12)	166	4	-	-	-	-	-	-	170	2%	4	0.022	0.006	0%
OR	Decon. & Recovery Services (DRS) (K-25)	38	1	-	-	-	-	-	-	39	3%	1	0.003	0.003	0%
CH	Environmental Meas. Lab.	14	1	-	-	-	-	-	-	15	7%	1	0.001	0.001	0%
AL	Kansas City Area Office	7	-	-	-	-	-	-	-	7	0%	0	-	-	0%

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

B-17: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 1998 (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
AL	Mason & Hanger - Amarillo	53	-	-	-	-	-	-	-	53	0%	-	-	-	0%
DOE	DOE Headquarters	2	-	-	-	-	-	-	-	2	0%	-	-	-	0%
ID	Babcock & Wilcox Idaho, Inc.	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
ID	LMITCO Subcontractor - Coleman	13	-	-	-	-	-	-	-	13	0%	-	-	-	0%
NV	Air Resources Laboratory	12	-	-	-	-	-	-	-	12	0%	-	-	-	0%
NV	Bechtel Nevada - Los Alamos	42	-	-	-	-	-	-	-	42	0%	-	-	-	0%
NV	Bechtel Nevada - NTS	101	-	-	-	-	-	-	-	101	0%	-	-	-	0%
NV	B.N. - Washington Aerial Meas.	37	-	-	-	-	-	-	-	37	0%	-	-	-	0%
NV	Defense Nuclear Agency-Kirtland AFB	76	-	-	-	-	-	-	-	76	0%	-	-	-	0%
NV	Nevada Field Office	340	-	-	-	-	-	-	-	340	0%	-	-	-	0%
NV	Nevada Operations	185	-	-	-	-	-	-	-	185	0%	-	-	-	0%
NV	Bechtel Nevada - NTS	7	-	-	-	-	-	-	-	7	0%	-	-	-	0%
OAK	LLNL Security	3	-	-	-	-	-	-	-	3	0%	-	-	-	0%
OAK	U. of Cal./Davis, Radiobiology Lab-LEHR	47	-	-	-	-	-	-	-	47	0%	-	-	-	0%
OH	Miamisburg Office Subs	28	-	-	-	-	-	-	-	28	0%	-	-	-	0%
OR	Bechtel-Jacobs Co., LLC – ETTP	6	-	-	-	-	-	-	-	6	0%	-	-	-	0%
OR	Oak Ridge Inst. for Sci. & Educ. (ORISE)	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
RL	Duke Eng. & Services Northwest, Inc.	8	-	-	-	-	-	-	-	8	0%	-	-	-	0%
RL	Dyncorp Harford	7	-	-	-	-	-	-	-	7	0%	-	-	-	0%
RL	Lockheed Martin Services, Inc.	11	-	-	-	-	-	-	-	11	0%	-	-	-	0%
RL	NUMATEC Hanford	19	-	-	-	-	-	-	-	19	0%	-	-	-	0%
SR	Miscellaneous DOE Contractors – SR	1	-	-	-	-	-	-	-	1	0%	-	-	-	0%
SR	Wackenhut Services, Inc. - SR	3	-	-	-	-	-	-	-	3	0	-	-	-	0%
	Totals	**19,231**	**1,846**	**285**	**100**	**37**	**8**	**8**	**0**	**21,515**	**11%**	**2,284**	**164.209**	**0.072**	**23%**

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

The 1997 trend of increasing collective dose for the Other category was reversed in 1998 as the total dropped by 12.3%. Bechtel Power Co. again had the highest collective dose in 1998 but their total was reduced by 46%. West Valley Nuclear Services had an increase in collective dose of 162% and Los Alamos National Laboratory dose increased 35% in 1998. Otherwise most site experienced decreases in collective dose in 1998.

B-18: Internal Dose by Facility Type and Nuclide, 1996-1998

Facility Type	Nuclide*	No. of Individuals with New Intakes**			Collective CEDE (person-rem)			Average CEDE (rem)		
		1996	1997	1998	1996	1997	1998	1996	1997	1998
Accelerator	Hydrogen-3	13	16	6	0.191	0.322	0.078	0.018	0.020	0.013
	Uranium	1	1	2	0.014	0.001	0.010	0.014	0.001	0.005
	Total	**14**	**17**	**8**	**0.205**	**0.323**	**0.088**	**0.013**	**0.019**	**0.011**
Fuel Fabrication	Hydrogen-3	2		6	0.009		0.012			0.002
	Plutonium		3			0.048			0.016	
	Thorium	31	8	9	0.612	0.132	0.057	0.020		0.006
	Uranium	34	13	9	0.438	0.051	0.026	0.006	0.004	0.002
	Total	**67**	**24**	**24**	**1.059**	**0.231**	**0.095**	**0.007**	**0.010**	**0.004**
Fuel Processing	Hydrogen-3	126	123	115	0.299	0.264	0.234	0.003	0.002	0.002
	Plutonium	7	3	1	**11.955** ◄	0.344	0.322	0.185	0.115	**0.322** ◄
	Uranium		1			0.016			0.016	
	Total	**133**	**127**	**116**	**12.254**	**0.624**	**0.556**	**0.020**	**0.005**	**0.005**
Fuel/Uranium Enrichment	Americium			1			0.055			0.055
	Hydrogen-3			2			0.003			0.002
	Other	1			0.002					
	Technetium	2	8	2	0.006	0.009	0.006	0.009	0.001	0.003
	Thorium	112	1		8.628	0.001		0.009	0.001	
	Uranium	33	34	86	0.176	0.157	0.321	0.005	0.005	0.004
	Total	**148**	**43**	**91**	**8.812**	**0.167**	**0.385**	**0.006**	**0.004**	**0.004**
Maintenance and Support	Americium	12		3	0.031		0.039	0.021	0.003	0.013
	Hydrogen-3	121	94	78	0.654	0.522	0.238	0.003	0.006	0.003
	Mixed and Other	8	1	16	0.040	0.069	0.039	0.061	0.069	0.002
	Plutonium	8	5	15	0.273	3.203	1.680	0.139	0.641	0.112
	Thorium		5	2		0.020	0.089	**0.323** ◄	0.004	0.045
	Uranium	28	11	10	0.176	0.035	0.038	0.008	0.003	0.004
	Total	**177**	**116**	**124**	**1.174**	**3.849**	**2.123**	**0.019**	**0.033**	**0.017**
Other	Americium			4			0.297			0.074
	Hydrogen-3	10	78	80	0.038	0.499	0.313	0.002	0.006	0.004
	Mixed and Other	5	6	1	0.025	4.038	0.300	0.042	**0.673** ◄	0.300
	Plutonium	5	3	5	3.334	0.177	0.378	0.302	0.059	0.076
	Radon-222		270	280		**27.834** ◄	**33.840** ◄		0.103	0.121
	Thorium			2			0.111			0.056
	Uranium	70	260	141	1.475	1.641	0.601	0.078	0.006	0.004
	Total	**90**	**617**	**513**	**4.872**	**34.189**	**35.840**	**0.115**	**0.049**	**0.070**
Reactor	Hydrogen-3	**328** ◄	304	287	4.049	3.305	1.433	0.014	0.011	0.005
	Mixed & Other		3			0.022			0.007	
	Total	**328**	**307**	**287**	**4.049**	**3.327**	**1.433**	**0.014**	**0.011**	**0.005**
Research, Fusion	Hydrogen-3	87	53	26	0.477	0.153	0.309	0.005	0.003	0.012
	Total	**87**	**53**	**26**	**0.477**	**0.153**	**0.309**	**0.005**	**0.003**	**0.012**
Research, General	Americium	4	3	8	0.541	0.059	0.828	0.135	0.020	0.104
	Hydrogen-3	36	36	44	0.294	0.177	0.500	0.006	0.005	0.011
	Mixed & Other	14	11	46	0.201	0.255	0.390	0.045	0.023	0.008
	Plutonium	6	14	11	5.022	7.232	1.391	0.072	0.517	0.126
	Uranium	33	20	17	0.208	0.136	0.083	0.008	0.007	0.005
	Total	**93**	**84**	**126**	**6.266**	**7.859**	**3.192**	**0.066**	**0.094**	**0.025**
Waste Processing	Americium		1			0.004			0.004	
	Hydrogen-3	20	8	15	0.469	0.015	0.028	0.023	0.002	0.002
	Mixed & Other	3	2		0.015	0.221		0.005	0.111	
	Plutonium	12		22	1.600		0.957	0.133		0.044
	Thorium	5	3		0.393	0.669		0.079	0.223	
	Uranium	22	16	5	6.409	3.858	0.157	0.291	0.241	0.031
	Total	**62**	**30**	**42**	**8.886**	**4.767**	**1.142**	**0.143**	**0.158**	**0.027**
Weapons Fab. and Testing	Americium		5			0.501			0.100	
	Hydrogen-3	54	22	14	0.210	0.193	0.051	0.004	0.009	0.004
	Plutonium	28	38	38	2.113	2.045	4.825	0.075	0.053	0.127
	Uranium	318	**431** ◄	**1,056** ◄	3.484	7.127	34.168	0.011	0.016	0.032
	Total	**400**	**496**	**1,108**	**5.807**	**9.866**	**39.044**	**0.015**	**0.019**	**0.035**
Totals		**1,599**	**1,914**	**2,465**	**53.861**	**65.355**	**84.207**	**0.033**	**0.034**	**0.034**

* 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.

In 1997 and 1998, Radon-222 intakes resulted in the largest collective internal dose. However, in 1998 the highest average internal dose was from plutonium fuel processing activities.

B-19a: Distribution of TEDE by Labor Category, 1996

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	53	7	1									61	13%	8	0.379	0.047
Construction	8,200	2,129	304	108	28	10	9					10,788	24%	2,588	176.814	0.068
Laborers	867	429	49	49	11	2	2					1,409	**38%** ◄	542	48.967	0.090
Management	15,451	1,083	94	29	6							16,663	7%	1,212	57.154	0.047
Misc.	16,807	4,503	362	86	31	19	11					21,819	23%	**5,012** ◄	259.840	0.052
Production	4,281	1,790	324	217	80	14	8				1	6,715	36%	2,434	267.423	0.110
Scientists	28,509	3,503	228	63	17	9	8					**32,337** ◄	12%	3,828	164.366	0.043
Service	4,418	501	44	18	3	1	2					4,987	11%	569	31.678	0.056
Technicians	7,964	2,364	758	315	94	25	19	1				11,540	31%	3,576	**416.642** ◄	**0.117** ◄
Transport	1,179	371	13	8	6	3						1,580	25%	401	18.760	0.047
Unknown	12,870	2,079	264	110	63	16	21	1	1			15,425	17%	2,555	209.937	0.082
Totals	**100,599**	**18,759**	**2,441**	**1,003**	**339**	**99**	**80**	**2**	**1**	**0**	**1**	**123,324**	**18%**	**22,725**	**1,651.960**	**0.073**

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

B-19b: 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	43	5	2		1							51	16%	8	1.072	0.134
Construction	5,017	1,383	183	85	27	15	2					6,712	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	2,853	1,404	250	103	27	6	4					4,647	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	154	18	4		1						1,455	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-19c: 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	37	2	2									41	10%	4	0.490	**0.123** ◄
Construction	4,548	1,422	173	47	18	4						6,212	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	120.211	0.053
Production	2,716	1,349	266	117	36	10	3					4,497	40%	1,781	155.408	0.087
Scientists	24,359	2,512	200	53	11	6	2					27,143	10%	2,784	119.910	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	**353.860** ◄	0.121
Transport	1,315	122	11	8	3							1,459	10%	144	9.136	0.063
Unknown	26,745	2,723	424	158	58	26	21	1				**30,156** ◄	11%	**3,411** ◄	271.973	0.080
Totals	**90,951**	**14,053**	**2,253**	**841**	**268**	**74**	**41**	**1**	**0**	**0**	**0**	**108,482**	**16%**	**17,531**	**1,302.652**	**0.074**

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

Subcontracting and outsourcing has increased the Unknown category 11% during 1998, comprising nearly 28% of the labor force. Technicians remains the category with the highest collective TEDE with Laborers retaining the highest percentage of personnel receiving measurable dose.

B-20: Internal Dose by Labor Category, 1996 - 1998

Labor Category	Number of Individuals with New Intakes*			Collective CEDE (person-rem)			Average CEDE (rem)		
	1996	1997	1998	1996	1997	1998	1996	1997	1998
Construction	226	278	**488** ◄	7.707	5.580	7.808	0.034	0.020	0.016
Laborers	41	91	66	0.900	9.687	9.305	0.022	0.106	0.141
Management	105	100	173	1.472	1.779	7.053	0.014	0.018	0.041
Misc.	219	283	253	12.655	2.214	4.829	**0.058** ◄	0.007	0.019
Production	**370** ◄	320	412	**16.286** ◄	4.224	15.942	0.044	0.013	0.039
Scientists	200	214	297	4.366	4.137	1.974	0.022	0.019	0.007
Service	46	42	80	0.282	0.214	0.925	0.006	0.005	0.012
Technicians	219	221	287	3.705	8.960	7.113	0.016	0.041	0.025
Transport	10	2	8	0.504	0.312	1.882	0.050	**0.156** ◄	**0.235** ◄
Unknown	163	**363** ◄	401	5.647	**28.248** ◄	**27.376** ◄	0.035	0.078	0.068
Totals	**1,599**	**1,914**	**2,465**	**53.524**	**65.355**	**84.207**	**0.033**	**0.034**	**0.034**

* 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.

The Unknown labor category, which includes those Grand Junction employees reporting Radon-222 exposure, remains the category with the highest collective CEDE, while Transport remains the category with the highest average CEDE. Construction had the greatest number of new reported cases during 1998.

B-21: Dose Distribution by Labor Category and Occupation, 1998

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	Total Monitored	Percent with Meas.	No. with Meas.	Collective TEDE	Average Meas. TEDE
Agriculture	Groundskeepers	36	2	2	-	-	-	-	-	-	-	40	10%	4	0.490	0.123
	Misc. Agriculture	1	-	-	-	-	-	-	-	-	-	1	0%	-	-	-
Construction	Carpenters	221	94	12	3	-	-	-	-	-	-	330	33%	109	5.383	0.049
	Electricians	1,232	343	27	15	7	-	-	-	-	-	1,624	24%	392	21.358	0.054
	Masons	16	6	-	-	-	-	-	-	-	-	22	27%	6	0.058	0.010
	Mechanics/Repairers	885	306	31	6	-	-	-	-	-	-	1,228	28%	343	13.639	0.040
	Miners/Drillers	96	1	-	-	-	-	-	-	-	-	97	1%	1	0.001	0.001
	Misc. Repair/Construction	1,539	469	52	13	7	3	-	-	-	-	2,083	26%	544	29.182	0.054
	Painters	143	34	5	1	-	-	-	-	-	-	183	22%	40	2.219	0.055
	Pipe Fitters	416	169	46	10	3	1	-	-	-	-	645	36%	229	18.582	0.081
Laborers	Handlers/Laborers/Helpers	658	353	78	37	14	6	4	-	-	-	1,150	43%	492	53.594	0.109
Management	Admin. Support and Clerical	3,950	413	45	12	-	1	-	-	-	-	4,421	11%	471	25.486	0.054
	Manager - Administrator	6,607	801	77	31	9	3	2	-	-	-	7,530	12%	923	55.025	0.060
	Sales	54	1	-	-	-	-	-	-	-	-	55	2%	1	0.010	0.010
Misc.	Military	11	-	-	-	-	-	-	-	-	-	11	0%	-	-	-
	Miscellaneous	10,488	1,947	254	57	12	2	-	-	-	-	12,760	18%	2,272	120.281	0.053
Production	Machine Setup/Operators	77	8	3	-	-	-	-	-	-	-	88	13%	11	0.798	0.073
	Machinists	249	32	16	2	-	-	-	-	-	-	299	17%	50	4.595	0.092
	Misc. Precision/Production	144	7	2	-	-	-	-	-	-	-	153	6%	9	0.523	0.058
	Operators, Plant/System/Util.	2,030	1,243	232	112	36	10	3	-	-	-	3,666	45%	1,636	144.760	0.088
	Sheet Metal Workers	109	38	10	1	-	-	-	-	-	-	158	31%	49	2.885	0.059
	Welders and Solderers	107	21	3	2	-	-	-	-	-	-	133	20%	26	1.847	0.071
Scientists	Doctors and Nurses	213	22	1	-	-	-	-	-	-	-	236	10%	23	0.481	0.021
	Engineers	8,341	1,073	66	21	6	4	1	-	-	-	9,512	12%	1,171	48.453	0.041
	Health Physicists	509	99	22	6	1	-	-	-	-	-	637	20%	128	8.494	0.066
	Misc. Professionals	6,647	713	49	10	2	-	-	-	-	-	7,421	10%	774	30.023	0.039
	Scientists	8,649	605	62	16	2	2	1	-	-	-	9,337	7%	688	32.554	0.047
Service	Firefighters	498	67	2	-	-	-	-	-	-	-	567	12%	69	1.691	0.025
	Food Service Employees	41	1	-	-	-	-	-	-	-	-	42	2%	1	0.010	0.010
	Janitors	511	54	6	4	-	-	-	-	-	-	575	11%	64	4.043	0.063
	Misc. Service	546	56	16	1	-	-	-	-	-	-	619	12%	73	4.892	0.067
	Security Guards	1,872	353	92	8	3	2	-	-	-	-	2,330	20%	458	33.236	0.073
Technicians	Engineering Technicians	1,139	193	51	37	10	3	3	-	-	-	1,436	21%	297	39.857	0.134
	Health Technicians	297	93	30	18	7	2	-	-	-	-	447	34%	150	21.294	0.142
	Misc. Technicians	2,198	418	65	16	21	-	-	-	-	-	2,718	19%	520	41.413	0.080
	Radiation Monitors/Techs.	941	681	327	132	28	2	1	-	-	-	2,112	**55%** ◄	1,171	142.976	0.122
	Science Technicians	489	188	77	84	29	7	5	-	-	-	879	44%	390	79.614	**0.204** ◄
	Technicians	930	304	57	21	9	-	-	-	-	-	1,321	30%	391	31.006	0.079
Transport	Bus Drivers	34	1	-	-	-	-	-	-	-	-	35	3%	1	0.036	0.036
	Equipment Operators	266	77	10	5	2	-	-	-	-	-	360	26%	94	6.290	0.067
	Misc. Transport	357	11	-	3	1	-	-	-	-	-	372	4%	15	1.978	0.132
	Pilots	4	-	-	-	-	-	-	-	-	-	4	0%	-	-	-
	Truck Drivers	654	33	1	-	-	-	-	-	-	-	688	5%	34	0.832	0.024
Unknown	Unknown	26,745	2,723	424	158	58	26	21	1	-	-	**30,156** ◄	11%	**3,411** ◄	**272.763** ◄	0.080
Totals		**90,951**	**14,053**	**2,253**	**841**	**268**	**74**	**41**	**1**	**0**	**0**	**108,482**	**16%**	**17,531**	**1,302.652**	**0.074**

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

Although the number of personnel monitored increased by 1% during 1998, the number receiving exposure decreased by 6%. When coupled with an overall reduction of 4% in the collective TEDE the result was a slight (1.4%) increase in the average TEDE. Radiation Monitors/Techs. remained the group with the highest percent receiving TEDE, however science technicians received a higher average dose per individual.

B-22: Internal Dose Distribution by Site and Nuclide, 1998

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			
Albuquerque	Los Alamos Nat'l. Lab (LANL)	Americium			1			1					2	0.909	0.455
		Hydrogen-3	41	5									46	0.386	0.008
		Plutonium		1	2	1	1						5	1.382	0.276
		Uranium	27										27	0.104	0.004
	Pantex Plant (PP)	Hydrogen-3	4										4	0.004	0.001
	Grand Junction	Radon-222		165	90	18	4	2	1				280	33.840	0.121
Chicago	Ops. and Other Facilities	Hydrogen-3	16	4									20	0.240	0.012
	Argonne Nat'l. Lab - East (ANL-E)	Americium	5	1									6	0.049	0.008
		Hydrogen-3	7										7	0.012	0.002
		Mixed	1										1	0.004	0.004
		Plutonium	12	15	2								29	1.085	0.037
	Argonne Nat'l. Lab - West (ANL-W)	Plutonium		1									1	0.070	0.070
	Brookhaven Nat'l. Lab (BNL)	Hydrogen-3	47	11									58	0.623	0.011
Idaho	Idaho Site	Uranium	1										1	0.016	0.016
Nevada	NTS	Plutonium	2	6									8	0.383	0.048
Oakland	Lawrence Berkeley Lab. (LBL)	Hydrogen-3	3	2	1								6	0.310	0.052
	Lawrence Livermore Nat'l. Lab. (LLNL)	Hydrogen-3	6										6	0.041	0.007
Oak Ridge	Ops. and Other Facilities	Uranium	28	5									33	0.301	0.009
	Oak Ridge Site	Americium	1	1									2	0.060	0.030
		Hydrogen-3	1										1	0.002	0.002
		Other	40	3	1								44	0.311	0.007
		Technetium	2										2	0.006	0.003
		Uranium	1,058	108	26	20	11	5	4				**1,232** ◀	**34.884** ◀	0.028
	Paducah Gaseous Diff. Plant (PGDP)	Uranium	1										1	0.012	0.012
Ohio	Ops. and Other Facilities	Americium	2										2	0.002	0.001
		Other	16										16	0.039	0.002
		Plutonium	11										11	0.021	0.002
	Fernald Environmental Mgmt. Project	Thorium	9										9	0.057	0.006
		Uranium	9										9	0.026	0.003
	Mound Plant	Americium	1	2									3	0.162	0.054
		Hydrogen-3	65										65	0.173	0.003
		Plutonium	1	3	1								5	0.378	0.076
		Thorium		4									4	0.200	0.050
		Uranium	20										20	0.052	0.003
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	Plutonium	10	12	4	1				1			28	3.977	0.142
		Uranium	3										3	0.009	0.003
Richland	Hanford Site	Hydrogen-3	8										8	0.022	0.003
		Other				1							1	0.300	0.300
		Plutonium					2						2	1.470	**0.735** ◀
Savannah River	Savannah River Site (SRS)	Americium		1									1	0.037	0.037
		Hydrogen-3	451	1									452	1.386	0.003
		Other		1									1	0.075	0.075
		Plutonium		1		2							3	0.787	0.262
Totals			**1,909**	**353**	**128**	**43**	**18**	**8**	**5**	**1**	**0**	**0**	**2,465**	**84.207**	**0.034**

The 1998 collective uranium dose from Oak Ridge was the highest, with the Grand Junction Radon-222 dose second. The highest individual internal exposure (at Rocky Flats) and highest average internal exposure (Hanford) were from Plutonium.

B-23: Extremity Dose Distribution by Operations/Site, 1998

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	694	22	1	-	-	-	-	-	-	717	23	-	1.087	0.047
	Los Alamos National Lab. (LANL)	10,696	71	298	85	4	4	1	-	-	11,159	463	9	407.089	0.879
	Pantex Plant (PP)	5,666	58	99	16	-	-	-	-	-	5,839	173	-	63.555	0.367
	Sandia National Lab. (SNL)	3,401	32	26	2	1	-	-	-	-	3,462	61	1	19.071	0.313
	Grand Junction	184	116	7	-	-	-	-	-	-	307	123	-	5.563	0.045
Chicago	Chicago Operations	519	-	1	-	-	-	-	-	-	520	1	-	0.155	0.155
	Argonne Nat'l. Lab. - East (ANL-E)	2,783	107	34	11	2	1	-	-	-	2,938	155	3	59.295	0.383
	Argonne Nat'l. Lab. - West (ANL-W)	619	147	88	11	-	-	-	-	-	865	246	-	56.164	0.228
	Brookhaven Nat'l. Lab. (BNL)	4,740	662	183	10	1	-	-	-	-	5,596	856	1	89.052	0.104
	Fermi Nat'l. Accelerator Lab. (FERMI)	2,052	3	8	2	1	-	-	-	-	2,066	14	1	13.520	**0.966◄**
DOE HQ	DOE Headquarters	4	-	-	-	-	-	-	-	-	4	-	-	-	-
	North Korea Project	24	-	-	-	-	-	-	-	-	24	-	-	-	-
Idaho	Idaho Site	4,293	504	257	21	-	-	-	-	-	5,075	782	-	120.998	0.155
Nevada	Nevada Test Site (NTS)	4,875	10	5	3	-	-	-	-	-	4,893	18	-	7.549	0.419
Oakland	Oakland Operations	234	48	-	-	-	-	-	-	-	282	48	-	1.110	0.023
	Lawrence Berkeley Lab. (LBL)	1,957	14	18	3	-	-	-	-	-	1,992	35	-	14.444	0.413
	Lawrence Livermore Nat'l. Lab. (LLNL)	7,546	70	93	8	1	-	-	-	-	7,718	172	1	49.153	0.286
	Stanford Linear Accelerator Center (SLAC)	2,276	-	7	-	-	-	-	-	-	2,283	7	-	2.090	0.299
Oak Ridge	Oak Ridge Operations	2,559	-	-	-	-	-	-	-	-	2,559	-	-	-	-
	Oak Ridge Site	14,761	35	79	15	3	-	-	-	-	**14,893◄**	132	3	79.416	0.602
	Paducah Gaseous Diff. Plant (PGDP)	530	-	-	-	-	-	-	-	-	530	-	-	-	-
	Portsmouth Gaseous Diff. Plant (PORTS)	176	-	-	-	-	-	-	-	-	176	-	-	-	-
Ohio	Ohio Field Office	385	26	30	27	-	-	-	-	-	468	83	-	46.820	0.564
	Fernald Environmental Mgmt. Project	4,332	3	3	-	-	-	-	-	-	4,338	6	-	0.469	0.078
	Mound Plant	928	-	-	-	-	-	-	-	-	928	-	-	-	-
	West Valley	852	188	75	-	-	-	-	-	-	1,115	263	-	25.489	0.097
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	3,031	2,239	844	171	32	1	-	-	-	6,318	**3,287◄**	**33◄**	**912.372◄**	0.278
Richland	Hanford Site	7,496	1,885	843	209	6	2	-	-	-	10,441	2,945	8	806.189	0.274
Savannah River	Savannah River Site (SRS)	7,797	2,107	939	128	5	-	-	-	-	10,976	3,179	5	609.443	0.192
	Totals	**95,410**	**8,347**	**3,938**	**722**	**56**	**8**	**1**	**0**	**0**	**108,482**	**13,072**	**65**	**3,390.093**	**0.259**

* 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.

Rocky Flats had the greatest number of people receiving an extremity dose and 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.

Appendix C

Facility Type Code Descriptions

DOE Manual 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 policy decision of 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. Average annual doses at these facilities are slightly higher than the overall average for DOE; however, the collective dose is lower than the collective dose for most other DOE facility categories because of the relatively small number of employees at accelerator facilities. Regarding internal exposures, tritium and short-lived airborne activation products exist at some accelerator facilities, although annual internal doses are generally quite low.

Fuel/Uranium Enrichment

The DOE involvement in the nuclear fuel cycle generally begins with uranium enrichment operations and facilities [15]. 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 [15]. 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

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

exposures, although neutron exposures can occur, especially when work is performed near highly enriched uranium. Both the average and collective external doses at these facilities are among the lowest of any DOE facility category.

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 [15]. 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. Average external doses at fuel fabrication facilities are generally higher than at other types of DOE facilities; however, collective doses are relatively low because the number of employees is low. Internal doses from inhalation of uranium are kept very low.

Fuel Processing

The DOE administers several facilities that reprocess spent reactor fuel. These facilities separate the plutonium produced in reactors for use in defense programs. 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.

The very high radioactivity of fission products in spent nuclear fuel results in employees at fuel processing facilities consistently having among the highest average doses of any DOE facility type. However, the collective dose at these facilities is less significant because of the small total number of employees. Penetrating doses are attributable primarily to gamma photons, although some neutron exposures do occur. Skin and extremity doses from handling samples are also significant, although only a few employees typically receive skin doses greater than 5 rem/year. 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, and annual effective dose equivalents from the depositions are typically less than 0.5 rem.

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.

Because many maintenance and support activities at DOE sites do not involve work near sources of ionizing radiation, the average dose equivalent per monitored employee is typically among the lowest of any facility type. However, those employees who do perform work near radiation sources receive relatively high average annual doses, as is indicated by the relatively high average annual dose per employee who receives a measurable exposure. Also, collective doses are relatively high because there is a large number of these employees relative to the number classified under other facility types. 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. The average and collective external doses relative to other facility types are highly dependent on the status of reactor operations. Inhalation of airborne radioactive material such as H-3 is a concern in some plant areas. However, protective measures, such as area ventilation or use of respiratory-protection equipment, result in low internal doses.

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. Relative to other facility types, average annual individual doses are slightly above average at general research facilities. The collective dose equivalent is higher than at most other facility types because of the many individuals employed at general research facilities.

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. Relative to other DOE facility types, average individual doses and collective doses are typically the lowest at fusion research facilities. Regarding internal exposures, airborne tritium is a concern at some fusion research facilities, although the current level of operation results in minimal doses.

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 relatively high, sometimes exceeding 1 rem/year. Penetrating doses at waste processing facilities are attributable primarily to gamma photons; however, neutron exposures are significant at the large-scale facilities. Skin doses are generally not a significant problem. Overall, average annual doses at waste processing/management facilities are among the highest of any DOE facility type, which is attributable primarily to the two large-scale facilities and the shift in DOE mission from national defense production to waste management and environmental restoration. The annual collective doses are closer to the average of all facility types, however, because of the relatively small number of employees at this type of facility.

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 the testing facilities, radiation doses received by personnel are generally minimal because of the strict controls over personnel access to testing areas, although extremity doses can be relatively high from handling neutron-activated materials. Radiation doses are a greater concern at facilities where weapons and weapons-grade nuclear material are handled. At these facilities, neutron radiation dose rates can be significant when processing relatively small quantities of ^{238}Pu or larger quantities of mixed plutonium isotopes [16]. Penetrating doses from gamma photons and plutonium x-rays can also be significant in some situations, as can skin and extremity doses from plutonium x-rays. Overall, average individual annual doses at these facilities are slightly higher than the DOE average. The collective doses received by employees at these facilities are generally higher than the collective doses at other facility types because of the large number of individuals employed.

Also of significant concern at these facilities is inhalation of plutonium, where inhalation of very small amounts can result in doses exceeding limits. To prevent plutonium intakes, strict controls are in place including process containment, contamination control procedures, and air monitoring and bioassay programs [16]. As a result, significant internal exposures are very rare at these facilities.

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. In general, employees classified under this facility type receive annual doses significantly less than the annual doses averaged over all DOE facilities. However, the wide variation in the type of work performed by these individuals results in a wide variation in the types and levels of exposures. 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

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.

Monitoring Practices

Radiation monitoring practices differ widely 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 on which workers to monitor. While all sites have achieved compliance with the DOE Laboratory Accreditation Program (DOELAP), which standardizes the quality of dosimetry measurements, there are still differences in the dosimeters used that can contribute to differences in the collective dose from site to site. 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 inflate the number of monitored workers with no dose, it also can add a large 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 add significantly to the site 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 in the higher dose ranges. 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. 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 1994 to 1998. 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.

Occupation Codes

Each individual's dose record includes the occupation code for the individual while he or she 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 are 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. It is recommended that Sites and Operations Offices evaluate their recordkeeping and reporting process and report the information to the REMS system as specified in DOE M 231.1-1 to improve the analysis of radiation exposure by occupation, and thus make this report more useful to line manager and worker protection decision makers.

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. A "phase of operation" status code could be added to the occupational radiation reporting requirements for individual dose records (see Appendix A-4). In combination with the facility type codes already reported, this would provide an indication of the operational mode and type of activities being conducted at a given facility. This will become increasingly important as more facilities transition from stabilization activities into D&D. It is recommended that Sites and Operations Offices begin reviewing their data collection process in anticipation of collecting the phase of operation data in the future.

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. Two such changes are noteworthy within the past several years. The Fernald Field Office began reporting independently in 1993. Prior to 1993 it reported under the Oak Ridge Field Office. In 1994, Fernald was incorporated into the newly created Ohio Field Office. The Ohio Field Office began reporting in 1994. For this reason, the Fernald data are shown under the Ohio Field Office. The Mound Plant and West Valley Project also 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 seven 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".

Updates to the Data

The data in the REMS database are subject to correction and update on a continual basis. Data for prior years are subject to correction as well as the data for the most recent year included in this report. The most common reason for correction to a dose record is because of a final dose determination of an internal dose after the original dose record was submitted to REMS. This delay is due to the time needed to assess the bioassay results and determine the dose from long-lived radionuclides. It is recommended that sites review their dose record update and reporting process, specifically for internal dose determination, and consider the addition of a mechanism whereby they report dose updates to REMS in a timely fashion when updates occur. Corrections will be reflected in subsequent annual reports. For the most up-to-date status of radiation exposure information, contact:

Ms. Nirmala Rao
REMS Project Manager
U.S. Department of Energy
Office of Worker Protection Programs and
Hazards Management (EH-52)
Germantown, MD 20874

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. Recently, the REMS has undergone 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-tiered approach has been developed to allow researchers flexibility in accessing the REMS data.

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 and skill sets needed for each method. Descriptions of the intended research audience and experience level (for computer systems) are also provided. To obtain further information, a contact name and phone number are provided.

A brief summary of the multi-tier access to the REMS information is shown in *Exhibit E-1*.

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 is the health risk associated with worker exposure to radiation. While the health risk from occupational exposure is 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 risk 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 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 risks of radiation exposure 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	Experience Requirements			Software Requirements[3]	Eligibility Requirements	To Get Access
	Knowledge of REMS Data	Computer Expertise				
		User	System Adminstrator-Setup			
Hardcopy Annual Report	**None.** Data explained in report.	**N/A**	**N/A**	**None.**	**None.**	Contact EH-52[1] to request that you be added to Annual Report mailing list.
Web Page	**Low.** General knowledge/interest in radiation data.	**Minimal** computer skills. Only a knowledge of how to use the Web browser, and an Internet connection.	**Medium.** Supply LAN connection to Internet or Internet Provider. Support Web browser.	Internet access. Web browser client software.	**None.**	Connect to http://rems.eh.doe.gov/
InfoMaker - Pre-defined reports	**Medium.** Need to know the data limitations of the data in REMS, and what the exposure data represent.	**Minimal.** Familiarity with Windows applications. Need to understand difference between Query and Reports.	**Medium.** Client-server computer configuration can be complex, but this is a one-time effort. InfoMaker support provided by DOE HQ.	Internet access (TCP/IP). Oracle SQLNet. PowerSoft InfoMaker. [Oracle SNS software if Category 1 user]	No requirements for Category 2 users[4]. Category 1 users must get "need to know" Privacy Act authorization from EH-52[1].	Contact OIM[2] to request access. EH-52 authorization required for Category 1 users.
InfoMaker - Ad Hoc Queries	**High.** Need to thoroughly understand the data dictionary, relationships and structure of the database. Limitations of the data.	**Medium** (to High). Some knowledge of SQL highly recommended. Should be familiar with "Report generation"-type software.	**Medium.** Client-server computer configuration can be complex, but this is a one-time effort. InfoMaker support provided by DOE HQ.	Internet access (TCP/IP). Oracle SQLNet. PowerSoft InfoMaker. [Oracle SNS software if Category 1 user]	No requirements for Category 2 users[4]. Category 1 users must get "need to know" Privacy Act authorization from EH-52[1].	Contact OIM[2] to request access. EH-52 authorization required for Category 1 users.
Client query tool other than InfoMaker	**High.** Need to thoroughly understand the data dictionary, relationships and structure of the database. Limitations of the data.	**High.** Need to be skilled in SQL and connecting to the system. Need to be skilled in the use of whatever query tool is used.	**Medium.** Support for LAN connection to Internet or Internet Provider. Support user query software.	Internet access (TCP/IP). Oracle SQLNet. ODBC Drivers. Query Tool client. [Oracle SNS software if Category 1 user]	No requirements for Category 2 users[4]. Category 1 users must get "need to know" Privacy Act authorization from EH-52[1].	Contact OIM[2] to request access. EH-52 authorization required for Category 1 users.

① EH-52 contact Ms. Nirmala Rao at — Phone: (301) 903-2297, Fax: (301) 903-7773, E-mail: Nimi.Rao@hq.doe.gov
② OIM contact Ms. Mary Cunningham at — Phone: (301) 903-2072, E-mail: mary.cunningham@eh.doe.gov
③ See REMS User Manual for detailed software requirements.
④ Category 1 - All data in the REMS system, including Privacy Act data such as name and social security number of the monitored individual.
Category 2 - Access to non-sensitive radiation monitoring information per monitored individual. See REMS Reference Manual for details.

Appendix F

User Survey

F

User Survey

DOE and DOE Contractor Employees Annual Radiation Exposure Report

User Survey

DOE, striving to meet the needs of its stakeholders, is looking for suggestions on ways to improve the DOE and DOE Contractor Employees Annual Radiation Exposure Report. **Your feedback is important.** Constructive feedback will ensure the report can continue to meet user needs. Please fill out the attached survey form and return it to:

Ms. Nirmala Rao
DOE EH-52 270/cc
19901 Germantown Road
Germantown, MD 20874

Questions concerning the survey should be directed to Ms. Rao at (301) 903-2297

---

1. Identification:

Name: ....

Title: ....

Mailing Address: ....

....

....

....

2. Distribution:

2.1 Do you wish to remain on distribution for the report? ___ yes ___ no

2.2 Do you wish to be added to the distribution? ___ yes ___ no

3. Was the presentation/discussion of dose distribution data for:

DOE-wide	adequate ___	inadequate ___
Sites	adequate ___	inadequate ___
Facilities	adequate ___	inadequate ___
Occupation/Labor	adequate ___	inadequate ___

Comments/areas for improvement:

....

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....

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....

....

4. Was the presentation/discussion of dose trends for:

DOE-wide .... adequate ___ inadequate ___
Sites .... adequate ___ inadequate ___
Facilities .... adequate ___ inadequate ___
Occupation/Labor .... adequate ___ inadequate ___

Comments/areas for improvement:

....
....
....
....
....
....
....

5. Was the discussion of ALARA Projects at specific sites:

Useful ___ Keep in future reports ___
Not useful ___ Delete from future reports ___

6. Was the discussion of AEDE vs CEDE helpful?

Useful ___ Keep in future reports ___
Not useful ___ Delete from future reports ___

7. Would additional/different breakouts of the data be helpful?

Yes ___ No ___

Comments/areas for improvement:

....
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....

8. Suggestions for new facility type, occupation, and/or labor codes.

....
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....

9. If/when the data become available, would person-rem/hr or person-rem/RWP be useful in this report?

Yes ___ No ___

Comments/areas for improvement:

....

....

....

....

....

....

....

10. To publish this report in the second quarter and to be able to use it as a management tool, we need the data *as soon as possible* after you have processed it. Please indicate when you can provide the data.

Quarterly ___
Semi-Annually ___
Yearly* ___

*By end of January, February, March

(please circle one)

11. DOE is considering the addition of a code for indicating the Phase of Operation of the facility type that is currently reported with each dose record (see A-4). The Phase of Operation will allow for expanded analysis of the dose information by considering the operational phase of the facility. Please indicate whether this information is available at your site, and the years the information would cover.

Available___ Years:________to_________

Not available___

Prepared by:
Science Applications International Corporation
301 Laboratory Road • Oak Ridge, TN 37830