DOE/EH-0660

DOE Occupational Radiation Exposure

2001 Report

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DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA

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DOE Occupational Radiation Exposure

2001 Report

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

Foreword

The goal of the U.S. Department of Energy (DOE) is to conduct its operations, including radiological, to ensure the safety and health of all DOE employees, 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 to levels that are "As Low As Reasonably Achievable" (ALARA).

The *2001 DOE Occupational Radiation Exposure Report* provides a 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 dose at DOE (as measured by the collective external whole body dose) has declined by 86% from 8,340 person-rem in 1985 to 1,171 person-rem in 2001 due to a cessation in opportunities for radiation exposure during the transition in DOE mission from weapons production to cleanup, deactivation, and decommissioning. In 2001, the collective dose decreased by 3% (from 1,267 person-rem to 1,231 person-rem) from the 2000 value due to decreased doses at three of the six highest dose DOE sites. Sites that reported decreases in the collective dose attributed it to a reduction of radioactive source material on site from the repackaging and shipment of these materials for off-site disposal (primarily at Rocky Flats), and the absence of any internal doses in excess of 2 rem (20 mSv) in 2001. In 2000, internal dose from intakes contributed significantly to the overall collective dose. The DOE average measurable total effective dose equivalent (TEDE) decreased by 6% (from 0.079 rem to 0.074 rem) from 2000 to 2001.

This report is intended to be a valuable tool for managers and workers in their management of radiological safety programs and commitment of resources. The process of data collection, analysis, and report generation is streamlined to provide 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.

Beverly A. Cook
Assistant Secretary
Environment, Safety and Health

C. Rick Jones
Acting Deputy Assistant Secretary
Office of Safety and Health

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10 CFR 820	Title 10 Code of Federal Regulation Part 820 "Procedural Rules for DOE Nuclear Activities," August 17, 1993
10 CFR 835	Title 10 Code of Federal Regulation Part 835 "Occupational Radiation Protection," December 14, 1993
10 CFR 835, Amendment	Issued on November 4, 1998
10 CFR 835.402.d	Amendment to be fully implemented by January 1, 2002
ACL	Administrative Control Level
ACM	Asbestos-Containing Material
AEDE	Annual Effective Dose Equivalent
AEC	Atomic Energy Commission
ALAP	As Low As Practicable
ALARA	As Low As Reasonably Achievable
ANL-E	Argonne National Laboratory - East
ANL-W	Argonne National Laboratory - West
ANSI	American National Standards Institute
ANSI N13.30-1996	ANSI Note on Performance Criteria for Radioassay
ARPR	Acid Recovery Pump Room
BHI	Bechtel Hanford, Inc.
BNFL	British Nuclear Fuels Limited
BNL	Brookhaven National Laboratory
CAM	Constant Air Monitor
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CEDR	Comprehensive Epidemiologic Data Resource
CHG	CH2M Hill Hanford Group
CSB	Canister Storage Building
DAC	Derived Air Concentration
D&D	Decontamination and Decommissioning
DDE	Deep Dose Equivalent
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DOE HQ	DOE Headquarters
DOE M 231.1-1	Manual for Environment, Safety and Health Reporting, September 10, 1995
DOE Notice 441.1	Radiological Protection for DOE Activities, September 29, 1995
DOE Order 5480.11	Radiation Protection for Occupational Workers, December 1988
DOE Order 5484.1	"Environmental Protection, Safety, and Health Protection Information Reporting Requirements," February 24, 1981, Change 7, October 17, 1990
DOELAP	DOE Laboratory Accreditation Program
DQO	Data Quality Objectives
DRS	Decontamination & Recovery Services
EDE	Effective Dose Equivalent
EH-52	DOE Office of Worker Protection Policy and Programs
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ES&H	Environment, Safety & Health
ETTP	East Tennessee Technology Park (formerly K-25)
EUO	Enriched Uranium Operations
FERMCO	Fernald Environmental Restoration Management Corporation
FERMI	Enrico Fermi National Accelerator Laboratory
HEPA	High-Efficiency Particulate Air (Filter)
HLW	High-Level Waste
HPT	Health Physics Technology
ICRP	International Commission on Radiological Protection
INEEL	Idaho National Engineering & Environmental Laboratory
ISMS	Integrated Safety Management System
ISOCS	In Situ Object Counting System
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory

TABLE OF ACRONYMS (continued)

LDE	Lens (of the eye) Dose Equivalent
LEHR	Laboratory for Energy-Related Health Research
LLNL	Lawrence Livermore National Laboratory
LLPIT	Lessons Learned Process Improvement Team
LLW	Low-Level Waste
M&H	Mason & Hanger
MDA	Minimum Detectable Activity
MSR	Molten Salt Reactor
mSv	MilliSievert
NAC	Nuclear Assurance Corporation
NCRP	National Council on Radiation Protection and Measurements
NRC	Nuclear Regulatory Commission
NREL	National Renewable Energy Laboratory
NTS	Nevada Test Site
NYSERDA	New York State Energy Research and Development Authority
ORISE	Oak Ridge Institute for Science & Education
ORNL	Oak Ridge National Laboratory
ORPS	Occurrence Reporting and Processing System
OSL	Optically Stimulated Luminescence
PFP	Plutonium Finishing Plant
PGDP	Paducah Gaseous Diffusion Plant
PIC	Pocket Ionization Chamber
PNNL	Pacific Northwest National Laboratory
PORTS	Portsmouth Gaseous Diffusion Plant
PP	Pantex Plant
PPE	Personal Protective Equipment
PPH	Plutonium Packaging & Handling
PSEs	Planned Special Exposures
PVU	Portable Ventilation Units
RadCon	Radiological Control Manual, June 1992
RCO	Radiological Control Operations
RCS	Radiological Control Standard
REC	Radiochemical Engineering Cells
REMS	Radiation Exposure Monitoring System
RFETS	Rocky Flats Environmental Technology Site
RW	Radiological Workers
SCO	Surface Contaminated Object
SDE	Shallow Dose Equivalent
SDE-ME	Shallow Dose Equivalent to the Maximally Exposed Extremity
SDE-WB	Shallow Dose Equivalent to the Skin of the Whole-Body
SLAC	Stanford Linear Accelerator Center
SNL	Sandia National Laboratory
SOC	Standard Occupational Classification
SRS	Savannah River Site
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent Dosimeters
TLND	Thermoluminescent Neutron Dosimeter
TODE	Total Organ Dose Equivalent
TRU	Transuranic
UMTRA	Uranium Mill Tailings Remedial Action
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WIPP	Waste Isolation Pilot Plant
WRAP	Waste Receiving and Processing
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services, Inc.
WVNSCO	West Valley Nuclear Services Company
Y-12 Plant	Y-12 National Security Complex

Executive Summary

The U.S. Department of Energy (DOE) Office of Safety and Health publishes the annual *DOE Occupational Radiation Exposure Report*. This report is intended to be a valuable tool for DOE and DOE contractor managers and workers 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 to make the report most useful.

This report includes occupational radiation exposure information for all monitored DOE employees, contractors, subcontractors, and members of the public. 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 years 2000 and 2001, the DOE collective Total Effective Dose Equivalent (TEDE) decreased by 3% from 1,267 person-rem (12,670 person-mSv) to 1,231 person-rem (12,310 person-mSv) primarily due to decreased doses at three of the six DOE sites with the highest radiation dose. The average dose to workers with measurable dose decreased by 6% from 0.079 rem (0.79 mSv) in 2000 to 0.074 rem (0.74 mSv) in 2001 as shown in *Exhibit ES-2* because of the decrease in the collective dose and an increase in the number of workers with measurable dose. The number of individuals with measurable dose increased from 15,983 in 2000 to 16,552 in 2001. The percentage of monitored individuals receiving measurable dose increased by 1.2% from 15.5% in 2000 to 16.7% in 2001. There were no exposures in excess of the DOE 5 rem (50 mSv) annual TEDE limit, and only one exposure in excess of the DOE Administrative Control Level (ACL) of 2 rem (20 mSv) TEDE.

Eighty-one percent of the collective TEDE for the DOE complex was accrued at six DOE sites in 2001. These six sites are (in descending order of collective dose for 2001) Rocky Flats, Hanford, Savannah River, Oak Ridge, Los Alamos, and Idaho. Sites reporting under the category of weapons fabrication and testing account for the highest collective dose. Even though these sites are now primarily involved in nuclear materials stabilization and waste management, they report under this facility type. For the past 3 years, technicians and production staff have received the highest collective dose of any specified labor category.

Exhibit ES-1:
Collective TEDE Dose (person-rem), 1997-2001.

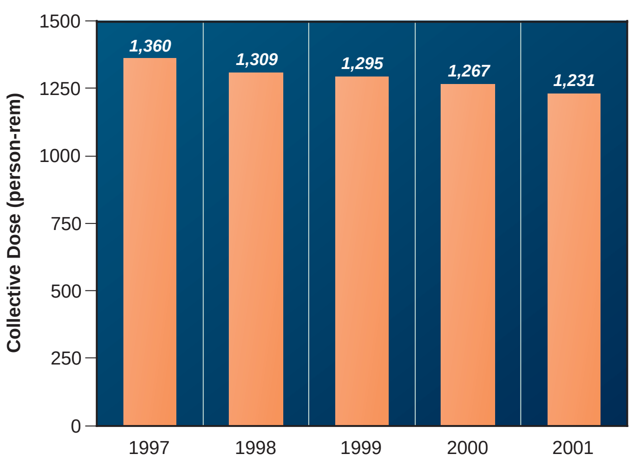
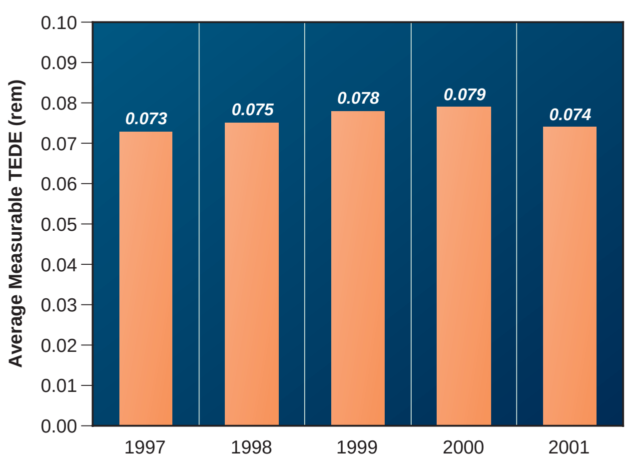


Exhibit ES-2:
Average Measurable TEDE (rem), 1997-2001.

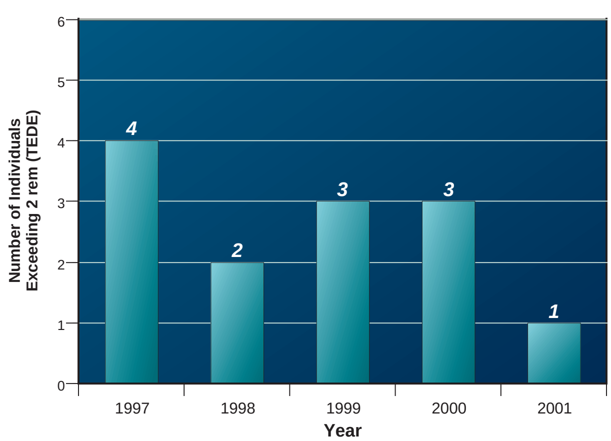


The change in operational status of DOE facilities has had the largest impact on radiation exposure over the past 5 years due to the shift in mission from production to cleanup activities and the shutdown of certain facilities. Reports submitted by two of the sites that experienced decreases in the collective dose (Rocky Flats and Oak Ridge) indicate that decreases in the collective dose were due to a reduction in source material from repackaging and shipping activities.

A statistical analysis was performed to analyze the trend in collective dose over the past 5 years. For the collective TEDE, there were small but significant differences for all 5 years, and the logarithmic mean TEDE per worker was significantly lower in 1998-2001 than in earlier years. The logarithmic mean dose in 2001 was 0.002 rem higher than in 2000, reflecting both an increase in the dose to individual workers and a larger number of individuals with measurable dose. However, the last 4 years show a consistently lower logarithmic mean TEDE compared to 1996 and 1997. The nonparametric tests showed no clear change in the distribution of dose among workers.

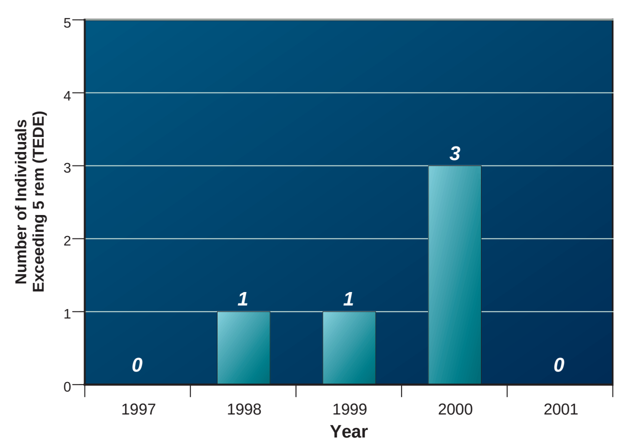
Over the past 5 years, few occupational doses at DOE facilities in excess of the 2 rem (20 mSv) ACL and 5 rem (50 mSv) TEDE regulatory limit have occurred, as shown in *Exhibits ES-3* and *ES-4*. All of the doses in excess of 2 rem (20 mSv) in the past 5 years were due to internal dose. Only one individual received a dose in excess of 2 rem (20 mSv) in 2001, and, in fact, the dose was equal to 2 rem (20 mSv) TEDE. No individuals received a dose in excess of the 5 rem (50 mSv) TEDE limit in 2001.

Exhibit ES-3:
Number of Individuals Exceeding 2 rem TEDE, 1997-2001.



Note: Number of individuals exceeding 2 rem TEDE includes those individuals that also exceeded 5 rem TEDE shown in Exhibit ES-4.

Exhibit ES-4:
Number of Individuals Exceeding 5 rem TEDE, 1997-2001.



The collective internal dose (CEDE) has decreased for the first time in 6 years with a 67% decrease between 2000 and 2001. Due to the increase in the number of individuals with measurable intakes and the decrease in the collective CEDE, the average measurable CEDE decreased by 68% from 2000 to 2001. The primary reason for this decrease was the absence of any intakes resulting in doses in excess of 2 rem (20 mSv) in 2001.

An analysis was performed on the transient workforce at DOE. A transient worker is defined as an individual monitored at more than one DOE site in a year. The results of this analysis show that the number of transient workers monitored has increased by 4% from 3,058 in 2000 to 3,183 in 2001, and still remains a very low percentage (3.2%) of the monitored workforce at DOE. The collective dose for these transients increased by 6% from 23.6 person-rem in 2000 to 25.1 person-rem in 2001, resulting in a 16% increase in the average measurable dose to transients from 0.045 rem in 2000 to 0.052 rem in 2001. The average measurable dose to transient workers has been between 50% and 70% of the value for the overall DOE workforce for the past 5 years.

Section 3.8,"External Dosimetry at DOE Sites", page 3-32 has been provided that describes the historical progression of external dosimetry used within the DOE complex. *Exhibit 3-37*, page 3-33 is provided showing information for several sites including how each has changed dosimetry methods in the past and, where available, the minimum detectable level for the dosimeters. *Exhibit 3-39*, page 3-36 shows the whole body dosimetry that is currently in use at DOE sites. All sites currently use thermoluminescent dosimetry to measure external exposure.

To access this report and other information on occupational radiation exposure at DOE, visit the Radiation Exposure Monitoring System (REMS) web site at:

http://rems.eh.doe.gov

Section One

Introduction

1

Introduction

The *DOE Occupational Radiation Exposure Report, 2001* reports occupational radiation exposures incurred by individuals at DOE facilities during the calendar year 2001. This report includes occupational radiation exposure information for all DOE employees, contractors, subcontractors, and members of the public. The 107 DOE organizations submitting radiation exposure reports for 2001 have been grouped into 30 geographic sites across the complex (see Appendix A.2). This information is analyzed and trended over time to provide a measure of DOE's performance in protecting its workers from radiation.

1.1 Report Organization

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

1.2 Report Availability

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

Ms. Nirmala Rao
DOE REMS Project Manager
EH-52, 270 Corporate Square Building
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20585-0270
E-mail: nimi.rao@eh.doe.gov

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

http://rems.eh.doe.gov

Section One	Provides a description of the content and organization of this report.
Section Two	Provides a discussion of the radiation protection and dose reporting requirements and their impacts on data interpretation. Additional information on dose calculation methodologies, personnel monitoring methods and reporting thresholds, regulatory dose limits, and ALARA is included.
Section Three	Presents the occupational radiation dose data from monitored individuals at DOE facilities for 2001. The data are analyzed to show trends over the past 5 years. A new section describing historical progression of external dosimetry used at DOE sites is included.
Section Four	Includes examples of successful ALARA projects within the DOE complex.
Section Five	Presents conclusions based on the analysis contained in this report.
Appendices	Lists reporting codes and organizations, a detailed breakdown of the data analyzed in this report, limitations of the data, and ways to access the REMS data.

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Section Two

Standards and Requirements

2

Standards and Requirements

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

This section discusses radiation protection standards and requirements in effect for the year 2001. 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 present DOE dose limits based on the TEDE were established from this guidance.

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

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

The 10 CFR 835 rule 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, provide a basis for the assessment of civil and criminal penalties under the Price-Anderson Amendments Act of 1988, Public Law 100-408, August 20, 1988 [8] as implemented by 10 CFR 820 "Procedural Rules for DOE Nuclear Activities," August 17, 1993. [9]

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

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

The requirements of DOE M 231.1-1 are basically the same as Order 5484.1; however, the dose terminology was revised to reflect the changes made in radiation protection standards and requirements. For 1995, DOE Order 5484.1 remained in effect. Most sites reported radiation monitoring results under the new DOE M 231.1-1 for 1996. Each site implemented the new requirements as operating contracts were issued or renegotiated.

2.1.1 Monitoring Requirements

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

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. External monitoring devices include thermoluminescent dosimeters (TLDs), optically stimulated luminescent dosimeters, pocket ionization chambers, electronic dosimeters, personnel nuclear accident dosimeters, bubble dosimeters, plastic dosimeters, and combinations of the above.

Beginning in 1986, the DOE Laboratory Accreditation Program (DOELAP) formalized accuracy and precision performance standards for external dosimeters and quality assurance/quality control requirements for external dosimetry programs at facilities within the DOE complex. All DOE facilities requiring accreditation 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 may receive higher doses or who enter higher radiation areas.

2.1.1.2 Internal Monitoring

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

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

2.2 Radiation Dose Limits

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

Under 835.204, Planned Special Exposures (PSEs) may be authorized under certain conditions allowing an individual to receive exposures in excess of the dose limits shown in *Exhibit 2-1*. With the appropriate prior authorization, the annual dose limit for an individual may be increased by an additional 5 rems (50 mSv) TEDE above the routine dose limit as long as the individual does not exceed a cumulative lifetime TEDE of 25 rems (250 mSv) from other PSEs and doses above the limits. PSE doses are required to be recorded separately and are only intended to be used in exceptional situations where dose reduction alternatives are unavailable or impractical. No PSEs have occurred during the past 7 years (since the requirement became effective).

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 in a Controlled Area	§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 initially established in the "RadCon Manual" and retained in the RCS. 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 RCS 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 RCS suggests an annual facility ACL of 0.5 rem (5 mSv) or less; however, the Manual also states that a control level greater than 1.5 rem (15 mSv) is, in most cases, not sufficiently challenging. Approval by the contractor senior site executive must be received prior to an individual exceeding the facility ACL. In addition to the annual ACL, the Manual recommends the establishment of a lifetime ACL of "N" rem, where N is the age of the person in years. Special control levels are also recommended to be established for personnel who have doses exceeding N rem.

2.2.2 ALARA Principle

Until the 1970s, the fundamental radiation protection principle was to limit occupational radiation dose to quantities less than the regulatory limits and to be concerned mainly with high dose and high-dose rate exposures. During the 1970s, there was a fundamental shift within the radiation protection community to be concerned with low dose and low-dose rate exposures because it could be inferred from the linear no-threshold dose response hypothesis that there was 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 and 10 CFR 835 require 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 10 CFR 835 that ALARA plans and procedures be implemented and documented. To help facilities meet this requirement, DOE developed a manual of good practices and an implementation guide 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 dose in one of 16 dose equivalent ranges. The revised Order required the reporting of the results of radiation exposure monitoring for each employee and member of the public. Required dose data reporting includes the TEDE; internal dose equivalent, Shallow Dose Equivalent (SDE) to the skin and extremities, and 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.

2.4 Change in Internal Dose Methodology

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

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

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

This report primarily analyzes dose information for the past 5 years, from 1997 to 2001. 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

3.1 Analysis of the Data

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

Key indicators for the analysis of aggregate data are: number of records for 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, facility type, and occurrence report information. Additional information is provided concerning activities at sites contributing to the collective dose. To determine the significance of trends, statistical analysis was performed on the data.

3.2 Analysis of Aggregate Data

3.2.1 Number of Records for Monitored Individuals

The number of records for monitored individuals represents the size of the DOE worker population provided with dosimetry. The number represents the sum of all records for monitored individuals, including all DOE employees, contractors, subcontractors, and members of the public. The number of monitored individuals is determined from the number of monitoring records submitted by each site. Because individuals may have more than one monitoring record, they may be counted more than once. The number of records for 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, the number of records for workers who receive a measurable dose best represents the exposed workforce.

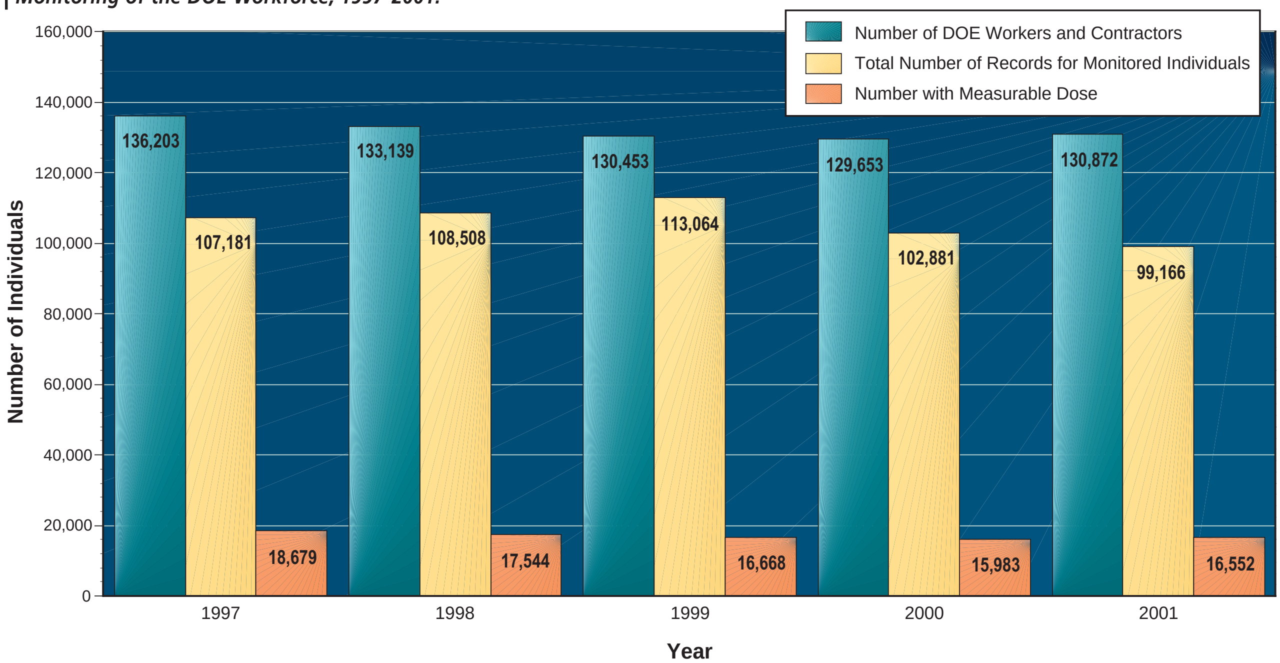
3.2.2 Number of Records for Individuals with Measurable Dose

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

Exhibit 3-1 shows the number of DOE workers and contractors, the total number of records for monitored individuals, and the number with measurable dose for the past 5 years. Although the total number of records of individuals monitored for radiation has decreased over the past 5 years by 7%, the percentage of the DOE workforce monitored for radiation exposure has increased by 3% from 1997 to 2001. However, most (84%) of the monitored individuals over the past 5 years did not receive any measurable radiation dose. An average of 16% of monitored individuals (13% of the DOE workforce) received a measurable dose during the past 5 years. The percentage of monitored workers receiving

Compared to 2000, a smaller percentage of the DOE workforce was monitored for radiation in 2001, while a larger percentage of monitored individuals received a measurable dose.

Exhibit 3-1:
Monitoring of the DOE Workforce, 1997-2001.



measurable dose has remained fairly constant for the past 5 years; 17% in 1997 and 17% in 2001. The overall DOE workforce has decreased by 4% over the past 5 years, but increased by 1% from 2000 to 2001. Compared to 2000, a smaller percentage of the DOE workforce was monitored for radiation in 2001, while a larger percentage of monitored individuals received a measurable dose.

Thirteen of the 30 reporting sites (see Appendix B-1c) experienced decreases in the number of workers with measurable dose from 2000 to 2001, with the largest decreases occurring at the Stanford Linear Accelerator Center (SLAC), Fernald, and Brookhaven National Laboratory (BNL). The largest increases in the number of workers receiving measurable dose occurred at the Oak Ridge Site, Hanford, and Savannah River. A discussion of activities at the six highest-dose facilities is included in Section 3.5.

The number of workers with measurable dose increased from 15,983 in 2000 to 16,552 in 2001.

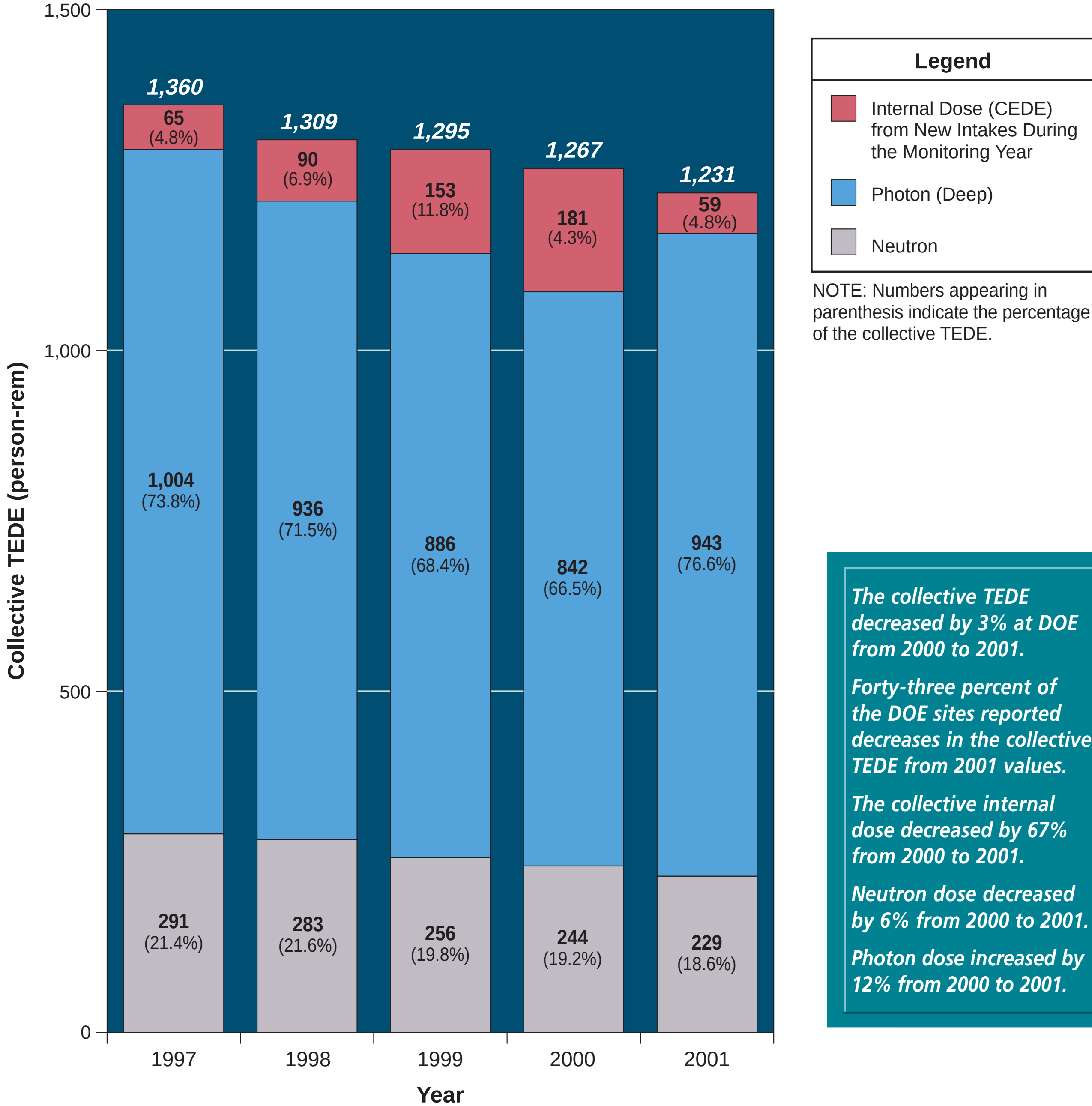
The percentage of monitored workers receiving measurable dose increased by one percentage point from 16% in 2000 to 17% in 2001.

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, subcontractors, and members of the public. 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 3% from 2000 to 2001. Forty-three percent of the DOE sites (13 out of 30 sites) reported decreases in the collective TEDE from the 2000 values. Three out of six of the highest dose sites reported decreases in the collective TEDE. The six highest dose sites are (in descending order of collective dose) Rocky Flats, Hanford, Savannah River, Oak Ridge, Los Alamos, and Idaho. Sites attributed the reduction in dose to a reduction in source material from repackaging and shipping activities. A discussion of the activities leading to this decrease is included in Section 3.5. Statistical analysis indicates that there were small but statistically

Exhibit 3-2:
Components of TEDE, 1997-2001.



NOTE: Numbers appearing in parenthesis indicate the percentage of the collective TEDE.

The collective TEDE decreased by 3% at DOE from 2000 to 2001.

Forty-three percent of the DOE sites reported decreases in the collective TEDE from 2001 values.

The collective internal dose decreased by 67% from 2000 to 2001.

Neutron dose decreased by 6% from 2000 to 2001.

Photon dose increased by 12% from 2000 to 2001.

Photon dose - the component of external dose from gamma or x-ray electromagnetic radiation. (Also includes energetic betas.)

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.

significant differences in the TEDE for the past 5 years, and the TEDE per worker was statistically lower in 1998-2001 than in earlier years. The logarithmic mean TEDE in 2001 increased to 0.028 rem (0.28 mSv) from 0.026 rem (0.26 mSv) in 2000, reflecting both an increase in the dose to individual workers, and a larger number of individuals with measurable dose. However, the last 4 years show a consistently lower logarithmic mean TEDE per worker compared to the 2-year period from 1996 to 1997. Note that the logarithmic mean used here is different from the average measurable dose discussed elsewhere in this report. 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 notable ALARA activities.

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

It should be noted that the internal dose shown in *Exhibit 3-2* for 1997 through 2001 is based on the 50-year CEDE methodology. The internal dose component decreased by 67% from 2000 to 2001 after five consecutive years of increase. There were no individuals with internal dose above 2 rem for the first time in 5 years. The collective internal dose can vary from year to year due to the relatively small number of uptakes of radioactive material and the fact that they often involve long-lived radionuclides, such as plutonium, which can result in relatively large committed doses. Due to the sporadic nature of these uptakes, care should be taken when attempting to identify trends from the internal dose records.

The external deep dose (comprised of photon and neutron dose) is shown in *Exhibit 3-2* in order to see the contribution of external dose to the collective TEDE. The collective photon dose increased by 12% between 2000 and 2001. Two of the sites that reported the largest increases in the photon dose attributed the increase to activities involving the preparation of waste shipments at Idaho and Savannah River and increased operations at the Savannah River FB-Line. See Section 3.5 for more information on activities at these sites.

The neutron component of the TEDE decreased by 21% from 1997 to 2001. This is primarily due to decreases in the neutron dose at Los Alamos National Laboratory (LANL) and Rocky Flats. Rocky Flats contributed 31% of the neutron dose at the DOE during 2001. Rocky Flats and LANL work with plutonium in gloveboxes, which can result in a neutron dose from the alpha/neutron reaction and from spontaneous fission of the plutonium. The collective neutron dose for 2001 by site is shown in Appendix B-5. External deep dose (DDE) and TEDE for prior years (1974-2001) can be found in Appendix B-3.

3.2.4 Average Measurable Dose

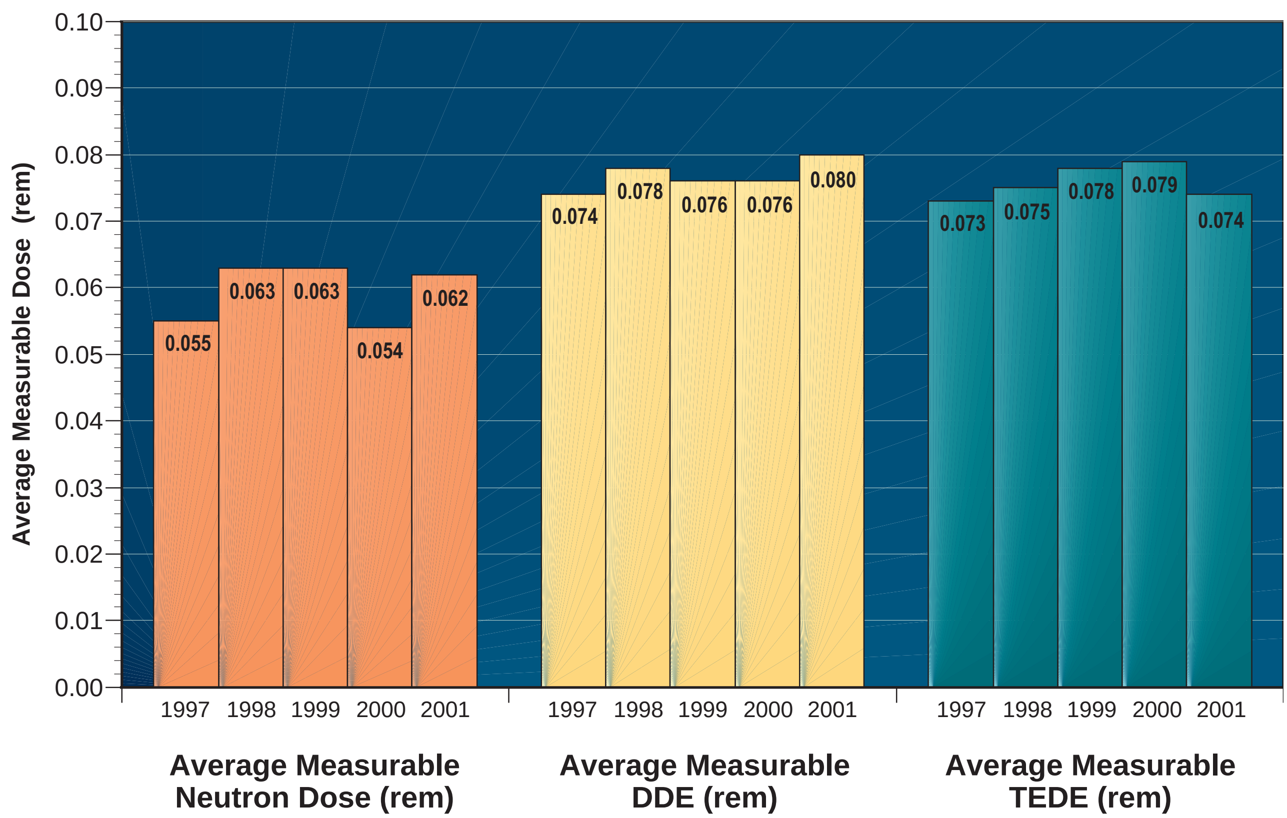
The average measurable dose to DOE workers presented in this report for TEDE, DDE, neutron, extremity, and CEDE is determined by dividing the collective dose for each dose type by the number of individuals with measurable dose for each dose type. This is one of the key indicators of the overall level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

The average measurable neutron, DDE, and TEDE is shown in *Exhibit 3-3*. The average measurable neutron dose increased by 15% from 2000 to 2001, primarily due to increases in neutron dose at LANL and Rocky Flats. The average measurable DDE increased by 5% from 2000 to 2001. While the collective TEDE decreased, the number with measurable dose increased, resulting in a 6% decrease in the average measurable TEDE. Statistical analysis indicates that there were small but statistically significant differences in the TEDE for the past 5 years, and the TEDE per worker was statistically lower in 1998–2001 than in earlier years. The logarithmic mean TEDE in 2001 increased to 0.028 rem (0.28 mSv) from 0.026 rem (0.26 mSv) in 2000, reflecting both an increase in the dose to individual workers, and an increased number of individuals with measurable dose. However, the last 4 years show a consistently lower logarithmic mean TEDE per worker compared to the 2-year period from 1996 to 1997. Note that the logarithmic mean used here is different from the average measurable dose discussed elsewhere in this report (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 neutron dose increased by 15% and the average measurable TEDE decreased by 6%, while the average measurable DDE increased by 5% from 2000 to 2001.

Exhibit 3-3:
Average Measurable Neutron, DDE, and TEDE, 1997-2001.



3.2.5 Dose Distribution

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

Exhibit 3-4 shows that few individuals receive doses in the higher ranges, that the vast majority of doses are at low levels, and that the collective TEDE dose has decreased every year for the past 5 years. 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.

The United Nations Scientific Committee on the Effects of Atomic Radiation's (UNSCEAR) 1993 report entitled "Sources and Effects of Ionizing Radiation" [14] recommends the calculation of a parameter "SR" (previously referred to as CR or MR) to aid in the examination of the distribution

Exhibit 3-4:
Distribution of Dose by Dose Range, 1997-2001.

	Dose Ranges (rem)	1997		1998		1999		2000		2001	
		TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE	TEDE	DDE
Number of Individuals in Each Dose Range*	Less than Measurable	88,502	89,805	90,964	92,803	96,396	98,125	86,898	88,621	82,614	84,490
	Measurable < 0.1	15,263	14,098	14,066	12,450	13,561	12,137	13,020	11,498	13,428	11,693
	0.10 - 0.25	2,142	2,046	2,253	2,120	1,898	1,763	1,873	1,722	1,887	1,778
	0.25 - 0.5	856	830	840	790	770	684	727	690	840	820
	0.5 - 0.75	265	258	268	245	238	206	211	203	259	250
	0.75 - 1.0	101	99	74	64	118	87	91	93	89	88
	1 - 2	48	45	41	36	80	62	58	54	48	47
	2 - 3	1		1		1				1	
	3 - 4	2				1					
	4 - 5	1									
	5 - 6										
	6 - 7			1		1					
	7 - 8										
	8 - 9										
	9 - 10							1			
	10 - 11										
	11 - 12							1			
	> 12							1			
Total Number of Records for Monitored Individuals		107,181	107,181	108,508	108,508	113,064	113,064	102,881	102,881	99,166	99,166
Number with Measurable Dose		18,679	17,376	17,544	15,705	16,668	14,939	15,983	14,260	16,552	14,676
Number with Dose >0.1rem		3,416	3,278	3,478	3,255	3,107	2,802	2,963	2,762	3,124	2,983
% of Individuals with Measurable Dose		17%	16%	16%	14%	15%	13%	16%	14%	17%	15%
Collective Dose (person-rem)		1,360	1,285	1,309	1,219	1,295	1,142	1,267	1,086	1,231	1,171
Average Measurable Dose (rem)		0.073	0.074	0.075	0.078	0.078	0.076	0.079	0.076	0.074	0.080

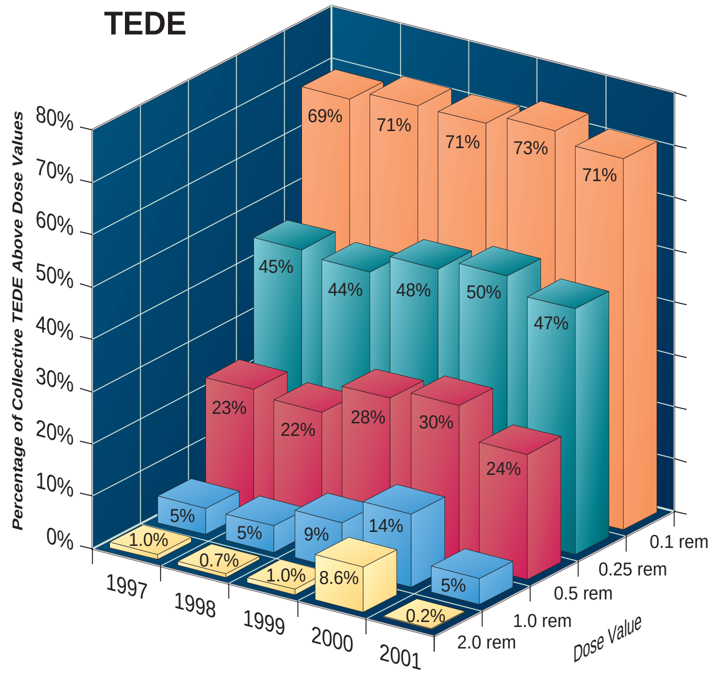
* Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.

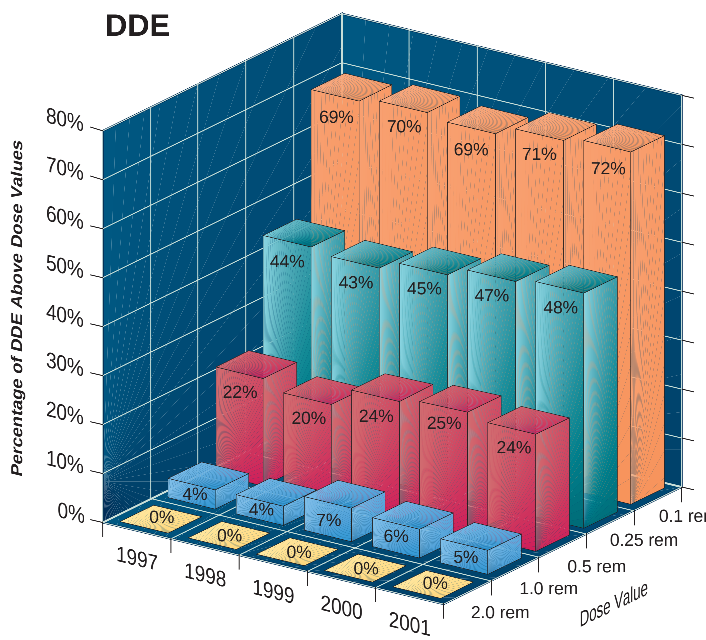
of radiation exposure among workers. SR is defined to be the ratio of the annual collective dose incurred by workers whose annual doses exceed 1.5 rem (15 mSv) to the total annual collective dose. The UNSCEAR report notes that a dose level of 1.5 rem (15 mSv) may not be useful where doses are consistently lower than this level, and they recommend that research organizations report SR values lower than 1.5 rem (15 mSv) where appropriate. For this reason, the DOE calculates and tracks the SR ratio at dose levels of 0.100 rem (1 mSv), 0.250 rem (2.5 mSv), 0.500 rem (5 mSv), 1.0 rem (10 mSv), and 2.0 rem (20 mSv). The SR values in this report were calculated by summing the TEDE to each individual who received a TEDE greater than or equal to the specified dose range divided by the total collective TEDE. This ratio is presented as a percentage rather than a decimal fraction.

Using this method of plotting the data, an ideal distribution would show only a small percentage of the collective dose delivered to individuals in the higher dose ranges. In addition, this method can be used to show the trend in the percentage of the collective dose above a certain dose range over time. For example, a significantly decreasing trend from year to year may indicate the effectiveness of ALARA programs to reduce doses to individuals, or may indicate an overall reduction in activities involving radiation exposure over time. An increasing trend over time may indicate deficiencies in the implementation of ALARA practices, or an increase in production or cleanup activities resulting in 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 facilitates the examination of 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 each successively higher dose range is responsible for a lower percentage of the collective dose. The values for the external dose (DDE) have fluctuated within a 5% margin for each dose range over the past 5 years. The values for TEDE in each dose range

Exhibit 3-5:
Percentage of Collective Dose above Dose Values During 1997-2001.





increased from 1998 to 2000, and decreased significantly in 2001. The increases from 1998 to 2000 were due to the increase in internal doses that exceeded the DOE limits. In 2000, three individuals received a TEDE above 5.0 rem (50 mSv) which contributed to 8.6% of the collective TEDE for the year, the highest percentage above 2 rem (20 mSv) since 1990. See Section 3.3 for more information on the exposures in excess of the DOE limit. In contrast, no individuals exceed the DOE limits in 2001 and collective internal dose decreased by 67% from 2000 to 2001.

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 2001, 3,677 individuals received measurable neutron dose, which is 22% of the individuals with measurable TEDE, and 4% of the total monitored individuals. The collective neutron dose in 2001 represents 19% of the collective TEDE. All neutron doses were below 2 rem (20 mSv) for the past 5 years. The collective neutron dose decreased by 6% from 2000 to 2001, and has decreased by 21% since 1997. The average measurable neutron dose increased by 15% from 2000 to 2001 to a level similar to 1998 and 1999. Statistical analysis of the neutron dose (see Section 3.2.6) reveals that the logarithmic mean neutron dose increased significantly to 0.027 rem, but remained below the 5-year peak of 0.031 rem that occurred in 1999. The change reflects an increase in the dose per worker, but the number of workers who received a measurable dose declined considerably between 2000 and 2001. The neutron dose distribution for 2001 by site is shown in Appendix B-5.

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*, less than 1% of individuals have received doses above the 5 rem (50 mSv) monitoring threshold over the past 5 years. All of the extremity exposures above 5 rem in 2001 were for the upper extremities. Forty-five percent of the extremity exposures above 5 rem in 2001 occurred at Hanford, where operations involving the manipulation of radioactive materials is more common. Seventy-three percent of individuals with measurable extremity dose were monitored at three sites: Savannah River, Hanford, and Rocky Flats. The number of individuals receiving a measurable extremity dose increased by 7% from 2000 to 2001, and the average extremity dose decreased by 17% from 2000 to 2001. 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 has received an extremity dose above

Exhibit 3-6:
Neutron Dose Distribution, 1997-2001.

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. Neutron Dose	Collective Neutron DDE (person-rem)	Average Meas. Neutron DDE (rem)
1997	101,862	4,500	631	149	29	6	4		107,181	**5,319** ◄	**290.610** ◄	0.055
1998	103,998	3,680	629	155	34	4	8		108,508	4,510	283.078	**0.063** ◄
1999	109,007	3,329	559	129	27	7	6		**113,064** ◄	4,057	256.075	**0.063** ◄
2000	98,353	3,809	554	144	17	4			102,881	4,528	243.802	0.054
2001	95,489	3,045	454	136	38	3	1		99,166	3,677	228.459	0.062

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.

Exhibit 3-7:
Extremity Dose Distribution, 1997-2001.

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)
1997	94,510	8,420	3,569	636	33	9	2	2		107,181	12,671	46	3,057.3	0.241
1998	95,436	8,347	3,938	722	56	8	1			108,508	13,072	65	3,390.1	0.259
1999	99,776	8,759	3,649	750	95	30	2			**113,064** ◄	**13,285** ◄	127	3,988.6	0.300
2000	91,329	7,279	3,322	818	88	37	8			102,881	11,552	133	**4,309.5** ◄	**0.373** ◄
2001	86,799	8,270	3,278	682	109	27		1		99,166	12,367	**137** ◄	3,838.0	0.310

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 extremity of 5 rem or more in 1 year.

the regulatory limit of 50 rem (500 mSv) since 1989. For the past 5 years, no individual has exceeded 40 rem (400 mSv) to the extremities. Statistical analysis indicates that the logarithmic mean measurable extremity dose decreased significantly from 2000 to 2001 for the first time in 5 years. While a larger number of workers received a measurable dose, the dose per worker decreased. The extremity dose distribution by site for 2001 is shown in Appendix B-22.

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 meaningful 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 is 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 nonparametric tests were used: 1) analysis of variance using ranks, and 2) the Kruskall-Wallis test.

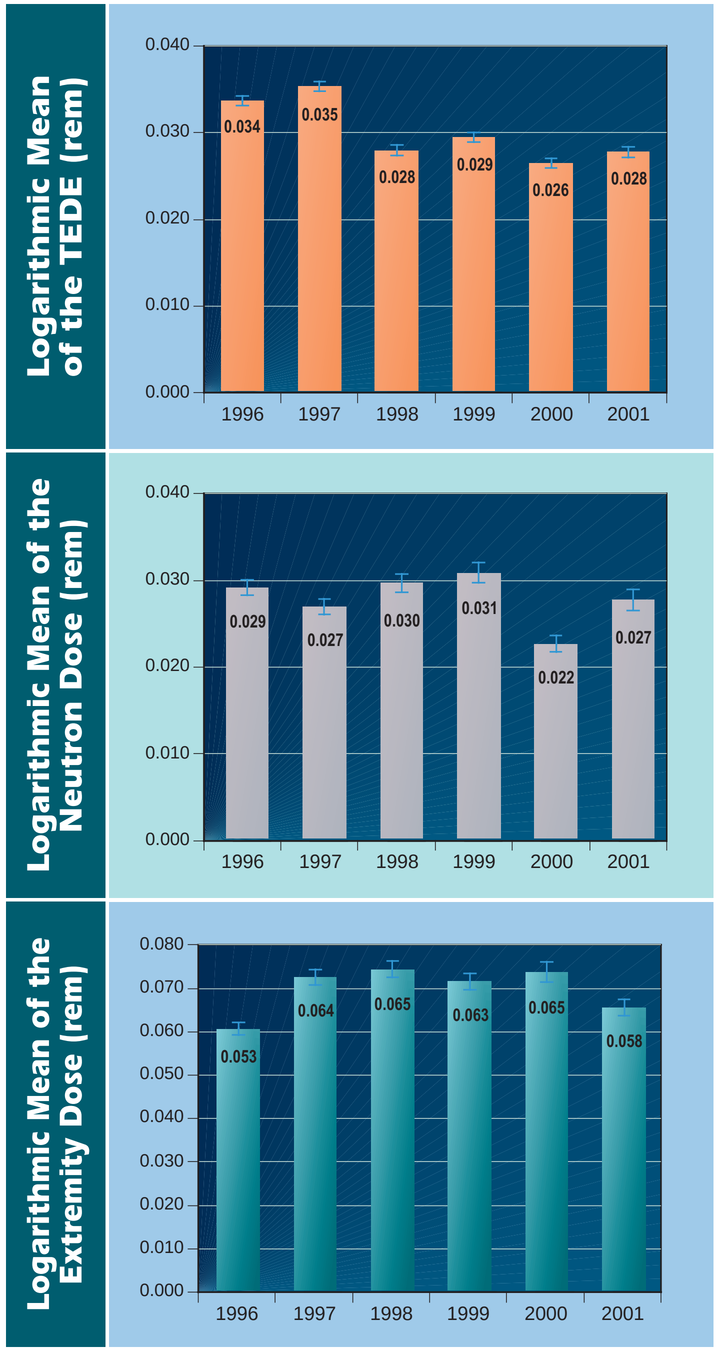
These statistical tests reveal trends that are not apparent when considering only the collective and average doses. In addition, the statistical analysis reveals that some of these trends are significant. *Exhibit 3-8* shows the results of pairwise T-tests for the collective TEDE, neutron, and extremity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

Statistical analysis indicates that there were small but statistically significant differences in the TEDE for the past 5 years, and the TEDE per worker was statistically lower in 1998–2001 than in earlier years. The logarithmic mean TEDE in 2001 increased to 0.028 rem (0.28 mSv) from 0.026 rem (0.26 mSv) in 2000, reflecting both an increase in the dose to individual workers, and a larger number of individuals with measurable dose. However, the last 4 years show a consistently lower logarithmic mean TEDE per worker compared to the 2-year period from 1996 to 1997. Note that the logarithmic mean used here is different from the average measurable dose discussed elsewhere in this report. The nonparametric tests showed no clear change in the distribution of dose among workers.

The mean neutron dose rose significantly to 0.027 rem, but remained below the 5-year peak of 0.031 rem that occurred in 1999. The change reflects an increase in the dose per worker, but the number of workers who received a measurable dose declined considerably between 2000 and 2001 (see *Exhibit 3-6*).

The logarithmic mean measurable extremity dose dropped significantly in 2001 for the first time in 5 years. While a larger number of workers received a measurable dose (see *Exhibit 3-7*), the dose per worker decreased. From 1995 to 1997, the mean extremity dose increased from 0.51 rem to 0.64 rem, and remained at the higher level from 1997-2000.

Exhibit 3-8:
DOE-Wide Summary Results for Statistical Tests, 1996-2001.



3.3 Analysis of Individual Dose Data

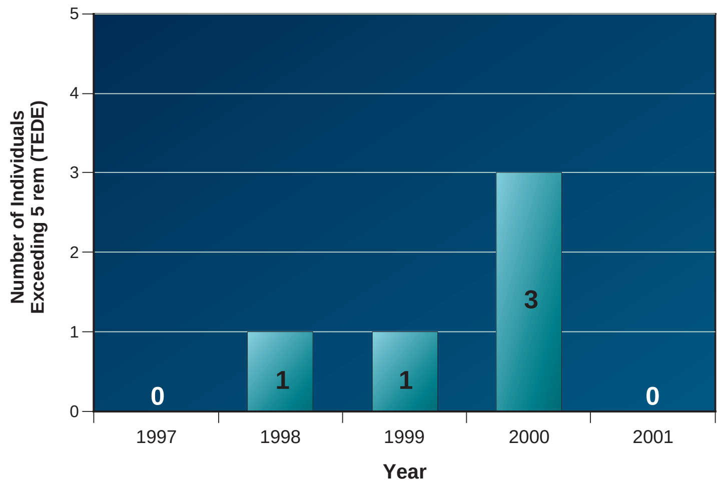
The above analysis is based on aggregate data for DOE. From an individual worker perspective as well as a regulatory perspective, it is important to closely examine the doses received by individuals in the elevated dose ranges to thoroughly understand the circumstances leading to these doses in the workplace and to better manage and avoid these doses 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 1997 through 2001. Further information concerning the individual dose, radionuclides involved, and site where the dose occurred is shown in *Exhibit 3-10*.

In 2001 there were no individuals reported who received doses in excess of the 5 rem (50 mSv) TEDE limit.

Exhibit 3-9:
Number of Individuals Exceeding 5 rem (TEDE), 1997-2001.



3.3.2 Doses in Excess of Administrative Control Level

The RCS [7] recommends a 2 rem (20 mSv) ACL for TEDE, which should not be exceeded without prior DOE approval. The RCS recommends that each DOE site establish its own, more restrictive ACL that would require 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.

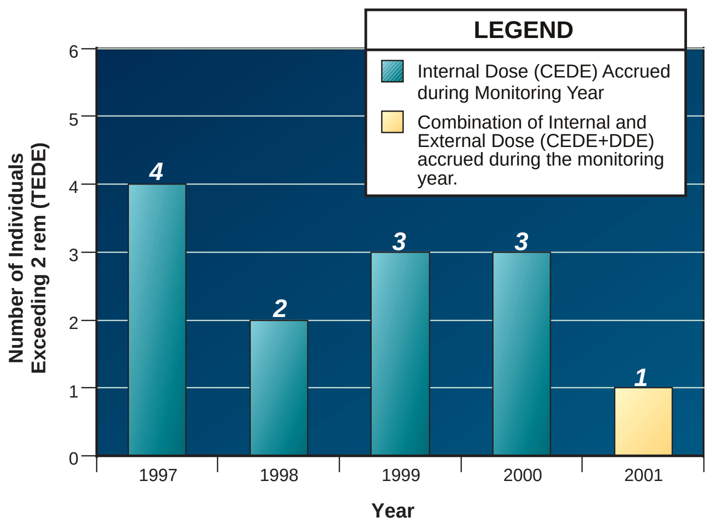
Exhibit 3-10:
Doses in Excess of DOE Limits, 1997-2001.

Year	TEDE (rem)	DDE (rem)	CEDE (rem)	Intake Nuclides	Facility Types	Site
1997				None Reported		
1998	6.292	0.282	6.010	Pu-238, Pu-239, Pu-240	Maintenance and Support	LANL
1999	6.964	0.245	6.719	Pu-238, Pu-239, Pu-241, Am-241	Weapons Fabrication and Testing	Savannah River
2000*	9.692	0.322	9.370	Pu-238, Pu-239, Pu-240	Research, General	LANL
	11.745	0.245	11.500	Pu-238, Pu-239, Pu-240	Research, General	LANL
	87.156	0.156	87.000	Pu-238, Pu-239, Pu-240	Maintenance and Support	LANL
2001				None Reported		

* *These three doses were all a result of the same occurrence.*

As shown in *Exhibit 3-11*, one individual received a TEDE above 2 rem (20 mSv) during 2001. In fact, the individual was reported to have received exactly 2 rem (20 mSv) TEDE, comprised of 1.510 rem (15.10 mSv) internal dose (CEDE) from Plutonium-239 and 0.490 rem (4.90 mSv) external dose (DDE) which includes 0.226 rem (2.26 mSv) from neutrons. For purposes of this report, individuals who receive doses that are equal to or above a certain dose level are considered to have "exceeded" that dose level.

Exhibit 3-11:
Number of Doses in Excess of the DOE 2 rem ACL, 1997-2001.



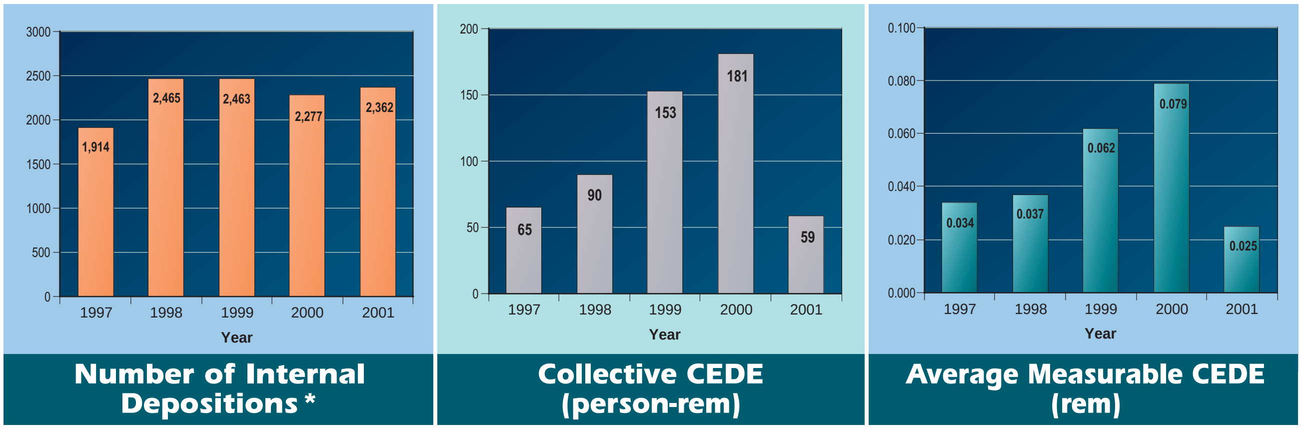
The incident occurred at LANL in September of 2001, when an employee was working on materials inside a glovebox in the TA-55 facility. The impact of hammering on the material inside the glovebox caused a gasket leak in the glovebox, resulting in a release of airborne radioactive material in the work area. The employees in the work area noted elevated readings from the continuous area monitors (CAMs) and shut down their activities to analyze the situation. Subsequently, four employees were put on a diagnostic bioassay program to determine the extent of their exposure from the event. One of these 4 individuals received a CEDE of 1.5 rem (15 mSv) from Plutonium-239 as a result of the release. The other three individuals received doses less than 0.028 rem (0.28 mSv). The direct cause was attributed to equipment failure and the root cause was identified as a management failure due to lack of appropriate procedures to identify and replace aging gaskets. Corrective actions included a repair of the glovebox gasket, a prohibition on hammering or other high impact activities in gloveboxes that may cause leakage of gaskets, a review of policies and practices, and an inspection of other similar equipment at the facility. For more details on this event, see the Occurrence Report ALO-LA-LANL-TA55-2001-0026.

3.3.3 Internal Depositions of Radioactive Material

As shown in *Exhibit 3-10*, some of the highest doses to individuals have been the result of intakes of radioactive material. For this reason, DOE emphasizes the need to avoid intakes and tracks the number of intakes as a performance measure.

The number of internal depositions of radioactive material (otherwise known as worker intakes), collective CEDE, and average measurable CEDE for 1997-2001 is shown in *Exhibit 3-12*. The number of internal depositions increased by 4% from 2000 to 2001, while the collective CEDE decreased by 67%. Due to the large decrease in the collective CEDE and slight increase in the number of internal depositions, the average measurable CEDE decreased by 68% from 2000 to 2001 and is the lowest average measurable CEDE in the past 5 years.

Exhibit 3-12:
Number of Internal Depositions, Collective CEDE, and Average Measurable CEDE, 1997-2001.



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

The number of internal depositions of radioactive material for 1999-2001 is also 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 each year 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 67% decrease in the collective CEDE from 2000 to 2001 was primarily due to the lack of internal doses above 2 rem in 2001. During the past 5 years, there have been several intakes from plutonium or uranium in excess of 2 rem each year, with some of the doses in excess of 5 rem (see *Exhibit 3-10*). While the number of internal depositions above 2 rem has been few, they have contributed significantly to the collective internal dose each year. With no such intakes reported for 2001, the collective CEDE has decreased significantly.

Exhibit 3-13:
Number of Intakes, Collective Internal Dose, and Average Dose by Nuclides, 1999-2001.

Nuclide	Number of Internal Depositions*			Collective CEDE (person-rem)			Average CEDE (rem)		
Year	**1999**	**2000**	**2001**	**1999**	**2000**	**2001**	**1999**	**2000**	**2001**
Hydrogen-3 (Tritium)	554	394	315	2.438	2.039	1.189	0.004	0.005	0.004
Technetium	1	0	0	0.007	0	0	0.007	0	0
Radon-222	39	4	2	2.147	0.118	0.076	0.055	0.030	0.038
Thorium	10	62	23	0.836	3.838	0.204	0.084	0.062	0.009
Uranium	**1,671** ◄	**1,630** ◄	**1,838** ◄	**126.163** ◄	60.226	**47.078** ◄	0.076	0.037	0.026
Plutonium	101	123	137	19.177	**113.020**** ◄	8.258	**0.190** ◄	**0.919** ◄	0.060
Americium-241	16	34	28	1.681	0.989	1.777	0.105	0.029	**0.063** ◄
Other	51	27	13	0.196	0.145	0.146	0.004	0.005	0.011
Mixed	20	3	6	0.223	0.205	0.226	0.011	0.068	0.038
Totals	**2,463**	**2,277**	**2,362**	**152.868**	**180.580**	**58.954**	**0.062**	**0.079**	**0.025**

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.
** Primarily the result of an event resulting in three individuals receiving a total of 107.87 person-rem at LANL.

The highest collective CEDE and number of depositions in 2001 is due to uranium intakes. The majority of the collective dose from uranium (94%) occurred at the Oak Ridge Y-12 facility during the continued operation and management of Enriched Uranium Operations (EUO) facilities at the site. The highest average measurable CEDE in 2001 is from americium, although the collective dose and number of depositions from americium are relatively small. Most (84%) of the CEDE from americium was received by three individuals at Savannah River, with none of these individuals receiving an internal dose of more than 0.650 rem (6.5 mSv). Due to the radiological characteristics and retention of americium in the body, relatively small intakes can result in large dose values when the CEDE is calculated over a 50-year period.

The number of intakes and collective CEDE for tritium intakes decreased for the fifth year in a row, with the decrease from 2000 to 2001 attributable to decreases in intakes at Savannah River. Intakes from radon have decreased significantly from 1999 to 2000 because the Grand Junction site is no longer in operation.

Because relatively few workers receive measurable internal dose, fluctuations in the number of workers and collective CEDE can occur from year to year.

Exhibit 3-14 shows the distribution of the internal dose from 1997 to 2001. The total number of individuals with intakes in each dose range is the sum of all records of intake in the 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 of the internal doses were below 2 rem (20 mSv) in 2001 for the first time in the past 5 years.

The internal dose records indicate that the majority of the intakes reported are at very low doses. In 2001, 71% of the internal dose records were for doses below 0.020 rem (0.20 mSv). Over the 5-year period, internal doses from new intakes accounted for only 8% of the collective TEDE, and only 8% of the individuals who received internal dose were above the monitoring threshold specified (100 mrem) in 10 CFR 835.402(c).

Exhibit 3-14:
Internal Dose Distribution from Intakes, 1997-2001.

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)
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			1	2,466	90.217
1999	1,726	443	137	78	32	26	19		1		1	2,463	152.868
2000	1,472	625	136	34	5	2					3	2,277	180.580
2001	1,673	574	90	19	4		2					2,362	58.954

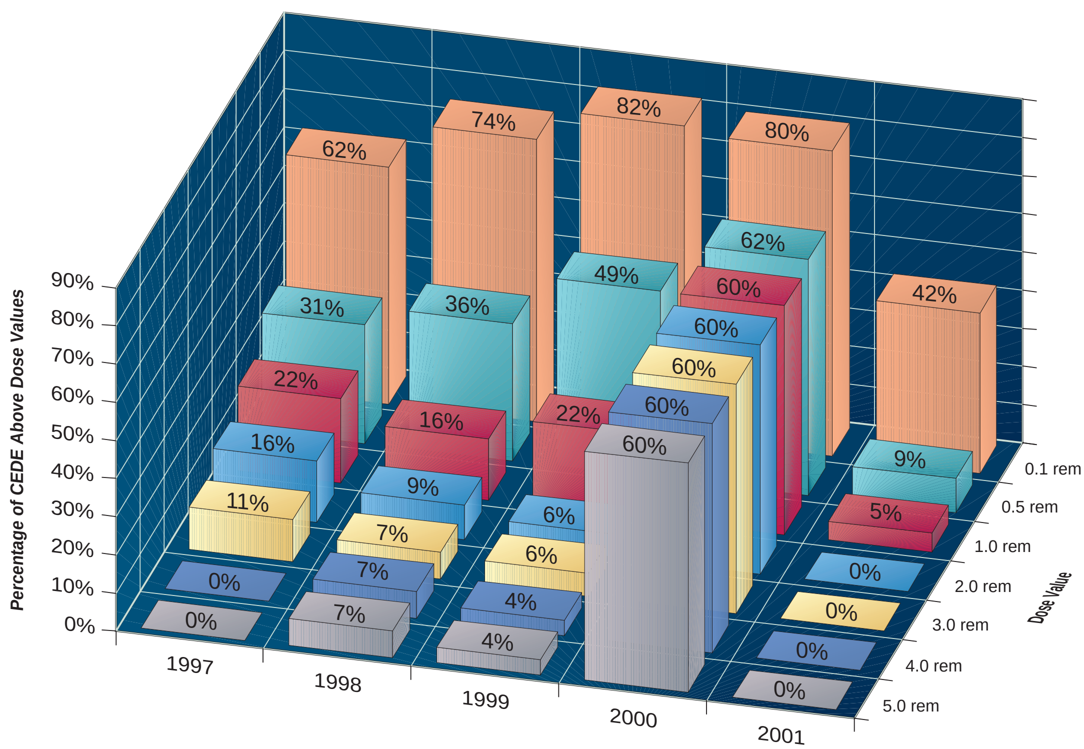
Note: Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.
* Individuals may have multiple intakes in a year and, therefore, may be counted more than once.

The internal dose 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 1997 to 2001. While the fluctuations in internal dose prohibit definitive trend analysis, it appears from the graph that from 1998 to 2000, there was an increase in the percentages above 2 rem (20 mSv) that was due to the individuals who exceeded the DOE annual limits. In 2000, the percentages above 2 rem (20 mSv) were dominated by the three doses in excess of the DOE annual limit that occurred at LANL. For 2001, the percentage of internal dose above each dose range decreased dramatically because of an overall decrease in the number of internal doses and particularly the lack of any internal doses above 2 rem (20 mSv). The distribution of internal dose by site and nuclide for 2001 is presented in Appendix B-21.

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 8% of the collective TEDE.

Exhibit 3-15:
Distribution of Collective CEDE vs. Dose Value, 1997-2001.



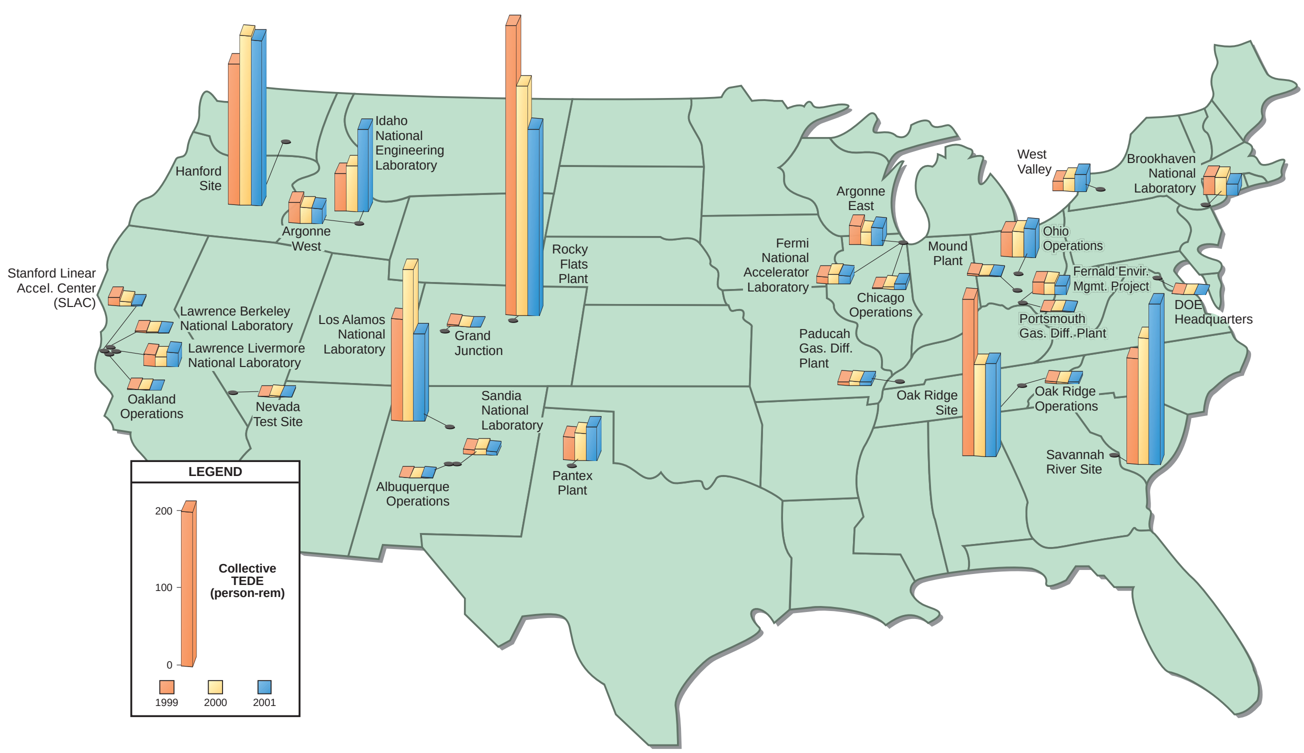
When examining trends involving internal dose, several factors should be considered. Some of the largest changes in the number of reported intakes over the years resulted from changes in internal dosimetry practices. Periodically, sites may implement new technology or change monitoring practices or procedures,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

3.4 Analysis of Site Data

3.4.1 Collective TEDE by Site and Operations/Field Offices

The collective TEDE for 1999-2001 for the major DOE sites and Operations/Field Offices is shown in *Exhibit 3-16*. A list of the collective TEDE and number of individuals with measurable TEDE for the DOE Sites and Operations/Field Offices is shown in *Exhibit 3-17*. Operations/Field Office dose is shown separately from the site dose where it is reported separately. Other small sites and facilities that do not contribute significantly to the collective dose are included within the numbers shown for "Ops. and Other Facilities." The collective TEDE decreased by 3% between 2000 and 2001, with six of the highest dose sites (Rocky Flats, Hanford, Savannah River, Oak Ridge, Los Alamos, and Idaho) contributing 81% of the total DOE collective TEDE.

Exhibit 3-16:
Collective TEDE by Site for 1999-2001.



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

Exhibit 3-17:
Collective TEDE and Number of Individuals with Measurable TEDE by Site, 1999-2001.

Operations/ Field Office	Site	1999 Collective TEDE (person-rem)	1999 Number with Meas. TEDE	2000 Collective TEDE (person-rem)	2000 Number with Meas. TEDE	2001 Collective TEDE (person-rem)	2001 Number with Meas. TEDE
Albuquerque	Ops. and Other Facilities	0.4	26	0.3	38	1.2	93
	Los Alamos National Lab. (LANL)	131.0	1,479	195.5	1,365	112.9	1,330
	Pantex Plant (PP)	29.3	353	35.0	277	43.6	293
	Sandia National Lab. (SNL)	6.4	120	7.6	105	4.7	99
	Grand Junction	2.5	48	0.1	6	0.1	2
Chicago	Ops. and Other Facilities	1.5	82	3.5	108	7.6	131
	Argonne Nat'l. Lab. - East (ANL-E)	24.6	187	17.2	183	23.0	187
	Argonne Nat'l. Lab. - West (ANL-W)	26.7	299	20.9	234	19.8	258
	Brookhaven Nat'l. Lab.(BNL)	23.4	521	22.4	430	14.6	385
	Fermi Nat'l. Accelerator Lab.(FERMI)	8.7	227	12.3	406	10.7	368
DOE HQ	DOE Headquarters	0.0	4	0.1	11	0.0	4
	DOE North Korea Project					1.0	8
	DOE Kazakhstan Project	0.1	3				
Idaho	Idaho Site	48.3	729	58.8	795	106.6	1,088
Nevada	Nevada Test Site (NTS)	0.4	6	1.6	24	1.3	32
Oakland	Ops. and Other Facilities	1.0	85	0.9	133		
	Lawrence Berkeley Nat'l. Lab. (LBNL)	1.8	46	1.1	44	0.7	21
	Lawrence Livermore Nat'l. Lab. (LLNL)	14.9	137	12.7	145	18.6	153
	Stanford Linear Accelerator Center (SLAC)	10.2	104	5.5	489	1.4	35
Oak Ridge	Ops. and Other Facilities	2.4	109	1.9	125	2.6	144
	Oak Ridge Site	202.2	2,493	118.1	2,276	120.0	2,577
	Paducah Gaseous Diff. Plant (PGDP)	4.3	58	5.0	63	5.0	122
	Portsmouth Gaseous Diff. Plant (PORTS)	0.5	25	1.5	44	1.2	35
Ohio	Ops. and Other Facilities	31.6	104	33.3	256	37.3	173
	Fernald Environmental Management Project	15.1	458	15.0	421	11.4	355
	Mound Plant	2.7	197	1.1	123	1.2	97
	West Valley	12.5	243	16.5	246	22.2	233
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**373.9** ◄	**3,517** ◄	**296.1** ◄	2,331	**241.5** ◄	2,471
Richland	Hanford Site	182.0	2,013	219.0	1,923	213.6	2,218
Savannah River	Savannah River Site (SRS)	136.5	2,995	163.2	**3,382** ◄	207.6	**3,640** ◄
Totals		**1,295.2**	**16,668**	**1,266.5**	**15,983**	**1,231.4**	**16,552**

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

Exhibit 3-18:
Number with Measurable Dose, Collective TEDE, and Average Measurable TEDE by Labor Category, 1999-2001.

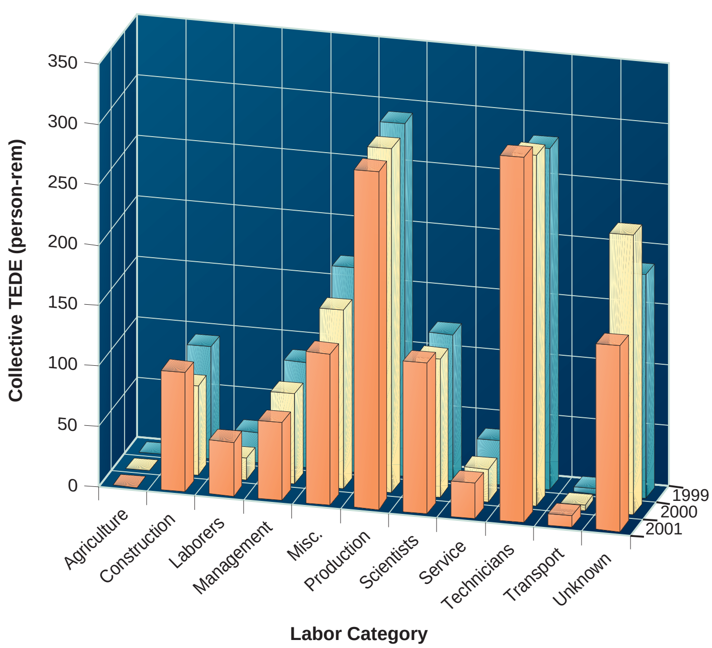
Labor Category	Number with Meas. Dose			Collective TEDE (person-rem)			Average Meas. TEDE (rem)		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
Agriculture	1	1	0	0.0	0.0	0.0	0.020	0.035	0.0
Construction	1,480	1,375	1,824	92.4	73.8	98.7	0.062	0.054	0.054
Laborers	285	281	433	25.2	17.8	44.6	0.089	0.063	0.103
Management	1,755	1,628	1,361	86.9	74.7	64.6	0.050	0.046	0.047
Misc.	2,001	1,563	1,599	168.9	147.4	125.0	0.084	0.094	0.078
Production	2,263	2,214	2,207	**291.6** ◄	284.6	279.6	**0.129** ◄	**0.129** ◄	**0.127** ◄
Scientists	2,617	**3,001** ◄	**2,948** ◄	121.0	114.5	124.7	0.046	0.038	0.042
Service	829	658	710	36.8	27.1	29.2	0.044	0.041	0.041
Technicians	**2,690** ◄	2,723	2,854	282.6	**290.5** ◄	**302.1** ◄	0.105	0.107	0.106
Transport	122	112	179	4.4	4.6	9.2	0.036	0.041	0.052
Unknown	2,625	2,427	2,437	185.2	231.4	153.7	0.071	0.095	0.063
Totals	**16,668**	**15,983**	**16,552**	**1,295.2**	**1,266.5**	**1,231.4**	**0.078**	**0.079**	**0.074**

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

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 assists 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 1999-2001 is shown in *Exhibits 3-18* and *3-19*. Technicians and production staff have the highest collective TEDE for the past 3 years because they generally handle more radioactive sources than individuals in the other labor categories. In 2001, 49% of the technician dose was attributed to radiation protection technicians, and 74% of the dose to production personnel is attributed to plant operators.

Exhibit 3-19:
Graph of Collective TEDE by Labor Category, 1999-2001.



The "unknown" and "miscellaneous" categories have the next highest collective TEDE totals. Seventy-three percent of the dose in the "unknown" category for 2001 is attributed to LANL. Currently, the LANL computer system does not maintain the data necessary to report occupation codes in accordance with DOE M 231.1-1. Other sites also report individuals with an occupation code of "unknown." Typically, these workers are subcontractors or temporary workers. Information concerning these workers tends to be limited.

An examination of internal dose from intake by labor category from 1999 to 2001 is presented in Appendix B-19. In addition, Appendix B-20 shows the TEDE distribution by labor category and occupation for 2001.

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. The contributions 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 from 1999 to 2001 is shown in Appendix B-7. An examination of internal dose from intake by facility type and nuclide for 1999 to 2001 is presented in Appendix B-17.

The collective TEDE for 1999-2001 was highest at weapons fabrication and testing facilities. Forty-eight percent of this dose was accrued at Rocky Flats in 2001, with 16% at Savannah River and 13% at the Oak Ridge Y-12 facility. 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. See Section 3.5 for information concerning the current activities at these sites.

Exhibit 3-20:
Graph of Collective TEDE by Facility Type, 1999-2001.

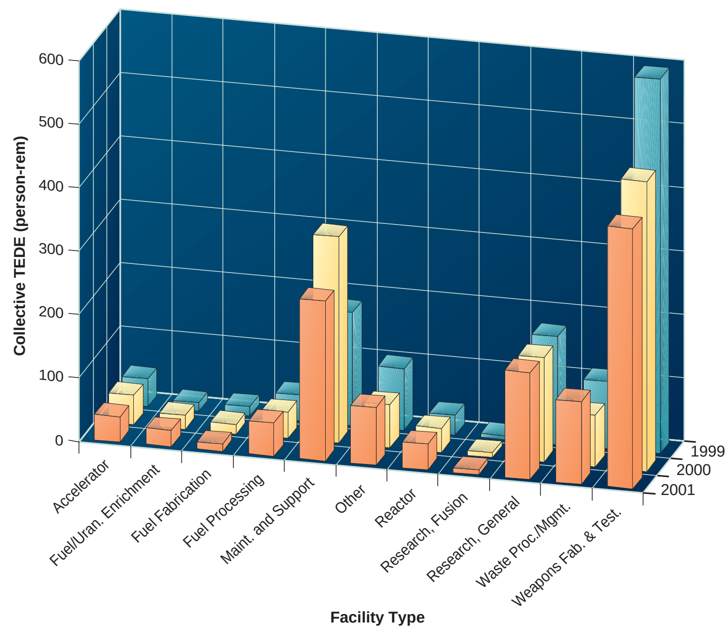


Exhibit 3-21:
Number with Measurable Dose, Collective TEDE, and Average Measurable TEDE by Facility Type, 1999-2001.

Facility Type	Number with Meas. Dose			Collective TEDE (person-rem)			Average Meas. TEDE (rem)		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
Accelerator	907	1,429	976	44.0	45.9	40.1	0.049	0.032	0.041
Fuel/Uranium Enrichment	416	679	846	13.6	21.6	25.8	0.033	0.032	0.031
Fuel Fabrication	459	424	355	15.1	15.1	11.4	0.033	0.036	0.032
Fuel Processing	1,107	1,115	1,155	41.2	41.6	52.5	0.037	0.037	0.045
Maintenance and Support	2,083	2,173	2,389	179.5	325.4	251.6	0.086	**0.150** ◄	**0.105** ◄
Other	1,533	1,434	1,433	97.2	68.2	91.6	0.063	0.048	0.064
Reactor	629	600	560	31.0	38.1	40.9	0.049	0.064	0.073
Research, Fusion	50	78	116	6.0	7.1	7.8	**0.120** ◄	0.092	0.067
Research, General	2,224	2,140	2,062	170.0	164.8	168.8	0.076	0.077	0.082
Waste Processing/Mgmt.	1,475	1,460	1,938	106.6	81.2	129.9	0.072	0.056	0.067
Weapons Fab. and Testing	**5,785** ◄	**4,451** ◄	**4,722** ◄	**591.0** ◄	**457.5** ◄	**411.0** ◄	0.102	0.103	0.087
Totals	**16,668**	**15,983**	**16,552**	**1,295.2**	**1266.5**	**1231.4**	**0.078**	**0.079**	**0.074**

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

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 *radiation exposure* occurrences, and Group 4B reports *personnel contamination* occurrences. 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 occurrences reported may reflect trends in radiation exposures, the effectiveness of DOE radiation protection programs, or changes to the reporting procedure or thresholds. The reporting thresholds and processes have stabilized over the years, and the insignificant increase in the number of radiation exposure occurrences and decrease in the number of contamination occurrences reported in 2001 may reflect statistical variability rather than any performance trend.

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 report may involve the roll up of similar or multiple occurrences. For the analysis included in this report, only the number of occurrences is considered. Also, it should be noted that some occurrences are reported based on an initial

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.

estimate of exposure, but may be recategorized later pending the receipt of the final determined exposure.

The number of occurrences reported under Personnel Radiological Protection is broken into two subcategories: *Radiation Exposure*, and *Personnel Contamination*. Results for those two subcategories are presented in *Exhibits 3-23* and *3-25*.

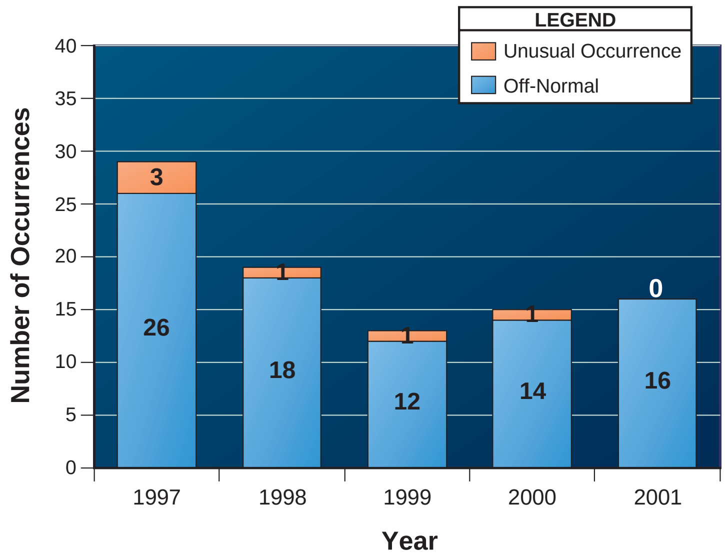
3.4.4.1 Radiation Exposure Occurrences

Radiation exposure occurrences are reported when individuals are exposed to radiation above anticipated levels, or when the resulting exposure exceeds 100 mrem (0.1 REM) external (whole-body, skin, or extremity) or internal. The number of *radiation exposure* occurrences increased by 7% in 2001 compared to the number reported in 2000 as shown in *Exhibit 3-23*. The collective radiation dose reported during 2001 for radiation exposure occurrences decreased from 11 person-rem to just over 5 person-rem when compared to 2000. Disregarding the largest dose in 2000 (7 rem), the average per employee exposure reported as an occurrence in 2001 was 160 mrem per employee, which is 11% less than the average per employee exposure occurrence (180 mrem) reported in 2000. The number of people covered in occurrences reported in 2001 (31 people) was 6% less than the number of people involved in radiation exposure occurrences in 2000 (33 people).

The number of radiation exposure occurrences increased by 7% from 2000 to 2001.

Only one reported occurrence involved an external (whole-body) exposure during 2001. This was a case (ORO-ORNL-X10EAST-2001-0011) where 7 employees were working in the target area of an experiment and the radiation source was inadvertently energized four times, exposing each worker to up to 35 mrem whole-body dose and 145 mrem extremity dose. In one other case (SR-WSRC-HTANKE-2001-0027), a worker not

Exhibit 3-23:
Number of Radiation Exposure Occurrences, 1997-2001.



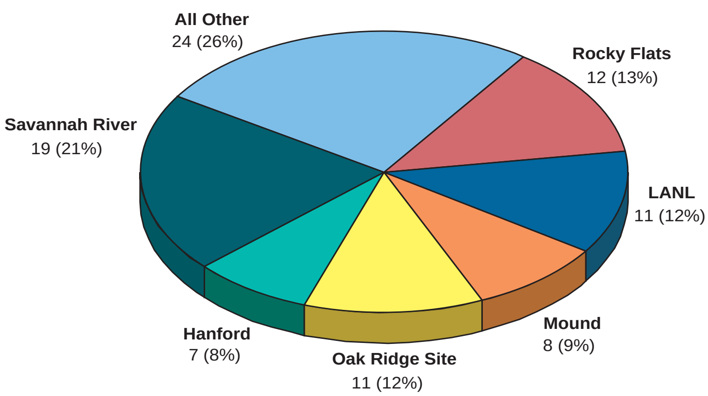
directly associated with the incident was exposed to radioactive materials when a pump seal failed, releasing contamination that drifted downwind to the worker who received an internal dose of 141 mrem. Four occurrences were documented involving tears or leaks in glovebox gloves, resulting in a total of 8 employee exposures totaling 720 mrem. In one of those cases (ALO-LA-LANL-TA55-2001-0021), 12 people were in the vicinity of the glovebox, but only 2 received any internal exposure.

In two cases of internal exposure totaling 210 mrem, the employees could have avoided internal exposure by wearing tear-resistant leather gloves when handling sharp-edged air filters or broken glass. Two tasks involving equipment cutting (re-sizing) caused internal exposures to 4 people totaling 650 mrem exposure. In four reported events, no specific source was cited for the internal deposition resulting in a total of 1,350 mrem exposure. In one case (ORO-BWXT-Y12NUCLEAR-2001-0060), an employee who was performing a routine job received an unexpected internal exposure (313 mrem) because the full-face air purifying respirator did not provide adequate protection because of the extensive number of equipment adjustments required.

None of the 92 *radiation exposure* occurrence reports submitted to the ORPS between 1997 and 2001 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 1997-2001. Seventy-four percent of the *radiation exposure* occurrences were reported by six sites: Savannah River, Rocky Flats, Oak Ridge, Los Alamos, Mound, and Hanford. During 2001, Savannah River, Rocky Flats, and Hanford had increases in reported occurrences, while Mound and Oak Ridge experienced decreases.

Exhibit 3-24:
Radiation Exposure Occurrences by Site, 1997-2001.

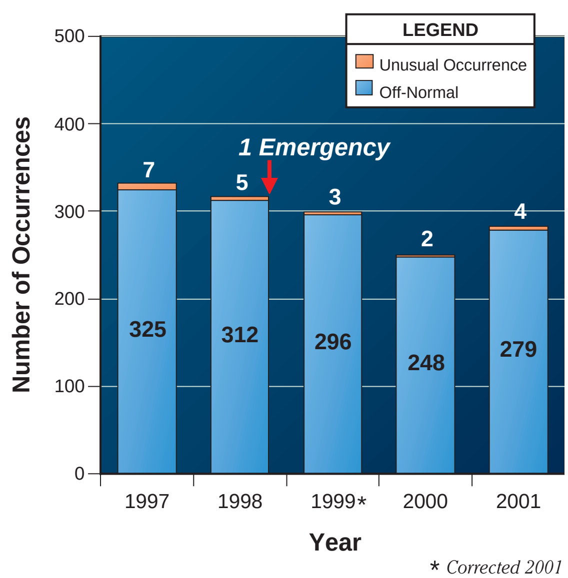


3.4.4.2 Personnel Contamination Occurrences

Personnel contamination occurrences are reported whenever personnel, clothing, or personal items are contaminated above threshold levels, generally five times the unconditional release limits. The number of *personnel contamination* occurrences reported in 2001 increased 13% over 2000. The number of *personnel contamination* occurrences reported since 1997 has decreased an average of 3% per year (see *Exhibit 3-25*). Four *personnel contamination* occurrences were classified as Unusual Events, twice as many as in 2000. The first case (CH-BH-BNL-BNL-2001-0025) involved contamination to a worker's shoe that was not detected until the worker reported for work the next day and was classified an Unusual Event because of low levels of contamination found in the worker's car. The second Unusual Event (ORO-BJC-X10ENVRES-2001-0027) involved an unexpected gust of wind spreading contamination outside of a controlled facility causing 6 individuals to become contaminated. The third (ORO-BWXT-Y12NUCLEAR-2001-0045) was declared an Unusual Event because a single action (a leak in a solid waste disposal bag) caused shoe contamination to 8 individuals. The fourth (SR-WRSC-FCAN-2001-0004) involved shoe contamination to 16 individuals as a result of the inadvertent spread of contamination past the step-off pad monitoring station.

In three cases reported as *personnel contamination* occurrences, employees received a measurable internal radiation dose. In the first case (ALO-LA-LANL-TA55-2001-0026), an airborne release exceeded 40 Derived Air Concentration (DAC)-hours after four employees were placed on a special bioassay program; calculations showed that three employees received no more than 100 mrem CEDE but one employee received 1,500 mrem CEDE. Although no skin, clothing, or shoe contamination was detected, this event was reported as a *personnel contamination* occurrence.

Exhibit 3-25:
Number of Personnel Contamination Occurrences, 1997-2001.



The second case (SR-WSRC-FCAN-2001-0015) was classified and reported as both a *personnel contamination* and *a radiation exposure* occurrence because the four workers involved had various levels of skin, clothing, and shoe contamination and the subsequent bioassays revealed internal doses of up to 627 mrem CEDE. The third case (SR-WSRC-HCAN-2001-0002) was also classified and reported as both a *personnel contamination* and a *radiation exposure* occurrence when an employee received in excess of 100 mrem CEDE due to internal contamination received when his thumb was cut while handling HEPA filters.

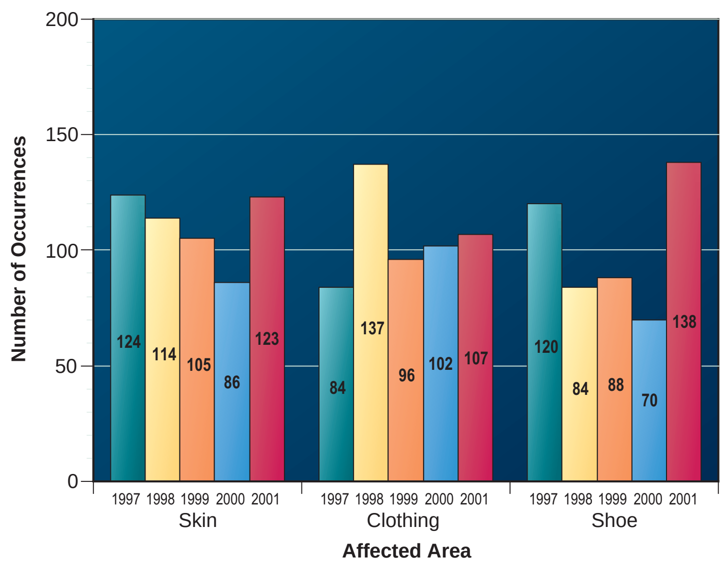
The number of Personnel Contamination occurrences has decreased by an average of 3% per year between 1997 and 2001.

In 21 occurrences during 2001, more than one individual became contaminated during work activities. In one case (OH-MB-BWO-BWO01-2001-0013), five occurrences were reported for skin contamination from tritium that emerged from facial skin as a result of perspiration. As indicated in the 2000 annual report, there was at least one occurrence involving two individuals who inadvertently touched contaminated items while operating machinery. In this work area, the machinists didn't wear protective clothing because it could get caught in the machinery. Also, in 2001 as was the case in 2000, a number of cases of personnel contamination were attributed to incomplete laundering of protective clothing where stray particles from the laundered items were dislodged and subsequently found on the individual when he or she was checked for contamination.

Exhibit 3-26 compares the *personnel contamination* occurrences by the affected area. Skin, clothing, and shoe contamination incidents increased from 2000 to 2001. Much of this increase is explained by a few cases where multiple people became contaminated in a single occurrence (notably the 16-person event described above).

It should be noted that the totals for *Exhibits 3-25*, *3-26*, and *3-27* are not equivalent because some occurrences involve more than one affected area, and some occurrences involve more than one individual. *Exhibit 3-25* presents the total number of occurrences. *Exhibit 3-26* presents the number of personnel contaminations by affected area and may count occurrences more than once if there is more than one affected area involved in the occurrence. *Exhibit 3-27* shows the number of individuals by affected area. Individuals may be counted more than once if they have more than one affected area.

Exhibit 3-26:
Personnel Contaminations by Affected Area, 1997-2001.



Although there were 283 reported *personnel contamination* occurrences reported in 2001, 324 individuals were contaminated on the skin, clothing, and/or shoes as shown in *Exhibit 3-27*.

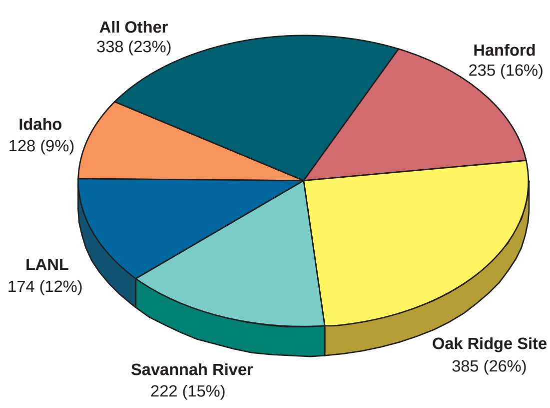
Exhibit 3-27:
Number of Individuals Contaminated by Affected Area in 2001.

Affected Area	Individuals Contaminated
Skin contamination only	89
Clothing (or other personal item) only	77
Shoes only	117
Skin and Clothing	26
Skin and Shoes	1
Clothing and Shoes	4
Skin, Clothing, and Shoes	10

The combination of skin and clothing (and many of the skin, clothing, and shoe) contamination usually involved situations where the contamination on the outer protective clothing was inadvertently transferred to the skin. Three modes of contamination are common among these occurrences. The first is personnel error in the removal of protective clothing that results in skin contamination. The second involves the transference or "wicking" of contaminated liquid through the protective clothing to the skin. This can occur as a result of kneeling in wet spots or from sweat-soaked clothing. The third common cause of skin contamination occurrences is from residual contamination remaining on the protective clothing after laundering. All of these problems have been reported in past years and the frequency of their occurrence has not changed significantly. A review of shoe contamination occurrences disclosed about the same number of right shoe contamination occurrences as left shoe occurrences. Also, for instances where the hands or arms had been reported, neither right hand or left hand dominated the number of occurrences.

Exhibit 3-28 shows the personnel *contamination occurrences* by site. Between 1997-2001 the number of *contamination occurrences* decreased at four of the top five sites, but increased by 6% at Oak Ridge from 2000 to 2001. This is attributed to a major shift from environmental characterization to environmental cleanup (i.e., excavation and disposal) activities.

Exhibit 3-28:
Personnel Contamination Occurrences by Site, 1997-2001.



3.4.4.3 Occurrence Cause

Exhibits 3-29 and *3-30* provide a breakdown of *radiation exposure* occurrences and *personnel contamination* occurrences by their root cause. For the ORPS, the "root-cause" is defined as that which, if corrected, would prevent recurrences. Only four significant root causes are considered here; other causes are included in the category entitled "All-Other."

Exhibit 3-29:
Radiation Exposure Occurrences by Root Cause, 1999-2001.

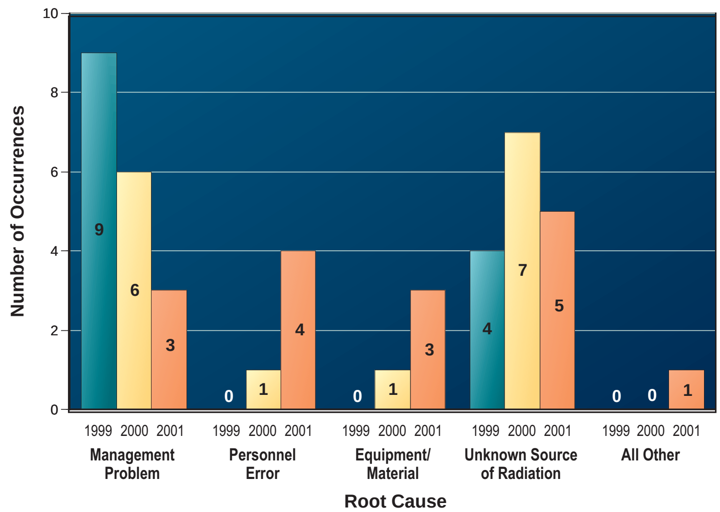
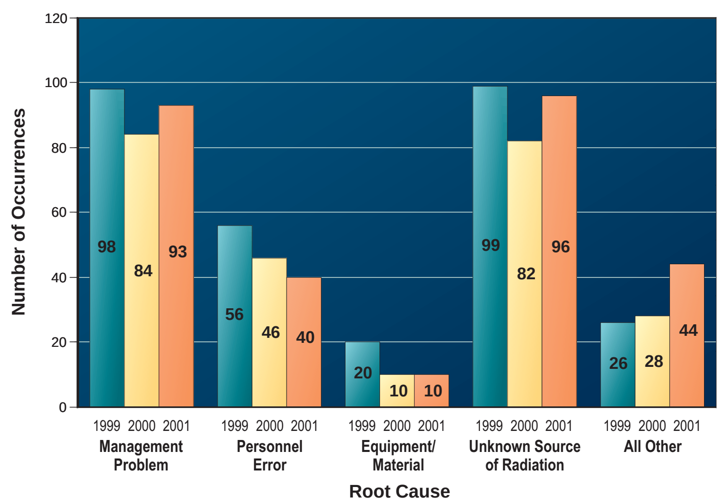


Exhibit 3-30:
Personnel Contamination Occurrences by Root Cause, 1999-2001.



In 2001, "Personnel Error" was cited as the root cause for four cases (25%) of the *radiation exposure* occurrences reported. The most common error was the use of inappropriate protective equipment (e.g., failure to wear leather gloves in an environment where sharp objects were handled). "Unknown Source of Radiation" was the root cause of five occurrences (31%) reported. The number of radiation occurrences of "Equipment or Material" failure (usually a failure of a glovebox glove) increased over the same category in 2000. "Management Problems," which has been one of the most prevalent causes in previous years, was down by 50% in 2001 over 2000. The "All-Other" category had one occurrence, which was a design problem.

The number of *personnel contamination* occurrences reported in 2001 was 13% higher than reported in 2000, with the largest increase in the "root cause" attributed to "Unknown Source of Radiation." This number increased 17% from 2000 to 2001 and includes unknown sources, as well as known sources from "legacy" contamination. The greatest increase was in the category "All-Other," where a 57% increase over 2000 results was reported. "All-Other" includes the categories Design Problems, Procedure Inadequacy, Training Deficiency, and None (no root cause reported). The only other area that saw an increase from 2000 was the category "Management Problems" which increased 11% from 2000 to 2001. The most prevalent cause was inadequate administrative control in failing to control worker activities, which led to a *personnel contamination* occurrence. The number of occurrences that were attributed to "Equipment/Material" and "Personnel Error" either stayed the same or were lower in 2001 when compared with the 2000 results. In two cases, the failure of a plastic bag containing waste caused the shoes of multiple individuals to become contaminated. In most of the other cases, the equipment failure included glovebox glove failures, or equipment piping or vessel leakage. Personnel Error generally involved an inadvertent act by an employee (such as scratching a facial itch in a contaminated area) or the failure to follow correct protective clothing doffing procedures, which resulted in cross-contaminating clothing or skin.

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

3.5 Activities Contributing to Collective Dose in 2001

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 2001. These sites (Rocky Flats, Hanford, Savannah River, Oak Ridge, Los Alamos, and Idaho) were the top six sites in their contribution to the collective TEDE for 2001 and comprised 81% of the total DOE dose. Three of the six sites reported decreases in the collective TEDE, which resulted in a 3% decrease in the DOE collective dose from 2000 to 2001. The six sites are shown in *Exhibit 3-31*, including a description of activities that contributed to the collective TEDE for 2001.

Exhibit 3-31:
Activities Contributing to Collective TEDE in 2001 for Six Sites.

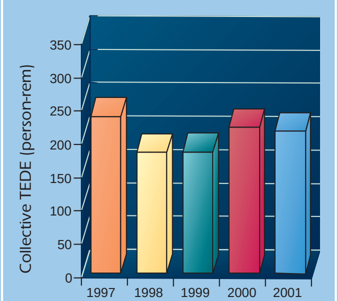
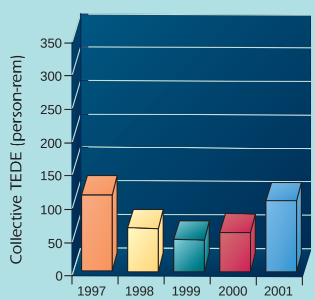
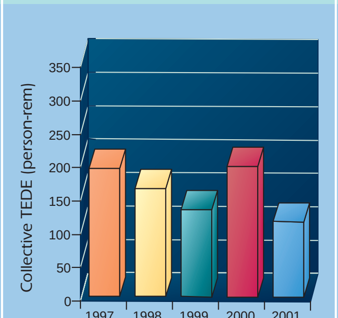
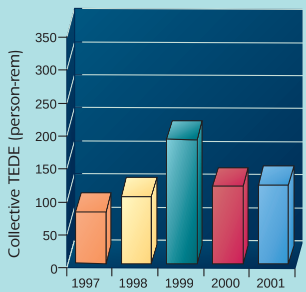
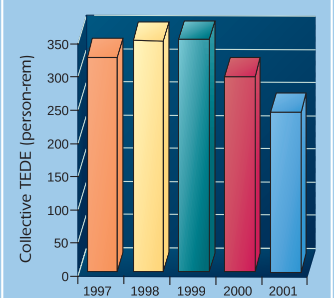
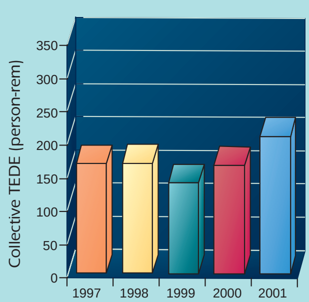
Site	Collective TEDE (person-rem)	Percent Change			Description of Activities at the Site
		2000-2001 (last yr.)	1999-2001 (3 yr.)	Since 1997 (5 yr.)	
Hanford		2% ↓	↑ 17%	9% ↓	The collective TEDE at Hanford decreased by 2% from 2000 to 2001. The largest contributors to the collective TEDE at Hanford were thermal stabilization and repackaging of plutonium-bearing materials at the Plutonium Finishing Plant (PFP) (38.3%) and cleanout activities of the River Corridor Project/324 Facility B-cell (14.2%). Other contributors to the dose included Pacific Northwest National Laboratory (PNNL) activities (8.2%), tank farm activities (8.2%), and processing of spent nuclear fuel in K-Basins for interim dry storage at the Canister Storage Building (CSB) (8.1%).
Idaho		↑ 81%	↑ 121%	8% ↓	The collective TEDE at INEEL increased by 81% from 2000 to 2001. Radiation exposure to INEEL employees is primarily the result of radiological work conducted in support of three major activities: 1) preparation of waste shipments to Waste Isolation Pilot Plant (WIPP) from the Radioactive Waste Management Complex, 2) spent nuclear fuel operations at Test Area North and Idaho Nuclear Technology and Engineering Center, and 3) the operation of the Advanced Test Reactor and the Hot Cells at the Test Reactor Area. The increase in dose from 2000 to 2001 was primarily associated with milestone work preparing shipments of waste to WIPP and completing the transfer of Three Mile Island fuel from wet storage to dry storage. A major effort was also completed (decontaminating one of the remotely operated hot cells at the Test Reactor Area with dose rates as high as 50,000 R/hr.). The decontamination work associated with the Hot Cell was successfully completed with less exposure than anticipated because of innovative ALARA techniques that were employed.
Los Alamos National Lab.		42% ↓	14% ↓	41% ↓	The collective TEDE at LANL decreased by 42% from 2000 to 2001. Of the total TEDE in 2001, 3 person-rem is from internal dose, and 110 person-rem is attributable to external dose. In terms of external dose, there was a 28% increase in dose from 2000 to 2001, which is attributable to increased workload. In terms of internal dose, there was a 97% decrease in dose from 2000 to 2001 due to the three individuals who received doses in excess of 5 rem in 2000 totaling 108 person-rem CEDE (see section 3.3.1). There was one individual who received a dose of 2 rem TEDE in 2001 (see Section 3.3.2, or Occurrence Report ALO-LA-LANL-TA55-2001-0026). All other occupational doses at LANL in 2001 were below 2 rem (TEDE).

Exhibit 3-31:
Activities Contributing to Collective TEDE in 2001 for Six Sites (continued).

Site	Collective TEDE (person-rem)	Percent Change 2000-2001 (last yr.)	Percent Change 1999-2001 (3 yr.)	Percent Change Since 1997 (5 yr.)	Description of Activities at the Site
Oak Ridge Site		↑ 2%	36% ↓	↑ 54%	Exposures at the Oak Ridge Site increased 2% from 2000 to 2001. The Oak Ridge Site includes the Oak Ridge National Laboratory (ORNL), Y-12 National Security Complex (Y-12 Plant), and East Tennessee Technology Park (ETTP), formerly known as K-25). The collective TEDE for the ORNL increased by 30.7% from 48.6 person-rem in 2000 to 63.5 person-rem in 2001. Major projects that contributed to exposure in 2001 included modifications made to the High Flux Isotope Reactor, including changing out the beryllium reflectors and installing two new beam ports. Other operations that contributed to the site exposure included uranium repackaging in Building 3019 and work associated with the Building 4501 complex. In addition, several major remediation projects involving uranium deposit removal at the Molten Salt Reactor Experiment, waste removal from Federal Facilities Agreement tanks, decontamination and decommissioning of the Old Hydrofracture Facility, clean up of Waste Tank W-1A, and decontamination and decommissioning of the Metal Recovery Facility were conducted in CY 2001. The collective TEDE at the Y-12 Plant decreased by 21% from 67.3 person-rem in 2000 to 53.3 person-rem in 2001. During 2001, continued operation and management of Enriched Uranium Operations (EUO) facilities at the Y-12 site were the primary activities that resulted in the total collective radiation exposure at Y-12. EUO facilities provided the major source of TEDE at Y-12, while product certification activities involving depleted uranium contributed to the shallow dose and dose to the extremities. The collective TEDE at the ETTP increased by 81% from 1.6 person-rem in 2000 to 2.9 person-rem in 2001. Projects that contributed to exposure in 2001 included environmental restoration; decontamination and decommissioning; and waste handling of legacy, solid, and liquid materials. The major project contributing to the increase in dose at ETTP was remediation of the K-33 gaseous diffusion building.
Rocky Flats		18% ↓	35% ↓	25% ↓	The collective TEDE at Rocky Flats decreased 18% from 2000 to 2001. Activities for 2001 included processing and shipment of plutonium residues, packaging and shipment of low-level waste, and the decontamination and decommissioning (D&D) of four major plutonium facilities, as well as of numerous uranium and administrative facilities. The collective dose decreased primarily due to a reduction of radioactive source material on site due to the repackaging and shipment of these materials for off-site disposal. Internal dose decreased by 37% from 2000 to 2001, which is partially attributed to a reduction in risk and exposure from activities involved in the removal and disposal of contaminated gloveboxes. RFETS developed an innovative chemical decontamination process to greatly reduce the level of contamination of the gloveboxes, allowing them to be shipped as Surface Contaminated Objects. This process avoids the inherent risk of internal doses that can occur during the physical and labor-intensive process of cutting up the contaminated gloveboxes and packaging them for shipment as highly contaminated waste. (See Section 4.3 for more details on this process.)
Savannah River Site		↑ 27%	↑ 52%	↑ 26%	The collective TEDE at SRS increased by 27% from 2000 to 2001. The collective TEDE increase was expected and planned for in calendar year 2001 based on the planned work scope for routine operations and for special work. The largest increase in collective exposure compared to 2000 (approximately 16 person-rem higher) occurred in the SRS FB-Line facility. Increased exposures were a result of completing Purex operations in accordance with the 94-1 DNFSB plan. FB-Line was successful in avoiding 34% of the projected collective exposure compared to previous campaign exposures. An active ALARA program provided reduction through a combination of ALARA and pre-planning initiatives. These included an aggressive campaign to remove source terms, where feasible; use of lead jackets; video camera surveillance; a training/mentoring program; equipment and Personal Protective Equipment changes; task and job-specific self-assessments to identify improvements; and a dose mapping program that identified and posted low dose areas throughout the facility. Another primary source of increased collective exposure in 2001 was the activities involved in waste removal at SRS's High Level Waste (HLW) tank farms. Activities with significant collective exposures during the year included excavations and work in preparation for waste removal from one tank that had been significantly contaminated in the past. Decontamination efforts and recovery associated with a neutralization tank spill accounted for approximately 5 person-rem in 2001 that was not anticipated. Numerous other activities in HLW occurred as part of planned outages to provide process equipment upgrades and modifications, and replacements of pumps and other equipment.

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.2 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.

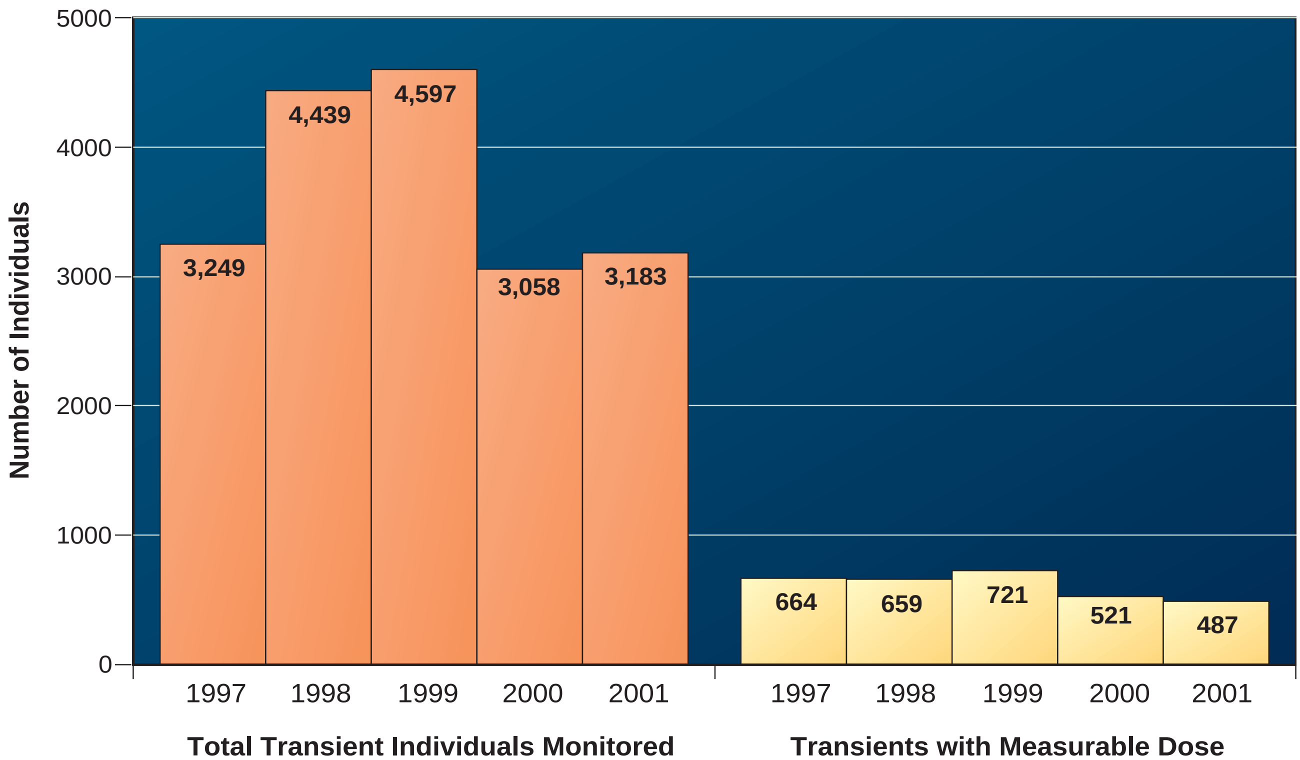
Exhibit 3-32 shows the distribution and total number of transient individuals from 1997 to 2001. Over the past 5 years, transient individuals have accounted for 3.5% of the total number of records for monitored individuals at DOE and received 2.3% of the collective dose. As shown in *Exhibits 3-33* and *3-34*, the number of transients with measurable dose decreased from 2000 to 2001. The collective dose for transients increased by 6% and the average measurable dose increased by 16%. The average measurable TEDE for transients in 2001 was 30% less than the average measurable TEDE for all monitored DOE workers. As shown in *Exhibit 3-35*, LANL was the site with the largest collective dose to transient workers from 1997 to 2001. LANL has the largest percentage of dose to transients because workers at TA-55 (who generally receive elevated doses) tend to perform temporary work at sites such as Nevada Test Site (NTS), Rocky Flats, and Pantex as part of their routine duties.

Exhibit 3-32:
Dose Distribution of Transient Workers, 1997-2001.

	Dose Ranges (rem)	1997	1998	1999	2000	2001
Transients	Less than Measurable Dose	2,585	3,780	3,876	2,537	2,696
	Measurable < 0.1	606	585	638	466	439
	0.10 - 0.25	41	49	50	37	31
	0.25 - 0.5	14	14	21	14	13
	0.5 - 0.75	2	8	6	4	1
	0.75 - 1.0		2	6		1
	1.0 - 2.0	1	1			2
	Total Number of Individuals Monitored *	3,249	4,439	4,597	3,058	3,183
	Number with Measurable Dose	664	659	721	521	487
	% with Measurable Dose	20%	15%	16%	17%	15%
	Collective TEDE (person rem)	27.426	34.742	39.521	23.632	25.138
	Average Measurable TEDE (rem)	0.041	0.053	0.055	0.045	0.052
All DOE	Total Number of Records for Monitored Individuals	107,181	108,508	113,064	102,881	99,166
	Number with Meas. Dose	18,689	17,544	16,668	15,983	16,552
	% of Total Monitored who are Transient	3.0%	4.1%	4.1%	3.0%	3.2%
	% of the Number with Measurable Dose Who are Transient	3.6%	3.8%	4.3%	3.3%	2.9%

* Total number of individuals represents the number of individuals monitored, and not the number of records.

Exhibit 3-33:
Individuals Monitored at More Than One Site (Transients) During the Year, 1997-2001.



One group of individuals who 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 2001, this group accounts for 17% of the monitored transient individuals and 4% of the collective dose to transients.

Over the past 5 years, only 13% of the transient individuals were monitored at three or more sites. DOE Headquarters and Field Office personnel make up a large percentage of these individuals. From 1997 to 2001, 29% of the individuals monitored at three or more sites were DOE Headquarters or Field Office employees, and 42% 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 2001 was five.

Exhibit 3-34:
Collective and Average Measurable Dose to Transient Individuals, 1997-2001.

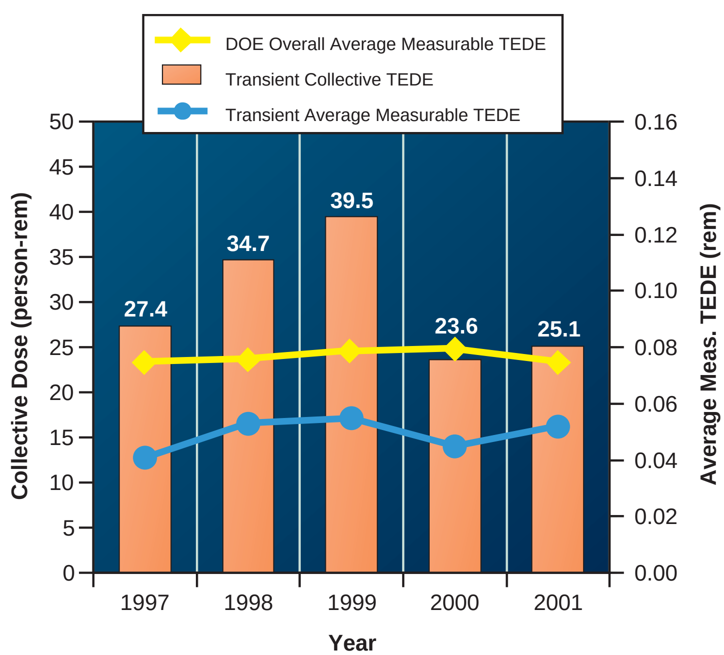
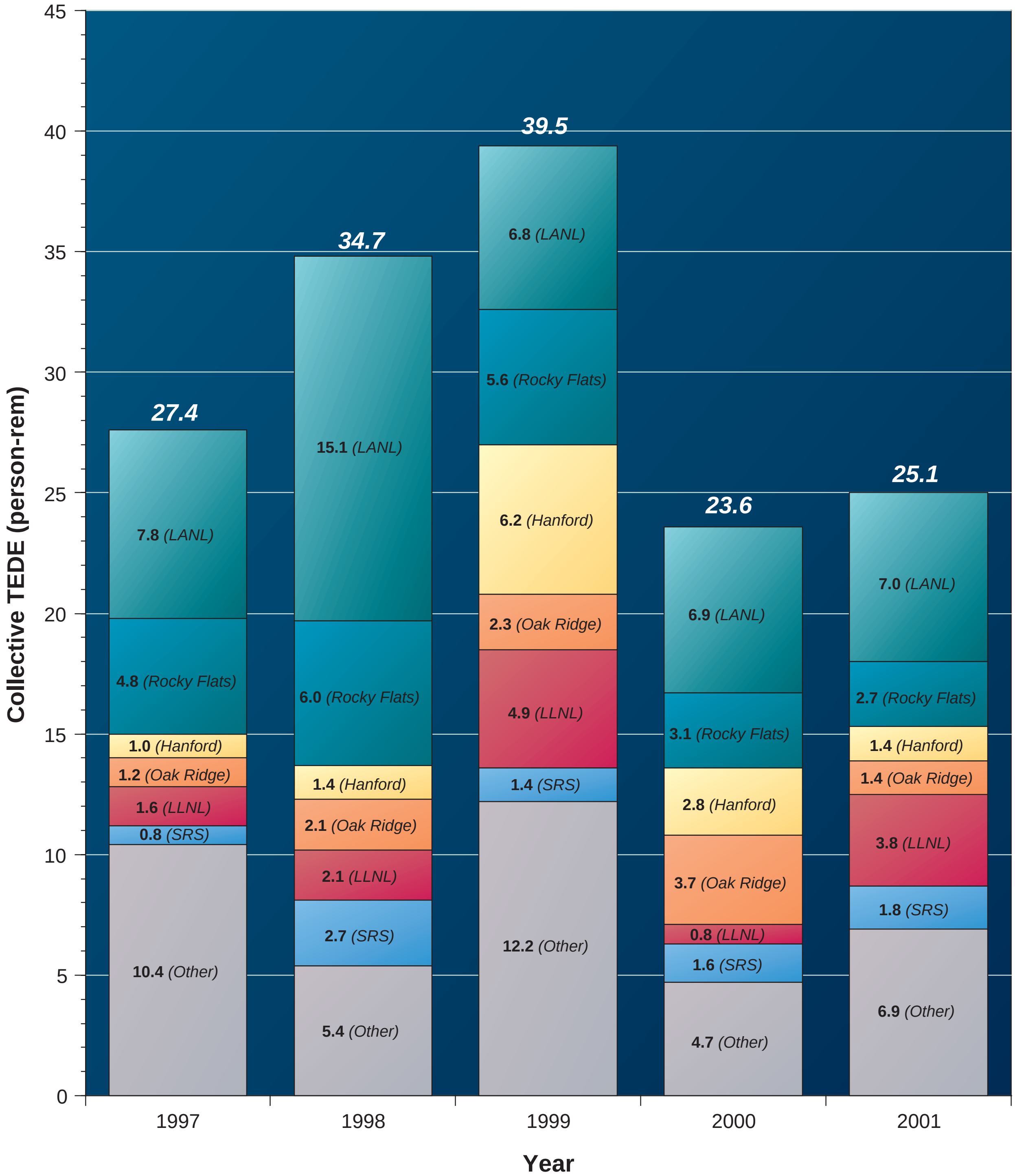


Exhibit 3-35:
Collective TEDE to Transient Workers by Site, 1997-2001.



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

Section 3.7 Historical Data Collection Update

In the 2000 annual report on occupational exposure, information was presented on historical data that have been collected to date from a request by EH-52 to the DOE sites to voluntarily provide historical exposure records that have not yet been reported to REMS. Since that time, another DOE site has reported historical exposure records, and another historical data set has been obtained.

During 2001, LBNL submitted records for the years 1982 to 1986. A total of 6,798 records were submitted. A summary of these records is presented in *Exhibit 3-36*.

Also during the past year, several boxes of paper records were discovered in storage at the U.S. NRC that contained exposure records for Atomic Energy Commission (AEC) personnel from 1968 to 1972. These records had not been entered into the NRC database or the DOE database and contained radiation exposure information for personnel who worked for the AEC. In 1975, the AEC split into two organizations, the NRC and the Energy Research and Development Administration (ERDA), which later became the DOE. An estimated 20,000 of these records were for individuals who worked at facilities that subsequently came under the responsibility of the DOE. These records are currently being processed for entry into the DOE REMS system and will be made available for responding to requests for dose histories for individuals, and for analysis in future annual reports.

Exhibit 3-36:
Summary of Historical Records.

Site	Years	Total Monitored Individuals Reported	Total Monitored Average Career Length (Yrs.)	Number with Measurable Career Dose (External)	Average Career Length for Individuals with Measurable Dose (Yrs.)	Average Measurable Career Dose (External in rem)
ETTP	1946 - 1999	17,936	7.4	7,565	12.0	0.646
Fernald	1952 - 1989	8,618	6.5	4,903	9.6	1.599
Hanford	1944 - 1998	182,323	5.1	80,691	9.8	1.428
INEEL	1951 - 1998	112,898	3.2	32,847	8.0	1.469
LBNL*	1982-1986	2,304	2.0	1,182	2.8	0.080
LLNL	1940 - 1999	17,200	12.8	4,772	22.8	0.687
NTS	1986 - 1999	140,863	1.6	1,346	7.2	0.123
Pantex	1952 - 1998	5,757	9.0	2,273	13.7	1.088
Portsmouth	1954 - 1995	9,901	9.9	6,081	13.8	0.372
Rocky Flats	1949 - 1992	27,736	6.1	16,053	9.1	2.107
Savannah River	1950 - 1999	43,998	10.1	32,043	12.6	1.459
Totals and Averages		**569,534**	**4.7**	**189,734**	**10.4**	**1.389**

* Data submitted during 2001.

3.8 External Dosimetry at DOE Sites

10 CFR 835.402 [6] requires that external dosimetry be provided for each individual at DOE sites when external radiation exposures may exceed the following:

§ 835.402 Individual monitoring.
(a) For the purpose of monitoring individual exposures to external radiation, personnel dosimeters shall be provided to and used by:
(1) Radiological workers (RW) who, under typical conditions, are likely to receive one or more of the following: (i) An effective dose equivalent to the whole body of 0.1 rem (0.001 sievert) or more in a year. (ii) A shallow dose equivalent to the skin or to any extremity of 5 rems (0.05 sievert) or more in a year; (iii) A lens of the eye dose equivalent of 1.5 rems (0.015 sievert) or more in a year.

Prior to these regulations DOE Orders (e.g., 5480.1A, Chapter 11 and 5480.11) regulated external radiation exposure to individuals at DOE sites. The ability to measure external exposure has evolved over the years with changes in technology. Early individual measurements were conducted using pocket-sized ionization chambers and later photographic film emulsions were used. Currently, all DOE site contractors use thermoluminescent dosimeters (TLDs) to measure external radiation exposure. Though newer technology is available (e.g., optically stimulated luminescence, solid state memory cells, etc.), they have not yet been implemented at any DOELAP accredited site. *Exhibit 3-37* shows the dosimetry used at several sites that historically have had some of the highest collective external dose. In addition, minimum detectable levels are given on the exhibit where the information was provided by site contractors.

3.8.1 Pocket Ionization Chambers/Film Badges

At the beginning of the Manhattan Project it was understood by radiation safety professionals that personal external exposure measuring devices would be necessary to document the amounts of external radiation received by workers. Initial external dose measurements were made using pocket ionization chambers (PICs), but this only measured deep dose equivalent and could not be used to quantify personal exposures to the skin or the lens of the eye. A major disadvantage to using PICs is that accumulated exposure can be altered by dropping or bumping the dosimeter. Because of the extremely large number of people who required monitoring, a small, accurate, rugged, and relatively inexpensive device was needed to quantify external exposure. Photographic film was the initial badge of choice at most early sites. During the early years of the Manhattan Project, film badges were used exclusively and in many cases the dosimeters were processed on-site.

Though film badges were excellent at detecting radiation exposure, the ability to quantify the amount of radiation was dependent on several important factors: the type of emulsion used on the film, the dose response of the film, how the film was processed, and the documenting of the amount of radiation exposure. Radiation exposure to the silver halide crystals present in the emulsion causes the formation of "latent image" centers to be formed and are then observed as a darkening of the film when the silver ions are reduced during film development. During the fixing of the film, all unreduced silver halide ions are dissolved from the film and the exposed portions appear as darkened areas.

Exhibit 3-37:
Historical Site External Dosimetry.

Site	Exposure Type	Dosimeter	Years	Monitoring Frequency	Minimum Detectable Level
Fernald	Whole Body (skin and deep)	Film	1952 – 1954	Weekly	
			1954 – 1958	Biweekly	
			1959 – 1985	Monthly	
		Panasonic TLD (UD 802)	1985 – 1993	Monthly	5 mrem
			1993 – present	Quarterly	5 mrem
	Extremity	Teledyne TLD	1983 – 1987	Monthly	
		Panasonic TLD	1988 – 2000	Monthly	30 mrem
			2001 – present	Quarterly	20 mrem
	Neutron	Landauer Neutrak	1999 – 2001	Quarterly	20 mrem
SRS*	Whole Body (skin and deep)	Film	1951 – 1965	Weekly	30 mrem
			1965 – 1970	Monthly	30 mrem
		TLD Chips	1970 – 1982	Monthly/Quarterly	5 mrem
		Panasonic TLD	1982 – Present	Monthly/Quarterly	5 mrem
	Extremity	Film	1953 – 1969	Monthly	30 mrem
		TLD Chips	1969 – 1982	Monthly	20 mrem
		Panasonic (UD-802 and 807)	1982 – present	Monthly	20 mrem
	Neutron	Nuclear Track (NTA)	1951 – 1960	Weekly	30 mrem
		Film	1960 – 1970	Biweekly	30 mrem
		Hoy TLND	1970 – 1995	Monthly	10 mrem
		TLD (UD-809)	1995 – present	Monthly/Quarterly	15 mrem
Hanford	Whole Body (skin and deep)	PICs	1943 – 1944	Daily	~20 mrem
		Two-Element Film (502) Dosimeter	1945 – 1956	Weekly	~40 mrem
		Multi-Element Film (502) Dosimeter	1957 – 1958	Biweekly	~30 mrem
		Multi-Element Film (508) Dosimeter	1958 – 1971	Monthly	~30 mrem
	Whole Body (skin and deep) and neutron	TLD	1972 – 1995	Monthly	15 mrem
		TLD (Harshaw)	1995 – present	Monthly Quarterly Annually	<10 mrem
	Extremity	Film	1945 – 1967	Daily Weekly	
		Ring TLD	1967 – present	Daily Weekly	~20 mrem
	Neutron	Boron Lined PICs	1945 – 1950	Biweekly	
		NTA Emulsion	1950 – 1971	Biweekly	
Rocky Flats	Whole Body (skin and deep)	Film (Dupont or Kodak	1952 – 1970	Weekly Biweekly Monthly	
	Whole Body (skin and deep) and neutron	Harshaw TLD	1969 – 1986	Weekly Biweekly Monthly, Quarterly	
		Panasonic TLD (UD 802 and 809)	1985 – 1991	Weekly Semimonthly Monthly	~10 mrem
			1991 – 2000	Annually	
			2000 – present	Quarterly Semiannually	

* References to Monthly/Quarterly frequencies reflect that SRS has used different exchange frequencies dependent on the SRS facility in these time intervals. Currently, all routine whole body TLD exchange frequencies are quarterly. Extremity routine badging is exchanged monthly. Also at SRS, the Hoy Thermoluminescent Neutron Dosimeter (TLND) was an albedo dosimeter designed at SRS by a Radiological Control Technician named Jack Hoy in the early 70s using LiF 6 and 7 chips contained in a stainless steel sphere that was lined with cadmium - big, bulky, and worn with a belt that pulled it in against the abdomen. It was used until 1993 with some enhancements along the way.

Exhibit 3-37:
Historical Site External Dosimetry (continued).

Site	Exposure Type	Dosimeter	Years	Monitoring Frequency	Minimum Detectable Level
Rocky Flats	Extremity, wrist	Film (Dupont or Kodak)	1952 – 1972	Weekly Biweekly Monthly	
		TLD (Harshaw 600 and 700 chips)	1972 – 1991	Weekly Biweekly Monthly	
		TLD (Panasonic UD 813)	1991 – 2000	Quarterly	
			2000 – present	Quarterly Semiannually	
	Neutron	Neutron track plates	1952 – 1956	Weekly Biweekly Monthly	
		NTA film	1956 – 1971	Weekly Biweekly Monthly Quarterly	
INEEL	Whole Body (skin and deep)	Film (Dupont 552)	1951 – 1958	Monthly	30 mrem
		Film (Dupont 558)	1958 – 1973	Monthly	10 mrem (gamma) 30 mrem (beta)
		TLD disks (Teledyne LiF given to those receiving < 500 mrem)	1966 – 1974	Monthly Quarterly Semiannually Annually	10 mrem
		TLD (LiF ATLAS)	1969 – 1975	Monthly	30 mR
		TLD (LiF chips)	1974 – 1985	Monthly Quarterly Annually	15 mrem
		TLD (Panasonic UD 808 and 814)	1986 – present	Monthly Quarterly	15 mrem (gamma from 1986 to 1993) 10 mrem (gamma from 1993 to present) 30 mrem (beta)
	Neutron	Film (Kodak Type A)	1951 – 1975	Monthly	10-14 mrem (fast neutron)
		TLD (TLD-600 and TLD-700)	1975 – present	Monthly Quarterly	15 mrem
LANL	Whole Body (skin and deep)	To be determined			
ORNL	Whole Body (skin and deep)	Film, supplemented by PIC	1943 – 1951	Weekly	10 mrem (film)
			1951 – 1956	Weekly (RW) Annually	10 mrem (film)
			1957 – 1974	Quarterly (RW) Annually	10 mrem (film)
		ORNL TLD - 4 chip	1975 – 1980	Quarterly (RW) Annually	20 mrem
		Harshaw TLD - 2 chip	1981 – 1988	Quarterly (RW) Annually	20 mrem
		Harshaw TLD - 4 chip	1989 – present	Quarterly	1 mrem
	Extremity	Film	1951 – 1974	As needed	10 mrem
		Harshaw TLD	1975 – 1988	As needed	10 mrem
			1989 – present	Monthly	10 mrem
	Neutron	NTA film	1951 – 1986	Quarterly	30 mrem
		Panasonic TLD	1987 – 1988	Quarterly	10 mrem
		Harshaw TLD	1989 – present	Quarterly	1 mrem

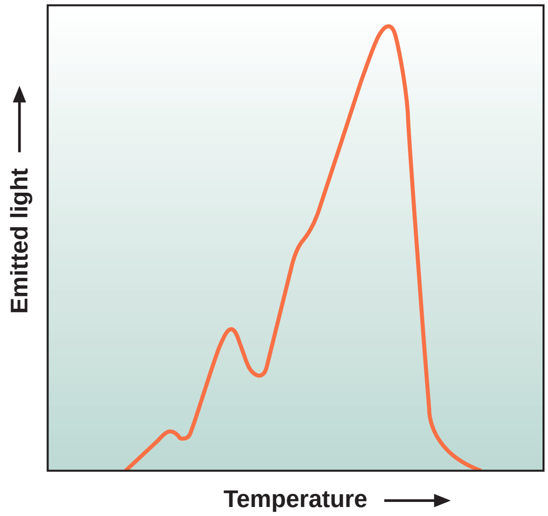
Source: Data provided by site external dosimetry personnel or designee from each DOE site shown.

Each film type has different sensitivity, fading characteristics, and energy dependence and must be chosen to meet the needs of the radiation types expected at the sites. The interpretation of the amount of exposure a film badge may have received is dependent on several other factors. Due to various parameters that rely solely upon human interpretation, the use of film has several drawbacks. A major advantage, though, of film badge dosimetry is that the developed film can be stored and re-quantified at any time after development. This fact is important in the event that final external exposures must be re-evaluated for dose assessment and recordkeeping purposes.

3.8.2 Thermoluminescent Dosimeters

TLDs are presently the radiation dosimeter of choice for all Department of Energy Laboratory Accreditation Program (DOELAP) accredited sites. Thermoluminescent (TL) materials that are used in personnel badges have a characteristic that causes electrons to be moved from their normal energy state to higher energy levels when exposed to ionizing radiation. At normal ambient temperatures, the energized electrons are trapped by lattice defects and stored there by impurities that were incorporated into the TL material during manufacture until the electrons are released by heating. The TL material gives off light (luminescence) when heated and the electrons fall back to their normal energy state. The amount of light given off during heating is proportional to the radiation exposure the badge received. The two major types of TL materials used in personal dosimetry include LiF (lithium fluoride) and LiB_4O_7 (lithium borate) due to their relative insensitivity to energy of the incident radiation. Some aspects that make TLDs more advantageous than using film are that the badges can be reused (reducing the cost), the energy dependence can be reduced, and that they can be manufactured in various sizes and shapes. Each TL material exhibits its own "glow curve" (see *Exhibit 3-38*) which is used to confirm that the absorbed dose is from exposure to radiation and not from a contaminant or other light source. (A glow curve is a plot of light intensity emitted as the temperature applied to the TL material increases. The area under the curve is proportional to the exposure received.) One disadvantage to TLDs is that once the electrons fall back to their normal energy levels the dose cannot be reassessed from the dosimeter at a later date.

Exhibit 3-38:
Sample Glow Curve for LiF.



Source: Herman Cember, *Introduction to Health Physics*, page 261, Pergamon Press, 1983.

3.8.3 Newer Dosimetry Techniques

Several external dosimetry techniques are being marketed commercially, but have not yet found their way into common use at DOELAP-certified sites. These are optically stimulated luminescence (OSL) and direct ion storage[1,TM]. These badges provide a means of reassessing exposure information more than once. The OSL badges provide measurement sensitivities as low as 1 mrem with correspondingly low measurement uncertainties using Al_2O_3. Dosimeters using direct ion storage™ allow individuals to wear a dosimeter and determine the amount of exposure that it measures more than once. The dosimeter uses a combination of an ion chamber and a nonvolatile electronic charge storage element to measure exposure. These dosimeters are technologically more advanced than film or TLDs and may be used by DOE sites in the near future due to their ability to measure much lower exposures with greater sensitivity. One current drawback to using these dosimetry systems is that sites that have existing DOELAP certifications would be required to retool and submit new documentation to get re-certified.

Exhibit 3-39 provides a table of the current external whole body dosimetry used at DOELAP-accredited programs, and includes the irradiation categories for which the dosimeter is qualified.

[1] Direct ion storage is trademarked by Landauer, Inc.

Exhibit 3-39:
Site External Whole Body Dosimetry and DOELAP Irradiation Categories.

Site	Whole Body: Dosimeter Type	Whole Body: Dosimeter Processor	DOELAP Irradiation Categories *: 1. Low-Energy Photons High Dose	2. High-Energy Photons High Dose	3A. Low-Energy Photons General	3B. Low-Energy Photons	4. High-Energy Photons	5A. Beta Particles General (Point Geometry)	5B. Beta Particles Special (Slab Geometry)	5C. Beta Particles Special (Point Geometry)	6. Neutron	7. Mixture Categories
ANL	ANL Panasonic UD-814AS + Albedo	Onsite	✔	✔	✔		✔		✔		✔	✔
	APS Panasonic UD-814	Onsite		✔			✔					
BNL	Harshaw 8814	Landauer	✔	✔	✔		✔	✔			✔	✔
	CR-39	Landauer									✔	
	Harshaw 8806	Landauer		✔			✔					
Fermilab	Landauer F1 (L1+ CR-39)	Landauer	✔	✔	✔		✔	✔	✔		✔	✔
Fernald	Panasonic UD-802AS2	Onsite	✔	✔	✔		✔	✔				✔
	Landauer Neutrak-ER	Landauer									✔	
INEEL	Panasonic UD-814	Onsite	✔	✔	✔	✔	✔		✔			✔
	Panasonic UD-808 + Albedo	Onsite	✔	✔	✔	✔	✔		✔		✔	✔
LANL	Harshaw 8823	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
LBL	Panasonic UD-802	Onsite	✔	✔	✔		✔			✔		✔
	Panasonic UD-810	Onsite	✔	✔	✔		✔			✔	✔	✔
	Panasonic UD-810 + CR-39	Onsite	✔	✔	✔		✔			✔	✔	✔
LLNL	Panasonic UD-802	Onsite	✔	✔	✔		✔	✔				✔
	Panasonic UD-810	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
	Panasonic UD-810 + CR-39	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
Mound	Hanford Std Dosimeter (HSD) (Harshaw 8825)	PNNL	✔	✔	✔	✔	✔	✔			✔	✔
	Hanford Combination Neutron Dosimeter (HCND)	PNNL	✔	✔	✔	✔	✔	✔			✔	✔
NTS	Panasonic UD-802	Onsite	✔	✔	✔	✔	✔	✔				✔
	Panasonic UD-809/UD-812	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
ORNL	Harshaw 8805	Onsite	✔	✔	✔	✔	✔	✔	✔			✔
	Harshaw 8805/8806	Onsite	✔	✔	✔	✔	✔	✔	✔		✔	✔
Y-12	Harshaw 8805	Onsite	✔	✔	✔	✔	✔	✔	✔			✔
	Harshaw 8805/8806	Onsite	✔	✔	✔	✔	✔	✔	✔		✔	✔
Pantex	Panasonic UD-802	Onsite	✔	✔	✔	✔	✔	✔				✔
	Panasonic UD-809/UD-812	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
PNNL	HSD	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
	HCND	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
	HCND w/ CR-39	Onsite	✔	✔	✔	✔	✔	✔			✔	✔
PPPL	Landauer Model L1	Landauer	✔	✔	✔		✔	✔				✔
	Landauer Model F1 (L1 + CR-39)	Landauer	✔	✔	✔		✔	✔			✔	✔
RF	Panasonic UD-802/UD-809	Onsite	✔	✔	✔	✔	✔			✔	✔	✔
SNL	Harshaw 8802	Onsite	✔	✔	✔		✔	✔			✔	✔
SLAC	Panasonic UD-802AT	Onsite	✔	✔	✔		✔				✔	✔
SRS	Panasonic UD-802	Onsite	✔	✔		✔	✔		✔	✔		✔
	Panasonic UD-809/812	Onsite	✔	✔		✔	✔		✔	✔	✔	✔
TJNAF	ICN Model 760 TLD/CR-39	ICN	✔	✔	✔		✔			✔	✔	✔
WIPP	Harshaw 8801	Onsite	✔	✔		✔	✔	✔			✔	✔
WVDP	Panasonic UD-814AS4	Onsite	✔	✔	✔		✔	✔				✔

* DOE/EH-0026, "Handbook for the Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems," DOE Laboratory Accreditation Program for Personnel Dosimetry Systems, December 1986.

Source: Data provided by R. Loesch, DOELAP Administrator, EH-52.

Section Four

ALARA Activities at DOE

4

This section on ALARA activities is a vehicle to document successes and to point all DOE sites to those programs whose managers have confronted radiation protection issues and 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 future reports.

4.1 ALARA Activities at the Hanford Site

4.1.1 Fluor Hanford Inc., Work Team at WRAP Implemented ALARA, Doubling Their Productivity

A major ALARA success has been achieved at the Waste Receiving and Processing (WRAP) facility, with improved radiological engineering controls and worker involvement in improving the work processes. A team of WRAP employees in management, operations, radiological control, and engineering developed new methods that save time and decrease the burden of wearing personal protective equipment.

WRAP went into operation in 1999 as the major facility working towards removal of transuranic (TRU) waste from Hanford. TRU waste received by the facility undergoes a stringent certification process that includes non-destructive evaluation to identify the presence of liquids or hazardous materials and radioassay to quantify the amount of plutonium and other radionuclides.

TRU waste drums that do not meet acceptance criteria for final disposal require repackaging. This operation is completed in the TRU glovebox enclosure located in the process area of WRAP. The contents are removed, non-compliant materials are segregated, and the TRU waste is repackaged in a "one-trip drum" – so named because it is not designed for reuse. Only drums that meet the certification standards are shipped to WIPP outside Carlsbad, New Mexico, for disposal.

In the older process, as the one-trip drums were readied for exit from the glovebox, respiratory protection was required for the entire room known as the process area. The drums were disconnected from the glovebox and the drum and exit port seal areas were decontaminated. This was labor-intensive, and the use of respiratory protection made it physically taxing. A U-shaped ventilation collar was attached to the box at the drum exit ports to reduce, but did not eliminate, the potential for airborne radioactivity releases. The work process, including required surveys, personnel monitoring, and air sample analysis took enough time that the removal of two drums was a full-day activity.

A team made up of bargaining-unit and exempt representatives of operations, radiological control, engineering, and maintenance finalized a process that resulted in improved radiological engineering controls, fewer controls on workers, and a more efficient process.

First, an improved ventilation collar, the "halo system," was designed, implemented, and verified to be effective. This ventilation collar completely surrounded the drum lid, providing better coverage and a higher flow rate than the U-shaped ventilation collar (see *Exhibit 4-1*). Additional radiation protection information was gathered with the use of breathing zone samplers and contamination surveys. After the effectiveness of the new ventilation system was demonstrated, respiratory protection requirements were reduced. The airborne radioactivity area was reduced to a small area around the exit conveyors and the glovebox exit ports.

Exhibit 4-1:
TRU Drum Processing Inside WRAP Facility.

Photo Courtesy of Hanford.

Next, the decontamination of the exit ports and seal areas was evaluated. The team determined decontamination of the exit ports and seal areas after each drum exit was not necessary. This was the activity with the greatest potential risk to personnel from radioactive contamination. Survey information was gathered to ensure that drum exits could be performed without the undue risk of spreading contamination to the surrounding radiological buffer area.

Once sufficient operational history was gathered on the new process, respiratory protection requirements were further reduced. Employees were allowed to perform the drum exit operation without wearing respirators, except when performing the periodic exit port and seal area decontamination.

With these process improvements, the WRAP facility has been able to double its TRU drum processing capability. The process changes improved contamination control, reduced manpower and material needs, and resulted in less physical stress for the workers performing the activity. The team effort made this a real ALARA success story.

4.1.2 Teamwork Results in the Development and Implementation of the Pit Viper, a Robotic Device Used to Significantly Reduce Dose to Workers at Hanford Tank Farms

CH2M HILL Hanford Group (CHG) is cleaning and upgrading some of the most radioactive areas in Hanford's tank farms using the Pit Viper, a robotic arm attached to a backhoe. The hydraulic Pit Viper arm has a reach of 8 feet, can lift 200 pounds when fully extended, and can be remotely manipulated to perform a variety of tasks that would otherwise be done by workers with tools on long poles (see *Exhibit 4-2*).

Exhibit 4-2:
Pit Viper Robotic Device.

Photo Courtesy of Hanford.

The Pit Viper is being used to make upgrades to pits that provide access to the tanks. These pits are made of concrete and contain valves, piping connections, pumps, (see *Exhibit 4-3*) and other tank waste transfer equipment. CHG personnel plan to upgrade 32 of these pits in preparation for transferring waste out of Hanford's tanks to the vitrification plant (currently under construction) for treatment. Work in these pits requires human skill and dexterity, but the job has to be performed in what is often a highly radioactive and contaminated environment.

Exhibit 4-3:
Contaminated Pit at the Hanford Tank Farm.

Photo Courtesy of Hanford.

The Pit Viper was developed through teamwork. CHG recognized the need for ways to do complex work in the pits with less personnel radiation exposure and greater efficiency. The DOE's Tanks Focus Area and Robotics Crosscutting Program provided a team of technology developers from PNNL, ORNL, and Numatec Hanford Company to work hand-in-hand with CHG from the initiation of the project through the first use of the system. Cold testing and mock-up training for the Pit Viper was performed in a Waste Tank prop at the Volpentest HAMMER Training and Education Center.

The Pit Viper's first job in the Hanford tank farms was at single-shell Tank C-104, making modifications to the tank's heel pit in preparation for the installation of waste retrieval equipment. The Pit Viper sliced through a deteriorated piece of foam using a water knife, removed debris from the pit floor, scraped clean a patch on the pit wall, and sprayed a fixative within the pit.

The Pit Viper operator sits at a control console located in a trailer outside the tank-farm fence line (see *Exhibit 4-4*). Eight cameras and four video monitoring screens give multiple views as the operator manipulates the robotic arm, which reaches through a sleeve in a containment tent and into the pit. The operator can choose to pick up and use a variety of tools such as brooms, spray nozzles, pincers, and knives. A rack located inside the pit holds the tools, each of which is fitted with a T-handle for ease of pickup.

Exhibit 4-4:
Pit Viper Operator at Control Console.

Photo Courtesy of Hanford.

The Pit Viper is a direct result of technology developers, engineers, and craftspeople combining efforts to develop a system that both reduces dose to workers and performs work more efficiently. Using the Pit Viper, the cumulative dose for Tank C-104 pit work was only 274 mrem. This represents more than a 75 percent reduction in dose to workers when compared to the traditional methods of performing work in pits. Significant dose reduction will be realized over the lifetime of the tank farms project.

4.1.3 Bechtel Hanford, Inc., Workers Use ALARA in Remediation of 116-N-3 Liquid Waste Disposal Facility

The 116-N-3 Liquid Waste Disposal Facility was built after the 116-N-3 crib and trench reached its holding capacity. The concrete-covered cribs and trenches were used to dispose of liquid from N-Reactor's fuel-storage basin and highly contaminated reactor cooling systems. The cribs and trenches were designed to absorb liquid waste through layers of gravel, sand, and soil before it could reach groundwater levels (see *Exhibit 4-5*).

Bechtel Hanford, Inc., and its subcontractor, Foster Wheeler Environmental Corp., were tasked to remediate the 116-N-3 Liquid Waste Disposal Facility to meet a rural residential occupancy scenario. Remediation of the waste site required demolishing concrete structures and excavating, hauling, and disposing of contaminated soils in work areas containing high levels of contamination (up to 3 million dpm/100 cm^2 beta-gamma and 11,000 dpm/100cm^2 alpha) and high dose rates (general area work dose rates as high as 250 mrem/hr), with some locations where whole body dose rates were in excess of 1 rem/hr. The total activity of the soil and debris was estimated to be over 1,500 curies. The principal radionuclides were ^{60}Co, ^{137}Cs, ^{239}Pu, and ^{90}Sr.

Since the project began, the work team developed methods to dramatically reduce radiation levels in the work area around the crib and trench. As a result of effective ALARA planning, the project saved 3.5 person-rem.

Exhibit 4-5:
116-N-3 Liquid Waste Disposal Facility Was Used to Dispose of Liquid from N-reactor's Fuel Storage Basin and Highly Contaminated Reactor Cooling System.

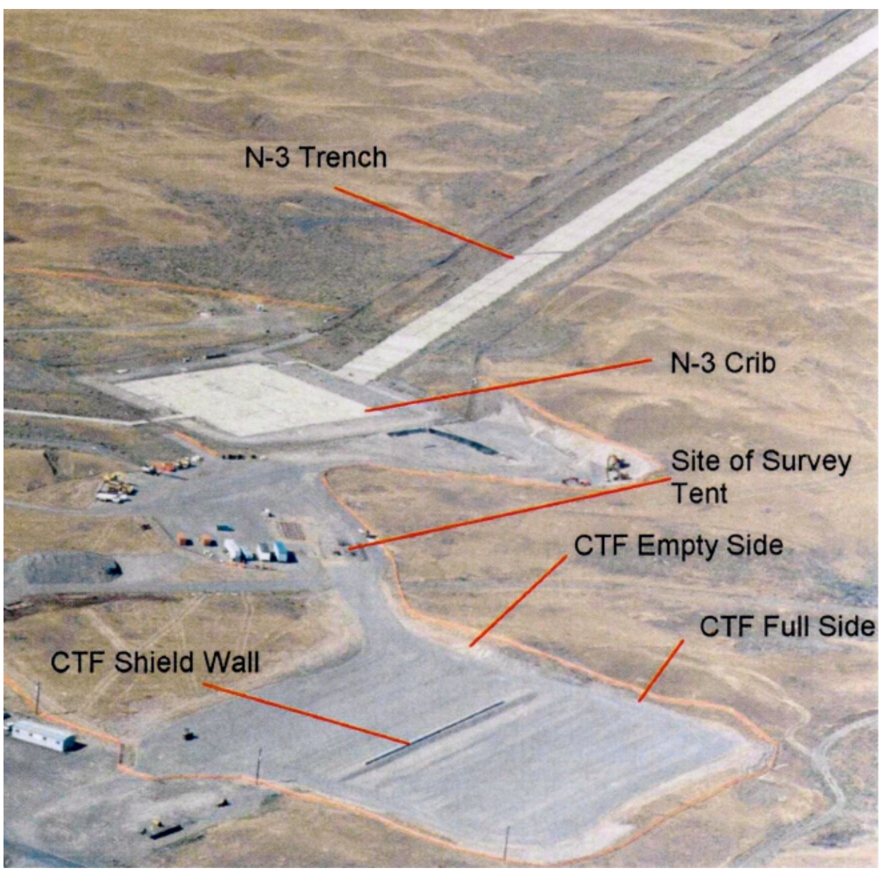


Photo Courtesy of Hanford.

Exhibit 4-6:
Free Flowing Grout System Was Used to Bind Contaminated Sludge Contained in the Troughs and Provide Additional Radiation Shielding.

Photo Courtesy of Hanford.

4.1.3.1 Use of Free Flowing Grout

The 116-N-3 Crib distribution troughs, located beneath concrete panels, contained highly concentrated radioactive sludge. This sludge posed an internal and external dose hazard to workers during demolition. To reduce this hazard, a free flowing grout system was used to fill the troughs with grout (see *Exhibit 4-6*). The grout had a two-fold effect – binding up the contaminated sludge to reduce potential airborne radioactivity and providing shielding to reduce the dose rates above the cover panels (see *Exhibit 4-7*). Average dose rates were reduced from 150 mrem/hr to less than 5 mrem/hr.

Exhibit 4-7:
Free Flowing Grout Mixture Solidified, Making It Easy to Demolish with Concrete Processing Equipment.

Photo Courtesy of Hanford.

4.1.3.2 Remotely Operated Diamond Saw Used to Cut Concrete Panels

The concrete cover panels had to be removed. The panels were tied together using a grout mixture. In the removal of the concrete crib cover, craft worker input resulted in the use of a remotely operated diamond saw. The saw traveled along a track, cutting the concrete crib cover into removable rectangular patterns (see *Exhibit 4-8*). Workers stood next to the crib using controls to operate the saw. The saw method used by workers was a timely way to get things done. Normally, the saw would have been manually guided. Use of the remotely operated saw significantly reduced worker exposure to concrete dust and particles while placing workers as far as possible from radiation sources.

The concrete cover panels were then remotely clamped down using C-shaped fixtures and lifted with a large crawler crane. Instead of using worker-guided "tag lines" attached to the end of a panel, the workforce devised a system that used electric winches, or "tuggers," to maneuver the panels. Two tuggers were installed at the base of the crane boom and controlled from the cab by the crane operator using toggle switches. Workers improved safety and reduced radiological doses and potential contamination by not having contact with the panels during removal operations. The panels were moved to a low dose area for size reduction.

Exhibit 4-8:
Remotely Operated Diamond Saw Traveled Along a Track Cutting the Concrete Crib Cover Into Removable Rectangular Patterns.

Photo Courtesy of Hanford.

4.1.3.3 Effective Use of Low-Level Waste Soil for Radiation Shielding

During the remediation, contaminated soils that had low concentrations of radioactivity, but were still above the clean-up standard, were used to cover high dose rate soils and act as shielding. As the concrete panels were removed, these soils were used to cover the highly contaminated soil that was exposed (see *Exhibit 4-9*). The low dose soils were blended with the highly contaminated soil, which reduced the overall concentration of radioactivity in the soils being handled. This reduction in concentration reduced dose rates and reduced the potential for airborne radioactivity. The contaminated soil was removed and transported to the Environmental Restoration Disposal Facility.

For additional information concerning any of these projects please contact: Brenda Pangborn of Hanford at (509) 372-3841.

Exhibit 4-9:
Contaminated Soils Had Low Concentrations of Radioactivity But Were Still Above the Clean-up Standard and Were Used to Cover High Dose Rate Soils and Act as Shielding.

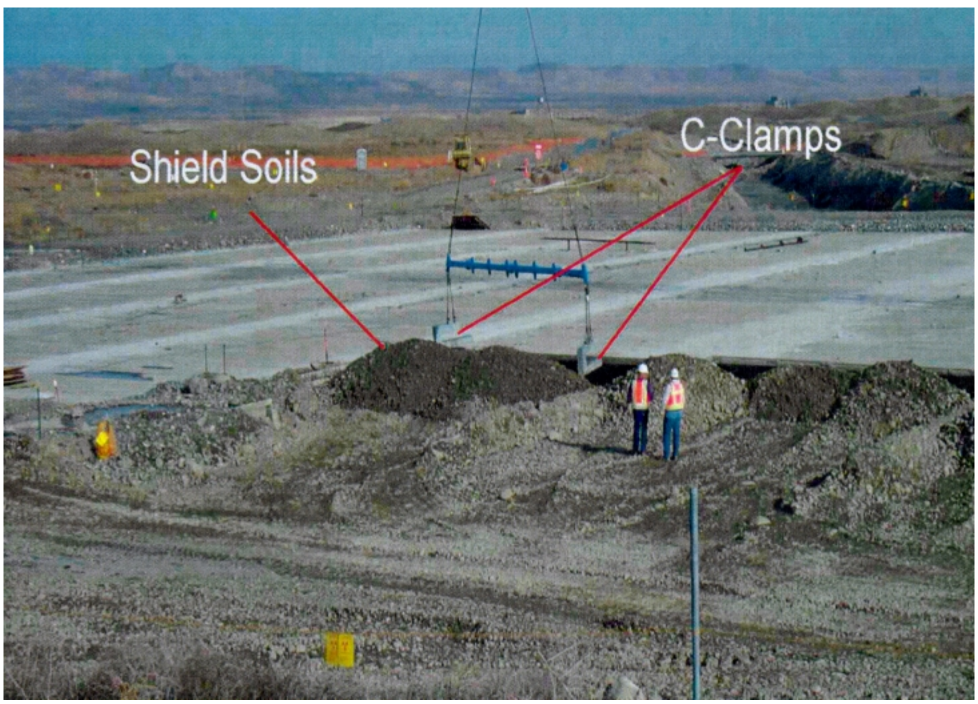


Photo Courtesy of Hanford.

4.2 ALARA Activities at the Idaho Site

4.2.1 Radiation Dose Reduction Methods Used During Decontamination of Hot Cells

For several years, Cell #1 at the TRA Hot Cells had been used to process various isotopes, including Gadolinium. This involved the separation of the various Europium contaminates; Europium is a very mobile material. During separation, thousands of curies of the Europium contaminate were distributed throughout the cell. Large amounts of this material were ultimately deposited on the cell's HEPA filter system located above the cell, which caused radiation levels outside the Hot Cell facility to become elevated.

Another isotope processed was Cobalt-60. During the removal of the Cobalt pellets from their holders, often the pellets would fall to the floor and tables in the cell.

Prior to this decontamination effort, no in-cell means to maintain cleanliness or to perform decontamination existed primarily because cell floor drains had become plugged and did not meet Federal and state requirements for use. As a result of environmental issues, the floor drains were grouted to prevent use.

During the decontamination effort, various innovative methods were used to reduce radiation exposure to workers performing the decontamination. One of the most effective methods was the use of strong magnets attached to a robotic vehicle. The magnets were used to collect the spilled cobalt pellets from table and floor surfaces. Magnets were also used in the successful collection of cobalt pellets as they were blasted with pressurized carbon dioxide into a HEPA-filtered collection system. This effort resulted in a reduction in the long-term exposure to personnel involved in the storage of the mixed waste generated during the project.

A robotic vehicle was used to retrieve hundreds of pounds of debris that had been abandoned in the cell. Under-Table Articulating Manipulators were used to collect larger items and transfer them to the tabletop for remote transfer from the cell. In-cell pre-filters, Glycol misting, cameras, and water shields were also used.

During the decontamination effort, many repairs were required on the cell's manipulators. Carbon dioxide pressure wands were used to clean the manipulators prior to their removal from the cell for repairs without generating additional waste for disposal. Normally, the manipulators would read up to 50 R/hr prior to decontamination. After decontamination it was not uncommon to see levels less than 1 R/hr.

Through the use of the above-described methods and a dedicated team of construction, radiological control, contractor, and facility project personnel, several Rem of exposure to decontamination personnel was avoided. Hot Cell radiation levels were reduced from an average of 30,000 R/hr to 280 R/hr.

Contact: John Edelmayer, Bechtel Babcox Wilcox Idaho; (208) 526-4058, e-mail: JOND@inel.gov

4.3 ALARA Activities at the Rocky Flats Site

4.3.1 Rocky Flats Reduces Risk with Innovations in Waste Characterization and Packaging

As Rocky Flats Environmental Technology Site continues D&D activities, several methods to characterize and package highly contaminated gloveboxes have been developed in parallel. The innovations have resulted in a significant reduction in risk to the workforce and the savings of millions of dollars and months of D&D.

After a worker cut his hand resulting in an intake while size-reducing a glovebox using manual cutting tools in 1997, the site started down two parallel paths – cutting up the gloveboxes more safely in Inner Tent Chambers (see DOE *Occupational Radiation Exposure 2000 Report*), and disposing of the gloveboxes without cutting them up. The second path uses the Surface Contaminated Object (SCO) characterization allowed by 49 CFR 173.403. An SCO is a solid object that is not itself radioactive, but which has radioactive material distributed on any of its surfaces. Rocky Flats was then faced with the first of two problems – no instrumentation was available that could reliably measure the high levels of alpha contamination present on the interior surfaces of the gloveboxes.

Rocky Flats has developed rigorous technical basis documents to allow the use of three different instruments in the past 2 years to survey the high levels of fixed contamination on the interior of the gloveboxes. The first to be certified was a Ludlum® 12-1A with an air proportional probe – the same instrument used for years at the site, but modified after much experimentation with the addition of an attenuator plate on the probe. The second instrument to be certified was a RadElec® Electret, an ion chamber modified by reducing the ion chamber volume to be very insensitive, thus making it usable to detect high alpha contamination levels. The third instrument to be certified, a Ludlum® 195 with Model 43-132 ion chamber probe, shows the greatest promise in reliability, accuracy, and flexibility in operational use.

Once appropriate instrumentation became available, the second of the two problems became apparent – it was noted that many glovebox interiors were so highly contaminated that even after normal decontamination methods (scrubbing with a surfactant and water), the contamination levels were still above the SCO limits. Several different decontamination solutions have been tried, and the use of a cerium nitrate solution appears to be the best. The 0.5N cerium IV nitrate solution oxidizes the plutonium bound to the glovebox walls, putting the plutonium into solution, while dissolving an ultra-thin (about 1-5 microns thick) layer of the stainless steel. The cerium nitrate is sprayed on either cold or hot, allowed to sit for a few minutes, and then wiped off. A ferrous sulfate solution is then sprayed on the surfaces, which stops the reaction and reduces the cerium IV and chromium VI (from the stainless steel) to the more benign trivalent state. A water rinse and wipe down follows to remove residual cerium and plutonium. The results have shown that the fixed contamination levels can be reduced by a thousand-fold or more, depending on the length of time of contact and temperature of the cerium nitrate solution.

Another innovation in SCO packaging that has reduced risk to the workplace has been the development of improved methods to make accessible areas inaccessible. If a glovebox has high removable contamination that is made inaccessible, then higher contamination limits apply. When gloveboxes are removed from the line, a multiple-layer wrap and attachment of a sheet metal plate on the open end of the sectioned glovebox make the interior of the glovebox inaccessible.

For more information about the instrumentation, contact Radiological Engineers Mr. Robert Morris, CHP, (303-966-6468) or Mr. Elliott Lesses (303-966-5726). For more information about the cerium nitrate solution, contact Dr. Thomas E. Boyd (303-499-2067).

4.4 ALARA Activities at the Savannah River Site

4.4.1 Canberra Alpha Sentry Constant Air Monitor at SRS

The Canberra Alpha Sentry Constant Air Monitors (CAMs) were selected by the WSRC Health Physics Technology (HPT) group to upgrade the SRS alpha continuous air monitors. *Exhibit 4-10* shows the Canberra Alpha Sentry CAM in a mobile configuration. To date, these CAMs have been installed in five facilities. The CAMS are installed in three distinct configurations: mobile, fixed, and fixed with manifold for remote sampling.

Exhibit 4-10:
Canberra Alpha Sentry CAM in Mobile Configuration.

Photo Courtesy of Savannah River Site.

The Canberra Alpha Sentry CAMs use multiple channel analysis and spectrum analysis to quantify the actinides in the presence of naturally occurring radionuclides. The analysis methods employed minimize the possibility of false alarms while providing very low detection capabilities.

To optimize performance of the CAMs, HPT performed air migration studies in each facility. Once the air migration studies were completed, specific locations were identified for CAM installation. These studies were designed to minimize the time between release of radioactive material and an alarm annunciation. With the enhanced detection capabilities and optimized positioning of the CAMs, worker doses due to inhalation may be avoided or at least minimized. This directly links the CAM upgrade to ALARA.

Other ALARA-related aspects have presented themselves through the use of the CAMs. These were based on observations Radiological Control Operations (RCO) made with respect to facility conditions and CAM alarms. Results of these observations changed specific work practices and housekeeping practices to reduce resuspension of radioactive particulates. Once the undesirable practices were corrected, there were no more airborne radioactivity alarms in those specific areas or with specific work, thus minimizing the possibility of an inhalation event. Due to the enhanced performance characteristics of the CAMs, an order of magnitude less false alarms are being reported. Confidence in the new equipment has improved worker attentiveness to CAM alarms. The new CAMs are a significant improvement, which will support the ALARA goals for years in the future.

For additional information about this project contact: Ron Smith, Health Physics Technology: (803) 952-6832, e-mail: ronj.smith@srs.gov

4.4.2 Canberra ISOCS Equipment at SRS

HPT purchased the In Situ Object Counting System (ISOCS) in mid 2000. ISOCS equipment is shown in *Exhibit 4-11*. The typical system is composed of a high-purity germanium detector; a digital 16,000 channel, multi-channel analyzer; a laptop computer; a stainless steel-encased lead collimator set; and a wheeled cart. The ISOCS is a portable gamma spectroscopy system using state-of-the-art software for nuclide identification and quantification. The ISOCS uses a three-dimensional model to mathematically generate an efficiency curve. ISOCS software inputs include spatial orientation of detector to target, material composition, material dimensions, and elemental composition.

Exhibit 4-11:
ISOCS Portable Gamma Spectroscopy System.

Photo Courtesy of Savannah River Site.

The ISOCS has been deployed to many on-site facilities to support RCO. Facility HPT engineers and RCO personnel request ISOCS measurements to support work planning activities. With ISOCS measurements, the presence of radioactive material can be determined in systems of interest prior to entry into the system. With the identification and quantification of radioactive materials in a system, job planning is most effective. Radiological controls, such as respiratory protection, containments, and waste handling, can be established based on activity measurements.

Legacy containers with poor or no characterization can be assayed with ISOCS to ensure that appropriate precautions are taken when handling the container during its disposition. In some cases, these containers had minimal external exposure rates, but once assayed with the ISOCS, the container had measurable transuranic nuclides inside. Improper handling of this type of container could have resulted in large inhalation doses.

The ISOCS equipment plays a valuable role supporting site ALARA initiatives for cost-effective methods to reduce worker risk and enhance worker safety overall.

For additional information about this project contact: Ron Smith, Health Physics Technology: (803) 952-6832, e-mail: ronj.smith@srs.gov

4.5 ALARA Activities at the West Valley Demonstration Project

The West Valley Demonstration Project (WVDP) is located approximately 30 miles south of Buffalo, New York, at the site of a former commercial nuclear fuel reprocessing plant. When the plant operated, more than 600,000 gallons of liquid high-level radioactive waste were generated and stored in an underground tank. The WVDP Act passed by Congress in 1980 directed DOE to solidify the liquid waste in the tank, clean and close the facilities used, and dispose of low-level and transuranic wastes left from project operations. West Valley Nuclear Services Company (WVNSCO) is the contractor at the WVDP site. The New York State Energy Research and Development Authority (NYSERDA) owns the site property. The solidification phase of the WVDP is complete, and the focus of work is now D&D projects. Two of the successfully completed D&D projects in 2001 are described below.

4.5.1 Decontamination, Dismantlement, and Packaging of a Plutonium-Contaminated Glovebox

The Plutonium Packaging & Handling (PPH) area is located in the Main Plant facility at the WVDP. The PPH glovebox was a large stainless steel glovebox used during reprocessing operations to package purified plutonium nitrate for off-site shipment. The box measured 18 feet long, 16 feet tall, and 4 feet deep and served as a containment structure that allowed the former plant operators to handle plutonium remotely. With no anticipated present or future need for the glovebox, it was scheduled for dismantlement and removal (see *Exhibit 4-12*).

Exhibit 4-12: Glovebox in Place.

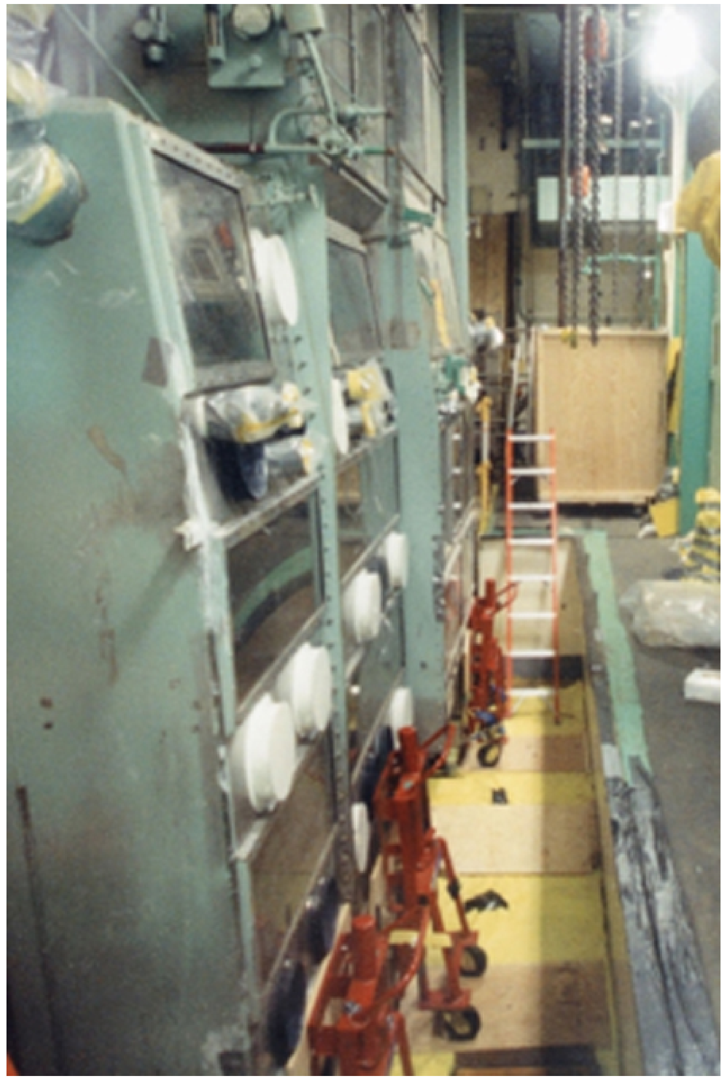


Photo Courtesy of WVDP.

The PPH glovebox project was challenging to complete due to the size of the box, the high internal levels of alpha contamination (3.0E+07 dpm/100cm2), and limited physical access and work space in the PPH area. Other challenges included the application of specialized hoisting and rigging requirements, the need to use fixatives to contain contamination, the inability to use standard containment techniques, and the need for engineered ventilation controls.
To provide a safe means of obtaining radiological surveys of the glovebox interior, ten existing deteriorated gloves were replaced, as well as a bag-out bag, which allowed operators to insert tools, instrumentation, and material into the glovebox. Pre-job mock-up training was conducted for the glovebox and bag-out bag replacements to ensure that the work could be completed and exposure maintained ALARA.

Once the glove and bag replacements were completed, extensive contamination surveys of the box interior and exterior were performed. The surveys provided a basis for the decontamination techniques that were used for the project. With the high levels of alpha contamination present, numerous precautions were taken to prevent airborne contamination. Data Quality Objectives (DQOs) were also prepared to ensure that necessary data was obtained that would permit proper characterization of the waste from the project. Using a hole saw, D&D operators obtained six, 2-inch-diameter samples of stainless steel from the body of the glovebox. The glovebox and associated HEPA filters were packaged as TRU waste based on analyses of contamination on the stainless steel samples. A transfer cart located inside the glovebox was disposed of as mixed waste due to lead shielding integral to the cart. All piping, conduit, and personnel protective equipment (PPE) were disposed as low-level radioactive waste. The vast majority of the alpha contamination was contained within the glovebox. Contamination also existed in the product fill line, drain lines, glovebox ventilation filters and piping, and the bottle fill vent line. This was expected because the lines and equipment had been in direct contact with plutonium nitrate. Contamination also was detected on the outside of the box, primarily in the PPH pit, a recessed area where the glovebox resided.

As previously designed and operated, the main plant ventilation system provided adequate negative pressure air flow into the glovebox, exhausting potentially contaminated air through a HEPA filter unit attached to the box. During dismantlement, once the HEPA filter was removed, the main plant ventilation system was no longer available. Two portable ventilation units (PVUs) were utilized: one PVU provided ventilation during preparation for box separation; a second was employed to increase airflow through the box during the separation process. After the loose debris was removed from the glovebox, additional contamination in the box was fixed in place using fogging technology. Capture polymers were injected into the box and a coating of fixative was applied to immobilize the contaminants. An additional coating of fixative was then applied to the piping for safe removal.

Actual removal of the box was performed by unbolting the sections at the flanges, inserting plexiglas covers to act as blind flanges, then moving them individually to a staging area for packaging. This was the most economical and safest method; however, the large sections had to be laid down horizontally to fit through the doorway into the area. New structural beams were required to be erected with chain-operated trolley hoists inside the PPH area. The beam and trolley hoist assembly was used for hoisting and rigging the individual glovebox sections.The installation process posed a challenge for engineers because an existing structural support beam was required to be removed first. A temporary support system was installed to facilitate removal of the support beam.

A successful readiness evaluation was completed before separating the box from its wall mounting. In accordance with the authorization, the HEPA filter unit was removed first. Then all exterior obstructions (piping, instrumentation, and electrical conduit) were removed along with the equipment within the box. The steel system for rigging of the individual sections of the box was then erected.

The first section was separated and staged in the PPH area while the remaining three sections were separated and removed. Once the separations were completed, each section was rigged out of the PPH pit, laid on rollers, and rolled out of the PPH area onto a flatbed truck. The individual sections were picked up with a mobile crane and packaged for disposal (see *Exhibit 4-13*).

Exhibit 4-13: Glovebox in Air.

Photo Courtesy of WVDP.

This project required the involvement and coordination of several groups. It was completed successfully because of the planning process used, which included weekly project meetings with team members and implementation of ALARA and Integrated Safety Management System (ISMS) principles. No personnel contamination, internal exposures, or injuries were incurred during the course of the project due to the use of sound radiological safety and ALARA principles. The project was completed between May and June 2001.

For additional information concerning this project, contact William Zuppinger at (716) 942-2404.

4.5.2 Decontamination of the Acid Recovery Pump Room

The WVDP Acid Recovery Pump Room (ARPR) housed components and piping that transferred radioactive nitric acid streams from the acid recovery cell to storage vessels in the Main Plant of the former reprocessing facility. The as-found condition of the room included extensive material clutter and debris, high levels of contamination, and radiation working levels that required abatement to ensure ALARA doses to workers. High alpha contamination levels, as well as high radiation exposure rates producing >50 mR/hr in the general area, presented a radiological safety challenge. The large amount of mechanical, electrical, instrumentation component, and process and utility piping debris that was left after reprocessing operations ceased also complicated the project. In addition, there were residual acids and process fluids that required removal (see *Exhibit 4-14*).

Exhibit 4-14: ARPR Before.

Photo Courtesy of WVDP.

Extensive preparation before the actual decontamination activities began provided a safe work environment and kept worker exposure to contaminated material and radiation ALARA. Facility preparation prior to entry included camera installation, ventilation system upgrades, and airlock installation for loading out waste and providing personnel access.

Decontamination efforts included removal of all loose debris and vacuuming of the floor. Utility connections to the ARPR were isolated. The process lines within the ARPR were drained of liquids, as necessary, and subsequently isolated to prevent the intrusion of additional liquids. The tanks, pumps, electrical and instrumentation components, process and utility piping, HEPA filters, and miscellaneous debris were all size reduced and removed. A pump niche, located in the corner of the room, contained unanticipated hose and piping that were also removed and packaged.

In addition to the decontamination activities, a layer of self-leveling grout was applied to the floor to fix potential airborne contaminants; to reduce floor radiation exposure rates; and to level the rough, pitted floor surface that posed a tripping hazard. Vinyl suits, supplied-air respirators, and bubble hoods had to be used by personnel as added protection from airborne alpha contamination during ten early entries into the ARPR. Workers vacuumed loose debris and applied fixative and grout to the floor during these entries.

The initial estimated collective dose for the work was 5.8 person-rem. By using ALARA work design, planning, and operating concepts, area exposure rates were reduced and the estimated dose was revised to 2.8 person-rem. Actual exposure for the work was 2.7 person-rem. Area radiation exposure rate levels were reduced to below 15 mR/hr from greater than 50 mR/hr.

Both TRU and low-level wastes (LLW) were generated during the ARPR cleanup. The TRU waste generated consisted of cement debris, miscellaneous debris, process piping, and asbestos-containing material (ACM). The LLW generated consisted of process piping and tank and pump material. The 598 cubic feet of TRU waste and 424 cubic feet of LLW were packaged and shipped offsite for disposal. Liquid removal activities generated approximately 100 gallons of liquid waste that was analyzed to determine its eventual disposition. The project was completed in April 2001 after 2 months of work (see *Exhibit 4-15*).

For additional information concerning this project, contact William Zuppinger at (716) 942-2404.

Exhibit 4-15: ARPR After.

Photo Courtesy of WVDP.

4.6 Hanford ALARA Center of Excellence

The Hanford ALARA Center of Excellence is committed to providing a centralized resource for others to gain insight into practical applications of the ALARA approach and to serve as a clearinghouse of ALARA information.

DOE's Hanford Site (586 square miles located in southeastern Washington State) was established during World War II as part of the Manhattan Project and played a pivotal role in the nation's defense for more than 50 years.

Currently, the Hanford Site is engaged in the world's largest environmental cleanup effort with many challenges to be resolved in the face of overlapping technical, regulatory, and cultural interests. The cleanup effort focuses on three outcomes: restoring the Columbia River corridor for other uses, transitioning the central plateau to long-term waste treatment and storage, and preparing for the future.

Over the years, the center has gathered a great deal of information in the application of the ALARA approach to daily operations. In 1996, DOE established the ALARA Center of Technology to provide a common resource for Hanford workers in the practical aspects of ALARA.

The Hanford ALARA Center is centrally located on the Hanford site to provide an informational resource to workers in the application of the ALARA approach in daily operations. While the focus of the ALARA Center has been at the Hanford site, ALARA Center staff routinely exchange information and ideas with others throughout the DOE complex for the benefit of all. Access the Center's web site for more information:

http://www.hanford.gov/alara/index.cfm

4.7 Submitting ALARA Success Stories for Future Annual Reports

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

The submittal should address the following:

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

4.8 Lessons Learned Process Improvement Team

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

The collected information is currently located on an Internet 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

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Section Five
Conclusions

5

5.1 Conclusions

The collective dose at DOE facilities has experienced a dramatic (85%) 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 worker radiation exposure. 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 and to the ongoing removal of radioactive material from sites undergoing cleanup.

The collective TEDE decreased 3% from 2000 to 2001 due to decreases in the collective dose at three of the six highest dose sites. These six sites accounted for 81% of the collective dose at DOE in 2001. Reports submitted by two of the sites that experienced decreases in the collective dose (Rocky Flats and Hanford) indicate that decreases in the collective dose were due to a reduction in radioactive material from repackaging and shipping activities. Statistical analysis reveals that there were small but significant differences in the TEDE for the past 5 years, and the TEDE per worker was significantly lower in 1998-2001 than in earlier years. The mean dose in 2001 was 0.002 rem higher than in 2000, reflecting both an increase in the dose to individual workers, and a larger number of individuals with measurable dose. However, the last 4 years show a consistently lower dose per worker compared to 1996 and 1997.

The collective internal dose (CEDE) decreased by 67% from 2000 to 2001. This is the first decrease in the collective internal dose since 1995. The decrease was primarily due to the lack of internal doses above 2 rem in 2001. During the past 5 years, there have been several intakes from plutonium or uranium in excess of 2 rem each year, with some of the doses in excess of 5 rem (see Section 3.3.1). While the number of internal depositions above 2 rem over the past 5 years has been few, they have contributed significantly to the collective internal dose each year. With no such intakes reported for 2001, the collective CEDE has decreased significantly. The number of internal depositions increased by 4% from 2000 to 2001, while the collective CEDE decreased by 67%. Due to the large decrease in the collective CEDE and slight increase in the number of internal depositions, the average measurable CEDE decreased by 68% from 2000 to 2001 and is the lowest average measurable CEDE in the past 5 years. Due to several factors such as changes in internal dosimetry practices, monitoring and reporting procedures, changes in the dosimetry equipment, and the relatively small number of internal doses, care should be taken in examining trends in internal dose.

An analysis was performed on the transient workforce at DOE. A transient worker is defined as an individual monitored at more than one DOE site in a year. The results of this analysis show that the number of transient workers monitored increased from 1997 to 1999, but decreased in 2000 and increased slightly from 3,058 in 2000 to 3,183 in 2001. The collective dose for these transients increased by 6% from 23.6 person-rem in 2000 to 25.1 person-rem in 2001, resulting in a 16% increase in the average measurable dose to transients. The average measurable dose to transient workers averages between 50% to 70% of the average measurable dose for the overall DOE workforce for the past 5 years.

The detailed nature of the data available has made it possible to investigate distribution and trends in data and to identify and correlate parameters having an effect on occupational radiation exposure at DOE sites. A summary of the findings for 2001 is shown in *Exhibit 5-1*.

Exhibit 5-1:
2001 Radiation Exposure Fact Sheet.

- The collective TEDE decreased by 3% (from 1,267 person-rem to 1,231 person-rem) from 2000 to 2001. Statistical analysis reveals that the logarithmic mean TEDE in 2000 increased by 0.002 rem from 2000 to 2001, reflecting both an increase in the dose to individual workers, and a larger number of individuals with measurable dose. However, the last 4 years show a consistently lower dose per worker compared to 1996 and 1997.
- The six highest dose sites (in decreasing order: Rocky Flats, Hanford, Savannah River, Oak Ridge, Los Alamos, and Idaho) accounted for 81% of the collective dose at DOE in 2001.
- Decreases in collective dose at two of the top six sites (Rocky Flats and Hanford) indicate that decreases in the collective dose were due to a reduction in radioactive material from repackaging and shipping activities.
- The collective internal dose (CEDE) decreased by 67% from 2000 to 2001. This is the first decrease in the collective internal dose since 1995. The decrease was primarily due to the lack of internal doses above 2 rem in 2001.
- The number of transient workers monitored at DOE increased from 1997 to 1999, decreased from 1999 to 2000, and increased slightly from 3,058 in 2000 to 3,183 in 2001. The average measurable dose to transient workers averages between 50% to 70% of the average measurable dose for the overall DOE workforce for the past 5 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.

Exposure
As used in this report, 'exposure' refers to individuals subjected to, or in the presence of, radioactive materials which may or may not result in occupational radiation dose.

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 dose 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.

Members of the Public
Individuals who are not occupationally exposed to radiation or radioactive material. This includes visitors and visiting dignitaries.

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 or lower limit of detection.

Non-parametric Procedures
Statistical tests that do not depend on a specific parent distribution.

Normal Log-transformed Data
Data that fit a normal distribution after being transformed to logarithms.

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

Occupational Dose
An individual's ionizing radiation dose (external and internal) as a result of that individual's work assignment. Occupational dose does not include doses received as a medical patient or doses resulting from background radiation or participation as a subject in medical research programs.

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

Shallow Dose Equivalent (SDE)
The dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

Statistical Normal Distribution

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

Total Effective Dose Equivalent (TEDE)

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

Total Number of Records for Monitored Individuals

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

Transient Individual

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

T-test

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

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

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

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

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

Appendix A

A

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 M 231.1-1 [12]. Occupation Codes are grouped into Labor Categories for the purposes of analysis and summary in this report. The occupation codes are listed in DOE M 231.1-1, Appendix G, Table 2 and represent a subset of the occupations listed in the Department of Commerce's Standard Occupational Classification (SOC) Manual (1980).

Exhibit A-1.
Labor Categories and Occupation Codes.

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

A.2 Organizations Reporting to DOE REMS, 1997-2001

The following is a listing of all organizations reporting to the DOE REMS from 1997 to 2001. The Operations Field 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, 1997-2001.

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'97	'98	'99	'00	'01
Albuquerque	Ops. and Other Facilities	501001	Albuquerque Field Office	●	●	●	●	
		502009	Albuquerque Transportation Division	●	●	●	●	
		530001	Kansas City Area Office	●	●	●	●	●
		531002	Honeywell Federal Manufacturing Tech.	●	●	●	●	●
		553002	Martin Marietta Specialty Components Inc.	●				
		590001	Waste Isolation Pilot Project (WIPP)	●	●	●	●	●
		593001	Carlsbad Area Office	●				
		593004	Carlsbad Area Miscellaneous Contractors	●	●	●	●	●
		2806003	National Renewable Energy Lab (NREL)-GO	●	●	●	●	●
	Grand Junction	560605	MACTEC - ERS		●	●	●	●
		560704	WASTREN			●	●	●
	Los Alamos National Lab. (LANL)	540001	Los Alamos Area Office	●	●	●	●	●
		544003	Los Alamos National Laboratory	●	●	●	●	●
		544809	Protection Technologies Los Alamos	●	●	●	●	●
		544904	Johnson Controls, Inc.	●	●	●	●	●
	Pantex Plant (PP)	510001	Amarillo Area Office	●	●	●	●	●
		514004	Battelle - Pantex	●	●	●		
		515002	Mason & Hanger - Amarillo	●	●	●	●	●
		515006	M&H - Amarillo - Subcontractors					●
		515009	M&H - Amarillo - Security Forces		●	●	●	●
	Sandia National Lab. (SNL)	570001	Kirtland Area Office	●	●		●	
		578003	Sandia National Laboratory	●	●	●	●	●
	Uranium Mill Tailings Remedial	582004	MK-Ferguson Subs - UMTRA	●				
	Action (UMTRA) Project	582005	MK-Ferguson Co. - UMTRA	●				
Chicago	Ops. and Other Facilities	1000503	Ames Laboratory (Iowa State)	●	●	●	●	●
		1001501	Chicago Field Office	●	●	●	●	●
		1001606	Chicago Office Subs			●	●	
		1002001	Environmental Meas. Lab. - Research	●	●	●	●	●
		1004031	New Brunswick Laboratory - Research	●	●	●	●	●
		1005003	Princeton Plasma Physics Laboratory	●	●	●	●	●
	Argonne Nat'l Lab. - East (ANL-E)	1000703	Argonne National Laboratory - East	●	●	●	●	●
	Argonne Nat'l Lab. - West (ANL-W)	1000713	Argonne National Laboratory - West	●	●	●	●	●
	Brookhaven Nat'l Lab. (BNL)	1001003	Brookhaven National Laboratory	●	●	●	●	●
	Fermi Nat'l. Accelerator Lab.(FERMI)	1002503	Fermilab	●	●	●	●	●
DOE HQ	DOE Headquarters	1504001	DOE Headquarters	●	●	●	●	●
	N. Korea Project	8009001	DOE North Korea Project	●	●			●
		8009104	CenTech 21 - North Korea	●				
		8009204	Nuclear Assurance Corp. (NAC)	●				
		8009304	Pacific Northwest Lab. - Korea	●				
		8009401	U.S. Dept. of State - North Korea	●				
	Kazakhstan	8010001	DOE Kazakhstan Project			●		●

Exhibit A-2.
Organizations Reporting to DOE REMS, 1997-2001. (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'97	'98	'99	'00	'01
Idaho	Idaho Site	3003402	Babcock & Wilcox Idaho, Inc.	●	●			
		3004001	Idaho Field Office	●	●	●	●	●
		3004004	Idaho Office Subs	●				
		3005004	Bechtel BWXT Idaho, LLC - Services	●	●	●	●	●
		3005005	Lockheed Martin Idaho Tech. Co. - Constr.	●				
		3005016	Bechtel BWXT Idaho, LLC - Subs - Constr.	●	●	●	●	●
		3005024	LMITCO Subcontractor - Coleman	●	●			
		3005034	LMITCO Subcontractor - Parsons	●	●			
		3005505	MK-Ferguson Company - ID	●				
Nevada	Nevada Test Site (NTS)	3500000	Nevada Operations	●	●	●	●	●
		3501104	Bechtel Nevada - Amador Valley		●			
		3501304	Bechtel Nevada - Los Alamos		●			
		3501405	Bechtel Nevada - NTS	●	●	●	●	●
		3501416	Bechtel Nevada - NTS Subcontractors	●	●	●	●	●
		3501503	Bechtel Nevada - Special Technologies Labs		●	●	●	
		3502004	Computer Sciences Corporation	●	●			
		3501604	Bechtel Nevada - Washington Aerial Meas.		●			●
		3502504	EG&G Kirtland	●				
		3502804	EG&G Special Technologies Laboratories	●				
		3504504	EG&G Santa Barbara	●	●			
		3506004	Raytheon Services - Nevada		●			
		3507501	Nevada Field Office	●	●	●		
		3507514	Nevada Miscellaneous Contractors	●	●	●	●	●
		3507521	Air Resources Laboratory		●			
		3507531	Defense Nuclear Agency - Kirtland AFB	●	●	●		
		3507551	Environmental Protection Agency (NERC)	●	●			
		3508004	Nye County Sheriff	●	●	●	●	●
		3508504	Bechtel Nevada Services	●				
		3508505	Bechtel Nevada - NTS	●	●			
		3508703	Science Applications Int'l. Corp. - NV	●	●	●	●	●
		3509009	Wackenhut Services, Inc. - NV	●	●	●	●	●
		3509504	Westinghouse Electric Corp. - NV	●	●			
Oak Ridge	Ops. and Other Facilities	4004203	Oak Ridge Inst. for Science & Educ. (ORISE)	●	●	●	●	●
		4004501	Oak Ridge Field Office	●	●	●	●	●
		4004704	Bechtel National, Inc. - (FUSRAP)	●				
		4009006	Morrison-Knudsen (WSSRAP)	●	●	●	●	●
		4009503	Thomas Jefferson National Accel. Facility	●	●	●	●	●
		4542005	RMI Company	●	●	●		
	Oak Ridge Site	4005505	LMES/MK - Ferguson Subcontractors	●	●	●		
		4006002	Bechtel-Jacobs Co., LLC – ETTP	●	●	●	●	●
		4006007	Decontam. & Recovery Services (DRS) (K-25)		●			
		4006302	British Nuclear Fuels Limited (BNFL) (ETTP)		●	●	●	●
		4006406	Decontamination & Recovery Services - ETTP			●	●	●

Exhibit A-2.
Organizations Reporting to DOE REMS, 1997-2001. (continued).

Operations/ Field Office		Organization Code	Organization Name	Year Reported *				
				'97	'98	'99	'00	'01
Oak Ridge	Oak Ridge Site	4006503	UT-Battelle - ORNL	●	●	●	●	●
		4006510	Bechtel Jacobs - ORNL				●	●
		4007509	Wackenhut Services				●	●
		4008002	BWXT Y-12, LLC	●	●	●	●	●
		4008010	Bechtel-Jacobs - Y-12				●	●
		4018102	BWXT, Y-12					●
	Paducah Gas. Diff. Plant (PGDP)	4007002	Bechtel-Jacobs Co., LLC – Paducah	●	●	●	●	●
	Portsmouth Gaseous Diff. Plant (PORTS)	4002502	Bechtel-Jacobs (Portsmouth)		●	●	●	●
Oakland	Ops. and Other Facilities	8001003	Boeing, Rocketdyne - ETEC	●	●	●	●	
		8006103	U. of Cal./Davis, Radiobiology Lab. - LEHR	●	●	●	●	●
	Lawrence Berkeley Nat'l. Lab. (LBNL)	8003003	Lawrence Berkeley National Laboratory	●	●	●	●	●
	Lawrence Livermore Nat'l. Lab. (LLNL)	8004003	Lawrence Livermore National Laboratory	●	●	●	●	●
		8004004	LLNL Subcontractors	●	●			●
		8004009	LLNL Security	●	●			
		8004024	LLNL Plant Services	●				
	Stanford Linear Acc. Center (SLAC)	8008003	Stanford Linear Accelerator Center	●	●	●	●	●
		8009005	Separation Process Research Unit					●
Ohio	Ops. and Other Facilities	4500001	Ohio Field Office	●	●	●	●	●
		4510001	Miamisburg Area Office	●	●	●	●	●
		4510006	Miamisburg Office Subs	●	●	●	●	●
		4517003	Battelle Memorial Institute - Columbus	●	●	●	●	●
		4542005	Earthline Technologies				●	●
	Fernald Environmental	4521001	Fernald Area Office	●	●	●	●	●
		4521004	Fernald Office Service Subcontractors	●	●	●	●	●
		4523702	Fernald Envir. Rest. Mgmt. Corp. (FERMCO)	●	●	●	●	●
		4523704	FERMCO Service Vendors			●	●	●
		4523706	FERMCO Subcontractors	●	●	●	●	●
	Mound Plant	4516002	BWX Technologies, Inc.	●	●	●	●	●
		4516004	BWX Technologies, Inc. - Subcontractors	●	●	●	●	●
		4516009	BWX Technologies, Inc. - Security Forces	●	●	●	●	●
	West Valley Project	4530001	West Valley Area Office					●
		4539004	West Valley Nuclear Services, Inc. (WVNS)	●	●	●	●	●
Richland	Hanford Site	4700805	Bechtel National, Inc. - WTP					●
		4707104	CH2M Hill Hanford Group				●	●
		7500503	Battelle Memorial Institute (PNL)	●	●	●	●	●
		7500705	Bechtel Power Co.	●	●	●	●	●
		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.	●	●	●		

Exhibit A-2.
Organizations Reporting to DOE REMS, 1997-2001. (continued).

Operations/ Field Office	Site	Organization Code	Organization Name	Year Reported *				
				'97	'98	'99	'00	'01
Richland	Hanford Site	7505024	Rust Services Hanford	●	●	●	●	●
		7505025	Rust Federal Services Northwest	●	●	●	●	●
		7505034	Duke Engineering Services Hanford	●	●	●	●	●
		7505035	Duke Engineering & Services Northwest, Inc.	●	●	●	●	●
		7505044	NUMATEC Hanford	●	●	●	●	●
		7505054	Lockheed Martin Hanford	●	●	●		
		7505055	Lockheed Martin Services, Inc.	●	●	●	●	●
		7505064	Dyncorp Hanford	●	●	●	●	●
		7505075	SGN Eurisys Services Corp.	●		●	●	●
		7505099	Hanford Security			●	●	●
		7506001	Richland Field Office	●	●	●	●	●
		7508805	US Corps of Engineers - RL	●	●			
		7509004	Westinghouse Hanford Services	●	●	●	●	
		7509104	Verizon/Qwest	●	●	●	●	●
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	7700001	Rocky Flats Office	●		●	●	●
		7700007	Rocky Flats Office Subs	●				
		7707002	Rocky Flats Prime Contractors	●				●
		7707004	Rocky Flats Subcontractors	●	●	●	●	●
Savannah River	Savannah River Site (SRS)	8500505	Bechtel Construction - SR	●	●	●	●	●
		8501002	Westinghouse Savannah River Co.	●	●	●	●	●
		8501004	Service America	●				
		8501014	Westinghouse S.R. Subcontractors	●	●	●	●	●
		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	Bechtel 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 M 231.1-1 [12]. A facility type code is reported with each individual's dose record and indicates 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.

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Additional Data

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

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

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

Exhibit B-1b: Operations Office/Site Dose Data (2000)

2000

Operations/ Field Office	Site	Collective TEDE (person-rem)	Percent Change from 1999	Number with Meas. Dose	Percent Change from 1999	Avg. Meas. TEDE (rem)	Percent Change from 1999	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 1999
Albuquerque	Ops. and Other Facilities	0.3	-35% ▼	38	46% ▲	0.007	-55% ▼	0%	0%
	Los Alamos National Lab. (LANL)	195.5	49% ▲	1,365	-8% ▼	**0.143**	62% ▲	**64%**	**25%** ▲
	Pantex Plant (PP)	35.0	19% ▲	277	-22% ▼	0.126	52% ▲	30%	19% ▲
	Sandia National Lab. (SNL)	7.6	19% ▲	105	-13% ▼	0.072	36% ▲	9%	-9% ▼
	Grand Junction	0.1	-97% ▼	6	-88% ▼	0.012	-78% ▼	0%	0%
Chicago	Ops. and Other Facilities	3.5	141% ▲	108	32% ▲	0.033	**83%** ▲	0%	0%
	Argonne National Lab. - East (ANL-E)	17.2	-30% ▼	183	-2% ▼	0.094	-28% ▼	37%	-5% ▼
	Argonne National Lab. - West (ANL-W)	20.9	-22% ▼	234	-22% ▼	0.089		5%	2% ▲
	Brookhaven National Lab. (BNL)	22.4	-4% ▼	430	-17% ▼	0.052	16% ▲	5%	-1% ▼
	Fermi Nat'l. Accelerator Lab. (FERMI)	12.3	41% ▲	406	79% ▲	0.030	-21% ▼	4%	-10% ▼
DOE HQ	DOE Headquarters (includes DNFSB)	0.1	187% ▲	11	175% ▲	0.006	4% ▲	0%	0%
	North Korea Project								
	Kazakhstan								
Idaho	Idaho Site	58.8	22% ▲	795	9% ▲	0.074	12% ▲	21%	17% ▲
Nevada	Nevada Test Site (NTS)	1.6	**257%** ▲	24	300% ▲	0.067	-11% ▼	0%	0%
Oakland	Ops. and Other Facilities	0.9	-10% ▼	133	56% ▲	0.007	-42% ▼	0%	0%
	Lawrence Berkeley National Lab. (LBNL)	1.1	-39% ▼	44	-4% ▼	0.025	-36% ▼	0%	0%
	Lawrence Livermore National Lab. (LLNL)	12.7	-15% ▼	145	6% ▲	0.088	-19% ▼	30%	-7% ▼
	Stanford Linear Accelerator Center (SLAC)	5.5	-46% ▼	489	**370%** ▲	0.011	-89% ▼	0%	-11% ▼
Oak Ridge	Ops. and Other Facilities	1.9	-20% ▼	125	15% ▲	0.015	-30% ▼	0%	0%
	Oak Ridge Site	118.1	-42% ▼	2,276	-9% ▼	0.052	-36% ▼	8%	-30% ▼
	Paducah Gaseous Diff. Plant (PGDP)	5.0	14% ▲	63	9% ▲	0.079	5% ▲	0%	0%
	Portsmouth Gaseous Diff. Plant (PORTS)	1.5	198% ▲	44	76% ▲	0.035	69% ▲	0%	0%
Ohio	Ops. and Other Facilities	33.3	5% ▲	256	146% ▲	0.130	-57% ▼	63%	-9% ▼
	Fernald Environmental Mgmt. Project	15.0		421	-8% ▼	0.036	8% ▲	0%	0%
	Mound Plant	1.1	-59% ▼	123	-38% ▼	0.009	-34% ▼	0%	0%
	West Valley Project	16.5	32% ▲	246	1% ▲	0.067	30% ▲	0%	0%
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**296.1**	-21% ▼	2,331	-34% ▼	0.127	19% ▲	35%	7% ▲
Richland	Hanford Site	219.0	20% ▲	1,923	-4% ▼	0.114	26% ▲	36%	1% ▲
Savannah River	Savannah River Site (SRS)	163.2	20% ▲	**3,382**	13% ▲	0.048	6% ▲	5%	-5% ▼
Totals		**1,266.5**	**-2%** ▼	**15,983**	**-4%** ▼	**0.079**	**2%** ▲	**30%**	**3%** ▲

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

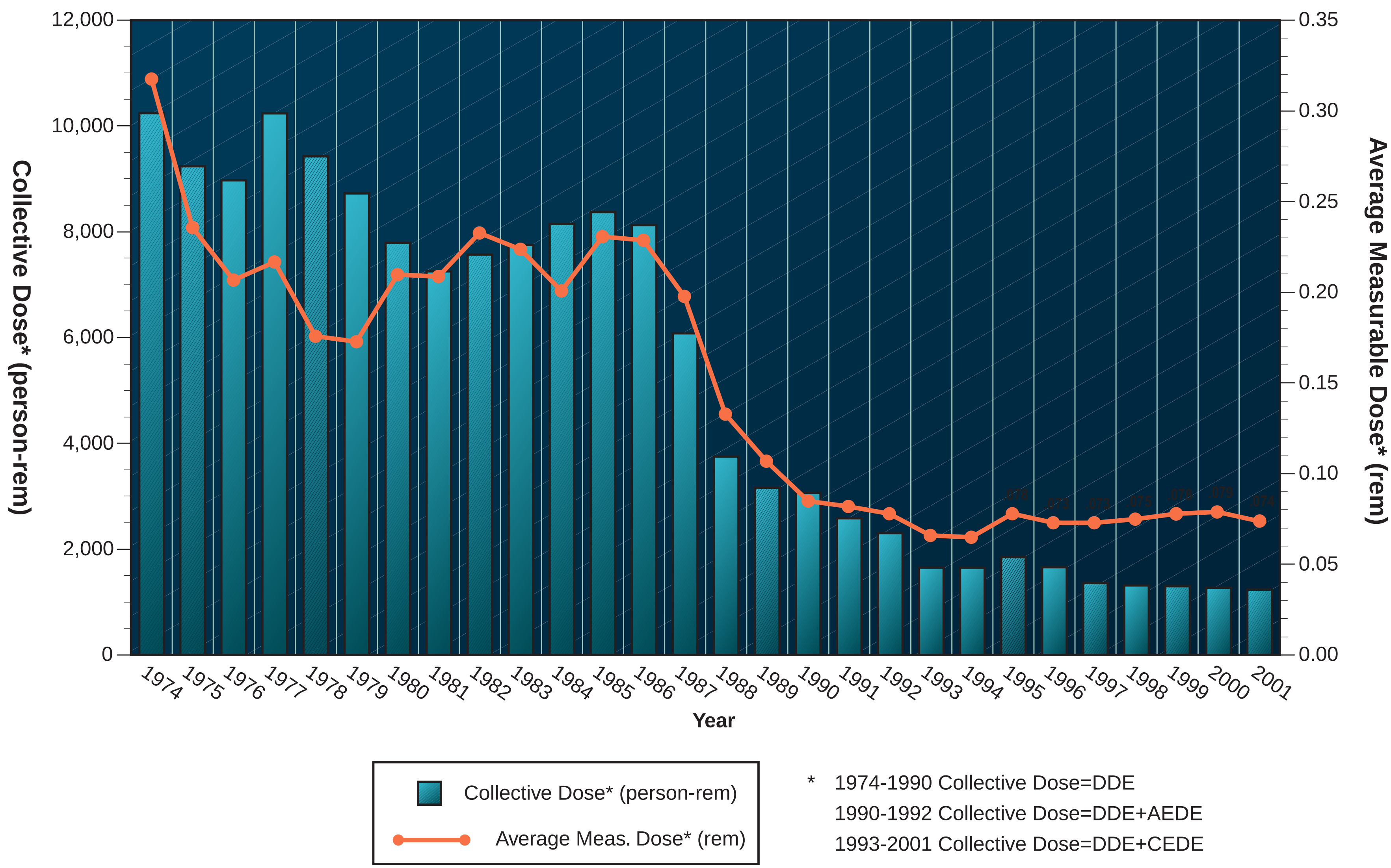
Exhibit B-1c: Operations Office/Site Dose Data (2001)

Operations/ Field Office	Site	2001 Collective TEDE (person-rem)	Percent Change from 2000	Number with Meas. Dose	Percent Change from 2000	Avg. Meas. TEDE (rem)	Percent Change from 2000	Percentage of Coll. TEDE above 0.500 rem	Percent Change from 2000
Albuquerque	Ops. and Other Facilities	1.2	**341%** ▲	93	**145%** ▲	0.013	80% ▲	0%	0%
	Los Alamos National Lab. (LANL)	112.9	-42% ▼	1,330	-3% ▼	0.085	-41% ▼	31%	-34% ▼
	Pantex Plant (PP)	43.6	25% ▲	293	6% ▲	0.149	18% ▲	32%	2% ▲
	Sandia National Lab. (SNL)	4.7	-38% ▼	99	-6% ▼	0.048	-34% ▼	0%	-9% ▼
	Grand Junction	0.1	9% ▲	2	-67% ▼	0.038	226% ▲	0%	0%
Chicago	Ops. and Other Facilities	7.6	115% ▲	131	21% ▲	0.058	77% ▲	0%	0%
	Argonne National Lab. - East (ANL-E)	23.0	34% ▲	187	2% ▲	0.123	31% ▲	47%	10% ▲
	Argonne National Lab. - West (ANL-W)	19.8	-5% ▼	258	10% ▲	0.077	-14% ▼	0%	-5% ▼
	Brookhaven National Lab. (BNL)	14.6	-35% ▼	385	-10% ▼	0.038	-27% ▼	0%	-5% ▼
	Fermi Nat'l. Accelerator Lab. (FERMI)	10.7	-14% ▼	368	-9% ▼	0.029	-5% ▼	0%	-4% ▼
DOE HQ	DOE Headquarters (includes DNFSB)	0.0	-62% ▼	4	-64% ▼	0.006	4% ▲	0%	0%
	North Korea Project	1.0		8		0.130			
	Kazakhstan								
Idaho	Idaho Site	106.6	81% ▲	1,088	37% ▲	0.098	32% ▲	20%	-2% ▼
Nevada	Nevada Test Site (NTS)	1.3	-18% ▼	32	33% ▲	0.041	-39% ▼	0%	0%
Oakland	Ops. and Other Facilities								
	Lawrence Berkeley National Lab. (LBNL)	0.7	-39% ▼	21	-52% ▼	0.032	28% ▲	0%	0%
	Lawrence Livermore National Lab. (LLNL)	18.6	46% ▲	153	6% ▲	0.121	38% ▲	50%	**20%** ▲
	Stanford Linear Accelerator Center (SLAC)	1.4	-75% ▼	35	-93% ▼	0.039	**250%** ▲	0%	0%
Oak Ridge	Ops. and Other Facilities	2.6	38% ▲	144	15% ▲	0.018	20% ▲	0%	0%
	Oak Ridge Site	120.0	2% ▲	2,577	13% ▲	0.047	-10% ▼	11%	3% ▲
	Paducah Gaseous Diff. Plant (PGDP)	5.0	2% ▲	122	94% ▲	0.041	-48% ▼	0%	0%
	Portsmouth Gaseous Diff. Plant (PORTS)	1.2	-23% ▼	35	-20% ▼	0.034	-3% ▼	0%	0%
Ohio	Ops. and Other Facilities	37.3	12% ▲	173	-32% ▼	**0.215**	66% ▲	**78%**	15% ▲
	Fernald Environmental Mgmt. Project	11.4	-24% ▼	355	-16% ▼	0.032	-10% ▼	0%	0%
	Mound Plant	1.2	11% ▲	97	-21% ▼	0.013	41% ▲	0%	0%
	West Valley Project	22.2	34% ▲	233	-5% ▼	0.095	42% ▲	2%	2% ▲
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	**241.5**	-18% ▼	2,471	6% ▲	0.098	-23% ▼	23%	-12% ▼
Richland	Hanford Site	213.6	-2% ▼	2,218	15% ▲	0.096	-15% ▼	32%	-4% ▼
Savannah River	Savannah River Site (SRS)	207.6	27% ▲	**3,640**	8% ▲	0.057	18% ▲	16%	11% ▲
Totals		**1,231.4**	**-3%** ▼	**16,552**	**4%** ▲	**0.074**	**-6%** ▼	**0%**	**-30%** ▼

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

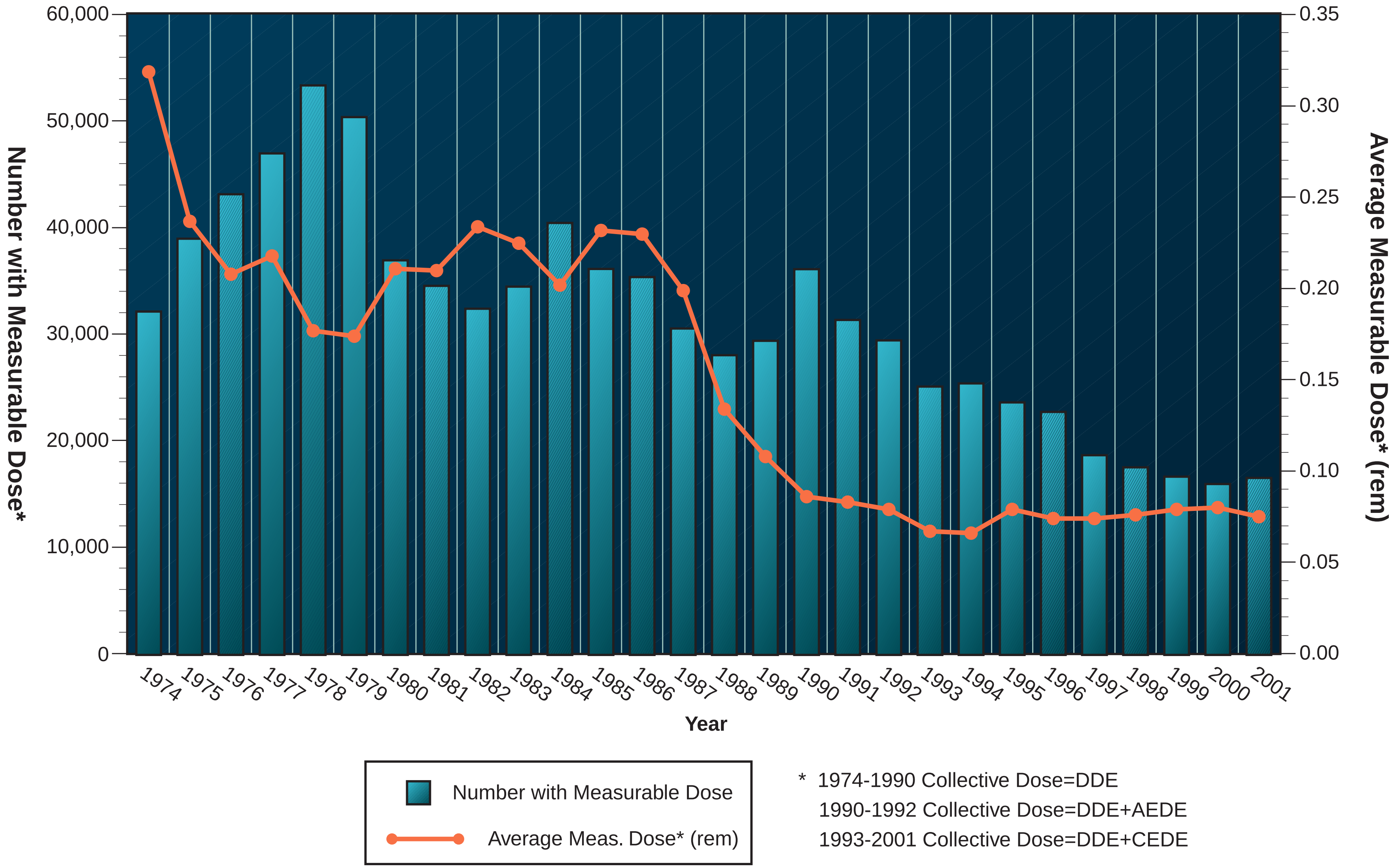
The collective dose decreased by 3% from 2000 to 2001. LANL and Rocky Flats were primary contributors to this decrease. The decrease at LANL was mainly due to a decrease in internal dose when compared to the three individuals that exceeded the annual DOE limit in 2000.

Exhibit B-2a: Collective TEDE and Average Measurable Dose 1974-2001



* 1974-1990 Collective Dose=DDE
1990-1992 Collective Dose=DDE+AEDE
1993-2001 Collective Dose=DDE+CEDE

Exhibit B-2b: Number with Measurable Dose and Average Measurable Dose 1974-2001



* 1974-1990 Collective Dose=DDE
1990-1992 Collective Dose=DDE+AEDE
1993-2001 Collective Dose=DDE+CEDE

Exhibit B-3: Distribution of Deep Dose Equivalent (DDE) 1974-2001 and Total Effective Dose Equivalent (TEDE) 1990-2001

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	92,803	15,669	36												108,508	15,705	1,219	0.078
1999	98,125	14,877	62												113,064	14,939	1,142	0.076
2000	88,621	14,206	54												102,881	14,260	1,086	0.076
2001	84,490	14,629	47												99,166	14,676	1,171	0.080

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	90,964	17,501	41	1				1							108,508	17,544	1,309	0.075
1999	96,396	16,585	80	1	1			1							113,064	16,668	1,295	0.078
2000	86,898	15,922	58								1		1	1	102,881	15,983	1,267	0.079
2001	82,614	16,503	48	1											99,166	16,552	1,231	0.074

* 1990-1992 TEDE=DDE+AEDE 1993-2001 TEDE=DDE+CEDE Note: Arrowed values indicate the greatest value in each column.

Exhibit B-4: Internal Dose by Operations/Site, 1999 - 2001

Operations/ Field Office	Site	No. of Individuals with New Intakes*			Collective CEDE Dose from Intake (person-rem)			Average CEDE (rem)		
		1999	2000	2001	1999	2000	2001	1999	2000	2001
Albuquerque	LANL	65	90	97	3.066	**109.816** ◀	2.948	0.047	**1.220** ◀	0.030
	Pantex	1	1	25	0.025	0.014	0.669	0.025	0.014	0.027
	Sandia National Lab	11	2	1	0.036	0.005	0.005	0.003	0.003	0.005
	Grand Junction	39	0	2	2.147	0	0.076	0.055	0	0.038
Chicago	Ops. and Other Facilities	12	1	12	0.017	0.001	0.038	0.001	0.001	0.003
	ANL-E	26	33	16	0.368	0.704	0.523	0.014	0.021	0.033
	BNL	36	29	30	0.524	0.817	0.223	0.015	0.028	0.007
Idaho	Idaho Site	1	7	5	0.016	0.116	0.083	0.016	0.017	0.017
Oakland	LBNL	7	20	7	0.154	0.354	0.124	0.022	0.018	0.018
	LLNL	1	3	0	0.01	0.006	0	0.010	0.002	0
Oak Ridge	Ops. and Other Facilities	35	0	0	0.519	0	0	0.015	0	0
	Oak Ridge Site	**1,622** ◀	**1,518** ◀	**1,779** ◀	**125.418** ◀	59.506	**46.193** ◀	0.077	0.039	0.026
	Paducah	0	11	2	0	0.231	0.041	0	0	0
	Portsmouth	0	1	2	0	0.018	0.013	0	0	0
Ohio	OH	35	62	74	0.129	0.434	0.530	0.004	0.007	0.007
	Fernald	35	60	20	0.191	3.450	0.093	0.005	0.058	0.005
	Mound Plant	100	108	77	0.602	0.642	0.538	0.006	0.006	0.007
Rocky Flats	Rocky Flats	61	76	47	6.626	3.398	3.327	**0.109** ◀	0.045	**0.071** ◀
Richland	Hanford Site	19	18	23	0.226	0.208	0.919	0.012	0.012	0.040
Savannah River	Savannah River Site	357	237	143	12.794	0.860	2.611	0.036	0.004	0.018
Totals		**2,463**	**2,277**	**2,362**	**152.868**	**180.580**	**58.954**	**0.062**	**0.079**	**0.025**

Facilities with no new intakes reported during the past 3 years: Albuquerque Ops., ANL-W, DOE-HQ, Fermi Lab, NTS, Oakland Ops., SLAC, Umtra, and WVNS.

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

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

The collective internal dose (CEDE) decreased by 67% from 2000 to 2001. This is the first decrease in 6 years. The decrease is primarily due to a lack of internal exposures above 2 rem in 2001. In 2000, three individuals received internal dose in excess of 5 rem, which accounted for 60% of the collective internal dose in 2000. Oak Ridge has the highest collective internal dose in 2001 consisting of a large amount of workers receiving relatively low doses from uranium.

Exhibit B-5: Neutron Dose Distribution by Operations/Site, 2001

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	665	1							666	1	0%	0.011	0.011
	Grand Junction	28								28	0	0%	0	0
	Los Alamos National Lab. (LANL)	9,562	752	98	37	16	1			10,466	**904** ◄	9%	55.524	0.061
	Pantex Plant (PP)	4,989	120	24						5,133	144	3%	7.702	0.053
	Sandia National Lab. (SNL)	2,833	31							2,864	31	1%	0.782	0.025
Chicago	Chicago Operations	739								739	0	0%	0	0
	Argonne Nat'l. Lab. - East (ANL-E)	2,729	84	6						2,819	90	3%	3.105	0.035
	Argonne Nat'l. Lab. - West (ANL-W)	718	8	1						727	9	1%	0.486	0.054
	Brookhaven Nat'l. Lab. (BNL)	4,988	49							5,037	49	1%	0.716	0.015
	Fermi Nat'l. Accelerator Lab. (FERMI)	1,343	1							1,344	1		0.020	0.020
DOE HQ	DOE Headquarters	72								72	0	0%	0	0
	Kazakhstan	9								9	0	0%	0	0
	North Korea Project	10								10	0	0%	0	0
Idaho	Idaho Site	4,855	74							4,929	74	2%	1.665	0.023
Nevada	Nevada Test Site (NTS)	2,963	3							2,966	3	0%	0.085	0.028
Oakland	Oakland Operations	26								26	0	0%	0	0
	Lawrence Berkeley National Lab. (LBNL)	1,692	2							1,694	2	0%	0.033	0.017
	Lawrence Livermore National Lab. (LLNL)	8,898	37	4	5					8,944	46	1%	3.387	0.074
	Stanford Linear Accelerator Center (SLAC)	3,143	12							3,155	12	0%	0.245	0.020
Oak Ridge	Oak Ridge Operations	1,746	5							1,751	5	0%	0.215	0.043
	Oak Ridge Site	13,846	71	17	6	1				**13,941** ◄	95	1%	7.978	0.084
	Paducah Gaseous Diff. Plant (PGDP)	823	46	5						874	51	6%	1.829	0.036
	Portsmouth Gaseous Diff. Plant (PORTS)	633	7							640	7	1%	0.179	0.026
Ohio	Ohio Field Office	734								734	0	0%	0	0
	Fernald Environmental Mgmt. Project	2,178	1							2,179	1	0%	0.020	0.020
	Mound Plant	836	23							859	23	3%	0.383	0.017
	West Valley	886								886	0	0%	0	0
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	4,894	666	151	46	7				5,764	870	**15%** ◄	**70.545** ◄	0.081
Richland	Hanford Site	9,610	766	79	23	4	2	1		10,485	875	8%	39.040	0.045
Savannah River	Savannah River Site (SRS)	9,041	286	69	19	10				9,425	384	4%	34.509	**0.090** ◄
	Totals	**95,489**	**3,045**	**454**	**136**	**38**	**3**	**1**		**99,166**	**3,677**	**4%**	**228.459**	**0.062**

* Represents the total number of monitoring records. The number of individuals specifically monitored for neutron radiation cannot be determined.
Note: Arrowed values indicate the greatest value in each column.

Rocky flats and LANL continue to contribute the majority (55%) of the collective neutron dose for 2001. These sites receive neutron dose from the handling and processing of plutonium in gloveboxes.

Exhibit B-6a: Distribution of TEDE by Facility Type - 1999

Total Effective Dose Equivalent (TEDE)

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

Facility Type	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	4-5	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Accelerator	9,866	797	86	19	4	1						10,773	8%	907	44.024	0.049
Fuel/Uran. Enrich.	3,463	382	27	6	1							3,879	11%	416	13.626	0.033
Fuel Fabrication	3,760	420	26	13								4,219	11%	459	15.081	0.033
Fuel Processing	3,865	1,019	74	14								4,972	22%	1,107	41.187	0.037
Maint. and Support	17,123	1,665	239	89	54	23	13					19,206	11%	2,083	179.522	0.086
Other	18,795	1,358	91	45	20	12	7					**20,328** ◄	8%	1,533	97.156	0.063
Reactor	2,121	554	45	22	7	1						2,750	23%	629	30.958	0.049
Research, General	17,260	1,759	312	108	24	10	11					19,484	11%	2,224	170.016	0.076
Research, Fusion	618	40	3	3	1	2	1					668	7%	50	6.000	**0.120** ◄
Waste Proc./Mgmt.	5,664	1,223	175	40	17	8	12					7,139	21%	1,475	106.617	0.072
Weapons Fab. & Test	13,861	4,344	820	411	110	62	35	1	1		1	19,646	**29%** ◄	**5,785** ◄	**590.993** ◄	0.102
Totals	**96,396**	**13,561**	**1,898**	**770**	**238**	**119**	**79**	**1**	**1**	**0**	**1**	**113,064**	**15%**	**16,668**	**1,295.180**	**0.078**

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

Exhibit B-6b: Distribution of TEDE by Facility Type - 2000

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	9,591	1,327	81	17	4							11,020	13%	1,429	45.932	0.032
Fuel/Uran. Enrich.	4,169	627	37	14	1							4,848	14%	679	21.591	0.032
Fuel Fabrication	3,048	395	24	5								3,472	12%	424	15.121	0.036
Fuel Processing	2,908	1,025	80	9	1							4,023	28%	1,115	41.609	0.037
Maint. and Support	14,810	1,614	294	150	56	30	28				1	16,983	13%	2,173	325.407	**0.150** ◄
Other	16,948	1,280	93	49	9	2	1					**18,382** ◄	8%	1,434	68.201	0.048
Reactor	1,355	506	59	20	9	6						1,955	**31%** ◄	600	38.123	0.064
Research, General	15,023	1,721	288	101	23	1	4				2	17,163	12%	2,140	164.751	0.077
Research, Fusion	522	62	12	1		2	1					600	13%	78	7.149	0.092
Waste Proc./Mgmt.	4,701	1,246	172	30	4	3	5					6,161	24%	1,460	81.168	0.056
Weapons Fab. & Test	13,823	3,217	733	331	104	47	19					18,274	24%	**4,451** ◄	**457.482** ◄	0.103
Totals	**86,898**	**13,020**	**1,873**	**727**	**211**	**91**	**58**	**0**	**0**	**0**	**3**	**102,881**	**16%**	**15,983**	**1,266.534**	**0.079**

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

Exhibit B-6c: Distribution of TEDE by Facility Type - 2001

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	10,472	882	67	22	3	2						11,448	9%	976	40.147	0.041
Fuel/Uran. Enrich.	4,454	782	46	17	1							5,300	16%	846	25.845	0.031
Fuel Fabrication	1,824	330	24	1								2,179	16%	355	11.355	0.032
Fuel Processing	2,594	1,020	112	21	2							3,749	31%	1,155	52.461	0.045
Maint. and Support	11,670	1,800	275	175	83	41	15					14,059	17%	2,389	251.554	**0.105** ◄
Other	13,015	1,188	153	72	15	4	1					14,448	10%	1,433	91.557	0.064
Reactor	1,023	461	55	26	13	3	2					1,583	**35%** ◄	560	40.873	0.073
Research, General	21,756	1,648	249	110	32	8	14	1				**23,818** ◄	9%	2,062	168.848	0.082
Research, Fusion	455	94	11	10	1							571	20%	116	7.803	0.067
Waste Proc./Mgmt.	3,849	1,554	276	94	14							5,787	33%	1,938	129.898	0.067
Weapons Fab. & Test	11,502	3,669	619	292	95	31	16					16,224	29%	**4,722** ◄	**411.046** ◄	0.087
Totals	**82,614**	**13,428**	**1,887**	**840**	**259**	**89**	**48**	**1**	**0**	**0**	**0**	**99,166**	**17%**	**16,552**	**1,231.387**	**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. 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. Maintenance and Support facilities received the highest average measurable TEDE since individuals reported under this facility type tend to perform maintenance and support work at multiple facility types involving work with radiological materials.

Exhibit B-7a: Collective TEDE by Facility Type, 1999

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

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

Exhibit B-7b: Collective TEDE by Facility Type, 2000

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	0.0	0.1	**0.3**
	Los Alamos National Lab. (LANL)	7.5				117.0	0.0	**50.1** ◄	0.2	1.1		19.6	**195.5**
	Pantex Plant (PP)										35.0		**35.0**
	Sandia National Lab. (SNL)	0.1				0.3	4.1	1.8		0.2	0.3	0.8	**7.6**
	Grand Junction											0.1	**0.1**
Chicago	Ops. and Other Facilities							0.6	2.9			0.0	**3.5**
	Argonne Nat'l. Lab. - East (ANL-E)	6.0				0.1		8.4		2.3		0.4	**17.2**
	Argonne Nat'l. Lab. - West (ANL-W)							20.9					**20.9**
	Brookhaven Nat'l. Lab. (BNL)	**12.8** ◄				1.7	1.6	3.0		2.7		0.7	**22.4**
	Fermi Nat'l. Accelerator Lab. (FERMI)	12.3											**12.3**
DOE HQ	DOE Headquarters											0.1	**0.1**
	North Korea												
	Kazakhstan												
Idaho	Idaho Site				6.8	3.0	**26.9** ◄	15.6		5.6		0.9	**58.8**
Nevada	Nevada Test Site (NTS)					1.6							**1.6**
Oakland	Ops. and Other Facilities							0.9					**0.9**
	Lawrence Berkeley National Lab. (LBNL)	0.1						1.0					**1.1**
	Lawrence Livermore National Lab. (LLNL)	0.0	0.1			0.9		1.6	**4.0** ◄	0.0	2.6	3.4	**12.7**
	Stanford Linear Accelerator Center (SLAC)	5.5											**5.5**
Oak Ridge	Ops. and Other Facilities	1.6						0.3					**1.9**
	Oak Ridge Site		**15.0** ◄					35.8			67.3		**118.1**
	Paducah Gaseous Diff. Plant (PGDP)		5.0										**5.0**
	Portsmouth Gaseous Diff. Plant (PORTS)		1.5										**1.5**
Ohio	Ops. and Other Facilities					31.4						1.9	**33.3**
	Fernald Environmental Mgmt. Project			**15.0** ◄									**15.0**
	Mound Plant					0.9					0.2	0.0	**1.1**
	West Valley											16.5	**16.5**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**294.8** ◄	1.3	**296.1** ◄
Richland	Hanford Site			0.1	0.4	**157.7** ◄	2.2	10.1		26.7		**21.8** ◄	**219.0**
Savannah River	Savannah River Site (SRS)				**34.4** ◄	10.8	3.3	14.6		**42.3** ◄	57.3	0.5	**163.2**
	Totals	**45.9**	**21.6**	**15.1**	**41.6**	**325.4**	**38.1**	**164.8**	**7.1**	**81.2**	**457.5**	**68.2**	**1,266.5**

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

Exhibit B-7c: Collective TEDE by Facility Type, 2001

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									1.1		0.1	**1.2**
	Los Alamos National Lab. (LANL)	**11.3** ◄				34.6	0.0	37.1	0.4	0.9		28.6	**112.9**
	Pantex Plant (PP)										43.6		**43.6**
	Sandia National Lab. (SNL)	0.1				0.4	2.3	0.7		0.1	0.6	0.6	**4.7**
	Grand Junction											0.1	**0.1**
Chicago	Ops. and Other Facilities	0.0						0.2	**7.4** ◄			0.0	**7.6**
	Argonne Nat'l. Lab. - East (ANL-E)	6.3				0.3		13.1		3.3		0.0	**23.0**
	Argonne Nat'l. Lab. - West (ANL-W)						0.0	19.6		0.2			**19.8**
	Brookhaven Nat'l. Lab. (BNL)	8.1				1.2	0.5	2.9		1.5		0.4	**14.6**
	Fermi Nat'l. Accelerator Lab. (FERMI)	10.7											**10.7**
DOE HQ	DOE Headquarters											0.0	**0.0**
	North Korea											1.0	**1.0**
	Kazakhstan												
Idaho	Idaho Site				13.9	7.3	**33.3** ◄	4.0		44.0		4.0	**106.6**
Nevada	Nevada Test Site (NTS)					1.3							**1.3**
Oakland	Ops. and Other Facilities												
	Lawrence Berkeley National Lab. (LBNL)	0.1						0.6					**0.7**
	Lawrence Livermore National Lab. (LLNL)							18.6					**18.6**
	Stanford Linear Accelerator Center (SLAC)	1.4											**1.4**
Oak Ridge	Ops. and Other Facilities	2.3						0.3					**2.6**
	Oak Ridge Site		**19.6** ◄					**47.2** ◄			53.2	0.0	**120.0**
	Paducah Gaseous Diff. Plant (PGDP)		5.0										**5.0**
	Portsmouth Gaseous Diff. Plant (PORTS)		1.2										**1.2**
Ohio	Ops. and Other Facilities					35.2						2.0	**37.3**
	Fernald Environmental Mgmt. Project			**11.4** ◄									**11.4**
	Mound Plant					0.8					0.5		**1.2**
	West Valley											22.2	**22.2**
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)										**240.7** ◄	0.8	**241.5** ◄
Richland	Hanford Site					**154.3** ◄		11.1		17.3		**31.0** ◄	**213.6**
Savannah River	Savannah River Site (SRS)				**38.5** ◄	16.3	4.7	13.3		**61.6** ◄	72.5	0.7	**207.6**
	Totals	**40.1**	**25.8**	**11.4**	**52.5**	**251.6**	**40.9**	**168.8**	**7.8**	**129.9**	**411.0**	**91.6**	**1,231.4**

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

Weapons Fabrication and Testing reported the highest collective dose for 2001 since Rocky Flats reports nearly all of the site collective dose under this facility type, although the site is primarily involved in materials stabilization and waste management.

Exhibit B-8: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Accelerator Facilities, 2001

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)
AL	Los Alamos National Laboratory	576	127	15	11	3	1			733	21%	157	**11.187** ◄	**0.071** ◄
AL	Johnson Controls, Inc.	1	1							2	**50%** ◄	1	0.070	0.070
CH	Argonne National Laboratory - East	506	81	17	3		1			608	17%	102	6.315	0.062
OAK	Stanford Linear Accelerator Center	3,120	32	3						**3,155** ◄	1%	35	1.368	0.039
CH	Brookhaven National Laboratory	2,905	189	17	5					3,116	7%	211	8.076	0.038
CH	Fermilab	976	352	13	3					1,344	27%	**368** ◄	10.650	0.029
OR	Thomas Jefferson Nat'l. Accel. Facility	1,536	87	2						1,625	5%	89	2.317	0.026
OAK	Lawrence Berkeley Laboratory	531	4							535	1%	4	0.075	0.019
AL	Sandia National Laboratory	310	5							315	2%	5	0.085	0.017
CH	Chicago Operations Office	7	4							11	36%	4	0.004	0.001
OR	Oak Ridge Field Office	3								3	0%	0	0	0
RL	Battelle Memorial Institute (PNL)	1								1	0%	0	0	0
	Totals	**10,472**	**882**	**67**	**22**	**3**	**2**	**0**	**0**	**11,448**	**9%**	**976**	**40.147**	**0.041**

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

LANL reported the highest collective dose for accelerator facilities in 2001, which is a change from the past 3 years where BNL has reported the highest collective dose. The collective dose for accelerator facilities decreased by 13% from 2000 to 2001 and accounts for only 3% of the overall DOE collective dose.

Exhibit B-9: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 2001

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)
ENRICHMENT														
OR	Bechtel Jacobs - ORNL			1	1					2	**100%◄**	2	0.584	**0.292◄**
OR	Bechtel Jacobs - ETTP	2,387	240	38	12	1				**2,678◄**	11%	291	**17.366◄**	0.060
OR	Bechtel Jacobs - Paducah	752	112	6	4					874	14%	122	5.038	0.041
OR	Bechtel Jacobs - Portsmouth	605	34	1						640	5%	35	1.176	0.034
OR	Bechtel Jacobs - Y-12		1							1	**100%◄**	1	0.010	0.010
OR	British Nuclear Fuels Ltd. - (BNFL) - ETTP	681	395							1,076	37%	**395◄**	1.671	0.004
OR	Decontamination & Recovery Services-ETTP	29								29	0%	0	0	0
	Totals	**4,454**	**782**	**46**	**17**	**1**	**0**	**0**	**0**	**5,300**	**16%**	**846**	**25.845**	**0.031**
FABRICATION														
OH	Fernald Envir. Rest. Mgmt. Corp. (FERMCO)	1,174	237	21	1					**1,433◄**	**18%◄**	**259◄**	**9.078◄**	**0.035◄**
OH	FERMCO Subcontractors	598	93	3						694	14%	96	2.277	0.024
OH	FERMCO Service Vendors	2								2	0%	0	0	0
OH	Fernald Area Office	37								37	0%	0	0	0
OH	Fernald Office Services Subcontractors	13								13	0%	0	0	0
	Totals	**1,824**	**330**	**24**	**1**	**0**	**0**	**0**	**0**	**2,179**	**16%**	**355**	**11.355**	**0.032**

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

The parameters for Fuel Enrichment and Fuel Fabrication remain nearly the same for 2001 as for 2000 with the Oak Ridge facilities contributing the majority of dose for Enrichment facilities, and Fernald contributing the majority of dose for Fuel Fabrication facilities.

Exhibit B-9: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Fuel Facilities, 2001 (Continued)

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)
FUEL FACILITIES — Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)														
PROCESSING														
ID	Bechtel BWXT Idaho - Services	736	131	27	13					907	19%	171	12.646	**0.074** ◄
SR	Bechtel Construction - SR	183	168	11	5					367	**50%** ◄	184	8.337	0.045
SR	Westinghouse Savannah River Co.	1,359	644	73	3	2				**2,081** ◄	35%	**722** ◄	**29.519** ◄	0.041
ID	Bechtel BWXT Idaho - Construction	111	39	1						151	26%	40	1.276	0.032
SR	Savannah River Field Office	48	5							53	9%	5	0.11	0.022
SR	Wackenhut Services, Inc. - SR	95	24							119	20%	24	0.514	0.021
SR	Westinghouse S.R. Subcontractors	56	9							65	14%	9	0.059	0.007
AL	Johnson Controls, Inc.	2								2	0%	0	0	0
AL	Los Alamos National Laboratory	1								1	0%	0	0	0
CH	Argonne National Laboratory - West	1								1	0%	0	0	0
OH	West Valley Nuclear Services, Inc.	1								1	0%	0	0	0
SR	Miscellaneous DOE Contractors - SR	1								1	0%	0	0	0
	Totals	**2,594**	**1,020**	**112**	**21**	**2**	**0**	**0**	**0**	**3,749**	**31%**	**1,155**	**52.461**	**0.045**

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

The collective dose for Fuel Processing facilities increased by 26% from 2000 to 2001 primarily from increases at Idaho and Savannah River.

Exhibit B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 2001

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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
OH	Battelle Memorial Institute - Columbus	252	29	10	10	12	16	7				336	25%	84	35.228	**0.419**◄
RL	Duke Engineering Services Hanford	15			1							16	6%	1	0.256	0.256
RL	Fluor Daniel - Hanford	2,137	858	153	100	60	23	8				**3,339**◄	36%	**1,202**◄	**145.967**◄	0.121
AL	Los Alamos National Laboratory	1,037	121	25	21	8	2					1,214	15%	177	21.066	0.119
RL	Fluor Daniel Northwest Services	49	33	14	8							104	**53%**◄	55	6.053	0.110
AL	Johnson Controls, Inc.	1,267	127	29	8	3						1,434	12%	167	12.725	0.076
SR	Westinghouse Savannah River Co.	200	179	24	20							423	**53%**◄	223	15.220	0.068
RL	Fluor Daniel Northwest	69	21	1	1							92	25%	23	1.054	0.046
ID	Bechtel BWXT Idaho - Services	358	147	10	5							520	31%	162	7.178	0.044
CH	Argonne National Laboratory - East	370	7									377	2%	7	0.295	0.042
NV	Bechtel Nevada - NTS	2,114	29	3								2,146	1%	32	1.303	0.041
RL	Rust Services Hanford	60	6	1								67	10%	7	0.272	0.039
SR	Bechtel Construction - SR	45	30	1								76	41%	31	1.012	0.033
RL	Rust Federal Services Northwest	17	4									21	19%	4	0.126	0.032
AL	Sandia National Laboratory	630	13									643	2%	13	0.351	0.027
RL	Hanford Security	95	19	1								115	17%	20	0.436	0.022
CH	Brookhaven National Laboratory	786	57	1								844	7%	58	1.158	0.020
ID	Bechtel BWXT Idaho - Construction	13	7									20	35%	7	0.137	0.020
AL	Protection Technologies Los Alamos	411	38		1							450	9%	39	0.743	0.019
SR	Univ. of Georgia Ecology Laboratory	3	2									5	40%	2	0.038	0.019
OH	BWX Technologies, Inc. - Subcontractors	226	14	1								241	6%	15	0.282	0.019
RL	Battelle Memorial Institute (PNL)	18	4									22	18%	4	0.072	0.018
AL	Los Alamos Area Office	41	3									44	7%	3	0.046	0.015
SR	Westinghouse S.R. Subcontractors	28	2									30	7%	2	0.021	0.011
OH	BWX Technologies, Inc.	387	47	1								435	11%	48	0.496	0.010

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

Exhibit B-10: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Maintenance and Support, 2001 (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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
RL	Lockheed Martin Services, Inc.	25	2									27	7%	2	0.013	0.007
RL	CH2M Hill Hanford Group	5	1									6	17%	1	0.006	0.006
NV	B.N. - NTS Subcontractors	3										3	0%	0	0	0
NV	Bechtel Nevada - Washington Aerial Meas.	3										3	0%	0	0	0
NV	Nevada Miscellaneous Contractors	106										106	0%	0	0	0
NV	Nevada Operations	487										487	0%	0	0	0
NV	Nye County Sheriff	9										9	0%	0	0	0
NV	Science Applications Int'l Corp. - NV	21										21	0%	0	0	0
NV	Wackenhut Services, Inc. - NV	187										187	0%	0	0	0
OH	BWX Technologies, Inc. - Security Forces	30										30	0%	0	0	0
OH	Miamisburg Area Office	17										17	0%	0	0	0
OH	Miamisburg Office Subs	10										10	0%	0	0	0
OH	Ohio Field Office	17										17	0%	0	0	0
OH	West Valley Nuclear Services, Inc.	1										1	0%	0	0	0
RL	Bechtel Power Co.	19										19	0%	0	0	0
RL	Dyncorp Hanford	31										31	0%	0	0	0
RL	NUMATEC Hanford	40										40	0%	0	0	0
RL	Richland Field Office	11										11	0%	0	0	0
RL	SGN Eurisys Services Corp.	9										9	0%	0	0	0
RL	Verizon/Qwest	2										2	0%	0	0	0
SR	Savannah River Field Office	8										8	0%	0	0	0
SR	Wackenhut Services, Inc. - SR	1										1	0%	0	0	0
	Totals	**11,670**	**1,800**	**275**	**175**	**83**	**41**	**15**	**0**	**0**	**0**	**14,059**	**17%**	**2,389**	**251.554**	**0.105**

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

The collective dose for Maintenance and Support decreased by 23% from 2000 to 2001. Fluor Daniel at Hanford has reported the largest collective dose for this facility type for the past 5 years. Battelle Memorial Institute in Columbus has had the highest average measurable dose in this category for the past 4 years and reported the highest average measurable dose for any organization in 2001.

Exhibit B-11: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Reactor Facilities, 2001

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)
ID	Bechtel BWXT Idaho - Construction	11	19	3	1	4	2	2		42	74%	31	7.857	**0.253** ◄
AL	Sandia National Laboratory	54	8	2	5					69	22%	15	2.267	0.151
ID	Bechtel BWXT Idaho - Services	244	152	47	19	9	1			472	48%	**228** ◄	**25.460** ◄	0.112
AL	Los Alamos National Laboratory	4	1							5	20%	1	0.038	0.038
CH	Argonne National Laboratory - West		1							1	**100%** ◄	1	0.037	0.037
CH	Brookhaven National Laboratory	122	14		1					137	11%	15	0.501	0.033
SR	Wackenhut Services, Inc. - SR	64	62							126	49%	62	1.830	0.030
SR	Bechtel Construction - SR	42	17							59	29%	17	0.330	0.019
SR	Westinghouse Savannah River Co.	458	181	3						**642** ◄	29%	184	2.512	0.014
SR	Savannah River Field Office	8	6							14	43%	6	0.041	0.007
CH	Chicago Operations Office	1								1	0%	0	0	0
RL	Battelle Memorial Institute (PNL)	1								1	0%	0	0	0
RL	Bechtel Power Co.	1								1	0%	0	0	0
SR	Miscellaneous DOE Contractors - SR	1								1	0%	0	0	0
SR	Westinghouse S.R. Subcontractors	12								12	0%	0	0	0
	Totals	**1,023**	**461**	**55**	**26**	**13**	**3**	**2**	**0**	**1,583**	**35%**	**560**	**40.873**	**0.073**

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

The parameters for this facility type are similar to the values in 2000. Bechtel BWXT Idaho Services has reported the highest collective dose in this category for the past 3 years and accounts for 62% of the collective dose in 2001.

Exhibit B-12: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 2001

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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
CH	Argonne National Laboratory - East	1,705	25	4	5	1		7				1,747	2%	42	13.133	**0.313** ◄
OAK	Lawrence Livermore National Lab.	8,213	115	20	6	3	3	4				**8,364** ◄	2%	151	18.547	0.123
OR	UT-Battelle: ORNL	4,943	255	73	43	14	4					5,332	7%	**389** ◄	**47.039** ◄	0.121
AL	Los Alamos National Laboratory	1,294	260	49	25	12	1	3	1			1,645	21%	351	37.140	0.106
RL	Battelle Memorial Institute (PNL)	544	116	16	8	2						686	21%	142	11.104	0.078
CH	Argonne National Laboratory - West	468	196	44	16							724	35%	256	19.597	0.077
CH	Brookhaven National Laboratory	615	43	6	2							666	8%	51	2.908	0.057
SR	Bechtel Construction - SR	49	37	6	1							93	47%	44	1.949	0.044
AL	Sandia National Laboratory	412	16	2								430	4%	18	0.730	0.041
ID	Bechtel BWXT Idaho - Services	610	83	3	3							699	13%	89	3.554	0.040
OAK	Lawrence Berkeley Laboratory	1,142	17									1,159	1%	17	0.607	0.036
ID	Bechtel BWXT Idaho - Construction	40	13	1								54	26%	14	0.492	0.035
SR	Miscellaneous DOE Contractors - SR	1	2									3	**67%** ◄	2	0.067	0.034
SR	Westinghouse Savannah River Co.	718	331	25	1							1,075	33%	357	10.398	0.029
SR	Westinghouse S.R. Subcontractors	37	23									60	38%	23	0.492	0.021

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

Exhibit B-12: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, General, 2001 (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	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
OAK	LLNL Subcontractors	537	2									539		2	0.038	0.019
CH	Ames Laboratory (Iowa State)	112	11									123	9%	11	0.165	0.015
SR	Savannah River Field Office	58	16									74	22%	16	0.221	0.014
SR	Wackenhut Services, Inc. - SR	20	12									32	38%	12	0.149	0.012
OR	Wackenhut Services	53	13									66	20%	13	0.140	0.011
SR	Univ. of Georgia Ecology Laboratory	24	5									29	17%	5	0.043	0.009
AL	Protection Technologies Los Alamos	8	1									9	11%	1	0.007	0.007
OR	Oak Ridge Inst. for Sci. & Educ. (ORISE)	32	55									87	63%	55	0.327	0.006
CH	Chicago Operations Office	57	1									58	2%	1	0.001	0.001
AL	Johnson Controls, Inc.	7										7	0%	0	0	0
AL	Los Alamos Area Office	2										2	0%	0	0	0
AL	Nat. Renewable Energy Lab (NREL)-GO	21										21	0%	0	0	0
CH	New Brunswick Laboratory-Research	33										33	0%	0	0	0
OH	West Valley Nuclear Services, Inc.	1										1	0%	0	0	0
	Totals	**21,756**	**1,648**	**249**	**110**	**32**	**8**	**14**	**1**	**0**	**0**	**23,818**	**9%**	**2,062**	**168.848**	**0.082**

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

ORNL and LANL contribute the highest collective doses in this category and have done so for the past 5 years. However, Argonne National Lab (East) has reported the highest average measurable dose for the past 5 years. The average measurable dose for ANL-East increased by 86% from 0.168 rem in 2000 to 0.313 in 2001.

Exhibit B-13: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Research, Fusion, 2001

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)
CH	Princeton Plasma Physics Laboratory	376	87	11	9	1				484 ◄	22% ◄	108 ◄	7.420 ◄	0.069 ◄
AL	Los Alamos National Laboratory	37	7		1					45	18%	8	0.38	0.048
AL	Sandia National Laboratory	34								34	0%	0	0	0
CH	Chicago Operations Office	8								8	0%	0	0	0
	Totals	**455**	**94**	**11**	**10**	**1**	**0**	**0**	**0**	**571**	**20%**	**116**	**7.803**	**0.067**

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

Fusion Research accounted for only 0.6% of the collective TEDE in 2001 with only four organizations reporting in this category.

Exhibit B-14: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 2001

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)
ID	Bechtel BWXT Idaho - Services	242	109	48	61	13				473	49%	231	41.932	**0.182** ◄
CH	Argonne National Laboratory - West			1						1	**100%** ◄	1	0.161	0.161
CH	Argonne National Laboratory - East	51	22	11	2					86	41%	35	3.285	0.094
SR	Bechtel Construction - SR	147	183	43	15					388	62%	241	17.470	0.072
RL	CH2M Hill Hanford Group	913	244	46	4					1,207	24%	294	17.277	0.059
ID	Bechtel BWXT Idaho - Construction	48	31	4		1				84	43%	36	2.044	0.057
AL	Los Alamos National Laboratory	85	15	1	1					102	17%	17	0.895	0.053
SR	Westinghouse Savannah River Co.	1,320	777	120	11					**2,228** ◄	41%	**908** ◄	**43.209** ◄	0.048
CH	Brookhaven National Laboratory	146	42	2						190	23%	44	1.544	0.035
AL	Carlsbad Area Misc. Contractors	477	60							537	11%	60	1.103	0.018
AL	Sandia National Laboratory	136	4							140	3%	4	0.068	0.017
SR	Westinghouse S.R. Subcontractors	127	62							189	33%	62	0.869	0.014
SR	Wackenhut Services, Inc. - SR	2	1							3	33%	1	0.011	0.011
SR	Savannah River Field Office	35	4							39	10%	4	0.030	0.008

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

Exhibit B-14: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Waste Processing, 2001 (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)
AL	Johnson Controls, Inc.	1								1	0%	0	0	0
AL	Los Alamos Area Office	1								1	0%	0	0	0
AL	Waste Isolation Pilot Project (WIPP)	21								21	0%	0	0	0
CH	Chicago Operations Office	1								1	0%	0	0	0
OH	West Valley Area Office	1								1	0%	0	0	0
OH	West Valley Nuclear Services, Inc.	43								43	0%	0	0	0
OR	Morrison-Knudsen (WSSRAP)	36								36	0%	0	0	0
RL	Bechtel National Inc. - WTP	1								1	0%	0	0	0
RL	Battelle Memorial Institute (PNL)	1								1	0%	0	0	0
RL	Bechtel Power Co.	6								6	0%	0	0	0
RL	SGN Eurisys Services Corp.	1								1	0%	0	0	0
SR	Miscellaneous DOE Contractors - SR	6								6	0%	0	0	0
SR	S.R. Forest Station	1								1	0%	0	0	0
	Totals	**3,849**	**1,554**	**276**	**94**	**14**	**0**	**0**	**0**	**5,787**	**33%**	**1,938**	**129.898**	**0.067**

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

The collective dose for this facility type increased by 60% from 2000 to 2001. Westinghouse Savannah River reported the highest collective dose and increased by 29% from 33.381 rem in 2000 to 43.209 rem in 2001.

Exhibit B-15: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Weapons Fabrication, 2001

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)
SR	Westinghouse Savannah River Co.	215	134	43	59	20	9	11			491	56%	276	64.247	**0.233** ◄
AL	Mason & Hanger - Amarillo	4,141	174	48	41	19	3				4,426	6%	285	42.628	0.150
AL	M&H - Amarillo - Security Forces	569	3	3	1						576	1%	7	0.924	0.132
RFO	Rocky Flats Prime Contractors	884	1,155	328	140	50	19	4			2,580	**66%** ◄	**1,696** ◄	**196.126** ◄	0.116
RFO	Rocky Flats Subcontractors	1,422	563	70	35	5		1			2,096	32%	674	42.923	0.064
SR	Bechtel Construction - SR	40	63	14							117	**66%** ◄	77	4.127	0.054
SR	Wackenhut Services, Inc. - SR	78	93	2							173	55%	95	4.060	0.043
OR	BWXT Y-12, LLC	3,107	1,359	109	16	1					**4,592** ◄	32%	1,485	53.216	0.036
AL	Sandia National Laboratory	561	22	1							584	4%	23	0.629	0.027
RFO	Rocky Flats Office	215	65	1							281	23%	66	1.651	0.025
AL	Amarillo Area Office	91	1								92	1%	1	0.023	0.023
OH	BWX Technologies, Inc.	49	31								80	39%	31	0.434	0.014
OH	BWX Technologies, Inc. - Subcont.	23	3								26	12%	3	0.035	0.012
SR	Westinghouse S.R. Subcontractors	9	1								10	10%	1	0.009	0.009
SR	Savannah River Field Office	38	2								40	5%	2	0.014	0.007
AL	Los Alamos National Laboratory	10									10	0%	0	0	0
AL	M&H - Amarillo - Subcontractors	39									39	0%	0	0	0
OH	Miamisburg Area Office	6									6	0%	0	0	0
OH	Miamisburg Office Subs	1									1	0%	0	0	0
OH	Ohio Field Office	3									3	0%	0	0	0
SR	Southern Bell Tel. & Tel.	1									1	0%	0	0	0
	Totals	**11,502**	**3,669**	**619**	**292**	**95**	**31**	**16**			**16,224**	**29%**	**4,722**	**411.046**	**0.087**

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

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. The collective dose at Rocky Flats under this category decreased by 22% from 2000 to 2001. However, Westinghouse Savannah River reported an average measurable dose that is twice the value for Rocky Flats.

Exhibit B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 2001

OTHER

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)
		Number of Individuals Receiving Radiation Doses in Each Dose Range (rem)												
HQ	DOE North Korea Project	2	3	3	2					10	80%	8	1.042	**0.130** ◄
RL	Fluor Daniel Northwest Services	119	54	24	16					213	44%	94	10.531	0.112
RL	Battelle Memorial Institute (PNL)	698	40	13	7	1				759	8%	61	6.463	0.106
AL	Johnson Controls, Inc.	52	7	3	1					63	17%	11	1.111	0.101
OH	West Valley Nuclear Services, Inc.	606	175	32	25	1				839	28%	233	22.197	0.095
ID	Bechtel BWXT Idaho - Construction	55	15	3	3					76	28%	21	1.985	0.095
RL	Bechtel Power Co.	936	98	26	4	1	1			1,066	12%	130	10.063	0.077
AL	Los Alamos National Laboratory	4,213	318	38	13	11	3	1		**4,597** ◄	8%	**384** ◄	**27.223** ◄	0.071
CH	Brookhaven National Laboratory	78	4	2						84	7%	6	0.395	0.066
RL	SGN Eurisys Services Corp.	91	7	1						99	8%	8	0.369	0.046
RL	Rust Services Hanford	37	4							41	10%	4	0.170	0.043
AL	Mactec - ERS/Grand Junction	15	2							17	12%	2	0.076	0.038
ID	Bechtel BWXT Idaho - Services	1,344	53	2		1				1,400	4%	56	2.030	0.036
RL	Fluor Daniel Northwest	176	49	3	1					229	23%	53	1.589	0.030
AL	Sandia National Laboratory	628	20	1						649	3%	21	0.604	0.029
SR	Savannah River Field Office	5	3							8	38%	3	0.078	0.026
OH	Earthline Technologies	255	89							344	26%	89	2.042	0.023
RFO	Rocky Flats Office	772	35							807	4%	35	0.797	0.023

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

Exhibit B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 2001 (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)
RL	Richland Field Office	1,094	36	1						1,131	3%	37	0.806	0.022
SR	Wackenhut Services, Inc. - SR	19	2							21	10%	2	0.042	0.021
AL	Protection Technologies Los Alamos	72	13							85	15%	13	0.217	0.017
SR	Bechtel Construction - SR	10	4							14	29%	4	0.065	0.016
RL	Rust Federal Services Northwest	45	4							49	8%	4	0.063	0.016
SR	Westinghouse Savannah River Co.	198	25							223	11%	25	0.357	0.014
RL	Hanford Security	9	11							20	55%	11	0.153	0.014
SR	Westinghouse S.R. Subcontractors	11	9							20	45%	9	0.122	0.014
RL	Fluor Daniel - Hanford	859	57	1						917	6%	58	0.782	0.013
ID	Idaho Field Office	29	2							31	6%	2	0.026	0.013
HQ	DOE Headquarters	68	4							72	6%	4	0.025	0.006
CH	Argonne National Laboratory - East		1							1	**100%** ◄	1	0.005	0.005
OR	BWXT Y-12, LLC	151	1							152	1%	1	0.004	0.004
AL	Honeywell, Federal Mfg. & Tech.	46	32							78	41%	32	0.108	0.003
CH	Environmental Meas. Lab. - Research	13	7							20	35%	7	0.013	0.002
AL	Kansas City Area Office	8	1							9	11%	1	0.001	0.001
RL	Lockheed Martin Services, Inc.	13	2							15	13%	2	0.002	0.001
RL	Verizon/Qwest	24	1							25	4%	1	0.001	0.001
AL	Los Alamos Area Office	14								14	0%	0	0	0

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

Exhibit B-16: Distribution of TEDE by Facility Type Listed in Descending Order of Average Measurable TEDE for Other, 2001 (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)
AL	Wastren/Grand Junction	11								11	0%	0	0	0
HQ	DOE Kazakhstan Project	9								9	0%	0	0	0
NV	Bechtel Nevada - NTS	4								4	0%	0	0	0
OAK	Lawrence Livermore National Lab.	41								41	0%	0	0	0
OAK	Separation Process Research Unit	20								20	0%	0	0	0
OAK	U. of Cal./Davis, Radiobiology Lab-LEHR	6								6	0%	0	0	0
OH	BWX Technologies, Inc.	47								47	0%	0	0	0
OR	UT-Battelle: ORNL	13								13	0%	0	0	0
RL	Bechtel National, Inc. - WTP	1								1	0%	0	0	0
RL	Babcock Wilcox Hanford	1								1	0%	0	0	0
RL	CH2M Hill Hanford Group	44								44	0%	0	0	0
RL	Duke Eng. & Services Northwest, Inc.	2								2	0%	0	0	0
RL	Duke Engineering Services Hanford	6								6	0%	0	0	0
RL	Dyncorp Hanford	2								2	0%	0	0	0
RL	Hanford Envir. Health Foundation	29								29	0%	0	0	0
RL	NUMATEC Hanford	10								10	0%	0	0	0
SR	Miscellaneous DOE Contractors - SR	1								1	0%	0	0	0
SR	S.R. Forest Station	3								3	0%	0	0	0
	Totals	**13,015**	**1,188**	**153**	**72**	**15**	**4**	**1**	**0**	**14,448**	**10%**	**1,433**	**91.557**	**0.064**

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

Similar to previous years, the highest average measurable dose in this category is often reported by the organization with few monitored individuals. For 2001, the North Korean Project personnel received the highest average measurable dose even though no individual exceeded 0.5 rem. LANL reported the highest collective dose and number monitored as a large portion of the site personnel are reported under this facility type.

Exhibit B-17: Internal Dose by Facility Type and Nuclide, 1999-2001

Facility Type	Nuclide*	No. of Individuals with New Intakes**			Collective CEDE (person-rem)			Average CEDE (rem)		
		1999	2000	2001	1999	2000	2001	1999	2000	2001
Accelerator	Americium		1			0.015			0.015	
	Hydrogen-3	5	3	5	0.091	0.092	0.074	0.018	0.031	0.015
	Uranium	1	2	2	0.007	0.009	0.014	0.007	0.005	0.007
	Total	**6**	**6**	**7**	**0.098**	**0.116**	**0.088**	**0.016**	**0.019**	**0.013**
Fuel Fabrication	Thorium	5	46	10	0.060	3.376	0.046	0.012	0.073	0.005
	Uranium	30	14	10	0.131	0.074	0.047	0.004	0.005	0.005
	Total	**35**	**60**	**20**	**0.191**	**3.45**	**0.093**	**0.005**	**0.058**	**0.005**
Fuel Processing	Americium			4			1.543			**0.386** ◄
	Hydrogen-3	123	93	79	0.222	0.194	0.238	0.002	0.002	0.003
	Plutonium	2	1	3	0.042	0.011	0.286	0.021	0.001	0.095
	Total	**125**	**94**	**86**	**0.264**	**0.205**	**2.067**	**0.002**	**0.002**	**0.024**
Fuel/Uranium Enrichment	Other		1	3		0.017	0.103		0.017	0.034
	Thorium		7	1		0.159	0.002		0.023	0.002
	Uranium	177	308	397	0.560	0.929	1.712	0.003	0.003	0.004
	Total	**177**	**316**	**401**	**0.560**	**1.105**	**1.817**	**0.003**	**0.003**	**0.005**
Maintenance and Support	Americium	4	6	8	0.015	0.104	0.069	0.004	0.017	0.009
	Hydrogen-3	81	55	58	0.399	0.142	0.135	0.005	0.003	0.002
	Mixed and Other	18	13		0.203	0.082		0.011	0.006	
	Plutonium	25	25	55	0.293	**87.224** ◄	0.674	0.012	**3.489** ◄	0.012
	Thorium	4	9	2	0.091	0.303	0.058	0.023	0.034	0.029
	Uranium	16	43	14	0.055	0.103	0.102	0.003	0.002	0.007
	Total	**148**	**151**	**137**	**1.056**	**87.958**	**1.038**	**0.007**	**0.583**	**0.008**
Other	Americium	2	5	2	0.055	0.262	0.032	0.028	0.052	0.016
	Hydrogen-3	45	31	27	0.195	0.119	0.111	0.004	0.004	0.004
	Mixed and Other	1	2	2	0.007	0.191	0.002	0.007	0.096	0.001
	Plutonium	5	10	8	0.360	1.229	0.772	0.072	0.123	0.097
	Radon-222	39	2	2	2.147	0.020	0.076	0.055	0.010	0.038
	Uranium	190	42	42	13.726	0.409	0.413	0.072	0.010	0.010
	Total	**282**	**92**	**83**	**16.490**	**2.23**	**1.406**	**0.058**	**0.024**	**0.017**
Reactor	Hydrogen-3	212	136	43	0.949	0.761	0.101	0.004	0.006	0.002
	Total	**212**	**136**	**43**	**0.949**	**0.761**	**0.101**	**0.004**	**0.006**	**0.002**
Research, Fusion	Hydrogen-3	14	3	14	0.038	0.008	0.051	0.003	0.003	0.004
	Total	**14**	**3**	**14**	**0.038**	**0.008**	**0.051**	**0.003**	**0.003**	**0.004**
Research, General	Americium	3	6	1	0.111	0.129	0.002	0.037	0.022	0.002
	Hydrogen-3	31	37	60	0.336	0.602	0.383	0.011	0.016	0.006
	Mixed and Other	49	13	10	0.185	0.046	0.043	0.004	0.004	0.004
	Plutonium	4	8	10	1.465	21.108	2.399	0.366	2.639	0.240
	Radon-222		2			0.098			0.049	
	Thorium	1			0.685			**0.685** ◄		
	Uranium	19	22	25	0.088	0.096	0.172	0.005	0.004	0.007
	Total	**107**	**88**	**106**	**2.870**	**22.079**	**2.999**	**0.027**	**0.251**	**0.028**
Waste Processing	Americium	2	16	12	0.013	0.479	0.130	0.007	0.030	0.011
	Hydrogen-3	20	9	9	0.058	0.016	0.026	0.003	0.002	0.003
	Mixed and Other	3		1	0.006		0.003	0.002		0.003
	Plutonium	1	3	12	0.002	0.050	0.615	0.002	0.017	0.051
	Thorium			1			0.005			0.005
	Uranium	10			0.786			0.079		
	Total	**36**	**28**	**35**	**0.865**	**0.545**	**0.779**	**0.024**	**0.019**	**0.022**
Weapons Fab. and Testing	Americium	5		1	1.487		0.001	0.297		0.001
	Hydrogen-3	23	27	20	0.150	0.105	0.070	0.007	0.004	0.004
	Mixed and Other	1	1	3	0.025	0.014	0.221	0.025	0.014	0.074
	Plutonium	64	76	49	17.015	3.398	3.512	0.266	0.045	0.072
	Thorium			9			0.093			0.010
	Uranium	**1,228** ◄	**1,199** ◄	**1,348** ◄	**110.810** ◄	58.606	**44.618** ◄	0.090	0.049	0.033
	Total	**1,321**	**1,303**	**1,430**	**129.487**	**62.123**	**48.515**	**0.098**	**0.048**	**0.034**
	Totals	**2,463**	**2,277**	**2,362**	**152.868**	**180.580**	**58.954**	**0.062**	**0.079**	**0.025**

* 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.

This exhibit highlights one of the reasons for the reduction in collective dose (TEDE) form 2000 to 2001, which is the 67% reduction in the collective internal dose (CEDE). Note the high collective CEDE from plutonium in 2000 at Maintenance and General Research facilities. These were from doses in excess of 5 rem CEDE at LANL in 2000. No individual exceeded 2 rem CEDE in 2001.

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

Total Effective Dose Equivalent (TEDE)

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

Labor Category	Less than Meas.	Meas. 0-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1-2	2-3	3-4	>4	>5	Total Monitored	Percent of Monitored with Meas. TEDE	No. with Meas. TEDE	Collective TEDE (person-rem)	Avg. Meas. TEDE (rem)
Agriculture	58	1										59	2%	1	0.020	0.020
Construction	5,008	1,255	141	57	16	3	8					6,488	23%	1,480	92.392	0.062
Laborers	781	222	38	17	4	3	1					1,066	27%	285	25.243	0.089
Management	10,954	1,574	129	31	10	6	5					12,709	14%	1,755	86.947	0.050
Misc.	8,477	1,613	223	107	30	17	10		1			10,478	19%	2,001	168.940	0.084
Production	2,827	1,592	343	186	67	48	26				1	5,090	**44%** ◄	2,263	**291.609** ◄	**0.129** ◄
Scientists	22,972	2,352	187	58	15	2	3					25,589	10%	2,617	120.966	0.046
Service	3,745	760	57	9	2			1				4,574	18%	829	36.828	0.044
Technicians	5,415	1,886	507	206	58	23	10					8,105	33%	**2,690** ◄	282.647	0.105
Transport	1,094	109	13									1,216	10%	122	4.408	0.036
Unknown	35,065	2,197	260	99	36	16	17					**37,690** ◄	7%	2,625	185.180	0.071
Totals	**96,396**	**13,561**	**1,898**	**770**	**238**	**118**	**80**	**1**	**1**	**0**	**1**	**113,064**	**15%**	**16,668**	**1,295.180**	**0.078**

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

Exhibit B-18b: Distribution of TEDE by Labor Category, 2000

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	56	1										57	2%	1	0.035	0.035
Construction	3,729	1,203	117	34	13	5	3					5,104	27%	1,375	73.837	0.054
Laborers	720	228	40	12		1						1,001	28%	281	17.825	0.063
Management	10,392	1,452	134	35	5	1	1					12,020	14%	1,628	74.672	0.046
Misc.	4,823	1,207	207	83	34	20	12					6,386	24%	1,563	147.378	0.094
Production	2,747	1,520	354	212	61	38	29					4,961	**45%** ◀	2,214	284.647	**0.129** ◀
Scientists	22,880	2,754	176	50	15	3	3					25,881	12%	**3,001** ◀	114.503	0.038
Service	3,629	588	60	8	2							4,287	15%	658	27.101	0.041
Technicians	5,551	1,848	574	213	61	20	7					8,274	33%	2,723	**290.474** ◀	0.107
Transport	1,091	103	8	1								1,203	9%	112	4.622	0.041
Unknown	31,280	2,116	203	79	20	3	3				3	**33,707** ◀	7%	2,427	231.440	0.095
Totals	**86,898**	**13,020**	**1,873**	**727**	**211**	**91**	**58**	**0**	**0**	**0**	**3**	**102,881**	**16%**	**15,983**	**1,266.534**	**0.079**

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

Exhibit B-18c: Distribution of TEDE by Labor Category, 2001

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	44											44	0%	0	0	0
Construction	3,811	1,568	164	76	12	3	1					5,635	32%	1,824	98.669	0.054
Laborers	724	303	68	55	7							1,157	37%	433	44.634	0.103
Management	7,919	1,193	135	22	10		1					9,280	15%	1,361	64.553	0.047
Misc.	4,898	1,273	199	87	28	11	1					6,497	25%	1,599	125.044	0.078
Production	2,551	1,525	336	204	86	38	18					4,758	**46%** ◄	2,207	279.583	**0.127** ◄
Scientists	23,674	2,705	169	48	10	8	8					26,622	11%	**2,948** ◄	124.719	0.042
Service	3,547	658	33	15	3	1						4,257	17%	710	29.181	0.041
Technicians	7,228	1,982	558	218	60	21	15					10,082	28%	2,854	**302.086** ◄	0.106
Transport	900	161	7	9	2							1,079	17%	179	9.246	0.052
Unknown	27,318	2,060	218	106	41	7	4	1				**29,755** ◄	8%	2,437	153.672	0.063
Totals	**82,614**	**13,428**	**1,887**	**840**	**259**	**89**	**48**	**1**	**0**	**0**	**0**	**99,166**	**17%**	**16,552**	**1,231.387**	**0.074**

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

As in prior years, Production and Technician personnel received the highest collective dose of any labor category and accounted for 47% of the collective dose at DOE for 2001.

Exhibit B-19: Internal Dose by Labor Category, 1999 - 2001

Labor Category	Number of Individuals with New Intakes*			Collective CEDE (person-rem)			Average CEDE (rem)		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
Construction	537	453	502	22.710	8.269	7.905	0.042	0.018	0.016
Laborers	34	37	36	8.888	2.005	2.751	**0.261** ◄	0.054	**0.076** ◄
Management	239	182	216	14.917	7.565	7.242	0.062	0.042	0.034
Misc.	70	88	61	5.408	2.077	1.104	0.077	0.024	0.018
Production	**563** ◄	**541** ◄	**551** ◄	**63.049** ◄	23.883	**17.219** ◄	0.112	0.044	0.031
Scientists	276	254	263	5.003	7.543	5.310	0.018	0.030	0.020
Service	73	56	27	3.071	1.828	0.643	0.042	0.033	0.024
Technicians	265	269	295	13.769	11.727	8.781	0.052	0.044	0.030
Transport	3	2	3	0.008	0.008	0.024	0.003	0.004	0.008
Unknown	403	395	408	16.045	**115.675** ◄	7.975	0.040	**0.293** ◄	0.020
Totals	**2,463**	**2,277**	**2,362**	**152.868**	**180.580**	**58.954**	**0.062**	**0.079**	**0.025**

* 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.

Production and Testing personnel received the highest collective internal dose in 2001. The collective internal dose decreased by 67% from 2000 to 2001 and the average measurable CEDE decreased by 68%.

Exhibit B-20: Dose Distribution by Labor Category and Occupation, 2001

Labor Category	Occupation	Less Than Meas.	Meas. <0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.0	1-2	2-3	3-4	4-5	>5	Total Monitored	Percent with Meas.	No. with Meas.	Collective TEDE	Average Meas. TEDE
Agriculture	Groundskeepers	39											39	0%	0	0	0
	Forest Workers	4											4	0%	0	0	0
	Misc. Agriculture	1											1	0%	0	0	0
Construction	Carpenters	255	111	17	5								388	34%	133	8.004	0.060
	Electricians	953	454	41	8	1							1,457	35%	504	21.070	0.042
	Masons	17	19										36	53%	19	0.594	0.031
	Mechanics/Repairers	702	267	20	24	5							1,018	31%	316	21.677	0.069
	Miners/Drillers	43	8				1						52	17%	9	1.156	0.128
	Misc. Repair/Construction	1,306	424	36	17	5	1	1					1,790	27%	484	22.430	0.046
	Painters	135	48	3	6								192	30%	57	3.961	0.069
	Pipe Fitter	400	237	47	16	1	1						702	43%	302	19.777	0.065
Laborers	Handlers/Laborers/Helpers	724	303	68	55	7							1,157	37%	433	44.634	0.103
Management	Admin. Support and Clerical	3,121	466	69									3,656	15%	535	23.908	0.045
	Manager - Administrator	4,786	727	66	22	10		1					5,612	15%	826	40.645	0.049
	Sales	12											12	0%	0	0	0
Misc.	Military													0%	0	0	0
	Miscellaneous	4,898	1,273	199	87	28	11	1					6,497	25%	1,599	125.044	0.078
Production	Machine Setup/Operators	99	196	36	6								337	**71%**◄	238	13.000	0.055
	Machinists	323	37	3	2		1						366	12%	43	3.168	0.074
	Misc. Precision/Production	351	244	59	41	18	6	3					722	51%	371	51.307	0.138
	Operators, Plant/ System/Util.	1,577	965	226	151	68	31	15					3,033	48%	1,456	**206.429**◄	**0.142**◄
	Sheet Metal Workers	114	62	11	4								191	40%	77	5.045	0.066
	Welders and Solderers	87	21	1									109	20%	22	0.634	0.029
Scientists	Doctors and Nurses	135	33										168	20%	33	0.398	0.012
	Engineer	8,259	1,239	59	16	3	2	1					9,579	14%	1,320	43.858	0.033
	Health Physicist	464	146	11	4		1						626	26%	162	7.644	0.047
	Misc. Professional	4,764	753	55	16	3	3						5,594	15%	830	34.907	0.042
	Scientist	10,052	534	44	12	4	2	7					10,655	6%	603	37.912	0.063
Service	Firefighters	484	60		1		1						546	11%	62	2.025	0.033
	Food Service Employees	27	6										33	18%	6	0.150	0.025
	Janitors	671	45	8	6	3							733	8%	62	6.545	0.106
	Misc. Service	513	70	14	6								603	15%	90	6.612	0.073
	Security Guards	1,852	477	11	2								2,342	21%	490	13.849	0.028
Technicians	Engineering Technicians	2,103	195	29	10	1		3					2,341	10%	238	17.146	0.072
	Health Technicians	132	36	9	6	4	1						188	30%	56	7.727	0.138
	Misc. Technicians	2,327	359	85	41	19	7	8					2,846	18%	519	64.150	0.124
	Radiation Monitors/Techs	996	871	318	111	18	11	4					2,329	57%	1,333	147.201	0.110
	Science Technicians	740	112	34	11	10	2						909	19%	169	20.804	0.123
	Technicians	930	409	83	39	8							1,469	37%	539	45.058	0.084
Transport	Bus Drivers	11	6										17	35%	6	0.118	0.020
	Equipment Operators	193	78	7	7	2							287	33%	94	6.903	0.073
	Misc. Transport	419	41		1								461	9%	42	1.001	0.024
	Pilots	1											1	0%	0	0	0
	Truck Drivers	276	36		1								313	12%	37	1.224	0.033
Unknown	Unknown	27,318	2,060	218	106	41	7	4	1				**29,755**◄	8%	**2,437**◄	153.672	0.063
Totals		**82,614**	**13,428**	**1,887**	**840**	**259**	**89**	**48**	**1**	**-**	**-**	**-**	**99,166**	**17%**	**16,552**	**1,231.387**	**0.074**

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

The Unknown labor category comprises 30% of the monitored individuals in 2001. This labor category typically represents subcontractors for whom detailed information, such as labor classification, may not be available. In addition, LANL reports all personnel under the Unknown labor category, which accounts for 35% of the monitored individuals and 73% of the collective dose in this category. Plant Operations personnel received the highest collective and average measurable dose in 2001.

Exhibit B-21: Internal Dose Distribution by Site and Nuclide, 2001

Operations/ Field Office	Site	Nuclide	Number of Individuals Receiving Doses in Each Dose Range: Meas.-0.02	0.02-0.10	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	>5.0	Total Individuals with Meas. CEDE	Collective CEDE (person-rem)	Average CEDE (rem)
Albuquerque	Los Alamos National Lab (LANL)	Hydrogen-3	49	3										52	0.340	0.007
		Plutonium		4			1		1					6	2.310	0.385
		Other	1											1	0.001	0.001
		Uranium	36	2										38	0.297	0.008
	Pantex Plant	Thorium	7	2										9	0.093	0.010
		Uranium	8	5										13	0.355	0.027
		Mixed	1	1	1									3	0.221	0.074
	Sandia National Laboratory	Thorium	1											1	0.005	0.005
	Grand Junction	Radon-222		2										2	0.076	0.038
Chicago	Ops. and Other Facilities	Hydrogen-3	12											12	0.038	0.003
	Argonne National Lab - East (ANL-E)	Hydrogen-3	4	1										5	0.036	0.007
		Plutonium	4	7										11	0.487	0.044
	Brookhaven National Lab (BNL)	Americium	14	3										17	0.169	0.010
		Hydrogen-3	13											13	0.054	0.004
Idaho	Idaho Site	Uranium	4	1										5	0.083	0.017
Oakland	Lawrence Berkeley National Lab. (LBNL)	Hydrogen-3	6	1										7	0.124	0.018
Oak Ridge	Oak Ridge Site	Hydrogen-3	39											39	0.124	0.003
		Other	10	2										12	0.145	0.012
		Uranium	1,121	508	83	16								**1,728** ◄	**45.924** ◄	0.027
	Paducah	Uranium	1	1										2	0.041	0.021
	Portsmouth	Thorium	1											1	0.002	0.002
		Uranium	1											1	0.011	0.011
Ohio	Ops. and Other Facilities	Americium	4											4	0.035	0.009
		Uranium	27	4										31	0.302	0.010
		Plutonium	39											39	0.193	0.005
	Fernald Environmental Mgmt. Project	Thorium	10											10	0.046	0.005
		Uranium	10											10	0.047	0.005
	Mound Plant	Hydrogen-3	59											59	0.135	0.002
		Americium	1											1	0.013	0.013
		Plutonium	1	3	1									5	0.314	0.063
		Thorium		2										2	0.058	0.029
		Uranium	10											10	0.018	0.002
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	Americium	1											1	0.001	0.001
		Plutonium	33	7	3	2			1					46	3.326	0.072
Richland	Hanford Site	Hydrogen-3	1											1	0.001	0.001
		Americium	1											1	0.016	0.016
		Mixed & Other	3											3	0.005	0.002
		Plutonium	11	6			1							18	0.897	0.050
Savannah River	Savannah River Site (SRS)	Americium		1		1	2							4	1.543	**0.386** ◄
		Hydrogen-3	126	1										127	0.337	0.003
		Plutonium	3	7	2									12	0.731	0.061
Totals			**1,673**	**574**	**90**	**19**	**4**	**0**	**2**	**0**	**0**	**0**	**0**	**2,362**	**58.954**	**0.025**

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

The collective internal dose decreased by 67% from 2000 to 2001. This exhibit shows that no individual received an internal dose above 2 rem in 2001. Internal dose from uranium at the Oak Ridge Y-12 facility contributed the majority of the collective internal dose. A large number of people are monitored at Y-12 but few receive doses above 0.1 rem.

Exhibit B-22: Extremity Dose Distribution by Operations/Site, 2001

Operations	Site	No Meas. Dose	Meas. –0.1	0.1-1	1-5	5-10	10-20	20-30	>30	Total Monitored*	No. with Meas.	No. Above Monitoring Threshold. (5 rem)**	Collective Extremity Dose (person-rem)	Average Meas. Extremity Dose (rem)
Albuquerque	Albuquerque	589	71	6						666	77		4.037	0.052
	Grand Junction	28								28	0		0	0
	Los Alamos National Lab. (LANL)	9,990	192	210	69	3	2			10,466	476	5	268.226	0.564
	Pantex Plant (PP)	4,989	25	66	53					5,133	144		144.846	**1.006** ◄
	Sandia National Lab. (SNL)	2,822	32	6	4					2,864	42		7.585	0.181
Chicago	Chicago Operations	726	12	1						739	13		0.570	0.044
	Argonne Nat'l. Lab. - East (ANL-E)	2,633	148	26	9	3				2,819	186	3	56.386	0.303
	Argonne Nat'l. Lab. - West (ANL-W)	462	185	67	12	1				727	265	1	56.431	0.213
	Brookhaven National Lab. (BNL)	4,680	314	43						5,037	357		18.617	0.052
	Fermi Nat'l. Accelerator Lab. (FERMI)	1,341	2	1						1,344	3		0.530	0.177
DOE HQ	DOE Headquarters	72								72	0		0	0
	Kazakhstan	9								9	0		0	0
	North Korea	10								10	0		0	0
Idaho	Idaho Site	3,794	797	315	21	1	1			4,929	1,135	2	170.032	0.150
Nevada	Nevada Test Site (NTS)	2,957	4	2	3					2,966	9		4.299	0.478
Oakland	Oakland Operations	26								26	0		0	0
	Lawrence Berkeley National Lab. (LBNL)	1,675	8	9	2					1,694	19		9.427	0.496
	Lawrence Livermore Nat'l. Lab. (LLNL)	8,892	15	22	13	2				8,944	52	2	49.885	0.959
	Stanford Linear Accelerator Center (SLAC)	3,155								3,155	0		0	0
Ohio	Ohio Field Office	647	25	23	39					734	87		83.040	0.954
	Fernald Environmental Mgmt. Project	2,179								2,179	0		0	0
	Mound Plant	859								859	0		0	0
	West Valley	643	170	71	2					886	243		36.253	0.149
Oak Ridge	Oak Ridge Operations	1,751								1,751	0		0	0
	Oak Ridge Site	13,769	39	105	24	4				**13,941** ◄	172	4	123.688	0.719
	Paducah Gaseous Diff. Plant (PGDP)	870	4							874	4		0.161	0.040
	Portsmouth Gaseous Diff. Plant (PORTS)	640								640	0		0	0
Rocky Flats	Rocky Flats Env. Tech. Site (RFETS)	3,225	1,660	714	128	33	4			5,764	2,539	37	834.769	0.329
Richland	Hanford Site	7,652	1832	751	188	44	17		1	10,485	2,833	**62** ◄	**1,246.867** ◄	0.440
Savannah River	Savannah River Site (SRS)	5,714	2735	840	115	18	3			9,425	**3,711** ◄	21	722.309	0.195
	Totals	**86,799**	**8,270**	**3,278**	**682**	**109**	**27**	**0**	**1**	**99,166**	**12,367**	**137**	**3,837.958**	**0.310**

* 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.

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

The Oak Ridge Site reports the largest number of individuals monitored for extremity dose. However, Hanford, Rocky Flats, and Savannah River contribute 73% of the collective extremity dose. At Hanford, the majority of extremity dose is received by plant operations personnel.

Appendix C

Facility Type Code Descriptions

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

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

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

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

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.

In general, radiation doses received by occupational workers at accelerator facilities are largely attributable to the beta/gamma radiation emitted from the activated structural and mechanical components. The nature of the radiation fields and the magnitude of dose rates inside the primary shielding vary considerably depending upon the operational parameters of the machine, the types of particles accelerated, and the energies achieved. Doses received by personnel who enter the accelerator enclosures are dependent upon these factors. In many cases dependent upon the radiological conditions, personnel are prevented from entering the accelerator enclosures when the beam is operational. Outside of the shielding, exposure rates due to prompt radiation from the accelerator are typically very low. Average annual doses of exposed personnel at these facilities are comparable to the overall average for DOE. However, the collective dose is lower than the collective dose for most other DOE facilities categories because of the relatively small number of employees at accelerator facilities who work on or around the activated components. 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. The current method of enrichment is isotopic separation using the gaseous diffusion process, which involves diffusing uranium through a porous membrane and using the different atomic weights of the uranium isotopes to achieve separation.

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

Fuel Fabrication

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

Fuel Processing

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

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

Maintenance and Support

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

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

Reactor

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

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

Research, General

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

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

Research, Fusion

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

Waste Processing/Management

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

Weapons Fabrication and Testing

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

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

Other

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

Appendix D

Limitations of Data

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

Individual Dose Records vs Dose Distribution

Prior to 1987, exposure data were reported from each facility in terms of a statistical dose distribution wherein the number of individuals receiving a dose within specific dose ranges was reported. The collective dose was then calculated from the distribution by multiplying the number of individuals in each dose range by the midpoint value of the dose range. Starting in 1987, reports of individual exposures were collected that recorded the specific dose for each monitored individual. The collective dose can be accurately determined by summing the total dose for each individual. The dose distribution reporting method prior to 1987 resulted in up to a 20% overestimation of collective dose. The reason is that the distribution of doses within a range is usually skewed toward the lower end of the range. If the midpoint of the range is multiplied by the number of people in the range, the product overestimates the collective dose. This overestimation only affects the data prior to 1987 presented in Appendix B-2a, B-2b, and B-3.

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

Monitoring Practices

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

AEDE vs CEDE

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

With the implementation of the RadCon Manual in 1993, the required methodology used to calculate and report internal dose was changed from the AEDE to the 50-year CEDE. The CEDE represents the dose equivalent delivered to all organs and tissues over the next 50 years and the 50-year CEDE is reported to REMS and assigned to the individual in the year of intake. The change was made to provide consistency with scientific recommendations, facilitate the transfer of workers between DOE- and NRC-regulated facilities, and simplify recordkeeping 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 1997 to 2001. During these years, the CEDE methodology was used to calculate internal dose; therefore, the change in methodology from AEDE to CEDE between 1992 and 1993 does not affect the analysis contained in this report. Readers should keep in mind the change in methodology if analyzing TEDE data prior to 1993 in Exhibit B-2a, B-2b, and B-3.

Occupation Codes

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

Facility Type

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

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

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

Organization Code

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

Occurrence Reports

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

Additional Data Requirements

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

Naval Reactor Facilities

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

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

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

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Access to Radiation Exposure Information

Radiation Exposure Monitoring System

The data used to compile this report were obtained from the DOE Radiation Exposure Monitoring System (REMS), which serves as the central repository of radiation exposure information for DOE Headquarters. The database consists of individual monitoring records of occupational exposure for DOE workers from 1987 to the present. REMS also contains career exposure records for individuals that terminated employment between 1969 to 1986 and additional historical records voluntarily submitted to REMS from the sites that participated in the epidemiologic surveillance pilot project. Nearly 3 million exposure records are contained in the REMS central repository. In 1995, REMS underwent an extensive redesign effort in combination with the efforts involved in revising the annual report. One of the main goals of the redesign effort is to allow researchers better access to the REMS data. However, there is considerable diversity in the goals and needs of these researchers. For this reason, a multi-faceted approach has been developed to allow researchers flexibility in accessing the REMS data.

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

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

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

REMS Web Page

As noted in *Exhibit E-1*, a web page has been established to disseminate radiation exposure information at DOE. The web site contains the latest published annual report on occupational exposure, information on reporting exposure data to DOE, points of contact for requesting information from REMS, DOE Orders and Standards related to radiation exposure, and links to other related sites. The site contains a web-based data query tool that allows users to obtain specific data reported to REMS from 1987 to the most recent year available. The data can be selected and grouped by year, site, organization, facility type, labor category, occupation, and monitoring status. The web page query tool allows access to summary information for over 1.6 million monitoring records.

Visit the REMS web page at:

http://rems.eh.doe.gov

Comprehensive Epidemiologic Data Resource

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

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

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

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

http://cedr.lbl.gov

Or the CEDR Program Manager may be contacted at:

barbara.brooks@eh.doe.gov

Exhibit E-1: Methods of Accessing REMS Information

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

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