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Integrated Data Base Report—1993: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics

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Prepared by

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Stamp

Jerry A. Klein
Integrated Data Base Program
Oak Ridge National Laboratory
105 Mitchell Road
Mail Stop 6495
P. O. Box 2008
Oak Ridge TN 37831-6495

PREFACE

The information in this report summarizes the U.S. Department of Energy (DOE) data base for inventories, projections, and characteristics of domestic spent nuclear fuel and radioactive waste. This report is updated annually to keep abreast of continual waste inventory and projection changes in both the government and commercial sectors. Baseline information is provided for DOE program planning purposes and to support DOE program decisions. Although the primary purpose of this document is to provide background information for program planning within the DOE community, it has also been found useful by state and local governments, the academic community, and some private citizens. To sustain the objectives of this program in providing accurate and complete data in this field of operation, comments and suggestions to improve the quality and coverage are encouraged. Such comments and any general inquiries should be directed to the U.S. Department of Energy at either of the following:

Office of Civilian Radioactive Waste Management
Route Symbol RW-44
1000 Independence Avenue, SW
Washington, DC 20585-0001

Office of Environmental Management
Route Symbol EM-332 or 432
Trevion II
Washington, DC 20585-0002

This report was prepared by the Integrated Data Base Program, which is jointly sponsored by the DOE Office of Civilian Radioactive Waste Management and the DOE Office of Environmental Management. Suggestions, questions, and requests for information may be directed to any of the following:

M. L. Payton, DOE/RW-44, Washington, DC 20585-0001
Telephone: (202) 586-9867

M. J. Zenkovich, DOE/EM-332, Washington, DC 20585-0002
Telephone: (301) 903-7126

S. W. Meador, DOE/EM-432, Washington, DC 20585-0002
Telephone: (301) 427-1687

J. A. Klein, ORNL, P.O. Box 2008, Oak Ridge, TN 37831-6495
Telephone: (615) 574-6823

An important part of the Integrated Data Base Program is the Steering Committee, whose members provide both generic guidance and technical input. The membership of this committee, shown on the following page, represents all of the major DOE sites and programs for spent nuclear fuel and radioactive waste management. Each support committee member is assisted by a technical liaison as needed. The participation and assistance of these individuals are acknowledged with appreciation.

Samuel Rousso, Director
Office of Waste Acceptance,
Storage, and Transportation
Office of Civilian Radioactive
Waste Management

Jill E. Lytle
Deputy Assistant Secretary
Office of Waste Management
Office of Environmental
Management

J. E. Baublitz
Acting Deputy Assistant Secretary
Office of Environmental Restoration
Office of Environmental
Management

Integrated Data Base Program Steering Committee

Executive Committee

Voting members

M. J. Zenkovich, DOE/EM
K. L. Svinicki, DOE/RW
M. D. Tolbert-Smith, DOE/EM

Advisory members

J. A. Disbrow, DOE/EIA
J. A. Klein, ORNL

Support Committee

Chapter title/support area

Committee member

Technical liaison

Spent nuclear fuel
Commercial

K. L. Svinicki, DOE/RW

R. R. MacDonald, CRWMS-
M&O/JAI

DOE

J. J. Jicha, DOE/EM

D. G. Abbott, LITCO

High-level waste

H. Walter, DOE/EM

A. Sidpara, DOE/RL

Transuranic waste

M. L. Matthews, DOE/CAO

W. W. Weston, W/WIPP
T. E. Cowan, MACTEC

Low-level waste

DOE

G. J. Duggan, DOE/EM

J. Hwang, CADMUS

Commercial

T. Plummer, DOE/EM

R. L. Fuchs, LITCO

J. H. Boyd, DOE/ID

Uranium mill tailings

J. A. Disbrow, DOE/EIA

T. Chung, DOE/EIA

Environmental restoration wastes

M. D. Tolbert-Smith, DOE/EM

J. M. Peterson, ANL-E

DOE facility transition wastes

B. A. Smith, DOE/EM

K. T. Juroff, DOE/EM

Mixed low-level waste

J. L. Sands, DOE/EM

T. Kirkpatrick, LITCO

Miscellaneous radioactive materials

Commercial

K. L. Svinicki, DOE/RW

R. R. MacDonald, CRWMS-
M&O/JAI

DOE

M. E. Burandt, DOE/EM

P. J. McGinn, BDM

Authors and contributors providing direct support for the Integrated Data Base Program report (Rev. 10)

<i>Chapter topic</i>	<i>Author(s)</i>
Overview	J. A. Klein and S. N. Storch
Spent nuclear fuel	
Commercial	R. C. Ashline
DOE	R. Salmon and S. N. Storch
High-level waste	H. W. Godbee, S. L. Loghry, and M. L. Tharp
Transuranic waste	R. Salmon, S. L. Loghry, and E. W. Krieger (MACTEC)
Low-level waste	A. S. Icenhour and M. L. Tharp
Uranium mill tailings	T. Chung (DOE/EIA)
Environmental restoration wastes	M. Tolbert-Smith (DOE/EM-40) and J. M. Peterson (ANL-E)
Commercial decommissioning wastes	S. N. Storch
Mixed low-level waste	S. N. Storch and S. L. Loghry
Miscellaneous radioactive materials	R. Salmon
Waste source terms	H. W. Godbee, A. S. Icenhour, and S. L. Loghry
<i>Direct support service</i>	<i>Contributor(s)</i>
Clerical/IDB report	D. T. Brooksbank
Clerical/IDB Program	S. L. McDaniel
Computer support (data base setup and analysis)	M. L. Tharp and S. L. Loghry
Computer graphics	S. L. McDaniel
Editing	R. W. Sharpe and R. C. Ashline
Distribution	S. L. McDaniel, D. T. Brooksbank, and S. N. Storch
Indexing	R. C. Ashline, R. Salmon, R. W. Sharpe, and S. N. Storch

Major DOE data sources supporting the Integrated Data Base Program report

Name of data source	Waste type information provided	Supporting DOE program office	Principal contractor and mailing address (Phone number)
DOE Spent Nuclear Fuel Management Program	DOE spent nuclear fuel	Office of Spent Fuel Management (EM-37)	Lockheed Idaho Technologies Co. P.O. Box 1625 Idaho Falls, ID 83415 (208/526-0037)
Environmental Restoration Contaminated Media/Waste Data Base	DOE/EM-40 contaminated media/waste	Office of Environmental Restoration (EM-40)	DOE/EM-43 Office of Program Integration Quince Orchard U.S. Department of Energy 1000 Independence Avenue, S.W. Washington, DC 20585-0001 (301/903-8121)
International Nuclear Model, Personal Computer Version (PCINM)	Commercial spent nuclear fuel	Energy Information Administration (DOE/EIA)	DOE/EIA Analysis and Systems Division Supply Analysis Branch Route Symbol EI-532 1000 Independence Ave, S.W. Washington, DC 20585-0001 (202/254-5508)
Manifest Information Management System (MIMS)	Commercial low-level waste	Office of Waste Management (EM-30)	Lockheed Idaho Technologies Co. National Low-Level Waste Management Program P.O. Box 1625 Idaho Falls, ID 83415 (208/526-9717)
Uranium Supply Analysis System (USAS)	Commercial uranium mill tailings	Energy Information Administration (DOE/EIA)	DOE/EIA Analysis and Systems Division Energy Resources Assessment Branch Route Symbol EI-531 1000 Independence Avenue, S.W. Washington, DC 20585-0001 (202/254-5556)

Major DOE data sources supporting the Integrated Data Base Program report (continued)

Name of data source	Waste type information provided	Supporting DOE program office	Principal contractor and mailing address (Phone number)
Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report (WTWBIR)	DOE transuranic waste	DOE Carlsbad Area Office National Transuranic Program Office (NTPO)	Drez Environmental Associates 8816 Cherry Hills Road, N.E. Albuquerque, NM 87111 (505/828-9857)
Waste Management Information System (WMIS)	DOE high-level, transuranic, low-level, and mixed low-level wastes	Office of Waste Management (EM-30)	Hazardous Waste Remedial Actions Program Martin Marietta Energy Systems, Inc. Mail Stop 7606 P.O. Box 2003 Oak Ridge, TN 37831-7606 (615/435-3281)
1994 Mixed Waste Inventory Report (MWIR) Data Base	RCRA- and state-regulated DOE mixed wastes (high-level, transuranic, and low- level wastes)	Office of Waste Management (EM-30)	Lockheed Idaho Technologies Co. P.O. Box 1625 Idaho Falls, ID 83405 (208/526-2746)

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GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

In this report, all abbreviations, acronyms, and initialisms are defined in text before they are used. In some cases, they are redefined in text for the reader's convenience.

AEA	Atomic Energy Act of 1954
AEC	Atomic Energy Commission
AMES	Ames Laboratory, Ames, Iowa
ANL-E	Argonne National Laboratory-East, Argonne, Illinois
ANL-W	Argonne National Laboratory-West, INEL, Idaho
APPR	Army Package Power Reactor
ATL 1	Atlantic Site 1 (38°30'N, 72°06'W)
ATL 2	Atlantic Site 2 (37°50'N, 70°35'W)
ATR	Advanced test reactor
BAPL	Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania
BARN	Barnwell, South Carolina (commercial waste site)
BCL	Battelle Columbus Laboratories, Columbus, Ohio
BCLDP	Battelle Columbus Laboratories Decommissioning Project, Columbus, Ohio
BDM	BDM Federal, Inc., Germantown, Maryland
BETY	Beatty, Nevada (commercial waste site)
BMI	Battelle Memorial Institute
BNI	Bechtel National, Inc., Oak Ridge, Tennessee
BNL	Brookhaven National Laboratory, Upton, New York
BR	Belgium reactor
B&W-NES	Babcock and Wilcox Nuclear Environmental Services, Lynchburg, Virginia
BWR	Boiling-water reactor
CADMUS	The Cadmus Group, Inc.
CANDU	Canadian Deuterium Reactor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CEU	Consolidated Edison Uranium
CFC	Chlorinated fluorocarbon
CH	Contact-handled (transuranic waste)
CISS	Colonie Interim Storage Site, Colonie, New York
CRWMS-M&O	Civilian Radioactive Waste Management System—Management and Operating (contractor)
CY	Calendar year
DAW	Dry active waste
DOD	Department of Defense, U.S.
DOE	Department of Energy, U.S.
DOE/AL	DOE Albuquerque Operations Office, Albuquerque, New Mexico

DOE/CAO	DOE Carlsbad Area Office, Carlsbad, New Mexico
DOE/CH	DOE Chicago Operations Office, Argonne, Illinois
DOE/DP	DOE/Office of Defense Programs (Headquarters), Germantown, Maryland
DOE/EIA	DOE/Energy Information Administration, Washington, D.C.
DOE/EM	DOE/Office of Environmental Management (Headquarters), Germantown, Maryland
DOE/FN	DOE Fernald Area Office, Cincinnati, Ohio
DOE/HQ	DOE Headquarters, Washington, D.C. and Germantown, Maryland
DOE/ID	DOE Idaho Operations Office, Idaho Falls, Idaho
DOE/NV	DOE Nevada Operations Office, Las Vegas, Nevada
DOE/OAK	DOE Oakland Operations Office, Oakland, California
DOE/OH	DOE Ohio Field Office, Miamisburg, Ohio
DOE/OR	DOE Oak Ridge Operations Office, Oak Ridge, Tennessee
DOE/OSTI	DOE/Office of Scientific and Technical Information, Oak Ridge, Tennessee
DOE/RF	DOE Rocky Flats Office, Golden, Colorado
DOE/RL	DOE Richland Operations Office, Richland, Washington
DOE/RW	DOE/Office of Civilian Radioactive Waste Management (Headquarters), Washington, D.C.
DOE/SR	DOE Savannah River Operations Office, Aiken, South Carolina
DOE/WIPP	DOE/WIPP Project Office, Carlsbad, New Mexico
DOE/WVAO	DOE/West Valley Area Office, West Valley, New York
DOT	Department of Transportation, U.S.
DRCT	Dry rod consolidation technology
DWCS	Defueling water cleanup system
DWMP	Defense Waste Management Plan
DWPF	Defense Waste Processing Facility
D&D	Decontamination and decommissioning
EA	Environmental assessment
EBR	Experimental Breeder Reactor
EBWR	Experimental Boiling-Water Reactor
EG&G/ID	EG&G Idaho, Inc., Idaho Falls, Idaho (former management and operating contractor for Idaho National Engineering Laboratory)
EIA	Energy Information Administration
EIS	Environmental impact statement
EMAD	Engine maintenance assembly and disassembly
EPA	Environmental Protection Agency, U.S.
EPR	Experimental power reactor
ERR	Elk River Reactor
ETEC	Energy Technology Engineering Center, Canoga Park, California [also referred to as the Santa Susana Field Laboratory (SSFL)]
FEMP	Fernald Environmental Management Project, Fernald, Ohio
FFCA	Federal Facility Compliance Act of 1992
FFTF	Fast Flux Test Facility, Hanford, Washington
FIS	Farallon Islands (Pacific Ocean off Central California)
FNAL	Fermi National Accelerator Laboratory, Batavia, Illinois
FSVR	Fort St. Vrain Reactor, Platteville, Colorado
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	Fiscal year
GA	General Atomics, San Diego, California
GAP CON	Gap conductance
GCRE	Gas-Cooled Reactor Experiment

GDP	Gaseous diffusion plant
GE	General Electric
GETR	General Electric Test Reactor
GEVNC	General Electric Vallecitos Nuclear Center, Vallecitos, California
GJPO	(DOE) Grand Junction Projects Office, Grand Junction, Colorado
GJRAP	Grand Junction Remedial Action Project
GPU	General Public Utilities Corporation, Parsippany, New Jersey
GTCC	Greater-than-Class-C (low-level waste)
HANF	Hanford Site, Richland, Washington
HAZWRAP	Hazardous Waste Remedial Actions Program
HEDL	Hanford Engineering Development Laboratory
HEN	Cape Henry (Atlantic Ocean off Virginia)
HFBR	High-Flux Beam Reactor
HIC	High-integrity containers
HLW	High-level waste
HTGR	High-temperature, gas-cooled reactor
HTRE	High-Temperature Reactor Experiment
HWCTR	Heavy-water components test reactor
HWVP	Hanford Waste Vittrification Plant, Hanford Site
ICPP	Idaho Chemical Processing Plant, Idaho National Engineering Laboratory
IDB	Integrated Data Base (Program)
IE	Irradiation effects
II	Industrial and institutional (waste)
INEL	Idaho National Engineering Laboratory, Idaho Falls, Idaho
ISL	In situ leaching
ITRI	Inhalation Toxicology Research Institute, Kirtland Air Force Base, Albuquerque, New Mexico
JAI	(E.R.) Johnson Associates, Inc., Oakton, Virginia
JIO	Joint Integration Office, Albuquerque, New Mexico
K-25	Oak Ridge K-25 Site, Oak Ridge, Tennessee (formerly called the Oak Ridge Gaseous Diffusion Plant)
KAPL	Knolls Atomic Power Laboratory, Schenectady, New York
KCP	Kansas City Plant, Kansas City, Missouri
KESS	Kesselring Site, Knolls Atomic Power Laboratory (KAPL)
LANL	Los Alamos National Laboratory, Los Alamos, New Mexico
LBL	Lawrence Berkeley Laboratory, Berkeley, California
LDR	Land disposal restriction
LEHR	Laboratory for Energy-Related Health Research
LEU	Low-enriched uranium
LFRSB	Loose fuel-rod shipping basket
LGR	Light-water cooled, graphite-moderated reactor
LITCO	Lockheed Idaho Technologies Company, Idaho Falls, Idaho (new management and operating contractor for Idaho National Engineering Laboratory)
LLNL	Lawrence Livermore National Laboratory, Livermore, California
LLR	LOFT lead rod
LLRWPA	Low-Level Radioactive Waste Policy Act of 1980
LLRWPA	Low-Level Radioactive Waste Policy Amendments Act of 1985
LLW	Low-level waste

LLWMP	Low-Level Waste Management Program
LMFBR	Liquid Metal Fast Breeder Reactor
LOC	Loss of coolant
LOFT	Loss-of-fluid test
LSA	Low specific activity
LTC	Lynchburg Technology Center, Lynchburg, Virginia
LWBR	Light-water breeder reactor
LWR	Light-water reactor
MAPI	Mitsubishi Atomic Power Industries
MASS	Massachusetts Bay
MED	Manhattan Engineer District (Manhattan Project)
MFKY	Maxey Flats, Kentucky (commercial waste site)
MFRP	Midwest Fuel Recovery Plant, Morris, Illinois (commercial spent fuel storage site)
MIMS	Manifest Information Management System
MLLW	Mixed low-level waste
MMES	Martin Marietta Energy Systems, Inc.
MOUND	Mound Plant, Miamisburg, Ohio
MRM	Miscellaneous radioactive material
MSRE	Molten Salt Reactor Experiment
MTIHM	Metric tons initial heavy metal
MTRUW	Mixed transuranic waste
MTU	Metric tons uranium
MURR	Missouri University Research Reactor
MWIR	Mixed Waste Inventory Report
NA	Not applicable
NARM	Naturally occurring or accelerator-produced radioactive material
NEPA	National Environmental Policy Act of 1969
NFS	Nuclear Fuel Services, Erwin, Tennessee
NORM	Naturally occurring radioactive material
NPL	National priorities list
NR	Naval reactors
NRC	Nuclear Regulatory Commission
NRF	Naval Reactors Facility, INEL, Idaho
NTIS	National Technical Information Service, Springfield, Virginia
NTS	Nevada Test Site, Mercury, Nevada
NUMEC	Nuclear Uranium Materials and Equipment Corporation
NUS	NUS Corporation, Gaithersburg, Maryland
NWPA	Nuclear Waste Policy Act of 1982
NYSERDA	New York State Energy Research and Development Authority, Albany, New York
OPTRAN	Operational transit
OR	Oak Ridge complex: Oak Ridge National Laboratory, K-25 Site, and Y-12 Plant, Oak Ridge, Tennessee
ORAU	Oak Ridge Associated Universities, Oak Ridge, Tennessee
ORIGEN2	Oak Ridge Isotope Generation and Depletion Code (Version 2)
ORISE	Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee
ORNL	Oak Ridge National Laboratory, Oak Ridge, Tennessee
ORR	Oak Ridge Research Reactor
OTS	Office of Technical Services, Roy F. Weston, Inc./H&R Technical Associates, Inc., Germantown, Maryland

PAD	Paducah Gaseous Diffusion Plant, Paducah, Kentucky
PANT	Pantex Plant, Amarillo, Texas
PBF	Power Burst Facility
PCB	Polychlorinated biphenyl
PCM	Power coolant mismatch
PINELLAS	Pinellas Plant, Largo, Florida
PNL	Pacific Northwest Laboratory, Richland, Washington
PNRO	DOE Pittsburgh Naval Reactors Office, West Mifflin, Pennsylvania
PORTS	Portsmouth Gaseous Diffusion Plant, Portsmouth, Ohio
PPPL	Princeton Plasma Physics Laboratory, Princeton, New Jersey
PWR	Pressurized-water reactor
PUREX	Plutonium uranium extraction
RA	Remedial action
RAP	Remedial action project
RCF	RCRA (see below) facility assessment
RCRA	Resource Conservation and Recovery Act of 1976
REECO	Reynolds Electrical and Engineering Co., Inc., Mercury, Nevada
RFETS	Rocky Flats Environmental Technology Site, Golden, Colorado
RFP	Rocky Flats Plant, Golden, Colorado [recently renamed the Rocky Flats Environmental Technology Site (RFETS)]
RH	Remote-handled (transuranic waste)
RI	Rockwell International Corporation, Pittsburgh, Pennsylvania
RIA	Reactivity initiated accident
RICH	Richland, Washington (commercial waste site)
RMI	Reactive Metals, Incorporated Titanium Company Extrusion Plant, Ashtabula, Ohio
SCB	Santa Cruz Basin (Pacific Ocean off Santa Cruz, California)
SDG	San Diego (Pacific Ocean off San Diego, California)
SDS	Submerged demineralizer system
SEG	Scientific Ecology Group, Inc., Oak Ridge, Tennessee
SFD	Severe fuel damage
SFMP	Surplus Facilities Management Program
SHEF	Sheffield, Illinois (commercial waste site)
SLAC	Stanford Linear Accelerator Center, Palo Alto, California
SM	Stationary media
SNAP	Space Nuclear Auxiliary Power
SNF	Spent nuclear fuel
SNL/CA	Sandia National Laboratories/California, Livermore, California
SNL/NM	Sandia National Laboratories/New Mexico, Albuquerque, New Mexico
SNM	Special nuclear material
SNRO	DOE Schenectady Naval Reactors Office, Schenectady, New York
SPERT	Special Power Excursion Reactor Test
SRE	Sodium Reactor Experiment
SRS	Savannah River Site, Aiken, South Carolina
SS	Stainless steel
SSFL	Santa Susana Field Laboratory, Canoga Park, California [also referred to as the Energy Technology Engineering Center (ETEC)]
SWIMS	Solid Waste Information Management System
SWU	Separative work unit

TAN	Test Area North, Idaho National Engineering Laboratory
TBD	To be determined
TC	Thermocouple
TCLP	Toxicity characteristic leaching procedure
TESS	TRW Environmental Safety Systems, Inc.
THOREX	Thorium extraction
TMI	Three Mile Island reactor site, Middletown, Pennsylvania
TRIGA	Training Reactor, Isotopes, General Atomic
TRU	Transuranic
TRUW	Transuranic waste
TSCA	Toxic Substances Control Act of 1976
T/S/D	Treatment, storage, and disposal
TVA	Tennessee Valley Authority, Knoxville, Tennessee
UMT	Uranium mill tailings
UMTRAP	Uranium Mill Tailings Remedial Action Program
VBWR	Vallecitos Boiling-Water Reactor
VEPCO	Virginia Electric Power Company
WEC	Westinghouse Electric Corporation, Pittsburgh, Pennsylvania
WHC	Westinghouse Hanford Company, Richland, Washington
WHPP	(Transuranic) Waste Handling and Packaging Plant, Oak Ridge National Laboratory
WIND	Windsor Site, Knolls Atomic Power Laboratory (KAPL)
WIPP	Waste Isolation Pilot Plant, Carlsbad, New Mexico
WMin	Waste minimization
WMIS	Waste Management Information System
WPIO	Waste Isolation Pilot Plant Project Integration Office, Albuquerque, New Mexico
WSSRAP	Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri
WVDP	West Valley Demonstration Project, West Valley, New York
WVNS	West Valley Nuclear Services Company, Inc., West Valley, New York
WVNY	West Valley, New York (commercial waste site from 1963–1981)
W/WIPP	Westinghouse/WIPP Project, Carlsbad, New Mexico
Y-12	Oak Ridge Y-12 Plant, Oak Ridge, Tennessee

INTEGRATED DATA BASE REPORT—1993: U.S. SPENT NUCLEAR FUEL AND RADIOACTIVE WASTE INVENTORIES, PROJECTIONS, AND CHARACTERISTICS

ABSTRACT

The Integrated Data Base Program has compiled historic data on inventories and characteristics of both commercial and DOE spent nuclear fuel; also, commercial and U.S. government-owned radioactive wastes through December 31, 1993. These data are based on the most reliable information available from government sources, the open literature, technical reports, and direct contacts. The information forecasted is consistent with the latest U.S. Department of Energy/Energy Information Administration projections of U.S. commercial nuclear power growth and the expected DOE-related and private industrial and institutional activities.

The radioactive materials considered, on a chapter-by-chapter basis, are spent nuclear fuel, high-level waste, transuranic waste, low-level waste, commercial uranium mill tailings, DOE Environmental Restoration Program wastes, commercial reactor and fuel-cycle facility decommissioning wastes, and mixed (hazardous and radioactive) low-level waste. For most of these categories, current and projected inventories are given through the calendar-year 2030, and the radioactivity and thermal power are calculated based on reported or estimated isotopic compositions. In addition, characteristics and current inventories are reported for miscellaneous radioactive materials that may require geologic disposal.

0. OVERVIEW

0.1 INTRODUCTION

This report is an update of the previous document¹ on radioactive waste inventories and projections that was prepared for use in the planning and analysis of waste management functions. Quantities of radioactive wastes produced from both commercial and U.S. Department of Energy (DOE)-sponsored activities are reported. Historical waste inventories compiled as of December 31, 1993, are reported. Projections of future wastes are generally reported for the calendar-year (CY) period 1994–2030. Such projections may change in future revisions of this report as waste minimization (WMin), environmental restoration, and decontamination and decommissioning (D&D) programs and activities at various government and commercial sites are defined and become operative. In many tables of this report, historical waste inventories and projection data are reported on a CY basis. These tables use a horizontal line to mark the point in time when past history ends and future projections begin. Because historical waste inventories are reported as of December 31, 1993, the line is drawn between the data entries for 1993 and 1994. Data reported for 1994 in this document are regarded as projected information.

This document contains information that has been assembled as a part of the Integrated Data Base (IDB) Program at Oak Ridge National Laboratory (ORNL), which has the lead responsibility for maintaining and reporting summary files of pertinent data on current and projected inventories and characteristics of permanently discharged domestic spent nuclear fuel (SNF) and radioactive wastes. While this report documents inventories and projections of radioactive wastes from commercial and DOE site activities, estimates for certain other waste categories are not fully reported because of the current unavailability of data. These categories include naturally occurring or accelerator-produced radioactive materials (NARM), discussed in Sect. 0.2, and wastes from U.S. Department of Defense (DOD) activities, particularly those resulting from the cleanup of military sites contaminated with significant amounts of radioactive waste. A recent study² by the U.S. General Accounting

Office indicates that as many as 420 DOD locations could be contaminated with radioactive wastes. Future updates of this report will work toward reporting information and data on NARM and DOD site radioactive wastes as they become available.

Radioactive waste originates from five major sources: (1) the commercial nuclear fuel cycle; (2) DOE-related activities; (3) institutions such as hospitals, universities, and research foundations; (4) industrial uses of radioisotopes; and (5) mining and milling of uranium ore. The waste is broadly categorized as SNF, high-level waste (HLW), transuranic waste (TRUW), low-level waste (LLW), and uranium mill tailings (UMT). Large quantities of radioactive waste also result from DOE site environmental restoration activities and the D&D programs of DOE and commercial nuclear facilities. This report also documents inventories and projections of mixed low-level waste (MLLW), which is hazardous and radioactive; and miscellaneous radioactive material (MRM) that may go to a geologic repository.

The primary purpose of this document is to report U.S. SNF and radioactive waste inventories, projections, and characteristics. The data presented were obtained through the cooperation and assistance of the offices and programs that were established by DOE to oversee the management of the various radioactive wastes and SNFs. In addition, the recent literature was reviewed to aid in selecting the data that are presented here and to help establish a basis for many of the calculated radioactivity levels and heat-generation rates that are included. In this report, SNF and radioactive wastes are characterized from the standpoint of their volumes (or masses) and their nuclear, physical, and chemical properties. The data reported are selected from more extensive information; that information is available upon request.

This annual inventory report contains summarized data of types found to be useful for programmatic planning purposes within the DOE community. The data are intended to provide a common basis for both DOE management-level planning and for more detailed analyses of the waste management system that are conducted by DOE contractors and field offices. However, this report is

not intended to present the detailed types of information required as input to such analyses. The best sources of such information are the appropriate operations offices, waste sites, or relevant documents previously issued, some of which may be referenced in this report.

This report does not address the programmatic implications of the data presented, such as the possible future need for interim SNF storage facilities. Discussion of the data is minimized to explain mainly what the data represent. Major DOE data sources providing information and data for this report are identified in a table following the preface. Likewise, discussions of packaging details, shielding and transportation requirements, health and environmental effects, and costs are purposely avoided. Questions regarding the data presented may be addressed to the IDB Program.

The DOE waste data contained in this report are furnished by the DOE contractor sites listed in Table 0.1. This table also indicates the types of radioactive waste managed at each site. The DOE site data (waste inventories, projections, and characteristics) are used by DOE-Headquarters (DOE-HQ), operations offices, and operating contractors for the management and strategic planning of various waste programs. The objective of this report is to provide waste information that is consistent, reflects current inventories and projections, and includes the types of basic data best suited to meet DOE waste program planning needs.

Information for this report is provided by a variety of sources. The DOE site waste data reported were received from DOE contractors through DOE operations offices. DOE-HQ assigns to selected organizations major responsibilities for providing information on particular topics involving SNF and radioactive waste management. Further detailed information is generally available from data bases maintained at the specific DOE and commercial sites. Additional information on the reference sites and facilities referred to in this report is provided in Appendix D.

0.2 CHARACTERIZATION OF WASTE FORMS

The major characteristics of radioactive materials and wastes are described below.

● Spent Nuclear Fuel (SNF)

SNF consists of irradiated fuel discharged from a nuclear reactor. Unless otherwise identified, all SNFs discussed in this report are assumed to be permanently discharged and eligible for repository disposal. Three categories of permanently discharged

SNF are considered: (1) fuel from commercial light-water reactors (LWRs); (2) fuel from non-LWR commercial reactors [e.g., the Fort St. Vrain high-temperature, gas-cooled reactor (HTGR)]; and (3) special fuels associated with government-sponsored research and demonstration programs, universities, and private industries. This report does not track the inventories of government production reactor SNFs that have been reprocessed in the manufacture of nuclear weapons for national defense. However, the inventories of HLW resulting from the reprocessing of these fuels are reported in Chapter 2. Also, Chapter 1 reports quantities of DOE SNF.

Currently, most LWR SNF assemblies are stored in pools at the reactor sites. The bulk of the remainder is in storage at the West Valley Demonstration Project (WVDP) site at West Valley, New York; the Idaho National Engineering Laboratory (INEL) at Idaho Falls, Idaho; and the Midwest Fuel Recovery Plant (MFRP) at Morris, Illinois. The WVDP facility is currently being decommissioned. All utility-owned SNF assemblies previously stored there have been returned to the utilities, and the fuel remaining is DOE-owned material.

SNFs discharged from a variety of reactors are currently stored at the Hanford Site (HANF) and INEL. HANF contains inventories of fuel from the N Reactor, the Fast Flux Test Facility (FFTF), and pressurized-water reactor (PWR)—Core II fuel from Shippingport. Fuel from the damaged Three Mile Island (TMI)—Unit 2 reactor, as well as some of the SNF from the Fort St. Vrain HTGR, are stored at INEL. Some special SNFs are stored at the Savannah River Site (SRS) and at INEL. These special fuels are government owned and are not scheduled for reprocessing in support of DOE activities.

● High-Level Waste (HLW)

For this report, HLW means the highly radioactive material resulting from the reprocessing of SNF. This includes mainly the liquid wastes remaining from the recovery of uranium and plutonium in a fuel reprocessing plant. This HLW may also be in the form of sludge, calcine, or other products into which such liquid wastes are converted to facilitate their handling and storage. Such waste contains fission products that result in the release of considerable decay energy.³ For this reason, heavy shielding is required to absorb penetrating radiation, and provisions (e.g., cooling

systems) are needed to dissipate decay heat from HLW.

- **Transuranic Waste (TRUW)**

TRUW refers to radioactive waste that contains more than 100 nCi/g of alpha-emitting isotopes with atomic numbers greater than 92 and half-lives greater than 20 years.^{4,5} Such waste results primarily from fuel reprocessing and from the fabrication of plutonium weapons and plutonium-bearing reactor fuel. Generally, little or no shielding is required ["contact-handled" (CH) TRUW], but energetic gamma and neutron emissions from certain transuranic (TRU) nuclides and fission-product contaminants may require shielding or remote handling ["remote-handled" (RH) TRUW].

- **Low-Level Waste (LLW)**

Several statutes (refs. 3, 5, and 6) define LLW not by what it is, but by what it is not. In general, LLW is radioactive waste not classified as SNF, HLW, TRUW, or by-product materials such as UMT or thorium mill tailings. However, there are slight differences between the specific regulatory definitions of DOE-generated LLW and commercial LLW.

The definition of DOE LLW is based on DOE Order 5820.2A,⁵ which specifies DOE's policy for radioactive waste management. According to this order, LLW includes all radioactive waste not classified as either HLW, TRUW, SNF, or the bulk of the by-product tailings containing uranium or thorium from processed ore. The DOE policy, as stated in Order 5820.2A, allows small volumes of fissionable material to be irradiated for research and development (R&D) only—but not for the production of power or plutonium—and small concentrations of TRU (<100 nCi/g) radionuclides to be managed as LLW. The same DOE policy allows small volumes of DOE waste containing by-product material [specified in Sect. 11e(2) of the Atomic Energy Act of 1954 (AEA)]⁷ or NARM to be managed as LLW. Any LLW that also contains hazardous chemicals covered by either the Resource Conservation Recovery Act (RCRA)⁸ or the Toxic Substances Control Act (TSCA)⁹ requires management as a "mixed waste."

The definition of commercial LLW is based on two statutes, the Nuclear Waste Policy Act (NWPA)³ and the Low-Level Radioactive Waste Policy Amendments Act (LLRWPA).⁶ According to both

the NWPA and the LLRWPA, commercial LLW is radioactive material that (a) is not HLW, SNF, TRUW, or by-product material as defined in Sect. 11e(2) of the AEA; and (b) consistent with existing law, is classified by the U.S. Nuclear Regulatory Commission (NRC) as LLW.

The radiation level from LLW waste may sometimes be high enough to require shielding for handling and transport. For commercial LLWs, the NRC has defined, in ref. 10, four disposal categories of LLW that require differing degrees of confinement and/or monitoring: classes A, B, C, and Greater-Than-Class-C (GTCC). The NRC excludes NARM from the LLW category. DOE LLWs are classified by groupings of disposal categories that are site specific, yet similar to the NRC categories. This report documents only those inventories of solid LLW destined for disposal. It includes no liquid or gas waste in storage.

- **Commercial Uranium Mill Tailings (UMT)**

Commercial UMT are the earthen residues that remain after the extraction of uranium from ores. Tailings are generated in very large volumes and contain low concentrations of naturally occurring radioactive materials. These materials comprise a potential health hazard; the isotopes of major concern are ²²⁶Ra and its daughter, ²²²Rn.

- **Miscellaneous Radioactive Material (MRM)**

A variety of MRMs are currently stored at some DOE and commercial sites. These materials include hot-cell solid wastes as well as whole, sectioned, or damaged SNF rods or assemblies that originated in commercial reactors and were used in various DOE-related experimental programs. Many of these materials are highly radioactive and may eventually require geologic disposal.

- **Mixed Low-Level Waste (MLLW)**

MLLW contains concentrations of both low-level radioactive materials and hazardous chemicals. The hazardous component of mixed waste has characteristics identified by any or all of the following statutes: the RCRA, as amended;⁸ the TSCA;⁹ and state regulations. Typically, MLLW from activities supporting DOE programs includes a variety of contaminated materials, such as air filters, cleaning solutions, engine oils and grease, paint residues, soils,

construction and building materials, water-treatment chemicals, and decommissioned plant equipment. This report documents inventories and generation rates of various types of mixed wastes stored at DOE sites based on information reported in the Federal Facilities Compliance Act (FFCA) Mixed Waste Inventory Report (MWIR)¹¹ and TSCA waste information recently provided by DOE sites.

- **Naturally Occurring or Accelerator-Produced Radioactive Material (NARM)**

NARM wastes include both accelerator wastes (LLW) and naturally occurring radioactive material (NORM) that contain radionuclides (e.g., ²²⁶Ra, ²²²Rn, ²³²Th, ²³⁸U) existing throughout the earth's crust. Accelerator wastes include accelerator targets, wastes from accelerator maintenance or D&D, and wastes from radiopharmaceutical manufacture. Naturally occurring radioactive material (NORM) wastes are classified according to their specific activity as either discrete or diffuse. Discrete NORM wastes have a relatively small volume but large radioactivity and include industrial gauges, old radium watch and industrial dials, radium needles in medical equipment, and resins (filters) that remove radioactive radium and some radiopharmaceutical waste from contaminated public drinking water. Diffuse NORM wastes are characterized by a relatively large volume with small radioactivity. These materials result from industrial processes and include:

- tailings from metal (e.g., copper and uranium) mining and processing,
- fossil fuel wastes (viz., coal ash from utility electrical generation),
- phosphate mining ore wastes for fertilizer (ammonium phosphate) production,
- sludge from drinking water treatment,
- contaminated water and drilling equipment from oil and natural gas drilling, and
- wastes from geothermal energy production.¹²

Current inventories of domestic NARM wastes are not known. Future updates of this document will include additional information on NARM waste inventories, projections, and characteristics as they become available.

- **Generated, Treated, Stored, and Disposed Wastes**

It should be emphasized that all of the types of radioactive materials and wastes discussed in this report can exist either as material generated, treated,

stored, or disposed. The distinctions among these various waste conditions or "states" are as follows:

- *Generated waste.* A material recently discharged from a facility production process or operation that can be regarded as a waste because it has no economic value. In this report, quantities of generated waste are measured in units of volume [cubic meters (m³)] or mass (kg) produced during a calendar year.
- *Treated waste.* A waste that, following generation, has been altered chemically or physically to reduce its toxicity or prepare it for storage or disposal on- or off-site. Waste treatment can include volume-reduction activities, such as incineration or compaction, which may be done prior to either storage or disposal or both (discussed next).
- *Stored waste.* A waste that, following generation (and usually some treatment), is being (temporarily) retained and monitored in a retrievable manner pending disposal. In this report, inventories and projections of stored radioactive materials or wastes are reported in volume (m³) or mass (kg) units or both.
- *Disposed waste.* A waste that has been put in final emplacement to ensure its isolation from the biosphere, with no intention of retrieval. Deliberate action is required to regain access to the waste. Disposed waste includes materials placed in a geologic repository, buried underground in shallow pits, dumped at sea, or discarded by hydrofracture injection. The latter two techniques were past practices and are no longer performed.

Throughout this report, the reader is urged to note the distinctions among these waste conditions. Such conditions have a great impact on the regulatory status of the waste materials considered in this report.

0.3 METHODS AND ASSUMPTIONS USED IN REPORT PREPARATION

This report consolidates a large amount of information from many sources. Some of these data are historical in nature, some are current, and some are projected; some have been calculated or estimated, and some have been measured. Over the years, waste regulations have been

revised, waste category definitions have changed, measurement instruments and calibration methods have been improved, and record-keeping has been upgraded at all waste-generating and -receiving sites. In preparing this report, a major effort has been made to integrate waste data from many sources and to strive for a consistent and technically rational approach for the entire scope of coverage. Our primary sources of data are referenced, and, for calculated values (e.g., decayed radioactivity and thermal power), the bases for the calculations are identified. To achieve adequate integration of data, numerous factors had to be considered; these are cited in footnotes that generally accompany the tables and figures of this report. In some cases, a more thorough explanation is provided in the text.

Each chapter details the assumptions on which its waste inventories and projections are based. The broader assumptions are mentioned here and are listed in Table 0.2. These include the projected time frame and specific assumptions used for estimating commercial and government (DOE) waste projections. For the commercial fuel cycle, the SNF and waste projections depend upon the nuclear power growth scenario. The commercial fuel cycle waste projections reported in this document assume a reference projection of nuclear power growth and no SNF reprocessing. The reference nuclear power electrical growth projection (and associated discharged SNF schedule) used throughout this report is the 1994 DOE/EIA No New Orders Case (now being referred to by DOE/EIA as the Low Case).¹³ The No New Orders SNF and power-capacity projection cases are based on a set of assumptions involving nuclear electricity generation growth, reactor fuel burnup levels, reactor construction schedules, and reactor operating lifetimes and capacity factors. These assumptions are documented by DOE/EIA in ref. 13. In particular, the No New Orders Case assumes that all reactors will be retired upon the expiration date of their respective operating licenses, as published by the NRC.

Detailed information about reactors already built, being built, or planned in the United States for domestic use or export as of December 31, 1993, is provided in report DOE/OSTI-8200-R57 (ref. 14), which contains a comprehensive listing of all domestic reactors categorized by primary function or purpose: viz., civilian, production, military, export, and critical assembly.

The data for total waste inventories (which comprise historical data) are obviously less accurate than the values recorded for recent waste additions. The number of digits used in reporting these values is generally greater than justified in terms of numerical significance, but this proves useful and necessary for bookkeeping purposes. In some cases, the values cited are significantly different from those

previously reported. This is generally a result of improved estimates, new measurements, or redefinition of terms. Explanations are given in such cases. Many of the comments received during the final review stage of this report deal with changes that have occurred after December 31, 1993—some as recently as December 1994. These changes are generally cited in footnotes.

For the sake of brevity, many of the figures and tables of this report use the exponential (E) notation. As examples of this notation, the constant 1.234E+2 means 1.234×10^2 , or 123.4; and 1.234E-4 means 1.234×10^{-4} , which is 0.0001234.

0.4 WASTE CHARACTERISTICS AND UNITS REPORTED

Principal characteristics reported for most radioactive wastes discussed in this report include volume, radioactivity, and thermal power. All characteristics are reported in metric units and, depending on the waste form, can be significant considerations in meeting the requirements for waste treatment, storage, and disposal. Waste volume is reported in cubic meters (m^3) and generally reflects the amount of space occupied by the waste and its container. Radioactivity represents the rate of spontaneous disintegration of the radionuclides comprising the waste. In this report, radioactivity is measured by a unit called a curie (Ci), which is 3.7×10^{10} nuclear disintegrations per second. Over time, radionuclides decay to nonradioactive, stable isotopes. As an example, the short-lived radionuclides found in SNF rapidly decay during the first few years after the fuel is removed from a reactor.

It should be noted that while waste volumes accumulate with time by conventional addition, total radioactivity does not. Because of radioactive decay, cumulative activity cannot be based on reported annual additions; rather it must be estimated from knowledge of the waste composition, which includes the radionuclides comprising the waste, their concentrations, and decay attributes (e.g., half-lives and decay schemes). In this report, decayed radioactivity is generally estimated for various wastes by an abridged version of the ORIGEN2 code (ref. 15). Annual levels of radioactivity (Ci) reported in this document include contributions from both parent and daughter decay products.

Thermal power is a measure of the rate of heat-energy emission resulting from the decay of radionuclides in a waste. Like radioactivity, thermal power is not cumulative by conventional addition because of radioactive decay. Information on thermal power is needed in the design of shipping casks, storage facilities, and repositories where

temperature rise, especially with regard to SNF and HLW, is an important concern. Thermal energy generation rates are highest for SNF, HLW, and RH TRUW. They may also be important for certain types of LLW. The unit of thermal power used in this report is the watt (W), which represents 1 joule of thermal energy emitted per second. Estimates of thermal power are based on radionuclide composition as well as total activity. While levels of thermal power may not be significant for certain waste forms (particularly some types of LLW), they are nevertheless reported for the major radioactive waste categories referenced in this report to provide a standard for comparison.

For SNF and TRUW, mass is reported to provide better assurances of accountability. SNF is reported in units of metric tons of *initial* heavy metal (MTIHM) to avoid difficulties and confusion arising from the need to estimate ranges of varied heavy-metal content (MTHM) that result from different levels of enrichment and reactor fuel burnup. Mass is reported in kilograms (kg) for the TRU radionuclides comprising TRUWs.

In this report, quantities of generated wastes are expressed in terms of either the amount of mass (kg) or volume (m^3) produced in a given calendar year. Thus, generation rates for wastes are expressed in either kilograms per year (kg/year) or cubic meters per year (m^3 /year), depending on the availability of site information. Annual generation rates are reported in this document for SNF, TRUW, LLW, and MLLW. Annual generation rates are not reported for HLW in part because of security restrictions for the DOE nuclear weapon production activities that produce these wastes. Additionally, there are problems in accurately estimating HLW generation levels. One major difficulty is accounting for net waste-quantity changes due to the combined effects of various modes of site waste management operations such as evaporation and calcination.

Quantities of wastes can also be reported in terms of the number and types of waste containers. LWR SNF inventories and projections can be expressed in terms of the number of permanently discharged boiling-water reactor (BWR) and PWR fuel assemblies. HLW will be immobilized in either borosilicate glass or a glass/ceramic matrix solidified in stainless steel canisters. Estimates of the quantities of HLW to be disposed of in a geologic repository are based on the number and types of these canisters. Quantities of LLW and stored TRUW can be based on the number and types of drums, boxes, or containers used or scheduled for use.

Waste characteristics are also identified by waste composition. Throughout this report, waste composition is expressed in terms of the following:

- radioactivity (Ci) or specific-activity (Ci/ m^3) breakdown by radionuclide (with accompanying daughter products) and
- physical form (solid, liquid, gas, or sludge) or chemical content (by chemical component), expressed in terms of either volume (m^3) or mass (kg) or as a percentage of total weight (wt %), volume (vol %), or activity (act %).

This annual report also provides some information on the status of land usage at LLW burial and disposal sites. Such information includes total site area, estimated total usable land area, and estimated area currently utilized. To conform with the metric unit format used in this report, these land-usage-area parameters are reported in units of hectares, where 1 hectare (ha) = 10,000 m^2 , or 2.4710 acres.

0.5 SUMMARY DATA AND CHAPTER OVERVIEWS

A few graphical presentations and summary tables are included in this chapter to provide a broad overview. Figures 0.1 and 0.2, respectively, show the volumes and decayed radioactivities of commercial and DOE wastes and SNF accumulated through 1993.

Summaries of SNF and radioactive waste inventories and projections are provided in Tables 0.3 and 0.4. In general, material to be sent to R&D facilities or to the proposed national geologic repository for SNF and HLW is still listed in each individual site's inventory.

A brief summary of each chapter in this report is presented in the following paragraphs.

0.5.1 Spent Nuclear Fuel (SNF)

Chapter 1 of this report presents national data on the quantities of permanently discharged SNF from commercial nuclear power reactors. Historical data on commercial SNF inventories¹⁶ are reported along with 1994 DOE/EIA projections for the No New Orders Case.¹³ The No New Orders Case (without reactor license renewal) is the baseline commercial scenario used throughout this report to make waste projections. For the projection period considered in this report (CYs 1994–2030), the No New Orders Case assumes that no new reactors will be ordered.

DOE SNF inventories are reported in Chapter 1 and Appendix A. These include various types of research reactor SNFs which are stored at the SRS and the INEL.

In this report, the mass of discharged SNF is generally measured in MTIHM. The term "initial heavy metal" refers to the original mass of the actinide elements of the fuel, most of which is uranium. (Elements of the actinide group are those with atomic numbers greater than 89.)

0.5.2 High-Level Waste (HLW)

The inventories of HLW in storage at the end of CY 1993 and projected through CY 2030 are given in Chapter 2. The waste forms include liquid, sludge, salt cake, slurry, calcine, precipitate, zeolite, glass, and capsules of separated strontium and cesium. Vitrified defense HLW is projected after the startup of the Defense Waste Processing Facility (DWPF) at SRS in 1996, and projections of vitrified HLW from commercial reprocessing activities are given for the WVDP. Projections recently made of the number of canisters containing the final immobilized form for the DOE HLW at HANF and the INEL are also reported. In addition, Chapter 2 gives the locations, volumes, and radioactivities of HLW.

In 1992, DOE decided to phase out the reprocessing of its production reactor SNFs. Until then, the reprocessing activities recovered enriched uranium and plutonium which were used to support nuclear weapons production. As a consequence of ceasing to reprocess reactor SNFs, little additional HLW is expected to be generated at DOE sites in the future. However, DOE site D&D activities may generate some wastes with radioactivity levels high enough to require disposal in a deeply mined geologic repository.

0.5.3 Transuranic Waste (TRUW)

The locations, inventories, and projections of TRUW buried and stored at DOE sites are presented in Chapter 3. Current inventories of TRUW are virtually all derived from government operations. The inventories documented in this report are based on data provided by the sites and include waste volumes and the masses and radioactivities of contained radionuclides. Projected future TRUW volumes through CY 2020 were also requested from the sites, but the sites were not able to make such estimates in all cases. Projections are reported through CY 2020 for those sites that provided estimates.

In 1984, DOE (with input from other federal agencies) revised the minimum radioactivity concentration level for defining TRUW from greater than 10 nCi/g to greater than 100 nCi/g.¹⁷ Consequently, the waste currently in the inventory contains wastes stored under both criteria. This redefinition, as well as the development of instrumentation to detect these low levels of

radioactivity, will reduce the volume of TRUW. As the waste is assayed, that portion of it which is greater than 10 nCi/g and less than 100 nCi/g will be reclassified to other waste categories.

0.5.4 Low-Level Waste (LLW)

Data for LLW from commercial and government activities are given in Chapter 4 and Appendix C. Commercial fuel-cycle LLW is generated from the conversion of yellowcake to uranium hexafluoride (UF₆), enrichment, fuel fabrication, and reactor operation. LLW also results from commercial operations by private organizations that are licensed to use radioactive materials. These include institutions and industries engaged in research and various medical and industrial activities. DOE LLW is similar in nature to the commercial industrial and institutional (I/I) waste and the commercial fuel cycle LLW.

A wide variety of radionuclides are found in LLW. Uranium isotopes and their daughters dominate in the conversion, enrichment, and fuel-fabrication steps of the nuclear fuel cycle. Reactor operations produce LLW containing mostly activation products and fission products. A significant fraction of institutional LLW that is shipped to disposal sites is contaminated with small quantities of ³H and ¹⁴C.

By the end of 1993, approximately 66% of the total cumulative volume of disposed LLW resulted from various DOE activities. The remaining 34% resulted from domestic commercial activities. About 31% of the volume of LLW disposed during 1993 resulted from commercial activities.

0.5.5 Commercial Uranium Mill Tailings (UMT)

Current inventories and projections of tailings from commercial uranium mill operations are summarized in Chapter 5. Twenty-six licensed uranium mills have accumulated tailings from their operations. Half of these mills have accumulated both commercial and government tailings. By the end of 1993, only two of the NRC-licensed mills were still active. To date, almost all domestic uranium has been produced by conventional mining and milling methods from which these tailings derive. A small portion has been obtained via in situ leaching, recovery from mine water, recovery from copper/vanadium dump leach liquor, and recovery from wet-process phosphoric acid effluents. Projections of uranium mill tailings are based on commercial fuel-cycle requirements, adjusted for foreign imports, as specified by the DOE/EIA Lower Reference Case projection of commercial reactor power growth. (The Lower Reference Case is now being referred

to by DOE/EIA as the Mid Case.) Tailings from the now inactive mills that produced uranium only for government operations are classified as Environmental Restoration Program wastes (see Chapter 6).

0.5.6 Environmental Restoration Program Wastes

An overview of DOE environmental restoration projects and activities is given below. Further details are provided in Chapter 6. The scope of Chapter 6 is limited to radioactive and mixed (radioactive and chemically hazardous) wastes that could be generated by environmental restoration activities. Nonradioactive hazardous and sanitary wastes are outside the scope of this report.

The major objective for DOE environmental restoration activities is to ensure that risks to the environment and to human health and safety posed by inactive and surplus facilities and sites contaminated by radioactive and chemically hazardous materials are either eliminated or reduced to prescribed, safe levels. Projects within the Office of Environmental Restoration (EM-40) are comprised of remedial action (RA) and D&D activities. RA involves the assessment and cleanup of inactive sites and deals mainly with contaminated environmental media such as soil, sediment, and ground water. D&D activities are primarily concerned with the safe caretaking of surplus nuclear facilities following shutdown and for either their ensuing decontamination for reuse or their complete dismantlement. About 500 contaminated facilities are currently included under the EM-40 D&D Program. Activities associated with environmental restoration projects are found in 32 states.¹⁸

DOE EM-40 is currently undertaking a major initiative to determine the volumes and types of waste that may be generated during future environmental restoration activities. These studies have not yet reached the point at which realistic waste projections can be made. Results from these studies should be available within the next few years. For this reason, inventories and projections for actual environmental restoration wastes are not provided in this report. However, the volumes of contaminated solid media, such as soils and debris from which environmental restoration wastes will be generated, are known at most EM-40 project sites. Estimates of the volumes of such contaminated media are reported in Chapter 6.

0.5.7 Commercial Decommissioning Wastes

Chapter 7 presents waste projections for the decommissioning of commercial power reactors and fuel cycle facilities. The D&D activities at such installations may result in very large volumes of LLW, depending on the

methods selected. The major LLW volumes will result from the decommissioning of power reactors, which will also produce a small volume of high-activity waste. Unlike that for other waste generation activities, the timing of decommissioning operations is very uncertain, since facilities may be either decommissioned upon shutdown or put into a mothballed or protective storage condition to allow for sufficient radioactive decay before decommissioning. Chapter 7 reports a set of projected characteristics for wastes from commercial LWR decommissioning activities. These projections are based on the assumption that each power reactor is decommissioned soon after it is shut down. To date, only a few commercial reactors have been fully decommissioned, and several have been placed in protective storage. Wastes from completed decommissioning actions have been included with existing inventories discussed in other chapters. Because of timing uncertainties, projected commercial decommissioning wastes are not included in the projections of LLW (Chapter 4). Rather, commercial decommissioning waste projections are reported separately in Chapter 7.

0.5.8 Miscellaneous Radioactive Materials (MRMs)

Inventories and characteristics of MRMs are reported in Appendix A. Such materials consist mainly of permanently discharged or damaged SNF (pellets, rods, and other fuel-assembly components) from civilian and government-sponsored experimental nuclear programs.

0.5.9 Mixed Low-Level Waste (MLLW)

Current inventories and generation rates of MLLW from both DOE and commercial sources are summarized in Chapter 8. These wastes are contaminated with both low-level radioactivity and chemically hazardous substances. The radioactive components are defined by the AEA,⁷ while the hazardous components are defined by the RCRA,⁸ the TSCA,⁹ and pertinent state regulations. As of the end of 1993, inventories of MLLW at DOE sites totaled about 190,720 m³. It is estimated that about 49,340 m³ of MLLW will be generated during the period 1993–1997.

0.5.10 Appendixes

In addition to Appendix A, which documents MRMs that may possibly require repository disposal, several other appendixes are included in this report. A tabulation of the properties of important radionuclides is given in Appendix B. Appendix C is a compilation of waste flowsheets, source terms, and characteristics used for

waste projections. Source terms include both quantitative and descriptive characteristics used to describe radioactive wastes. As developed and used in the IDB Program, the source term for a particular waste is comprised of two components unique to that waste: (1) the number of curies of radioactivity, expressed either per unit of facility

production or per unit of waste volume or mass, and (2) a listing of the relative contributions of component radioisotopes per curie of radioactivity of the waste. Appendix D lists the sites and facilities referred to in this report, and Appendix E describes a reader comment form, which is provided in the front of this report.

0.6 REFERENCES

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*Commercial LWR fuel permanently discharged. Includes spacing between fuel assembly rods.

** DOE wastes include both retrievably stored and buried materials.

Fig. 0.1. Total volumes of DOE and commercial radioactive wastes and spent nuclear fuel through 1993.

*Commercial LWR fuel permanently discharged.

** DOE wastes include both retrievably stored and buried materials.

*** Includes contributions from disposed wastes only.

Fig. 0.2. Total decayed radioactivities of DOE and commercial radioactive wastes and spent nuclear fuel through 1993.

Table 0.1. Types of radioactive wastes managed at DOE sites referenced in this report ^a								
Site(s)	Symbol/label	SNF	HLW	TRUW	LLW	MLLW	UMT	MRM
Ames Laboratory	AMES			X	X	X		
Argonne National Laboratory-East	ANL-E	X		X	X	X		
Argonne National Laboratory-West	ANL-W	X			X	X		X
Brookhaven National Laboratory	BNL	X			X	X		
Fermi National Accelerator Laboratory	FNAL				X			
Fernald Environmental Management Project	FEMP				X	X		
Hanford Site ^b	HANF	X	X	X	X	X		
Idaho National Engineering Laboratory ^c	INEL	X	X	X	X	X		X
Inhalation Toxicology Research Institute	ITRI				X	X		
K-25 Site (Oak Ridge)	K-25				X	X		
Kansas City Plant	KCP				X	X		
Lawrence Berkeley Laboratory	LBL			X	X	X		
Lawrence Livermore National Laboratory	LLNL			X	X	X		
Los Alamos National Laboratory	LANL	X		X	X	X		X
Mound Plant	MOUND			X	X	X		
Naval Reactors Facilities and Shipyards ^d	NR Sites			X	X	X		X
Nevada Test Site	NTS			X	X	X		
Oak Ridge Institute of Science and Education	ORISE				X			
Oak Ridge National Laboratory	ORNL	X		X	X	X		X
Paducah Gaseous Diffusion Plant	PAD			X	X	X		
Pantex Plant	PANT			X	X	X		
Pinellas Plant	PINELLAS				X	X		
Portsmouth Gaseous Diffusion Plant	PORTS				X	X		
Princeton Plasma Physics Laboratory	PPPL				X	X		
Reactive Metals Inc., Extrusion Plant	RMI				X	X		
Remedial Action Program Sites ^e	RAP Sites			X	X	X	X	
Rocky Flats Plant	RFP			X	X	X		
Sandia National Laboratory/California	SNL/CA				X	X		
Sandia National Laboratory/New Mexico	SNL/NM	X		X	X	X		
Savannah River Site	SRS	X	X	X	X	X		X
Stanford Linear Accelerator Center	SLAC				X			

Table 0.1 (continued)							
West Valley Demonstration Project	WVDP	X	X	X	X	X	
Y-12 Plant (Oak Ridge)	Y-12	X			X	X	
^a An "X" entry in this table indicates that the listed site manages waste of the category indicated. General site information is given in Appendix D. ^b Includes Pacific Northwest Laboratory (PNL). ^c Includes the Idaho Chemical Processing Plant (ICPP); excludes ANL-W. ^d These sites are listed in Table D.2 of Appendix D. ^e These sites are listed in Chapter 6.							

Table 0.2. Major assumptions used in this report

Inventory/projection basis

- Inventories are reported for December 31, 1993
- Projections are made for the CYs 1994–2030

HLW solidification activities

- For WVDP, HLW solidification (glass production) starts in 1996 and is completed in 1998
- For SRS, HLW solidification [glass production at the Defense Waste Processing Facility (DWPF)] starts in 1996 and continues through 2018
- For INEL, HLW solidification (immobilization) starts in 2007 and continues through 2031
- For HANF, HLW solidification (borosilicate glass production at the Hanford Waste Vitrification Plant) starts in 2010 and continues through 2028

Commercial activities

- DOE/EIA projections of installed net LWR electrical capacity for the No New Orders Case^a of ref. 13:

No New Orders Case

Year	1994	1995	2000	2005	2010	2015	2020	2025	2030
GW(e)	99	100	103	104	91	65	50	26	6

- DOE/EIA assumptions for LWR fuel enrichment and burnup:

<u>LWR fuel</u>	<u>CY fuel is loaded</u>	<u>Fuel enrichment (% ²³⁵U)</u>	<u>Design burnup (MWd/MTIHM)</u>
BWR	1993	2.99	33,000
	1995	3.17	36,000
	2002	3.30	39,000
	2010	3.53	43,000
PWR	1993	3.78	42,000
	1998	4.04	46,000
	2004	4.35	50,000
	2007	4.73	55,000

- SNF from commercial reactors is not reprocessed. Thus, a fuel cycle without reprocessing is assumed for all commercial projections

^aThis case (now referred to by DOE/EIA as the Low Case) assumes that each reactor will be retired when the expiration date specified in its operating license is reached.

Table 0.3. Spent nuclear fuel and radioactive waste inventories as of December 31, 1993

Waste category	TRU isotopes (kg)	Mass (MTIHM)	Volume (m ³)	Activity ^a (10 ⁶ Ci)	Thermal power (10 ³ W)
Spent nuclear fuel					
Commercial					
BWRs		10,178	4,103 ^b	7,390	27,200
PWRs		17,851	7,196 ^b	20,300	77,700
DOE		>2,499	c	c	c
High-level waste					
Savannah River (DOE)			129,300	606.0	1,615
Idaho (DOE)			10,500	52.5	154
Hanford (DOE) ^d			261,700	361.4	1,043
West Valley (commercial)			1,990	25.3	74.1
Transuranic waste (DOE)					
Buried TRUW	>352		127,152	>0.73	>5.2
Potentially contaminated soil	c		>32,000	>0.08	c
Stored TRUW	3,071		105,489	1.86	36.2
Low-level waste					
DOE sites					
Generated			41,415	0.8	c
Cumulative stored			155,666	c	c
Cumulative disposed			2,911,177	13.1	20.4
Commercial sites					
Cumulative disposed			1,494,561	5.7	21.6
Uranium mill tailings (commercial)					
Licensed mill sites ^e			118,600,000	c	c
Environmental restoration program wastes (DOE) ^f			c	c	c
Commercial reactor decommissioning			25,026 ^g	c	c
Miscellaneous radioactive materials		244.0	c	c	c
MLLW (cumulative stored)					
DOE		137,102 ^h	190,720	c	c
Commercial		c	c	c	c

^aActivity data are calculated decayed values as of December 31, 1993.

^bIncludes volume of spacing between the fuel rods of each assembly.

^cInformation not available.

^dHanford tank wastes consist of HLW, TRUW, and LLW. However, in the interim storage mode, the tank wastes are managed as if they contain HLW and, therefore, are included in the HLW inventory.

^eIncludes contributions from 26 NRC-licensed mills.

^fInformation currently not available. DOE is undertaking several initiatives to better define the volumes and types of wastes currently in storage at environmental restoration sites and those which may be generated during future remediation activities across the entire DOE complex. This information, which should become available in a few years, will be included in future revisions of this report.

^gQuantity of LLW shipped from completed and ongoing projects involving reactor dismantlement. This inventory is included in the commercial LLW inventory listed above.

^hMass of MLLW is expressed in metric tons (t) and includes other elements in addition to heavy metals. Does not include contributions from some sites that reported volume data.

Table 0.4. Current and projected cumulative quantities of radioactive waste and spent nuclear fuel

[Quantities are expressed as volume (10^3 m^3) unless otherwise indicated]

Source and type of material	End of calendar year				
	1993	2000	2010	2020	2030
DOE					
SNF, mass, MTIHM ^a	>2,499	b	b	b	b
HLW					
Interim storage	401	350	306	264	264
Glass or glass/ceramic ^c	0	0.5	2.6	5.1	6.4
TRUW ^d					
Buried	127	127	127	127	127
Stored	105.5	b	b	b	b
LLW (buried) ^e	2,911	3,579	4,602	5,634	6,076
Environmental restoration program wastes ^f	b	b	b	b	b
MLLW	190.7	b	b	b	b
Miscellaneous radioactive materials, mass, MTIHM	244.0	b	b	b	b
Commercial					
LWR SNF, mass, MTIHM ^{a,g}					
(no reprocessing)					
No New Orders Case	28,030	42,300	62,500	77,800	85,700
HLW (WVDP)					
Interim storage	1.990	0.0	0.0	0.0	0.0
Glass	0.0	0.24	0.24	0.24	0.24
LLW (no reprocessing)	1,495	b	b	b	b
D&D (LLW) ^h					
Classes A, B, and C LLW	—	0.00	0.83	129.39	453.82
Greater-than-Class-C LLW	—	0.00	0.00	0.11	0.45
Mill tailings (no reprocessing)	118,600	118,900	123,100	b	b
MLLW	b	b	b	b	b

^aHistorically, spent nuclear fuel has been measured in units of mass (MTIHM) rather than units of volume.^bInformation not available.^cIncludes projections for glass at SRS and glass/ceramic at INEL.^dInventories and projections are updated mainly as a result of improvements in detection methods.^eProjections include contributions from SRS saltstone.^fInformation currently not available. DOE is undertaking several initiatives to better define the volumes and types of wastes currently in storage at environmental restoration sites and those which may be generated during future remediation activities across the entire DOE complex. This information, which should be available in a few years, will be included in future revisions of this report.^gThe 1993 discharged spent nuclear fuel mass is a BWR and PWR mass sum rounded to the nearest metric ton. Such rounding may result in slight differences between the spent nuclear fuel inventories and projections reported in this document and those reported by DOE/EIA.^hProjected D&D wastes from light-water reactors shut down after 1993. Wastes collected from historical D&D of reactors are included in the LLW inventories listed above.

The Palo Verde Nuclear Generating Station, three 1270-MW(e) pressurized-water reactors, located in Wintersburg, Arizona. Courtesy of the Arizona Public Service Company, Phoenix, Arizona.

1. SPENT NUCLEAR FUEL

1.1 INTRODUCTION

This chapter reports the quantities and characteristics of spent nuclear fuel that has been permanently discharged from commercial LWRs and one-of-a-kind reactors. In addition, this chapter contains a mass summary report of DOE spent nuclear fuel which is not scheduled for reprocessing. Though currently in storage at numerous commercial and DOE sites, this fuel will ultimately require geologic disposal.

For inventories of special fuels (from DOE/civilian development programs) stored at various DOE and commercial sites as of December 31, 1993, the reader is referred to Sect. 1.4 and Appendix A. Though now in storage at the locations cited in Sect. 1.4 and Appendix A, these special fuels also may possibly require geologic disposal.

Some commercial spent nuclear fuel in inventory will be reinserted into reactors for further irradiation. However, this amount is relatively small, and the schedules for reinsertion are not always predictable. Therefore, for the purposes of this report, all spent nuclear fuel is considered permanently discharged from the reactors.

Historical inventories of LWR spent nuclear fuel have been updated through December 31, 1993.¹ The data reported in this chapter include the inventories of spent nuclear fuel stored at the West Valley Demonstration Project (WVDP), the Midwest Fuel Recovery Plant (MFRP), and the Idaho National Engineering Laboratory (INEL) sites in addition to those stored at the various reactor sites. The map in Fig. 1.1 shows the locations of existing and planned power reactor sites and commercial LWR spent nuclear fuel storage facilities. A list of commercial reactors is given also in report DOE/OSTI-8200-R57 (ref. 2).

Projections of nuclear capacity and spent nuclear fuel discharges are given for the years 1994–2030 for the DOE/EIA No-New-Orders-Case forecast schedule reported in ref. 3. The No-New-Orders-Case forecast projects installed capacity to increase from 99.0 GW(e) at the end of 1993 to 102.5 GW(e) by the year 2000, ultimately decreasing to 5.9 GW(e) by 2030.

The No-New-Orders-Case reference scenario considered for projecting accumulated spent nuclear fuel assumes a fuel cycle with no reprocessing. Commercial spent nuclear fuel projections developed for the DOE/EIA No New Orders Case are illustrated, along with historical discharge data, in Figs. 1.2–1.4. Spent nuclear fuel discharge projections, in terms of annual mass discharged and accumulated radioactivity, are graphically illustrated in Figs. 1.2 and 1.3, respectively. A graph showing the increase in the cumulative mass of discharged spent nuclear fuel for the DOE/EIA No New Orders Case is shown in Fig. 1.4. This plot also shows both the age and mass distribution for spent nuclear fuel from 1970 to 2030.

DOE/EIA projections for the No New Orders Case assume that burnup levels of discharged spent nuclear fuel will increase from their current average levels of 30,318 and 38,884 MWd/MTIHM for BWR and PWR fuel, respectively, at the rate of about 1.0% per year for BWR fuel and about 1.3% per year for PWR fuel. This increase in burnup is projected to occur from 1993 to approximately 2018 for BWR fuel and from 1993 to approximately 2013 for PWR fuel, at which times the equilibrium cycle discharges will level out at values of roughly 42,000 and 52,000 MWd/MTIHM (ref. 3) for BWR and PWR fuel, respectively. The final cycle discharges will be somewhat lower because most of the final cycle cores will not have achieved the projected design burnups. Figure 1.5 graphically illustrates how the activity and thermal power of BWR and PWR spent nuclear fuels vary with burnup and time from discharge.⁴ A bar chart indicating the actual and projected cumulative mass of DOE spent nuclear fuel is shown in Fig. 1.6.

1.2 COMMERCIAL SPENT NUCLEAR FUEL

1.2.1 Inventories and projections

The total inventory of commercial LWR spent nuclear fuel in storage at the WVDP site, the MFRP, INEL, and the reactor sites as of December 31, 1993, amounted to

28,030 MTIHM. Of this total amount, 27 MTIHM are in storage at the WVDP site,⁵ 674 MTIHM are in storage at the MFRP,¹ and 43 MTIHM are in storage at INEL.¹ The remainder is stored at the reactor sites. These inventories do not include the spent nuclear fuel reprocessed at the WVDP site when the facility was operated as a fuel reprocessing plant. Additional information on WVDP spent nuclear fuel inventories is given in Chapter 7, Table 7.22. Details concerning the spent nuclear fuel reprocessed at West Valley may be obtained from ref. 6.

A BWR/PWR breakdown of the electric power generating capacity for the No-New-Orders-Case forecast, along with historical reactor capacity data, is given in Table 1.1. Table 1.2 gives the projected cumulative mass of commercial spent nuclear fuel discharges associated with the DOE/EIA capacity-growth forecast given in Table 1.1. The historical and projected buildups of permanently discharged BWR and PWR spent nuclear fuel mass, radioactivity, and thermal power are given for the DOE/EIA No New Orders Case in Table 1.3. Projections of the number of permanently discharged BWR and PWR spent nuclear fuel assemblies for the DOE/EIA No New Orders Case are given in Table 1.4.

The historical and projected mass of spent nuclear fuel discharged from a one-of-a-kind reactor, the Fort St. Vrain HTGR,⁷ is given in Table 1.5. All of the discharged nuclear fuel from the Fort St. Vrain reactor that has been shipped off-site is located at the ICPP (see Table A.3 in Appendix A). The Fort St. Vrain reactor was permanently shut down in 1989.

1.2.2 Characterization

Reference characteristics of BWR and PWR fuel assemblies, obtained from refs. 8 and 9, were used for this report. These characteristics are summarized in Table 1.6. Fuel assembly structural material masses and compositions, nonactinide fuel impurities, and other physical and irradiation characteristics of LWR spent nuclear fuel are discussed in ref. 10. More detailed information on spent nuclear fuel characteristics may be found in ref. 11. The BWR and PWR spent nuclear fuel annually discharged has a broad range of burnup levels, as illustrated in Tables 1.7 and 1.8, respectively. The mass, radioactivity, and thermal power of the nuclides contained in all stored domestic commercial LWR spent nuclear fuel as of December 31, 1993, are listed in Table C.2 in Appendix C.

1.3 DISPOSAL

Surface-based studies for the determination of the suitability of the Yucca Mountain site in Nevada for development of the nation's first geologic repository continued. In addition, the 25-ft diameter Tunnel Boring Machine is in place, and operational testing began on September 20, 1994. After approximately six months of testing, full Tunnel Boring Machine operations are scheduled to begin in the second quarter of FY 1995. A DOE decision on technical site suitability is expected in 1998.

The investigation of the multipurpose-canister concept involved the development of a conceptual design, numerous supporting studies, evaluations of alternative cask and canister concepts, and input from stakeholders. Based on these activities, the decision was made to invite private vendors to submit designs for components of the multipurpose-canister-based system. On June 3, 1994, a package of information was provided to individuals responding to a DOE contractor (TRW Environmental Safety Systems, Inc.) request for proposals announcement, which was published in the May 11, 1994, issue of the *Commerce Business Daily*. One or more design contracts are expected to be awarded in early 1995.

1.4 DOE SPENT NUCLEAR FUEL

Summary inventory characteristics of DOE spent nuclear fuel as of December 31, 1993 are given in Table 1.9 (based on refs. 12 and 13). Projected site inventories for the year 2035 reported to the DOE Office of Spent Fuel Management (DOE/EM-37) are reported in Table 1.10 (based on ref. 14).

For purposes of clarification, the quantities of spent nuclear fuel reported in Tables 1.9 and 1.10 include contributions from other nuclear fuels besides those permanently discharged from production reactors. Spent nuclear fuels reported in these tables also include DOE-owned nuclear fuel that has been withdrawn from or resides for storage in a nuclear reactor following irradiation, the constituent elements of which have not been separated by processing. In addition to intact fuel, reactor-irradiated fuel materials requiring special handling (e.g., defective fuel and special fuel forms) are also considered spent nuclear fuel and are eligible for inclusion in Tables 1.9 and 1.10. These tables also list some commercially generated nuclear fuels and nuclear fuels from foreign reactors and university research reactors which are stored at DOE sites. More detailed information on these special nuclear fuels will be included in future updates of this report.

1.5 REFERENCES

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COMMERCIAL NUCLEAR POWER REACTORS IN THE UNITED STATES

31 DECEMBER 1993

Fig. 1.1. Locations of existing and planned commercial reactors as of December 31, 1993. Courtesy of U.S. Department of Energy, Office of Scientific and Technical Information, Oak Ridge, Tennessee.

Fig. 1.2. Projected mass (MTIHM) of annual commercial spent nuclear fuel discharges for the DOE/EIA No New Orders Case.

Fig. 1.3. Projected cumulative radioactivity of commercial spent nuclear fuel discharges for the DOE/EIA No New Orders Case.

Fig. 1.4. Projected cumulative mass (MTIHM) of commercial spent nuclear fuel discharges for the DOE/EIA No New Orders Case.

BOILING-WATER REACTOR SPENT FUEL

PRESSURIZED-WATER REACTOR SPENT FUEL

Fig. 1.5. Radioactivity and thermal power of 1 MTIHM of BWR and PWR spent nuclear fuel as a function of burnup and time from reactor discharge.

Fig. 1.6. Actual and projected cumulative mass (MTHM) of DOE spent nuclear fuel.

Table 1.1. Historical and projected installed LWR electric power generating capacity for the DOE/EIA No New Orders Case

End of calendar year	Historical capacity ^a [GW(e)]			End of calendar year	No New Orders Case projected capacity ^b [GW(e)]		
	BWR	PWR	Total		BWR	PWR	Total
1960	0.1	0.2	0.3	1994	31.8	67.2	99.0
1961	0.1	0.2	0.3	1995	31.8	68.4	100.2
1962	0.1	0.2	0.4	1996	31.8	68.4	100.2
1963	0.1	0.2	0.4	1997	31.8	69.6	101.4
1964	0.1	0.2	0.4	1998	31.8	69.6	101.4
1965	0.1	0.2	0.4	1999	31.8	70.8	102.6
1966	0.1	0.2	0.4	2000	31.8	70.8	102.5
1967	0.1	1.3	1.4	2001	31.8	70.8	102.5
1968	0.2	1.2	1.4	2002	31.8	72.0	103.7
1969	0.8	1.7	2.6	2003	31.8	72.0	103.7
1970	2.9	2.9	5.8	2004	31.8	72.0	103.7
1971	4.3	3.7	8.0	2005	31.8	72.0	103.7
1972	7.0	6.5	13.5	2006	31.0	72.0	103.0
1973	8.1	14.1	22.1	2007	31.0	69.3	100.3
1974	13.3	19.4	32.7	2008	28.9	66.9	95.8
1975	15.0	23.3	38.3	2009	27.7	66.4	94.1
1976	16.8	27.9	44.7	2010	26.5	64.2	90.7
1977	16.8	30.4	47.2	2011	25.7	64.2	89.9
1978	17.6	32.2	49.8	2012	23.0	63.4	86.4
1979	17.6	32.2	49.8	2013	22.0	54.3	76.2
1980	17.6	34.3	51.9	2014	17.3	49.4	66.8
1981	17.6	38.6	56.2	2015	17.3	47.6	64.9
1982	18.7	40.5	59.2	2016	15.5	43.2	58.7
1983	19.7	43.6	63.3	2017	15.5	40.4	55.9
1984	24.2	45.8	70.0	2018	14.7	38.7	53.4
1985	26.8	51.7	78.5	2019	14.7	38.7	53.4
1986	28.9	55.2	84.1	2020	14.7	35.6	50.3
1987	31.8	60.8	92.6	2021	14.7	32.5	47.2
1988	31.8	63.1	94.9	2022	11.5	31.6	43.1
1989	33.8	64.1	97.9	2023	9.3	29.7	39.0
1990	32.9	66.7	99.6	2024	7.2	24.0	31.2
1991	32.0	67.7	99.6	2025	5.2	20.4	25.6
1992	31.8	67.1	98.9	2026	1.1	15.1	16.1
1993	31.8	67.2	99.0	2027	1.1	9.5	10.5
				2028	1.1	8.2	9.3
				2029	0.0	7.1	7.1
				2030	0.0	5.9	5.9

^aBased on ref. 1.

^bData from ref. 3. Assumes that no new reactors will be ordered.

Table 1.2. Projected cumulative mass of commercial spent nuclear fuel discharges for the DOE/EIA No New Orders Case

End of calendar year	Mass (10 ³ MTIHM)	End of calendar year	Mass (10 ³ MTIHM)
1993 ^a	28.0	2012	66.1
1994 ^b	29.9	2013	68.4
1995	32.3	2014	70.5
1996	34.1	2015	71.9
1997	36.1	2016	73.4
1998	38.1	2017	74.7
1999	40.0	2018	75.8
2000	42.2	2019	76.7
2001	44.2	2020	77.7
2002	46.2	2021	78.8
2003	48.2	2022	80.2
2004	50.4	2023	81.0
2005	51.9	2024	82.3
2006	54.4	2025	83.2
2007	56.3	2026	84.3
2008	58.6	2027	84.9
2009	60.6	2028	85.1
2010	62.5	2029	85.4
2011	64.3	2030	85.6

^aReported historical data from ref. 1.

^bData for years 1994–2030 from ref. 3.

Table 1.3. Historical and projected mass, radioactivity, and thermal power of permanently discharged spent nuclear fuel by reactor type for the DOE/EIA No New Orders Case

End of calendar year	Mass, ^{a,b} MTIHM		Radioactivity, 10 ⁶ Ci		Thermal power, 10 ⁶ W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Boiling-water reactor</i>						
1968–1970		16		11		0.0
1971	65	81	193	199	0.8	0.8
1972	146	226	446	481	1.7	1.9
1973	94	320	344	439	1.4	1.7
1974	241	561	897	1,033	3.5	4.0
1975	226	787	920	1,216	3.7	4.7
1976	297	1,084	1,151	1,580	4.5	6.1
1977	383	1,467	1,565	2,129	6.2	8.2
1978	383	1,850	1,618	2,411	6.5	9.3
1979	400	2,250	1,734	2,728	7.1	10.5
1980	620	2,870	2,685	3,888	10.9	15.1
1981	459	3,329	2,014	3,664	8.2	14.0
1982	357	3,686	1,582	3,362	6.5	12.6
1983	491	4,177	2,218	4,015	9.1	15.1
1984	498	4,675	2,210	4,283	9.0	16.0
1985	532	5,207	2,317	4,589	9.4	17.0
1986	458	5,665	1,963	4,424	8.0	16.1
1987	643	6,308	2,738	5,241	11.1	19.2
1988	536	6,844	2,363	5,158	9.7	18.8
1989	698	7,542	3,023	5,965	12.3	21.9
1990	633	8,175	2,821	6,082	11.6	22.2
1991	588	8,763	2,696	6,177	11.1	22.5
1992	695	9,458	3,213	6,885	13.3	25.3
1993	721	10,178	3,354	7,386	13.9	27.2
1994	700	10,800	3,100	7,500	13.1	27.6
1995	800	11,700	3,900	8,500	16.4	31.8
1996	600	12,200	2,700	7,900	11.6	28.8
1997	700	12,900	3,100	8,300	13.2	30.4
1998	700	13,600	3,500	8,900	14.7	32.7
1999	600	14,100	2,700	8,500	11.6	30.8
2000	800	14,900	3,800	9,600	16.1	35.3
2001	500	15,500	2,600	8,900	11.0	32.0
2002	700	16,100	3,300	9,600	14.2	34.9
2003	700	16,800	3,500	10,000	14.7	36.6
2004	700	17,500	3,400	10,300	14.5	37.5
2005	500	18,000	2,500	9,600	10.6	34.5
2006	800	18,800	3,900	10,900	16.3	39.7
2007	700	19,500	3,200	10,700	13.8	39.0
2008	800	20,300	3,800	11,400	15.8	41.6
2009	900	21,200	4,200	12,200	17.8	44.6
2010	600	21,700	2,600	11,000	11.0	39.4
2011	800	22,500	3,800	12,000	16.0	43.3
2012	800	23,300	3,700	12,300	15.3	44.1
2013	600	23,900	2,700	11,400	11.3	40.6
2014	1,000	24,800	4,500	13,100	18.4	47.1
2015	500	25,300	2,300	11,400	9.9	40.5
2016	400	25,700	1,900	10,700	7.8	37.3
2017	500	26,100	2,400	10,900	10.1	38.4
2018	300	26,400	1,500	10,100	6.2	34.9
2019	300	26,800	1,700	10,000	7.1	34.8
2020	300	27,100	1,600	9,900	6.9	34.5

Table 1.3 (continued)

End of calendar year	Mass, ^{a,b} MTIHM		Radioactivity, 10 ⁶ Ci		Thermal power, 10 ⁶ W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Boiling-water reactor (continued)</i>						
2021	200	27,300	1,100	9,300	4.8	32.3
2022	700	28,000	3,300	11,300	13.8	40.5
2023	300	28,300	1,400	10,000	5.9	34.8
2024	500	28,800	2,100	10,400	8.7	36.4
2025	300	29,100	1,600	9,800	6.4	34.3
2026	500	29,700	2,300	10,400	9.2	36.6
2027	0	29,700	200	8,400	1.0	28.7
2028	0	29,700	0	7,600	0.0	25.6
2029	100	29,800	600	7,800	2.5	26.6
2030	0	29,800	0	7,100	0.0	23.8
<i>Pressurized-water reactor</i>						
1970	39	39	204	204	0.8	0.8
1971	44	83	247	296	1.0	1.2
1972	100	183	545	638	2.2	2.5
1973	67	250	374	571	1.5	2.2
1974	208	458	1,097	1,320	4.4	5.2
1975	322	780	1,683	2,098	6.7	8.2
1976	401	1,181	2,222	2,894	8.9	11.3
1977	467	1,648	2,659	3,676	10.8	14.5
1978	699	2,347	4,030	5,428	16.4	21.5
1979	721	3,068	4,185	6,254	17.1	24.7
1980	618	3,686	3,667	6,248	15.0	24.5
1981	676	4,362	4,025	6,887	16.5	26.9
1982	640	5,002	3,797	7,038	15.6	27.2
1983	771	5,774	4,585	8,072	18.8	31.1
1984	841	6,615	4,975	8,939	20.4	34.4
1985	861	7,476	5,194	9,638	21.4	37.0
1986	996	8,472	5,944	10,883	24.4	41.7
1987	1,109	9,581	6,659	12,206	27.4	46.8
1988	1,122	10,703	6,848	13,103	28.3	50.2
1989	1,215	11,919	7,353	14,265	30.3	54.4
1990	1,517	13,435	9,314	16,905	38.5	65.0
1991	1,283	14,718	7,959	16,743	33.0	63.9
1992	1,600	16,318	10,026	19,309	41.7	74.1
1993	1,534	17,851	9,823	20,269	41.0	77.7
1994	1,300	19,100	8,400	19,700	35.0	74.9
1995	1,500	20,600	9,700	21,400	40.9	81.6
1996	1,200	21,900	8,100	20,700	34.3	78.3
1997	1,400	23,300	9,000	21,900	38.0	82.7
1998	1,300	24,600	8,600	22,100	36.1	83.2
1999	1,300	25,900	8,800	22,800	37.4	86.0
2000	1,400	27,300	9,300	23,900	39.3	90.1
2001	1,400	28,800	9,300	24,600	39.4	92.6
2002	1,300	30,100	8,900	24,800	37.4	92.8
2003	1,300	31,400	8,500	24,900	35.9	92.7
2004	1,500	32,900	9,900	26,600	41.9	99.8
2005	1,000	33,900	6,800	24,400	28.6	89.9
2006	1,700	35,600	11,300	28,600	48.3	107.8
2007	1,300	36,900	8,400	27,200	35.3	101.1
2008	1,500	38,300	9,800	28,600	41.4	107.0

Table 1.3 (continued)

End of calendar year	Mass, ^{a,b} MTIHM		Radioactivity, 10 ⁶ Ci		Thermal power, 10 ⁶ W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Pressurized-water reactor (continued)</i>						
2009	1,200	39,500	7,800	27,400	33.2	101.6
2010	1,300	40,800	8,700	28,300	37.3	105.5
2011	1,000	41,800	6,900	27,100	29.8	100.0
2012	1,000	42,800	6,800	26,800	29.0	98.7
2013	1,800	44,600	11,600	31,700	48.9	118.5
2014	1,100	45,700	7,300	29,000	31.0	107.0
2015	900	46,600	6,300	27,600	26.9	101.4
2016	1,200	47,800	7,800	28,900	33.3	106.6
2017	800	48,600	5,300	26,900	22.8	97.9
2018	800	49,400	5,500	26,500	23.4	96.4
2019	600	50,000	4,300	25,200	18.5	91.0
2020	700	50,700	4,400	24,900	18.7	89.6
2021	800	51,500	5,500	25,700	23.3	93.3
2022	700	52,200	4,700	25,100	20.0	91.0
2023	500	52,700	3,400	23,700	14.5	85.2
2024	800	53,500	5,400	25,100	22.4	91.2
2025	600	54,100	3,800	23,800	15.9	85.8
2026	600	54,600	3,500	23,200	14.5	83.0
2027	600	55,200	3,700	23,000	15.5	82.5
2028	200	55,400	1,400	20,400	5.7	72.2
2029	200	55,600	1,300	19,500	5.7	68.8
2030	200	55,800	1,200	18,800	5.0	66.2
<i>Total</i>						
1968–1970		55		215		0.8
1971	109	164	440	494	1.7	1.9
1972	245	410	991	1,119	3.9	4.4
1973	161	570	718	1,011	2.9	3.9
1974	449	1,019	1,995	2,353	7.9	9.2
1975	547	1,567	2,603	3,314	10.3	12.9
1976	698	2,265	3,373	4,474	13.4	17.4
1977	850	3,115	4,225	5,805	17.0	22.6
1978	1,082	4,197	5,648	7,840	22.9	30.8
1979	1,121	5,318	5,920	8,982	24.1	35.2
1980	1,238	6,556	6,351	10,136	26.0	39.6
1981	1,135	7,691	6,039	10,551	24.7	40.9
1982	998	8,688	5,378	10,399	22.0	39.8
1983	1,263	9,951	6,804	12,088	27.9	46.3
1984	1,339	11,290	7,185	13,222	29.4	50.4
1985	1,393	12,682	7,511	14,227	30.8	54.0
1986	1,454	14,137	7,907	15,307	32.4	57.9
1987	1,753	15,890	9,397	17,447	38.5	66.0
1988	1,658	17,547	9,211	18,261	37.9	69.0
1989	1,913	19,461	10,376	20,229	42.6	76.3
1990	2,149	21,610	12,135	22,988	50.1	87.2
1991	1,871	23,480	10,654	22,920	44.1	86.4
1992	2,295	25,775	13,239	26,194	55.0	99.4
1993	2,254	28,030	13,177	27,655	55.0	105.0
1994	1,900	30,000	11,500	27,200	48.1	102.5
1995	2,300	32,300	13,600	29,900	57.3	113.4
1996	1,800	34,100	10,900	28,600	45.9	107.1

Table 1.3 (continued)

End of calendar year	Mass, ^{a,b} MTIHM		Radioactivity, 10 ⁶ Ci		Thermal power, 10 ⁶ W	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Total (continued)</i>						
1997	2,000	36,100	12,200	30,200	51.3	113.1
1998	2,000	38,200	12,100	31,000	50.8	115.9
1999	1,900	40,100	11,600	31,300	49.0	116.8
2000	2,200	42,300	13,100	33,500	55.4	125.4
2001	1,900	44,200	11,900	33,500	50.4	124.7
2002	2,000	46,200	12,200	34,400	51.6	127.8
2003	2,000	48,200	11,900	34,900	50.6	129.3
2004	2,200	50,400	13,300	36,900	56.4	137.3
2005	1,500	51,900	9,300	34,000	39.2	124.4
2006	2,500	54,400	15,200	39,500	64.6	147.5
2007	1,900	56,400	11,600	37,900	49.1	140.1
2008	2,300	58,600	13,600	40,100	57.3	148.6
2009	2,000	60,700	12,000	39,600	51.0	146.2
2010	1,800	62,500	11,400	39,400	48.4	145.0
2011	1,800	64,300	10,700	39,000	45.7	143.3
2012	1,800	66,100	10,500	39,100	44.4	142.8
2013	2,300	68,400	14,300	43,100	60.2	159.1
2014	2,100	70,500	11,800	42,000	49.4	154.1
2015	1,400	71,900	8,600	39,100	36.8	141.9
2016	1,600	73,400	9,700	39,600	41.0	143.9
2017	1,300	74,700	7,700	37,800	32.9	136.3
2018	1,100	75,800	6,900	36,600	29.6	131.3
2019	1,000	76,800	5,900	35,200	25.7	125.8
2020	1,000	77,800	6,000	34,800	25.6	124.0
2021	1,000	78,800	6,600	35,100	28.1	125.5
2022	1,400	80,200	8,000	36,400	33.9	131.6
2023	800	81,000	4,800	33,700	20.3	120.0
2024	1,300	82,300	7,500	35,500	31.1	127.5
2025	900	83,200	5,300	33,700	22.3	120.2
2026	1,100	84,300	5,800	33,600	23.7	119.6
2027	600	84,900	3,900	31,400	16.4	111.2
2028	200	85,100	1,400	28,100	5.7	97.8
2029	300	85,500	1,900	27,300	8.1	95.3
2030	200	85,700	1,200	25,800	5.0	90.0

^aRef. 1 (1968–1993).^bRef. 3 (1994–2030). Assumes no future reprocessing.

Table 1.4. Projected number of permanently discharged LWR spent nuclear fuel assemblies for the DOE/EIA No New Orders Case

End of calendar year	BWR		PWR		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1993 ^a	3,997	56,106	3,535	41,684	7,532	97,790
1994 ^b	3,700	59,800	3,000	44,700	6,700	104,500
1995	4,600	64,400	3,500	48,100	8,000	112,500
1996	3,200	67,600	2,900	51,000	6,100	118,600
1997	3,700	71,300	3,200	54,200	6,900	125,500
1998	4,100	75,400	3,000	57,200	7,100	132,600
1999	3,200	78,600	3,100	60,300	6,300	138,900
2000	4,500	83,100	3,300	63,700	7,800	146,700
2001	3,000	86,100	3,300	67,000	6,300	153,100
2002	3,900	90,000	3,100	70,100	7,000	160,100
2003	4,000	94,100	3,000	73,100	7,000	167,100
2004	4,000	98,000	3,500	76,500	7,400	174,500
2005	2,900	100,900	2,400	78,900	5,300	179,800
2006	4,600	105,500	3,900	82,800	8,500	188,400
2007	3,800	109,300	3,000	85,800	6,800	195,100
2008	4,500	113,800	3,400	89,200	7,900	203,100
2009	5,000	118,900	2,700	91,900	7,700	210,800
2010	3,200	122,000	3,000	94,900	6,100	216,900
2011	4,500	126,500	2,400	97,300	6,900	223,800
2012	4,600	131,100	2,300	99,500	6,800	230,600
2013	3,200	134,200	4,100	103,600	7,300	237,900
2014	5,400	139,600	2,500	106,200	7,900	245,800
2015	2,700	142,200	2,100	108,300	4,800	250,600
2016	2,200	144,400	2,700	111,000	4,900	255,500
2017	2,700	147,100	1,800	112,800	4,500	259,900
2018	1,700	148,800	1,800	114,700	3,500	263,500
2019	1,900	150,700	1,500	116,100	3,300	266,800
2020	1,900	152,600	1,500	117,600	3,300	270,100
2021	1,300	153,800	1,900	119,500	3,200	273,300
2022	4,000	157,900	1,600	121,000	5,600	278,900
2023	1,800	159,600	1,200	122,200	3,000	281,900
2024	2,600	162,300	1,900	124,200	4,600	286,400
2025	1,800	164,100	1,300	125,500	3,200	289,600
2026	2,900	167,000	1,300	126,800	4,200	293,800
2027	200	167,300	1,300	128,100	1,500	295,300
2028	0	167,300	400	128,500	400	295,800
2029	800	168,000	500	129,000	1,200	297,000
2030	0	168,000	400	129,400	400	297,400

^aReported historical data (ref. 1).

^bData for years 1994–2030 are based on 102.5 GW(e) installed in the year 2000 and on 5.9 GW(e) installed in the year 2030 (ref. 3). Number of projected fuel assemblies reported has been rounded to the nearest 100.

Table 1.5. Spent nuclear fuel discharges from the Fort St. Vrain HTGR^a

End of calendar year	Number of fuel assemblies discharged		Mass of fuel discharged (MTIHM)	
	Annual	Cumulative	Annual	Cumulative
1979	246 ^b	246	2.80	2.80
1980	0	246	0.00	2.80
1981	240	486	2.77	5.57
1982	0	486	0.00	5.57
1983	0	486	0.00	5.57
1984	240	726	2.85	8.42
1985	0	726	0.00	8.42
1986	0	726	0.00	8.42
1987	0	726	0.00	8.42
1988	0	726 ^c	0.00	8.42
1989 ^{d,e}	126	852	1.32	9.74
1990 ^d	332	1,184	3.49	13.23
1991 ^f	42	1,226	0.48	13.71
1992 ^g	982	2,208	10.29	24.00
1993	0	2,208	0.00	24.00
1994–1998 ^h	0	2,208	0.00	24.00

^aData obtained from ref. 7. Discharges identified in this table are those made directly from the reactor.

^bThis refueling replaced 240 standard fuel elements and 6 fuel test elements.

^cAll spent nuclear fuel discharged prior to December 31, 1988, is located at the ICPP (see Table A.3 of Appendix A).

^dFuel removed from the reactor in 1989 and 1990 was temporarily stored in on-site storage wells.

^ePower operations effectively ceased on August 18, 1989.

^fIn 1991, 18 of the discharged spent nuclear fuel elements were sent to ICPP, 18 elements were transferred to an on-site independent spent nuclear fuel storage installation (ISFSI), and 6 elements were temporarily stored in on-site storage wells.

^gAll spent nuclear fuel elements have been discharged from the reactor and transferred to the ISFSI. All spent nuclear fuel elements in temporary on-site storage wells have been relocated to the ISFSI.

^hDuring this period, Public Service Company of Colorado plans to ship the 1,464 elements currently in the ISFSI to ICPP once legal issues have been resolved.

Table 1.6. IDB reference characteristics of LWR nuclear fuel assemblies

Characteristics	BWR ^a	PWR ^b
Overall assembly length, m	4.470	4.059
Cross section, cm	13.9 × 13.9	21.4 × 21.4
Fuel rod length, m	4.064	3.851
Active fuel height, m	3.759	3.658
Fuel rod outer diameter, cm	1.252	0.950
Fuel rod array	8 × 8	17 × 17
Fuel rods per assembly	63	264
Assembly total weight, kg	319.9	657.9
Uranium/assembly, kg	183.3	461.4
UO ₂ /assembly, kg	208.0	523.4
Zircaloy/assembly, kg	103.3 ^c	108.4 ^d
Hardware/assembly, kg	8.6 ^e	26.1 ^f
Total metal/assembly, kg	111.9	134.5
Nominal volume/assembly, m ³	0.0864 ^g	0.186 ^g

^aRef. 8.^bRef. 9.^cIncludes Zircaloy fuel-rod spacers and fuel channel.^dIncludes Zircaloy control-rod guide thimbles.^eIncludes stainless steel tie-plates, Inconel springs, and plenum springs.^fIncludes stainless steel nozzles and Inconel-718 grids.^gBased on overall outside dimension. Includes spacing between the stacked fuel rods of an assembly.

Table 1.7. Historical mass of commercial BWR spent nuclear fuel discharged at various ranges of burnup^{a,b}

End of calendar year	Annual mass of discharged spent nuclear fuel for various burnup ranges, MTIHM									Total annual mass over all burnup ranges (MTIHM)
	0- 4,999 ^c	5,000- 9,999	10,000- 14,999	15,000- 19,999	20,000- 24,999	25,000- 29,999	30,000- 34,999	35,000- 39,999	40,000- 44,999	
1968	0.6									0.6
1969		1.2	1.0	7.3	0.2	0.1				9.8
1970	5.6									5.6
1971	41.7	8.6	2.8	10.0	1.6					64.7
1972	97.9	11.9	31.1	4.2	0.5					145.6
1973	9.7	17.2	28.8	36.7	1.0	0.1				93.5
1974		78.6	114.2	44.8	3.8					241.4
1975	0.3	1.7	62.0	136.4	25.3					225.6
1976	0.9	67.1	108.7	118.4	2.3					297.3
1977		48.0	40.3	235.0	58.9	0.7				382.9
1978	6.3	32.4	13.1	84.2	232.0	15.2				383.2
1979			18.6	108.7	149.2	123.0	0.2			399.8
1980	14.0	0.4	0.6	93.3	413.3	87.6	10.7			619.8
1981		0.2	0.2	58.1	265.4	133.3	0.7	0.7		458.7
1982		0.2	4.6	25.6	138.5	173.6	13.8	0.6	0.4	357.2
1983			0.9	2.9	113.5	337.8	35.7	0.4		491.3
1984		7.9	43.0	0.3	136.0	239.5	70.8		0.4	497.9
1985	16.9	42.5	18.5	39.5	106.3	297.4	10.2		0.2	531.6
1986	50.8	32.4	42.5	66.6	43.1	180.8	41.7	0.4		458.3
1987	77.5	36.1	68.8	40.8	24.7	352.5	42.9		0.4	643.5
1988	17.0	24.5	1.8	42.9	168.3	192.4	88.7			535.6
1989	30.9	16.9	68.4	71.8	193.2	227.7	85.5	3.6		698.0
1990	17.0		34.0	67.6	106.2	247.5	158.9	1.6		632.8
1991	17.8	24.6		7.2	23.9	215.0	287.2	12.1		588.0
1992			7.6	75.7	62.5	83.9	361.9	103.4		695.0
1993				31.0	47.4	144.8	374.9	122.7		720.9

^aBased on ref. 1.

^bDoes not include commercial spent nuclear fuel reprocessed at WVDP.

^cBurnup range is given in units of MWd/MTIHM.

Table 1.8. Historical mass of commercial PWR spent nuclear fuel discharged at various ranges of burnup^{a,b}

End of calendar year	Annual mass of discharged spent nuclear fuel for various burnup ranges, MTIHM												Total annual mass over all burnup ranges (MTIHM)
	0- 4,999 ^c	5,000- 9,999	10,000- 14,999	15,000- 19,999	20,000- 24,999	25,000- 29,999	30,000- 34,999	35,000- 39,999	40,000- 44,999	45,000- 49,999	50,000- 54,999	55,000- 59,999	
1970			1.7	37.3									39.0
1971		4.6			6.2	33.7							44.5
1972			11.9	29.3	27.8	8.9	22.1						99.9
1973				26.1		33.3	7.6						67.1
1974	7.4	1.5	86.4	13.6	40.5	57.2	1.1						207.7
1975	2.7	42.6	95.0	53.6	79.3	25.3	23.1						321.8
1976			5.6	194.2	82.4	63.3	55.4						401.0
1977			2.8	108.3	113.0	140.3	87.1	15.4					466.9
1978		1.4	47.9	89.8	45.6	330.4	123.1	60.4	0.4				699.1
1979			30.6	109.4	64.0	232.3	234.3	50.1	0.5				721.2
1980			0.4		66.8	241.8	280.6	26.3	2.0				618.1
1981			17.2	1.9	25.8	228.5	351.1	50.1	1.3				675.9
1982			1.8	81.2	80.4	61.4	290.2	120.2	2.7	0.4	1.3	0.9	640.4
1983		5.5	3.1	80.6	44.2	170.3	330.4	131.4	5.4		0.5		771.3
1984			58.0	45.2	56.3	191.6	381.2	104.9	4.1				841.3
1985				49.0	13.6	216.7	317.8	239.4	24.1	0.4			860.9
1986		0.8	27.6	131.1	15.6	179.8	337.7	265.6	35.5	1.3	1.3		996.2
1987			27.2	77.7	53.4	175.3	411.8	312.1	51.8				1,109.2
1988				83.9	14.7	139.2	345.1	429.3	103.1	4.6	0.4	2.0	1,122.2
1989			47.1	91.4	68.6	112.1	283.0	408.4	189.1	15.2		0.4	1,215.3
1990			24.0	85.2	20.3	121.2	398.0	611.3	249.2	7.0	0.3		1,516.6
1991		9.2	53.2	1.4	79.0	60.5	148.8	606.2	256.8	64.2	3.4		1,282.6
1992		19.8	14.8	43.7	15.0	115.5	287.7	464.8	504.9	118.9	14.8		1,600.0
1993			0.5	4.1	22.4	66.9	167.3	446.5	629.7	194.0	2.1		1,533.6

^aBased on ref. 1.

^bDoes not include commercial spent nuclear fuel reprocessed at WVDP.

^cBurnup range is given in units of MWd/MTIHM.

Table 1.9. Summary inventory characteristics of DOE spent nuclear fuel as of December 31, 1993^a

Site	Spent nuclear fuel source/type	Number/type of fuel components	Discharged mass		
			Total mass (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
ANL-E	Dresden Unit-2, H. B. Robinson, BR-3, Big Rock Point, and TMI-Unit 2	Fuel rod segments	b	b	0.019 ^c
	EBR-II and TREAT experiments	Whole pins, pin segments, and pellet fragments	b	b	0.014 ^c
	EBR-II, FFTF, and MTR experiments	Whole pins, pin segments, and pellet fragments	b	b	0.003 ^c
	EBR-II, FFTF, and TREAT experiments	Whole pins and pin segments; sodium-bonded	b	b	0.0042 ^c
	EBR-II, TREAT, and MTR experiments-IPNS target	Pin segments and clad pellets	b	b	0.033 ^c
	Oak Ridge Reactor experiments	Miniplates and plate segments	b	b	0.001 ^c
	Shippingport	Metallography mounts	b	b	<0.0001 ^c
	ANL-E mass total		>0.074	>0.074	0.074 ^c
ANL-W	EBR-II fuel and material in RSWF	Assemblies, blankets, and waste materials	b	b	11.330
	EBR-II fuel in EBR-II	Assemblies	b	b	17.810
	EBR-II fuel in HFEF	Assemblies, fuel elements, rods, plates	b	b	1.630
	NRAD fuel at NRAD	Assemblies and fuel elements	b	b	0.010
	TREAT and NRAD fuel at TREAT	Assemblies	b	b	0.010
	ZPPR fuel at ZPPR	Plates and rods in canisters	d	d	9.470
	ANL-W mass total		>40.260	>40.260	40.260
BNL ^c	Brookhaven Medical Research Reactor (BMRR)	35 fuel assemblies	0.1565	0.0053	0.0033
	High Flux Beam Reactor (HFBR)	867 fuel assemblies	3.7992	0.3295	0.2230
	BNL mass total		3.9557	0.3348	0.2263
HANF	DOE and commercial fuel	Fuel pieces	0.3	0.3	0.3
	FFTF DFA and TDFA	275 assemblies	47	9.6	9.0
	FFTF TFA	54 assemblies	9.5	2.1	2.0
	LWR commercial fuel	7 assemblies and pieces	3.20	2.5	2.3
	N-Reactor Mark IV and 1A fuel	103,661 assemblies	2,263	2,113.3	2,100
	Shippingport PWR Core II	72 assemblies	38.5	16.2	15.8

Table 1.9 (continued)					
Site	Spent nuclear fuel source/type	Number/type of fuel components	Discharged mass		
			Total mass (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
HANF (contd.)	Single Pass Reactor fuel	964 elements	3.4	3.4	3.38
	TRIGA	191 assemblies	0.46	0.04	0.036
	HANF mass total		2,365.36	2,147.44	2,132.816
INEL	ICPP Irradiated Fuel Storage Facility (IFSF)				
	Commercial fuel, TORY IIC, and TRIGA	2,216 fuel handling units	b	b	10.011
	ICPP 603 Pool				
	Navy, test reactor, and commercial fuel	4,149 fuel handling units	b	b	2.899
	ICPP 666 Pool				
	Navy, test reactor, and commercial fuel	3,654 fuel handling units	b	b	10.802
	ICPP 749 Drywells				
	Commercial fuel	1,347 fuel handling units	b	b	78.371
	MTR-type ARMF and CFRMF core in ARMF/CFRMF Canal	Elements and core filter assembly	b	0.231	0.231
	Naval Reactors Facility Extended Core Facility				
	Navy and commercial fuel	Elements and modules	230	b	4.1
	PBF Canal				
	PBF driver core rods	2,425 rods in 72 canisters	b	0.85	0.834
	TAN Pool				
	Commercial-type fuel rods	Rods	b	b	1.164
	LOFT fuel	Core assembly modules	b	b	2.178
	Loose fuel rod storage basket	Rods	b	b	0.312
	TMI fuel debris	Debris	b	b	81.595
TAN Test Pad	PWR commercial fuel	Assemblies and rods	b	b	38.370
	Test Reactor Area				
	ATR fuel in Canal	Elements	b	b	0.679
	ATR fuel in the reactor	Elements	b	b	0.046
	Commercial fuel, PBF driver core, and other test fuel in MTR Canal	110 canisters (rods, sections, pellets, etc.)	b	b	0.257
	INEL mass total		>457.765	>231.865	231.849

Table 1.9 (continued)					
Site	Spent nuclear fuel source/type	Number/type of fuel components	Discharged mass		
			Total mass (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
LANL ^f	CMR Building, MTR-type fuel	86 elements	0.51	0.020 ^g	0.026
	LANL mass total		0.51	0.020 ^g	0.026
ORNL	Building 4501 fuel sections	40 sections	0.0078	0.0069	0.0067
	Bulk Shielding Reactor fuel storage				
	BSR fuel	41 elements	0.184	0.007	b
	ORR fuel	32 elements	0.143	0.052	b
	High Flux Isotope Reactor fuel ^h	43 assemblies	6.02	0.434	0.3
	Homogeneous reactor fuel	135 gallons (0.511 m ³)	0.500	0.004	b
	MSRE fuel	Solidified salt	11.55	0.038	0.038
	Research fuel in Building 7920	Sheared fuel pins	0.006	0.004	0.004
	Research fuel in Buildings 3525, 7823A, 7827, and 7829	Fuel samples, targets, pieces, etc.	2.128	0.096	b
	Tower Shielding Reactor fuel	1 assembly	0.182	0.009	0.009
	ORNL mass total		20.721	0.651	>0.358
SNL/NM	Fuel in ACRR Facility	b	b	b	0.0006
	Fuel in Hot Cell Facility	b	b	b	0.0088
	Fuel in Manzano Storage Structure	b	b	b	0.0249
	Fuel in SNM Storage Structure	b	b	b	0.01118
	Fuel in SPR Facility	b	b	b	0.0290
	SNL/NM mass total	b	>0.07448	>0.07448	0.07448
SRS ⁱ	Receiving basin for off-site fuel	Assemblies and cans	b	b	43.3
	Other storage facilities (F-Canyon, H-Canyon, K, L, C, and P Reactor Basins)	Production fuel, sections, etc.	b	b	7.31
	SRS mass total		>50.61	>50.61	50.61

Table 1.9 (continued)					
Site	Spent nuclear fuel source/type	Number/type of fuel components	Discharged mass		
			Total mass (t)	Initial heavy metal (MTHM)	Discharged heavy metal (MTHM)
WVDP	Big Rock Point (BRP) fuel	85 assemblies	18.87	11.666	10.506 ^c
	Robert E Ginna (REG) fuel	40 assemblies	23.04	15.28	15.06 ^c
	WVDP mass total		41.91	26.946	25.566 ^c
Y-12	DOE Demonstration Reactor fuel	Core assembly	>0.002	0.002	0.002
	Health Physics Research Reactor fuel	Plates, rods, pins, and samples	0.204	0.184	0.184
	KSTR fuel	Grouted microspheres	0.132	0.023	0.023
	SNAP 10A Reactor fuel	Core assembly	>0.005	0.005	0.005
	Y-12 mass total		>0.343	0.214	0.214
Other	Foreign reactor fuel	b	b	b	b
	Non-DOE government-owned test reactors	b	b	b	b
	Non-government commercial test reactors	b	b	b	b
	University reactors	b	b	b	b
	Other mass total	b	b	b	b
	DOE complex mass total		>2,981.6	>2,498.5	>2,482.1
(Footnotes on next page.)					

Table 1.9 (continued)					
Site	Spent nuclear fuel source/type	Number/type of fuel components	Discharged mass		
			Total mass (t)	Initial heavy metal (MTIHM)	Discharged heavy metal (MTHM)
^a Based on refs. 12 and 13. Information as of January 1, 1994, unless otherwise indicated. The following abbreviations are used in this table: ACRR—Annular Core Research Reactor; ARMF—Advanced Reactivity Measurement Facility; ATR—Advanced Test Reactor; BR—Belgium Reactor; BSR—Bulk Shielding Reactor; CFRMF—Coupled Fast Reactivity Measurement Facility; CMR—Chemistry and Metallurgical Research; DFA—Driver fuel assemblies; EBR—Experimental Breeder Reactor; FFTF—Fast Flux Test Facility; HFEF—Hot Fuel Examination Facility; IFSF—Irradiated Fuel Storage Facility; IPNS—Intense pulsed neutron source; KSTR—Keuring van Electrotechnische Materialen Suspension Test Reactor; LOFT—Loss of Fluid Test; MSRE—Molten Salt Reactor Experiment; MTR—Materials Testing Reactor; NRAD—Neutron Radiography (Reactor); ORRR—Oak Ridge Research Reactor; PBF—Power Burst Facility; RSWF—Radioactive Scrap and Waste Facility; SNAP—Space Nuclear Auxiliary Power; SNM—special nuclear material; SPR—Sandia Pulsed Reactor; TAN—Test Area North; TDFA—test driver fuel assemblies; TFA—test fuel assemblies; TMI—Three Mile Island; TORY—Test of Rocket Yield (experimental propulsion reactor); TREAT—Transient Reactor Test Facility; TSR—Tower Shielding Reactor; and ZPPR—Zero Power Physics Reactor.					
^b Information not available.					
^c Metric tons of uranium (MTU).					
^d Classified.					
^e As of July 6, 1994.					
^f As of July 11, 1994.					
^g Metric tons of initial U-235.					
^h As of August 11, 1993.					
ⁱ Targets and similar materials are not included.					

Table 1.10. Projections of cumulative DOE spent nuclear fuel as of year 2035, by site and classification ^a						
Site	Spent nuclear fuel classification	Discharged mass			Total volume (m ³)	Thermal power (W)
		Total (t)	Uranium (MTU)	Heavy metal (MTHM)		
ANL-E	Commercial-type ^b fuel	0.04	0.02	0.02	<<0.1	0
	Test and experimental reactor/SSC	0.07	0.05	0.06	<<0.1	0
	ANL-E total	0.11	0.07	0.08	0	0
ANL-W	Test and experimental reactor fuel					
	SSC fuel	215.02	58.01	67.00	263.0	0
	ZC fuel	0.01	0.01	0.01	11.0	0
	ANL-W total	215.03	58.02	67.01	274.0	0
BNL	Al-clad fuel from High Flux Beam Reactor and Medical Research Reactor	8.03	1.74	1.75	15.1	0
HANF	Commercial-type fuel	3.2	2.30	2.32	5.2	0
	Defense production reactor fuel	2,266.44	2,099.34	2,103.40	205.3	c
	Test and experimental reactor fuel					
	SSC fuel	57.26	8.9	11.31	41.2	0
	ZC fuel (Shippingport PWR Core 2 blanket)	38.50	15.66	15.78	9.6	104
	HANF total	2,365.40	2,126.20	2,132.81	261.2	104
INEL	Commercial-type fuel	179.96	123.65	123.66	145.4	5
	Graphite fuel/Fort St. Vrain ^d	190.00	0.62	16.00	160.0	c
	Graphite fuel/other	161.00	0.64	11.60	132.7	50
	Naval reactors fuel					
	ICPP	350.00	6.85	6.85	95.0	0
	NRF/Shippingport PWR fuel	80.00	1.60	1.60	23.0	0
	NRF/other fuel	189.00	3.07	3.10	48.0	0
	Savannah River defense production and other Al-based fuel	29.17	2.83	2.84	28.7	1,368
	Test and experimental reactor fuel					
	SSC fuel	72.84	37.12	37.23	32.9	1,002
	ZC fuel	102.60	5.17	47.16	36.5	659
	INEL total	1,354.57	181.55	250.04	702.2	3,084

Table 1.10 (continued)						
Site	Spent nuclear fuel classification	Discharged mass			Total volume (m ³)	Thermal power (W)
		Total (t)	Uranium (MTU)	Heavy metal (MTHM)		
LANL	Savannah River defense production and other Al-based fuel	0.46	0.09	0.09	3.1	0
LTC	Commercial-type fuel	0.06	0.04	0.04	0.1	0
ORNL	Al-based fuel	23.66	1.67	1.66	22.1	c
	Commercial-type fuel	1.58	0.10	0.10	2.0	0
	Graphite fuel	0.55	0.01	0.01	0.5	0
	MSRE fuel	11.55	0.04	0.04	8.3	200
	Test and experimental reactor fuel	>0.84	0.20	0.22	c	0
	ORNL total	>38.18	2.02	2.03	>32.9	>200
SNL/NM	Savannah River defense production and other Al-based fuel	0.83	0.39	0.37	0.5	0
	Test and experimental reactor fuel					
	SSC fuel	0.22	0.07	0.08	1.2	0
	SNL/NM total	1.05	0.46	0.45	1.7	0
SRS	Commercial-type LWR fuel	3.62	11.09	4.55	3.1	0
	Savannah River defense production and other Al-based fuel	418.22	183.69	184.41	150.7	0
	Test and experimental reactor fuel					
	SSC fuel	1.32	0.62	0.62	4.4	0
	ZC fuel	120.48	11.88	11.93	5.8	0
	SRS total	543.64	207.28	201.51	164.1	0
WVDP	Commercial-type LWR fuel	42.00	26.00	27.00	4.8	0
Other	DOE fuel in foreign reactors					
	Al-based fuel	20.00	11.10	11.41	4.0	c
	SC fuel	1.00	0.22	0.22	1.0	c
	Foreign fuel total	21.00	11.32	11.63	5.0	c

Table 1.10 (continued)						
Site	Spent nuclear fuel classification	Discharged mass			Total volume (m ³)	Thermal power (W)
		Total (t)	Uranium (MTU)	Heavy metal (MTHM)		
Other (contd.)	Non-DOE government-owned test reactor fuel					
	Al-based fuel	1.48	0.31	0.31	1.5	0
	SSC fuel	1.93	0.14	0.14	3.5	0
	Non-DOE government fuel total	3.41	0.45	0.45	5.0	0
	Other Navy fuel	3,100.00	54.50	55.00	730.0	c
	University reactor fuel					
	Al-based fuel	25.65	4.70	4.70	6.5	0
	SSC research/test fuel	10.53	1.35	1.30	2.4	0
	ZC research/test fuel	2.00	0.59	0.59	1.0	0
	University fuel total	38.18	6.64	6.59	9.9	0
	Other total	3,162.59	72.91	73.67	749.9	0
	DOE complex total (CY 2035)	7,731.12	2,676.38	2,756.48	2,209.2	3,388
	DOE complex totals (other CYs)					
	CY 2005	5,362.02	2,627.75	2,710.71	1,641.1	3,388
	CY 1995	4,503.10	2,592.67	2,671.81	1,372.5	3,388
<p>^aBased on ref. 14. DOE totals for CYs 2005 and 1995 are also reported at the end of this table. DOE site abbreviations used are given in Appendix D. Other abbreviations used are: MSRE—Molten Salt Reactor Experiment; NRF—Naval Reactors Facility (at INEL); SSC—stainless steel clad; and ZC—Zircaloy-clad.</p> <p>^bCommercial-type fuel means commercial fuel sent to a DOE site for research and demonstration purposes.</p> <p>^cInformation not available.</p> <p>^dPublic Service Company of Colorado plans to ship the remainder of the discharged Fort St. Vrain fuel to the ICPP of INEL after legal issues have been fully resolved. Currently, this fuel is being held in the Independent Spent Fuel Storage Installation (ISFSI), which is adjacent to the Fort St. Vrain Reactor site.</p>						

LEGEND:

1. Control Room
2. Late Wash Facility
3. Cold Chemical Feeds
4. Nitrogen Storage
5. Waste Storage Tanks
6. Filter/Stripper Building

An aerial view of the In-Tank Precipitation Facility at the Savannah River Site. Courtesy of the U.S. Department of Energy, Savannah River Operations Office, Aiken, South Carolina.

2. HIGH-LEVEL WASTE

2.1 INTRODUCTION

High-level waste (HLW) is generated by the chemical reprocessing of spent research and production reactor fuel, irradiated targets, and naval propulsion fuel. It generally contains more than 99% of the nonvolatile fission products produced during reactor operation. HLW from a facility that recovers uranium and plutonium contains a residual amount of about 0.5% of those elements, while HLW from a facility that recovers only uranium contains a residual 0.5% of the uranium and essentially all of the plutonium. Most fission products have short half-lives and therefore quickly decay away. HLW radioactivity results primarily from radionuclides of cesium (^{137}Cs) and strontium (^{90}Sr); a very small amount results from the decay of transuranic (TRU) radionuclides.

As generated, HLW is a highly radioactive, acidic liquid which generates heat and must be handled remotely behind heavy shielding in corrosion-resistant vessels, usually made of stainless steel. At the Hanford Site (HANF), because stainless steel was in short supply, HLW was neutralized with caustic soda, and sodium nitrite was added for corrosion control so that HLW could be stored safely in carbon-steel tanks. This practice continued at HANF and the Savannah River Site (SRS) even when stainless steel became more readily available. Neutralization forms sodium nitrate (which remains in solution) and hydrated oxides of certain radionuclides and nonradioactive chemicals (which precipitate and collect as a sludge on the floor of the tank). In addition, ^{137}Cs is a major radionuclide which remains largely in solution. At the Idaho National Engineering Laboratory (INEL), however, the waste has always been stored as an acidic liquid initially and then converted later to a granular solid (calcine) by thermal processing which drives off water and decomposes nitrate salts to oxides.

The supernatant liquid from neutralization may become concentrated by evaporation, either by self-boiling or in evaporators. If enough water is removed from the waste, sodium nitrate and sodium nitrite will crystallize from the solution. The crystals then will settle to the bottom of the tank and on top of the sludge. If there are many crystals, a salt cake will form.

To reduce heat generation in tanks, the radionuclides ^{137}Cs and ^{90}Sr were removed from some HANF HLW and stored in concentrated form as purified compounds in capsules. Some of these capsules were leased to non-DOE organizations for beneficial uses. All capsules will be returned to DOE by the end of the leases.

Thus, HLW exists in a variety of physical or chemical forms (alkaline or acidic, supernatant liquid, sludge, salt cake, and calcine solid), all of which must be stored behind heavy shielding and usually in underground tanks or bins.

Most of the current U.S. inventory of HLW has resulted from DOE activities. It is stored at the SRS (Aiken, South Carolina), INEL (Idaho Falls, Idaho), and HANF (Richland, Washington). A small amount of HLW was generated by commercial operations at the Nuclear Fuel Services (NFS) plant near West Valley, New York, between 1966 and 1972, at a site owned by the New York State Energy Research and Development Authority (NYSERDA). After 1972, fuel reprocessing operations at this plant were discontinued permanently. In 1980, Congress passed the West Valley Demonstration Project (WVDP) Act (P.L. 96-368), which authorized DOE to conduct, jointly with NYSERDA (90% DOE, 10% NYSERDA), a demonstration of solidification of HLW for disposal and the decontamination and decommissioning (D&D) of facilities used in the demonstration. The HLW data presented in this chapter are based on separate submittals provided by HANF, INEL, SRS, and WVDP in ref. 1.

In 1992, DOE decided to phase out the reprocessing of irradiated nuclear fuel for the recovery of enriched uranium or plutonium in support of defense activities; thus, little additional HLW is expected to be generated by this source for the immediate future. However, some D&D activities may generate waste with radioactivity levels high enough such as to require management in ways similar to HLW. An example of such future activities would be the flushing of residual wastes found in reprocessing facilities.

2.2 INVENTORIES

Table 2.1 presents historical and projected volumes, radioactivity, and thermal power inventories of HLW

currently in storage. The radioactivity and resultant thermal power of HLW decay, over time, in a manner characteristic of the constituent radionuclides, but the volume depends, in large measure, on the specific treatment history of the waste as mentioned previously. Roughly speaking, taking into account all radionuclides in HLW, total radioactivity and thermal power each decrease about 2 to 4% per year within storage units to which no new waste has been added.

The relative volumes and radioactivity for the HLW stored at the four sites is shown graphically in Fig. 2.1. This information is further subdivided into physical form in Fig. 2.2. Locations of the four HLW sites and the relative volumes of HLW are shown in Fig. 2.3. Historical and projected volumes of HLW stored at each site are graphically illustrated in Fig. 2.4.

HLW will be immobilized and packaged for disposal in a licensed, mined geologic repository. Figs. 2.5–2.8 show, for each of the four sites, the general treatment processes by which the HLW will be immobilized to a form acceptable for disposal in a repository. Table 2.2 gives the projected volume, radioactivity, and thermal power for HLW immobilized as borosilicate glass or glass/ceramic at SRS, INEL, and WVDP. Projections for HANF are not included because material balances have not been finalized. Table 2.3 gives estimates, year-by-year and by site, of the number of HLW canisters to be produced based on reference flowsheets. Canister estimates for SRS [Defense Waste Processing Facility (DWPF)] and WVDP are fairly well established (both projects are scheduled to begin radioactive operations in FY 1996), while canister estimates for INEL and HANF are much less certain (pretreatment and waste minimization processes have not yet been finalized). Tables 2.4–2.5 give, respectively, the volume and radioactivity of stored HLW by site and by physical form. The history of HLW volumes (Table 2.6), radioactivity (Table 2.7), and thermal power (Table 2.8) is given by physical form; projections take into account current schedules for converting HLW to a form suitable for repository disposal. Significant changes in any of these tables from the previous edition are presented in Table 2.9. It should be noted that the radioactivity reported in Table 2.7 includes contributions from both parent and daughter products.

2.2.1 HLW Inventories at SRS (DOE)

SRS HLW is stored as alkaline liquid, sludge, salt cake, and precipitate. Current inventory of about 129,300 m³ is stored in underground, single- and double-shelled carbon-steel tanks. This waste consists mainly of alkaline liquid (61,400 m³), sludge (13,900 m³), and salt

cake (53,800 m³). Although reprocessing operations are being phased out, the preparation of some HLW for vitrification operations has generated cesium precipitate from the In-Tank Precipitation process. See Tables 2.4–2.5.

2.2.2 HLW Inventories at INEL (DOE)

INEL HLW is presently being stored as both acidic liquid and calcined solids. Underground, high-integrity, stainless-steel tanks contain about 6,800 m³ of acidic liquid waste. (Of this waste inventory, only 1,306 m³ is actual HLW; the rest is sodium-bearing waste which is managed the same way as HLW because of site practice.) Underground stainless-steel bins currently store (retrievably) about 3,838 m³ of calcine solids, an interim waste form. More than 90% of the total radioactivity is in the calcine. All liquid HLW at the INEL is expected to be calcined by the end of 1997. See Tables 2.4–2.5.

2.2.3 HLW Inventories at HANF (DOE)

HANF HLW is stored in underground carbon-steel tanks. Current inventory consists of 261,700 m³ of HLW stored as alkaline liquid (24,900 m³), sludge (46,000 m³), and salt cake (93,000 m³) in single-shell tanks; as slurry (97,800 m³) in double-shell tanks; as cesium and strontium salts in double-metal alloy capsules [commonly referred to as cesium (¹³⁷Cs) and strontium (⁹⁰Sr) capsules]. Currently, 1,328 cesium capsules and 605 strontium capsules require storage. Of the cesium capsules, 369 are off-site, and 959 are at HANF; of the strontium capsules, 4 are off-site, and 601 are at HANF. All off-site capsules are leased for beneficial purposes, and all are planned to be returned to HANF by 1996 for storage. At HANF, waste in single-shell and double-shell tanks consist of HLW, TRUW, and several LLWs. However, in the interim storage mode, the tanks are managed as if they contain only HLW. Thus, their contents are included in the HLW inventory. See Tables 2.4–2.5.

2.2.4 HLW Inventories at WVDP (Commercial)

Reprocessing at the West Valley NFS plant was terminated in 1972, and no additional HLW has been generated since that time. HLW at WVDP is stored in underground tanks. The current HLW inventory of 1,990 m³ consists of 1,800 m³ of liquid waste (1,750 m³ alkaline, 50 m³ acidic), 30 m³ of sludge, and 160 m³ of inorganic ion-exchange material (a zeolite) contaminated with radioactive cesium. The small volume of acidic waste was generated by reprocessing a batch of thorium-uranium fuel from the Indian Point-1 Reactor. The alkaline waste

is stored in an underground carbon-steel tank, the acidic waste is stored in an underground stainless-steel tank, and the zeolite is stored in an underground tank covered by an alkaline aqueous solution. See Tables 2.4–2.5.

In May 1988, the processing of high-level alkaline liquid waste started at the WVDP. This liquid was decontaminated to LLW in the WVDP Supernatant Treatment System (STS) in preparation for the incorporation of all HLW at the WVDP into a glass. In the STS, an ion-exchange process, operated in a batch mode, is employed to remove cesium from alkaline liquid waste, as depicted in Fig. 2.8. The ion-exchange columns are located in the underground carbon-steel tank, which was originally installed as a backup tank for the storage of alkaline HLW. The sludge in the bottom of the tank has been mixed with the residual supernatant and an alkaline was solution. The first of three sludge-wash processing cycles are in progress. The wash solutions are also treated in the STS prior to incorporation in cement.

The washed sludge, acidic waste, and loaded zeolite will be combined and incorporated into a glass. The current inventories of HLW at WVDP are presented in Tables 2.4 and 2.5. The glass will be stored on-site until it is transferred to a federal repository.

2.3 WASTE CHARACTERIZATION

Generic characterization of HLW at some sites is hampered by the use, over the years, of several different flowsheets for the processes that generated the waste or prepared the wastes for storage (e.g., nuclide separation, precipitation, and evaporation). In some instances, wastes have been blended. Information for all sites is based on historic records of reprocessing feeds; information for SRS and WVDP includes data gathered from extensive sampling of stored HLW. INEL has commenced extensive waste characterization, as is required by applicable environmental regulations. At HANF, an extensive tank characterization program supports operations, safety, and future waste processing. A Tank Waste Analysis Plan provides the technical approach for characterization of all tanks (ref. 4). Chemical and radionuclide compositions and inventories are given for the current and projected HLW at SRS (Tables 2.10–2.11); and current HLW at INEL (Tables 2.12–2.14), HANF (Tables 2.15–2.16), and WVDP (Tables 2.17–2.21).

2.4 AGREEMENTS AND INTERFACES

HLW is a mixed waste (one containing radioactivity and hazardous substances) unless demonstrated to the

contrary. The hazardous substances of HLW are defined under the Resource Conservation and Recovery Act (RCRA).² Liquid HLW is *characteristic* mixed waste (as stored, it shows the characteristic of either corrosivity due to acidity or alkalinity, ignitability, reactivity, or toxicity). Some HLW may also be *listed* mixed waste (containing substances on any one of several lists regulated under RCRA). Mixed wastes must be managed according to RCRA² requirements.

The Federal Facility Compliance Act (FFCA)³ of 1992 (signed October 6, 1992), amends the Solid Waste Disposal Act and requires (among other things) that DOE prepare a site treatment plan for each site which generates, stores, or treats mixed waste. This site treatment plan, which is to be approved by the host state for the site by October 6, 1995, in effect constitutes a legally enforceable agreement between DOE and the host state that DOE will comply with certain requirements for mixed waste. These agreements must be in place by October 6, 1995, unless another agreement was in place before the law was enacted. Concerning the latter, two such prior agreements have been reached; each involving tri-party arrangements. One was among DOE, the U.S. Environmental Protection Agency (EPA), and the state of Washington for HANF. This Tri-Party Agreement⁴ serves as a site treatment plan and requires DOE to undertake specific actions at HANF on a prescriptive timetable and is legally enforceable. The other tri-party agreement involves DOE, EPA, and the state of South Carolina for SRS. However, the agreement for SRS applies only to those waste storage tanks that do not meet current DOE and regulatory criteria for secondary containment and leak detection. Consequently, a site treatment plan is still being prepared for SRS. In addition, there were no prior agreements for INEL and WVDP; thus, site treatment plans are also being prepared for these sites.

2.5 SOLIDIFICATION FOR PERMANENT DISPOSAL

All HLW will be processed and solidified to a form acceptable for permanent disposal in a geologic repository.^{5–9} Borosilicate glass has been selected as the reference waste forms for SRS and WVDP; it is also the reference designation waste form for HANF. A glass/ceramic and a borosilicate glass material are both under consideration as the reference waste form for INEL.¹⁰

Summary flowsheets of the reference solidification processes are given for SRS (Fig. 2.5), INEL (Fig. 2.6), HANF (Fig. 2.7), and WVDP (Fig. 2.8). Overall, the flowsheets are very similar; process differences reflect differences among sites in waste characteristics.

Summary information about the characteristics of solidified HLW is given for SRS (Table 2.11) and WVDP (Tables 2.20 and 2.21). Specific information is not yet available for HANF or INEL, but it is expected to be similar.

2.6 PROJECTIONS

Projected inventories (volume, radioactivity, and thermal power) for HLW presented in Tables 2.6–2.8 were generated by each site based on assumptions given in the following and should be considered only as current best estimates. It is possible that new treatment methods or waste forms may be developed and supersede current baseline projections for HANF or INEL. All sites are moving toward a shutdown situation; consequently, very little additional HLW will be generated. Major HLW activities will be continued safe storage, preparation for solidification, solidification, and interim storage pending shipment to a national repository. Thus, the inventory of liquid HLW in storage generally will decrease, and the inventory of solidified HLW in interim storage, pending shipment to a national repository, will increase. An estimate, by each site, of the number of canisters of solidified HLW that may be produced is shown in Table 2.3. The Mission Plan¹¹ for the national repository states that receipt of DOE HLW will begin no sooner than 6 years after initial receipt of utility spent nuclear fuel. Thus, the canisters of solidified HLW will remain in interim storage, most likely at the production site, for a few decades before shipment to a national repository.

The HLW projections for HANF are based on the assumptions that (1) the fuel reprocessing plant is not restarted, (2) the irradiated fuel remains in wet storage, (3) pumpable liquids are transferred from single-shell tanks to double-shell tanks, (4) double-shell tanks will continue to receive any newly generated waste, and (5) volume reduction of stored wastes through evaporation will continue.

Future plans are to retrieve waste from both single-shell tanks and double-shell tanks, pretreat as necessary to provide HLW and LLW fractions, and immobilize both fractions by vitrification (see Fig. 2.7). Waste retrieval will begin in December 2003, and pretreatment operations will begin in December 2004. Initiation of operations at an LLW vitrification facility and at an HLW vitrification facility are planned for June 2005 and December 2009,

respectively. Vitrification of HLW from all tanks is expected to be completed by December 2028. The projections in Tables 2.2, 2.6–2.8, and Fig. 2.4 do not include vitrification starting in 2005, because material balances for these processes have not been finalized. Thus, the projections do not reflect the volume reduction that will be achieved through vitrification.

Pretreatment maximizes routing the radioactivity of retrieved waste to the HLW vitrification facility while directing the bulk of the tank waste material to the LLW vitrification facility. The current baseline pretreatment processes are enhanced (caustic) sludge washing, liquid-solid separation, and cesium removal for liquids. Other pretreatment processes that will be evaluated in the Tank Waste Remediation System Program Environmental Impact Statement¹² are acid dissolution, advanced separations of wastes, and organic destruction.

Cesium and strontium salts currently contained in capsules will be vitrified if it is decided that overpacking of existing capsules would not result in an acceptable waste form for the national repository.

For INEL, HLW projections are based on calcination of the remaining inventory of liquid acidic HLW (1,306 m³). No new HLW from reprocessing activities was produced after FY 1992; spent nuclear fuel reprocessing facilities are being placed into cold standby pending D&D. By June 1995, DOE must select a waste form, a process technology, and a facility to treat the sodium-bearing waste and immobilized calcine. The current reference waste form at INEL is a glass-glass ceramic. Currently, it is assumed that INEL will begin radioactive operations producing canisters in 2007 and continue this operation through 2031 (see Fig. 2.6). The projections reported in Tables 2.2, 2.3, and 2.6–2.8 reflect this assumption.

For SRS, reprocessing operations are scheduled to be completed by FY 2002. Additional HLW from reprocessing activities between now and then, at most, will represent an increase of about 14.5% of current inventory. Pretreatment (sludge washing) of liquid HLW has been started, and the DWPF will begin producing canisters of solidified HLW in FY 1996. The HLW glass waste forms will be stored at SRS until a national repository is ready to accept them (see Fig. 2.5).

At WVDP, pretreatment is essentially completed. Vitrification of the HLW will start in FY 1996 and be completed in FY 1998. No HLW has been generated since 1972 (see Fig. 2.8).

2.7 REFERENCES

1. DOE site HLW data submittal attachments, submitted to the IDB Program during July–November 1994. The following HLW submittals were received and reviewed by the IDB Program before analysis and integration. Preceding each submittal is the site (in parentheses) to which it refers.
 - a. (HANF) R. W. Powell, Westinghouse Hanford Company, Richland, Washington, correspondence to L. Erickson, DOE Richland Operations Office, Richland, Washington, "Request for Office of Waste Management Integrated Data Base High-Level Waste Data Information Update," 9404636B R2, dated Nov. 4, 1994.
 - b. (INEL) C. B. Millet, Westinghouse Idaho Nuclear Company, Idaho Falls, Idaho, correspondence to Stephen N. Storch, IDB Program, ORNL, Oak Ridge, Tennessee, "Data requested for the 1994 ORNL HLW Integrated Data Base," Mil-6-94, dated Aug. 23, 1994.
 - c. (SRS) Steven D. Richardson, DOE Savannah River Operations Office, Aiken, South Carolina, correspondence to Stephen N. Storch, IDB Program, ORNL, Oak Ridge, Tennessee, "Savannah River Site High Level Waste Information for the 1994 Integrated Data Base Report," DOE-ED-FY94-052, dated Aug. 10, 1994.
 - d. (WVDP) P. S. Klanian, West Valley Nuclear Services Company, Inc., West Valley, New York, correspondence to Stephen N. Storch, IDB Program, ORNL, Oak Ridge, Tennessee, "Submittal of High-Level Waste Information for the 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," WZ:94:0112, dated July 7, 1994.
2. U.S. Congress, Resource Conservation and Recovery Act of 1976, P.L. 94-580, 1976, as amended.
3. U.S. Congress, The Federal Facility Compliance Act of 1992, P.L. 102-386, Oct. 6, 1992.
4. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, *Hanford Federal Facility Agreement and Consent Order*, EPA Docket Number 1089-03-040120, Ecology Docket Number 89-54, Richland, Washington (May 1989).
5. U.S. Department of Energy, *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic, and Tank Waste, Hanford Site, Richland, Washington*, DOE/EIS-0113, DOE Richland Operations Office, Richland, Washington (December 1987).
6. U.S. Congress, The Nuclear Waste Policy Act of 1982, P.L. 97-425, Sect. 8, Jan. 7, 1983, as amended.
7. Ronald Reagan, President of the United States, Washington, D.C., letter to John S. Herrington, Secretary of Energy, "Disposal of Defense Waste in a Commercial Repository," dated Apr. 30, 1985.
8. U.S. Department of Energy, "Civilian Radioactive Waste Management: Calculating Nuclear Waste Fund Disposal Fees for Department of Energy Defense Program Waste; Notice," *Fed. Regis.* 56(161), 31508 (Aug. 20, 1987).
9. U.S. Congress, The Nuclear Waste Policy Amendments Act of 1987, P.L. 100-203, Title V, Subtitle A, Dec. 22, 1987.
10. U.S. Department of Energy, Office of Defense Waste and Transportation Management, *Defense Waste and Transportation Management Program Implementation Plan*, DOE/DP-0059, Washington, D.C. (August 1988).
11. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Draft 1988 Mission Plan Amendment, DOE/RW-0187 (June 1988).
12. U.S. Department of Energy, "Notice of Intent to Prepare the Hanford Site Tank Waste Remediation System Environmental Impact Statement," *Fed. Regis.* 59(19), 4052 (Jan. 28, 1994).

Fig. 2.1. Total volume and radioactivity of HLW through 1993.

Fig. 2.2. Distribution of total cumulative volume and radioactivity of HLW by site and type through 1993.

Fig. 2.3. Locations and total volumes of HLW through 1993.

Table 2.4. Historical and projected volumes of HLW.

SRS HLW Management Process

Fig. 2.5. Treatment methods for HLW in tanks and canisters at SRS.

Fig. 2.6. Treatment methods for HLW in tanks, bins, and canisters at INEL.

Treatment Methods for Hanford Tank Waste and Capsules

Fig. 2.7. Treatment methods for tank waste and capsules at HANF.

Fig. 2.8. Treatment methods for HLW in tanks and canisters at WVDP.

Table 2.1. Historical and projected cumulative volume, radioactivity, and thermal power of HLW stored in tanks, bins, and capsules by source^{a,b,c}

End of calendar year	DOE (SRS, INEL, and HANF)			Commercial (WVDP)			Total		
	Volume ^d (10 ³ m ³)	Radioactivity (10 ⁶ Ci)	Thermal power (10 ³ W)	Volume (10 ³ m ³)	Radioactivity (10 ⁶ Ci)	Thermal power (10 ³ W)	Volume (10 ³ m ³)	Radioactivity (10 ⁶ Ci)	Thermal power (10 ³ W)
1980	328	1,329	3,362	2.2	33.5	96.9	330	1,363	3,459
1981	337	1,596	4,781	2.2	32.7	94.8	339	1,628	4,876
1982	340	1,338	3,969	2.2	31.9	92.6	342	1,369	4,061
1983	351	1,268	3,703	2.2	31.2	90.5	353	1,300	3,794
1984	361	1,325	3,909	2.2	30.5	88.4	363	1,355	3,998
1985	355	1,430	4,304	2.2	29.7	86.4	357	1,459	4,391
1986	364	1,390	4,357	2.2	29.1	84.5	366	1,419	4,442
1987	379	1,275	3,730	2.2	28.4	81.2	381	1,303	3,811
1988	383	1,179	3,386	2.1	27.9	80.9	385	1,207	3,467
1989	379	1,087	3,085	2.4	27.3	79.3	381	1,114	3,164
1990	397	1,024	2,901	1.2	26.7	76.9	398	1,051	2,978
1991	395	981	2,788	1.7	26.2	75.9	396	1,007	2,864
1992	397	1,055	2,945	1.6	25.9	79.1	398	1,081	3,024
1993	401	1,020	2,812	2.0	25.3	74.1	403	1,045	2,886
1994	396	945	2,576	2.6	24.7	72.4	399	970	2,649
1995	382	926	2,525	0.9	14.2	36.7	383	940	2,562
1996	362	895	2,446	0.6	9.3	24.0	363	904	2,470
1997	359	839	2,306	0.3	4.5	11.6	359	843	2,318
1998	356	789	2,181	0.0	0.0	0.0	356	789	2,181
1999	354	746	2,074	0.0	0.0	0.0	354	746	2,074
2000	350	693	1,942	0.0	0.0	0.0	350	693	1,942
2001	345	663	1,864	0.0	0.0	0.0	345	663	1,864
2002	340	620	1,751	0.0	0.0	0.0	340	620	1,751
2003	339	580	1,647	0.0	0.0	0.0	339	580	1,647
2004	332	561	1,588	0.0	0.0	0.0	332	561	1,588
2005	328	536	1,513	0.0	0.0	0.0	328	536	1,513
2006	323	496	1,406	0.0	0.0	0.0	323	496	1,406
2007	318	469	1,328	0.0	0.0	0.0	318	469	1,328
2008	313	447	1,266	0.0	0.0	0.0	313	447	1,266
2009	308	424	1,200	0.0	0.0	0.0	308	424	1,200
2010	306	397	1,121	0.0	0.0	0.0	306	397	1,121
2011	303	369	1,041	0.0	0.0	0.0	303	369	1,041
2012	299	343	969	0.0	0.0	0.0	299	343	969
2013	294	307	873	0.0	0.0	0.0	294	307	873
2014	295	283	807	0.0	0.0	0.0	295	283	807

Table 2.1 (continued)

End of calendar year	DOE (SRS, INEL, and HANF)			Commercial (WVDP)			Total		
	Volume ^d (10 ³ m ³)	Radioactivity (10 ⁶ Ci)	Thermal power (10 ³ W)	Volume (10 ³ m ³)	Radioactivity (10 ⁶ Ci)	Thermal power (10 ³ W)	Volume (10 ³ m ³)	Radioactivity (10 ⁶ Ci)	Thermal power (10 ³ W)
2015	286	265	753	0.0	0.0	0.0	286	265	753
2016	277	249	708	0.0	0.0	0.0	277	249	708
2017	274	235	672	0.0	0.0	0.0	274	235	672
2018	268	220	634	0.0	0.0	0.0	268	220	634
2019	264	212	610	0.0	0.0	0.0	264	212	610
2020	264	204	589	0.0	0.0	0.0	264	204	589
2021	264	198	570	0.0	0.0	0.0	264	198	570
2022	264	192	553	0.0	0.0	0.0	264	192	553
2023	264	186	536	0.0	0.0	0.0	264	186	536
2024	264	180	519	0.0	0.0	0.0	264	180	519
2025	264	175	505	0.0	0.0	0.0	264	175	505
2026	264	171	492	0.0	0.0	0.0	264	171	492
2027	264	167	481	0.0	0.0	0.0	264	167	481
2028	264	163	469	0.0	0.0	0.0	264	163	469
2029	264	159	458	0.0	0.0	0.0	264	159	458
2030	264	155	447	0.0	0.0	0.0	264	155	447

^aHistorical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 9 (March 1994)]. The inventories for 1993 and the projections through 2030 are taken from ref. 1.

^bAnnual rates for volume are not given because they can fluctuate widely depending upon waste generation coupled with interim waste management operations such as evaporation and/or calcination. Annual rates for radioactivity and thermal power are not given for these same reasons and because radioactive decay, especially for short-lived activity, causes apparent perturbations.

^cRadioactive decay is taken into account by each site through isotope generation/depletion codes.

^dProjections after 2005 do not reflect volume reduction at HANF, as a result of vitrification.

Table 2.2. Projected volume, radioactivity, and thermal power of HLW glass and glass/ceramic stored in canisters by source^a

End of calendar year	Volume (10 ³ m ³)		Radioactivity (10 ⁶ Ci)		Thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>DOE (SRS and INEL)^b</i>						
1996	0.09	0.09	7.9	7.9	9.2	9.2
1997	0.10	0.20	22.7	30.6	23.8	33.0
1998	0.10	0.30	2.5	33.1	3.8	36.8
1999	0.10	0.40	7.1	40.3	8.4	45.2
2000	0.10	0.50	2.3	42.5	3.5	48.7
2001	0.24	0.74	7.7	50.3	9.8	58.4
2002	0.20	0.94	17.0	67.3	24.5	82.9
2003	0.20	1.13	18.2	85.5	26.2	109.0
2004	0.20	1.33	18.1	104.0	25.2	134.0
2005	0.20	1.52	21.8	125.0	31.5	166.0
2006	0.20	1.72	24.5	150.0	34.3	200.0
2007	0.23	1.95	21.9	172.0	30.2	230.1
2008	0.26	2.20	21.1	192.8	31.1	261.3
2009	0.12	2.33	14.4	207.0	20.9	281.8
2010	0.27	2.60	23.1	230.2	35.0	317.2
2011	0.32	2.92	23.1	253.6	36.0	353.2
2012	0.29	3.21	19.0	272.2	29.0	381.8
2013	0.27	3.48	20.3	291.9	28.6	409.7
2014	0.27	3.75	18.3	310.5	24.5	433.3
2015	0.28	4.02	18.8	329.0	26.6	459.5
2016	0.23	4.26	9.3	338.3	15.0	473.3
2017	0.24	4.50	1.6	335.5	4.5	470.8
2018	0.28	4.78	1.5	336.7	4.4	473.2
2019	0.16	4.94	1.6	329.9	4.6	463.7
2020	0.16	5.09	1.9	322.4	5.5	455.1
2021	0.16	5.25	1.8	315.7	5.1	448.9
2022	0.16	5.40	1.5	309.8	4.4	441.9
2023	0.16	5.56	1.5	303.8	4.3	435.7
2024	0.16	5.72	1.5	297.7	4.2	429.4
2025	0.14	5.86	0.9	292.1	2.7	421.6
2026	0.12	5.98	0.2	284.7	0.5	412.5
2027	0.12	6.10	0.2	278.4	0.5	403.5
2028	0.12	6.23	0.2	272.0	0.5	393.5
2029	0.12	6.35	0.2	265.7	0.5	384.5
2030	0.12	6.47	0.2	259.3	0.5	376.5
<i>Commercial (WVDP)^c</i>						
1996	0.08	0.08	4.6	4.6	11.8	11.8
1997	0.08	0.16	4.5	9.1	11.6	23.5
1998	0.08	0.24	4.2	13.2	10.8	34.2
1999		0.24		12.9		33.4
2000		0.24		12.6		32.7
2001		0.24		12.4		31.9
2002		0.24		12.1		31.2
2003		0.24		11.8		30.5
2004		0.24		11.5		29.8
2005		0.24		11.3		29.1

Table 2.2 (continued)

End of calendar year	Volume (10 ³ m ³)		Radioactivity (10 ⁶ Ci)		Thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Commercial (WVDP)^c (continued)</i>						
2006		0.24		11.0		28.4
2007		0.24		10.8		27.8
2008		0.24		10.5		27.1
2009		0.24		10.3		26.5
2010		0.24		10.0		25.9
2011		0.24		9.8		25.3
2012		0.24		9.6		24.7
2013		0.24		9.4		24.2
2014		0.24		9.2		23.6
2015		0.24		8.9		23.1
2016		0.24		8.7		22.6
2017		0.24		8.5		22.0
2018		0.24		8.3		21.5
2019		0.24		8.2		21.0
2020		0.24		8.0		20.6
2021		0.24		7.8		20.1
2022		0.24		7.6		19.6
2023		0.24		7.4		19.2
2024		0.24		7.3		18.7
2025		0.24		7.1		18.3
2026		0.24		6.9		17.9
2027		0.24		6.8		17.5
2028		0.24		6.6		17.1
2029		0.24		6.5		16.7
2030		0.24		6.3		16.3
<i>Total</i>						
1996	0.17	0.17	12.5	13	21.0	21
1997	0.18	0.36	27.2	40	35.4	56
1998	0.18	0.54	6.7	46	14.6	71
1999	0.10	0.64	7.1	53	8.4	79
2000	0.10	0.74	2.3	55	3.5	81
2001	0.24	0.98	7.7	63	9.8	90
2002	0.20	1.18	17.0	79	24.5	114
2003	0.20	1.37	18.2	97	26.2	139
2004	0.20	1.57	18.1	116	25.2	164
2005	0.20	1.76	21.8	136	31.5	195
2006	0.20	1.96	24.5	161	34.3	228
2007	0.23	2.19	21.9	183	30.2	258
2008	0.26	2.44	21.1	203	31.1	288
2009	0.12	2.57	14.4	217	20.9	308
2010	0.27	2.84	23.1	240	35.0	343
2011	0.32	3.16	23.1	263	36.0	379
2012	0.29	3.45	19.0	282	29.0	407
2013	0.27	3.72	20.3	301	28.6	434
2014	0.27	3.99	18.3	320	24.5	457
2015	0.28	4.26	18.8	338	26.6	483
2016	0.23	4.50	9.3	347	15.0	496

Table 2.2 (continued)

End of calendar year	Volume (10 ³ m ³)		Radioactivity (10 ⁶ Ci)		Thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Total (continued)</i>						
2017	0.24	4.74	1.6	344	4.5	493
2018	0.28	5.02	1.5	345	4.4	495
2019	0.16	5.18	1.6	338	4.6	485
2020	0.16	5.33	1.9	330	5.5	476
2021	0.16	5.49	1.8	323	5.1	469
2022	0.16	5.64	1.5	317	4.4	462
2023	0.16	5.80	1.5	311	4.3	455
2024	0.16	5.96	1.5	305	4.2	448
2025	0.14	6.10	0.9	299	2.7	440
2026	0.12	6.22	0.2	292	0.5	430
2027	0.12	6.34	0.2	285	0.5	421
2028	0.12	6.47	0.2	279	0.5	411
2029	0.12	6.59	0.2	272	0.5	401
2030	0.12	6.71	0.2	266	0.5	393

^aGlass and glass/ceramic may be in storage at the site, in transit to a repository, or in a repository.

^bTaken from, or calculated with, data given in refs. 1(a), 1(b), and 1(c). At SRS, the DWPF canisters are 0.6 m in diam by 3.0 m in length (about 2 ft in diam by about 10 ft in length). Each is assumed to be filled with 0.625 m³ of glass [i.e., 85% of the usable capacity (0.735 m³)] made with HLW from the reprocessing of spent fuel at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from spent fuel and 8 wt % from processing chemicals) and 64 wt % oxides from nonradioactive glass frit. Volumes reported are for the glass waste form and not the canisters (see Table 2.3 for the number of canisters and Table 2.6 for the volume of glass). At INEL, each canister is assumed to contain nominally 0.92 m³ of a glass/ceramic waste form made with HLW from the reprocessing of spent fuel. See Table 2.3 for the number of canisters and Table 2.6 for the volume of glass/ceramic at INEL. Projections are not provided for HANF because material balances for future waste processing have not been finalized.

^cTaken from data given in ref. 1(d). For WVDP, it is assumed that 300 canisters 0.6 m in diam by 3.0 m in length (2 ft in diam by 10 ft in length) are filled with waste glass during 1996–1998 and that each canister contains 0.8 m³ of glass at the filling temperature.

Table 2.3. Estimated potential number of HLW canisters by source^a

Year	Number of canisters							
	SRS ^b		INEL ^c		HANF ^d		WVDP ^e	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1996	176	176					100	100
1997	193	369					100	200
1998	193	562					100	300
1999	193	755						300
2000	193	948						300
2001	183	1,131						300
2002	213	1,344						300
2003	213	1,557						300
2004	213	1,770						300
2005	292	2,062						300
2006	395	2,457						300
2007	395	2,852	27	27				300
2008	395	3,271	55	82				300
2009	289	3,560	54	136				300
2010	291	3,851	79	215	720	720		300
2011	291	4,142	120	335	730	1,450		300
2012	291	4,433	123	458	730	2,180		300
2013	242	4,675	129	587	720	2,900		300
2014	182	4,857	130	717	730	3,630		300
2015	182	5,039	135	852	730	4,360		300
2016	173	5,212	136	988	720	5,080		300
2017	220	5,432	135	1,123	730	5,810		300
2018	161	5,593	136	1,259	730	6,540		300
2019		5,593	135	1,394	720	7,260		300
2020		5,593	136	1,530	730	7,990		300
2021		5,593	136	1,666	730	8,720		300
2022		5,593	135	1,801	720	9,440		300
2023		5,593	135	1,936	730	10,170		300
2024		5,593	136	2,072	730	10,900		300
2025		5,593	124	2,196	720	11,620		300
2026		5,593	108	2,304	730	12,350		300
2027		5,593	107	2,411	730	13,080		300
2028		5,593	107	2,518	720	13,800		300
2029		5,593	108	2,626				300
2030		5,593	107	2,733				300

^aTaken from ref. 1. The projected waste volume, radioactivity, and thermal power values at SRS, INEL, and WVDP are consistent with the number of canisters reported because these sites have developed material balances for their solidification facilities.

^bCanisters are 0.6 m in diam by 3.0 m in length (about 2 ft in diam by about 10 ft in length). Each canister is assumed to contain 0.625 m³ of glass made with HLW from the reprocessing of spent fuel at SRS. The glass incorporates 36 wt % oxides from waste (28 wt % from spent fuel and 8 wt % from processing chemicals) and 64 wt % oxides from nonradioactive glass frit.

^cDimensions of canisters have not been set. Each canister is assumed to contain nominally 1.15 m³ of a glass/ceramic waste form.

^dCanisters are 0.6 m in diam by 3.0 m in length (about 2 ft in diam by about 10 ft in length). Each canister of vitrified waste is assumed to contain 0.62 m³ of a borosilicate glass incorporating waste solids. Presently, HANF is evaluating a canister with a larger volume.

^eCanisters are 0.6 m in diam by 3.0 m in length (about 2 ft in diam by 10 ft in length). Each canister is assumed to contain 0.8 m³ of a borosilicate glass incorporating waste solids.

Table 2.4. Current volume of HLW in storage by site through 1993

Site ^a	Volume, 10 ³ m ³								Total	
	Liquid	Sludge	Salt cake	Slurry ^b	Calcine	Precipitate ^c	Zeolite	Capsules ^d		
								Sr		Cs
DOE ^e										
SRS	61.4	13.9	53.8	f	f	0.2	f	f	f	129.3
INEL	6.8	f	f	f	3.7	f	f	f	f	10.5
HANF ^g	24.9	46.0	93.0	97.8	f	f	f	0.00108	0.00245	261.7
Subtotal	93.1	59.9	146.8	97.8	3.7	0.2	f	0.00108	0.00245	401.5
Commercial ^h										
WVDP										
Acid waste	0.05	f	f	f	f	f	f	f	f	0.05
Alkaline waste	1.75	0.03	f	f	f	f	f	f	f	1.78
Zeolite waste	f	f	f	f	f	f	0.16	f	f	0.16
Subtotal	1.80	0.03	f	f	f	f	0.16	f	f	1.99
Total	94.91	59.9	146.8	97.8	3.7	0.2	0.16	0.00108	0.00245	403.47

^aSRS is Savannah River Site, INEL is Idaho National Engineering Laboratory, HANF is Hanford Site, and WVDP is West Valley Demonstration Project.

^bSlurry refers to all waste (regardless of when it was generated) contained in double-shell tanks.

^cPrecipitate (non-Newtonian fluid) from the in-tank precipitation process.

^dCapsules contain either strontium (⁹⁰Sr-⁹⁰Y) fluoride or cesium (¹³⁷Cs-^{137m}Ba) chloride.

^eTaken from refs. 1(a)-1(c).

^fNot applicable.

^gHanford single-shell tank wastes (i.e., liquid, sludge, and salt cake) and double-shell tank wastes (i.e., slurry) consist of HLW and TRUW; several tanks contain only LLW. However, in storage practice, all tanks are managed as if they contain only HLW. Thus, their contents are included in the HLW inventory.

^hTaken from ref. 1(d).

Table 2.5. Current radioactivity of HLW in storage by site through 1993

Site ^b	Radioactivity, ^a 10 ⁶ Ci									Thermal power (10 ⁶ W)	
	Liquid	Sludge	Salt cake	Slurry ^c	Calcine	Precipitate ^d	Zeolite	Capsules ^e			Total
								Sr	Cs		
DOE ^f											
SRS	83.9	412.0	110.0	g	g	0.1	g	g	g	606.0	1.615
INEL	2.6	g	g	g	49.9	g	g	g	g	52.5	0.154
HANF ^h	15.5	101.3	7.3	84.3	g	g	g	47.1	105.9	361.4	1.043
Subtotal	102.1	513.3	117.3	84.3	49.9	0.1	g	47.1	105.9	1,020.0	2.812
Commercial ⁱ											
WVDP											
Acid waste	1.8	g	g	g	g	g	g	g	g	1.8	0.009
Alkaline waste	1.8	11.3	g	g	g	g	g	g	g	13.1	0.039
Zeolite waste	g	g	g	g	g	g	10.4	g	g	10.4	0.026
Subtotal	3.6	11.3	g	g	g	g	10.4	g	g	25.3	0.074
Total	105.6	524.6	117.3	84.3	49.9	0.1	10.4	47.1	105.9	1,045.2	2.886

^aCalculated values allowing for radioactive decay.

^bSRS is Savannah River Site, INEL is Idaho National Engineering Laboratory, HANF is Hanford Site, and WVDP is West Valley Demonstration Project.

^cSlurry refers to all waste (regardless of when it was generated) contained in double-shell tanks.

^dPrecipitate (non-Newtonian fluid) from the in-tank precipitation process.

^eCapsules contain either strontium (⁹⁰Sr-⁹⁰Y) fluoride or cesium (¹³⁷Cs-^{137m}Ba) chloride. Radioactivity values are for the pair, that is, parent plus daughter radionuclide.

^fTaken from refs. 1(a)-1(c).

^gNot applicable.

^hHanford single-shell tank wastes (i.e., liquid, sludge, and salt cake) and double-shell tank wastes (i.e., slurry) consist of HLW and TRUW; several tanks contain only LLW. However, in storage practice, all tanks are managed as if they contain only HLW. Thus, their contents are included in the HLW inventory.

ⁱTaken from ref. 1(d).

Table 2.6. Historical and projected total volume of HLW in storage by site through 2030^a

End of calendar year	Volume, 10 ³ m ³									Total
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^b	Glass or glass/ceramic ^c	
<i>Savannah River Site</i>										
1980	59.8	10.5	26.4							96.7
1985	71.3	13.8	37.6							122.7
1986	72.8	13.8	41.2							127.8
1987	63.2	13.8	50.5			0.1				127.6
1988	64.2	14.1	50.0			0.1				128.4
1989	53.3	13.8	54.8			0.1				122.0
1990	61.3	14.8	55.5			0.1				131.7
1991	57.2	14.5	55.7			0.5				127.9
1992	59.3	14.3	53.1			0.2				126.9
1993	61.4	13.9	53.8			0.2				129.3
1994	59.6	13.9	53.4			0.4				127.3
1995	59.4	13.9	54.2			0.4				127.9
2000	49.9	11.8	40.8			0.2			0.5	103.2
2005	40.4	7.6	29.4			0.2			1.5	79.1
2010	31.0	4.1	24.1			0.1			2.4	61.6
2015	19.6	1.2	14.4			0.5			3.0	38.7
2020	12.0		4.8			0.2			3.3	20.3
2025	12.0		4.8			0.2			3.3	20.3
2030	12.0		4.8			0.2			3.3	20.3
<i>Idaho National Engineering Laboratory</i>										
1980	9.3				2.1					11.4
1985	7.1				3.0					10.1
1986	6.5				3.0					9.5
1987	8.9				3.0					11.9
1988	7.6				3.4					11.0
1989	8.5				3.5					12.0
1990	8.5				3.5					12.0
1991	6.8				3.6					10.4
1992	7.7				3.5					11.2
1993	6.8				3.7					10.5
1994	7.5				3.7					11.3
1995	7.8				3.7					11.5

Table 2.6 (continued)

End of calendar year	Volume, 10 ³ m ³									Total
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^b	Glass or glass/ceramic ^c	
Idaho National Engineering Laboratory (continued)										
2000	4.8				5.0					9.8
2005	5.8				5.0					10.8
2010	0.1				4.9				0.2	5.3
2015	0.0				3.8				1.0	4.8
2020	0.1				2.5				1.8	4.4
2025	0.1				1.3				2.5	3.9
2030	0.1				0.1				3.1	3.4
Hanford Site ^d										
1980	39.0	49.0	95.0	36.4				0.0017		219.4
1985	28.1	46.0	93.0	55.1				0.0041		222.1
1986	28.0	46.0	93.0	59.5				0.0041		226.4
1987	27.3	46.0	93.0	73.4				0.0041		239.7
1988	26.8	46.0	93.0	77.7				0.0036		243.4
1989	26.5	46.0	93.0	79.3				0.0036		244.8
1990	26.4	46.0	93.0	88.2				0.0036		253.6
1991	25.5	46.0	93.0	92.0				0.0035		256.4
1992	25.1	46.0	93.0	94.7				0.0035		258.7
1993	24.9	46.0	93.0	97.8				0.0035		261.7
1994	24.2	46.0	93.0	94.8				0.0035		258.0
1995	23.7	46.0	93.0	80.0				0.0035		242.7
2000	11.3	46.0	93.0	87.3				0.0035		237.5
2005	11.3	46.0	93.0	89.7				0.0035		239.9
2010	11.3	46.0	93.0	91.1				0.0035		241.3
2015	11.3	46.0	93.0	96.0				0.0035		246.2
2020	11.3	46.0	93.0	93.8				0.0035		244.1
2025	11.3	46.0	93.0	95.0				0.0035		245.2
2030	11.3	46.0	93.0	96.1				0.0035		246.4

Table 2.6 (continued)

End of calendar year	Volume, 10 ³ m ³									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^b	Glass or glass/ceramic ^c	Total
<i>West Valley Demonstration Project</i>										
1980	2.145	0.046								2.191
1985	2.145	0.046								2.191
1986	2.145	0.046								2.191
1987	2.145	0.046								2.191
1988	2.065	0.046					0.013			2.124
1989	2.305	0.046					0.031			2.382
1990	1.135	0.046					0.045			1.226
1991	1.620	0.057					0.052			1.729
1992	1.440	0.050					0.060			1.550
1993	1.800	0.030					0.160			1.990
1994	2.350	0.040					0.230			2.620
1995				0.910						0.910 ^c
2000									0.240	0.240
2005									0.240	0.240
2010									0.240	0.240
2015									0.240	0.240
2020									0.240	0.240
2025									0.240	0.240
2030									0.240	0.240

^aHistorical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 9 (March 1994)]. The inventories for 1993 and the projections through 2030 are taken from ref. 1.

^bCapsules contain either strontium (⁹⁰Sr-⁹⁰Y) fluoride or cesium (¹³⁷Cs-^{137m}Ba) chloride.

^cGlass is waste form for SRS and WVDP. Glass/ceramic is waste form for INEL. Glass is most likely waste form for HANF.

^dThe projections for liquid, sludge, salt cake, and slurry at HANF do not include vitrification starting in 2005, as material balances for these processes have not been finalized.

^eVolume is a mixture of neutralized acidic liquid, alkaline liquid, alkaline sludge, and zeolite representing the blended waste for vitrification.

Table 2.7. Historical and projected total radioactivity of HLW in storage by site through 2030^a

End of calendar year	Radioactivity, ^b 10 ⁶ Ci									Total
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^c	Glass or glass/ceramic ^d	
Savannah River Site										
1980	187.4	429.0	82.6							699.0
1985	93.3	561.3	186.8							841.4
1986	88.1	517.2	189.4							794.7
1987	105.2	460.4	168.2			0.2				734.0
1988	99.0	403.1	162.1			0.2				664.4
1989	94.6	351.2	152.8			0.3				598.9
1990	91.6	319.8	150.1			0.1				561.6
1991	89.0	302.1	146.4			0.1				537.6
1992	86.4	400.9	145.0			0.1				632.4
1993	83.9	412.0	110.0			0.1				606.0
1994	80.5	352.0	107.0			3.3				542.8
1995	69.5	357.0	104.0			3.3				533.8
2000	61.0	237.0	48.2			0.4			42.5	389.1
2005	34.5	163.0	28.8			1.3			125.0	352.6
2010	17.6	88.9	17.8			1.5			227.0	352.8
2015	14.3	15.1	2.4			1.0			317.0	349.8
2020	4.2	1.1	0.4						304.0	309.8
2025	3.8	0.9	0.4						269.0	274.1
2030	3.4	0.8	0.4						238.0	242.6
Idaho National Engineering Laboratory										
1980	17.0				36.4					53.4
1985	21.7				47.7					69.4
1986	12.9				47.7					60.6
1987	14.3				48.2					62.5
1988	10.1				56.9					67.0
1989	11.5				56.9					68.4
1990	7.5				55.7					63.2
1991	2.4				57.0					59.4
1992	4.5				46.3					50.8
1993	2.6				49.9					52.5
1994	2.0				48.5					50.5
1995	1.9				47.3					49.2

Table 2.7 (continued)

End of calendar year	Radioactivity, ^b 10 ⁶ Ci									
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^c	Glass or glass/ceramic ^d	Total
<i>Idaho National Engineering Laboratory (continued)</i>										
2000	1.2				41.9					43.1
2005	1.1				37.2					38.3
2010					30.9				3.2	34.1
2015					18.4				12.0	30.4
2020					8.6				18.4	27.0
2025					1.0				23.1	24.1
2030					0.1				21.3	21.4
<i>Hanford Site^c</i>										
1980	24.2	163.6	10.4	46.5				332.0		576.7
1985	19.9	122.3	8.8	154.8				213.2		519.0
1986	19.4	119.5	8.6	178.9				208.3		534.6
1987	18.7	116.7	8.4	130.9				203.5		478.2
1988	18.1	113.9	8.2	132.5				174.7		447.4
1989	17.6	111.3	8.0	111.6				170.8		419.3
1990	17.1	108.7	7.8	99.7				166.0		399.3
1991	16.5	106.1	7.7	92.7				161.1		384.2
1992	15.9	103.7	7.5	88.0				157.0		372.1
1993	15.5	101.3	7.3	84.3				153.0		361.4
1994	15.0	98.9	7.1	81.5				149.5		352.0
1995	14.5	96.6	7.0	79.0				146.0		343.1
2000	9.7	85.8	6.2	71.9				130.0		303.6
2005	8.6	76.3	5.5	63.6				115.7		269.7
2010	7.7	67.8	4.9	56.5				102.9		239.8
2015	6.9	60.3	4.3	50.3				91.6		213.4
2020	6.1	53.6	3.8	44.8				81.5		189.9
2025	5.4	47.7	3.4	39.9				72.6		169.0
2030	4.8	42.4	3.0	35.5				64.6		150.4

Table 2.7 (continued)

End of calendar year	Radioactivity, ^b 10 ⁶ Ci									Total
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^c	Glass or glass/ceramic ^d	
<i>West Valley Demonstration Project</i>										
1980	18.5	15.0								33.5
1985	16.4	13.3								29.7
1986	16.1	13.0								29.1
1987	15.7	12.7								28.4
1988	12.9	12.4					2.6			27.9
1989	8.5	12.2					6.6			27.3
1990	5.5	11.9					9.3			26.7
1991	4.1	11.6					10.5			26.2
1992	3.7	11.6					10.6			25.9
1993	3.6	11.3					10.4			25.3
1994	2.6	11.9					10.2			24.7
1995				14.2						14.2 ^f
2000									12.6	12.6
2005									11.3	11.3
2010									10.0	10.0
2015									8.9	8.9
2020									8.0	8.0
2025									7.1	7.1
2030									6.3	6.3

^aHistorical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 9 (March 1994)]. The inventories for 1993 and the projections through 2030 are taken from ref. 1.

^bRadioactivities reported include contributions from both parent and daughter products (e.g., ⁹⁰Sr-⁹⁰Y).

^cCapsules contain either strontium (⁹⁰Sr-⁹⁰Y) fluoride or cesium (¹³⁷Cs-^{137m}Ba) chloride.

^dGlass is waste form for SRS and WVDP. Glass/ceramic is waste form for INEL. Glass is most likely waste form for HANF.

^eThe projections for liquid, sludge, salt cake, and slurry at HANF do not include vitrification starting in 2005, as material balances for these processes have not been finalized.

^fRadioactivity is contained in a mixture of neutralized acidic liquid, alkaline liquid, alkaline sludge, and zeolite representing the blended waste for vitrification.

Table 2.8. Historical and projected total thermal power of HLW in storage by site through 2030^a

End of calendar year	Thermal power, 10 ³ W									Total
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^b	Glass or glass/ceramic ^c	
Savannah River Site										
1980	213.5	1,440.5	396.0							2,050.0
1985	264.3	1,782.7	490.2							2,537.2
1986	302.2	1,794.1	479.0							2,575.3
1987	279.8	1,438.9	432.8			0.4				2,151.9
1988	231.9	1,280.5	370.9			0.4				1,883.7
1989	217.7	1,105.8	349.5			0.7				1,673.7
1990	209.0	1,015.6	341.7			0.4				1,566.7
1991	203.0	971.0	335.0			0.3				1,509.3
1992	197.0	1,194.0	333.0			0.3				1,724.3
1993	192.0	1,170.0	253.0			0.3				1,615.3
1994	184.0	976.0	245.0			7.6				1,412.6
1995	160.0	984.0	239.0			7.5				1,390.5
2000	141.0	684.0	111.0			1.0			48.7	985.7
2005	78.9	472.0	66.2			3.0			166.0	786.1
2010	40.3	252.0	40.8			3.4			308.0	644.5
2015	32.7	40.4	5.4			2.4			425.0	505.9
2020	9.7	2.4	1.0						402.0	415.2
2025	8.7	2.2	0.9						355.0	366.8
2030	7.7	1.9	0.8						315.0	325.5
Idaho National Engineering Laboratory										
1980	53.8				115.2					169.0
1985	72.5				137.4					209.9
1986	38.5				137.4					175.9
1987	43.5				139.0					182.5
1988	30.4				165.2					195.6
1989	34.3				164.9					199.2
1990	22.9				161.5					184.4
1991	7.0				165.0					172.0
1992	13.3				134.0					147.3
1993	7.7				146.0					153.7
1994	5.8				141.0					146.8
1995	5.6				137.0					142.6

Table 2.8 (continued)

End of calendar year	Thermal power, 10 ³ W									Total
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^b	Glass or glass/ceramic ^c	
Idaho National Engineering Laboratory (continued)										
2000	3.6				121.0					124.6
2005	3.2				108.0					111.2
2010					89.3				9.2	98.5
2015					53.2				34.5	87.7
2020					24.9				53.1	78.0
2025					2.8				66.6	69.4
2030					0.2				61.5	61.7
Hanford Site ^d										
1980	52.9	304.6	22.6	118.2				644.4		1,142.7
1985	50.1	404.4	26.4	492.1				584.4		1,557.4
1986	48.9	394.9	25.8	565.4				570.9		1,605.9
1987	47.2	385.6	25.2	379.5				557.7		1,395.3
1988	45.6	376.6	24.6	380.3				479.3		1,306.4
1989	44.4	367.8	24.0	306.9				468.8		1,211.9
1990	43.2	359.2	23.5	268.6				455.8		1,150.3
1991	41.5	350.8	22.9	248.6				442.6		1,106.5
1992	40.2	342.6	22.4	236.2				431.7		1,073.1
1993	39.2	334.6	21.9	227.3				420.3		1,043.1
1994	37.7	326.7	21.3	220.5				410.6		1,016.9
1995	36.5	319.1	20.8	214.6				401.1		992.1
2000	24.3	283.5	18.5	196.9				356.9		880.1
2005	21.6	252.0	16.4	174.7				317.5		782.2
2010	19.2	223.9	14.6	155.3				282.5		695.6
2015	17.1	199.0	12.9	138.3				251.4		618.8
2020	15.3	176.9	11.5	123.3				223.7		550.6
2025	13.6	157.3	10.2	109.9				199.0		490.0
2030	12.1	139.9	9.1	98.1				177.1		436.2

Table 2.8 (continued)

End of calendar year	Thermal power, 10 ³ W									Total
	Liquid	Sludge	Salt cake	Slurry	Calcine	Precipitate	Zeolite	Capsules ^b	Glass or glass/ceramic ^c	
<i>West Valley Demonstration Project</i>										
1980	47.8	49.1								96.9
1985	42.2	44.2								86.4
1986	41.3	43.2								84.5
1987	38.9	42.3								81.2
1988	32.9	41.5					6.5			80.9
1989	22.3	40.6					16.4			79.3
1990	14.1	39.7					23.1			76.9
1991	11.0	38.9					26.0			75.9
1992	10.0	42.7					26.4			79.1
1993	13.1	35.2					25.8			74.1
1994	6.5	40.7					25.2			72.4
1995				36.7						36.7 ^e
2000									32.7	32.7
2005									29.1	29.1
2010									25.9	25.9
2015									23.1	23.1
2020									20.6	20.6
2025									18.3	18.3
2030									16.3	16.3

^aHistorical inventories for HLW are taken from the previous edition of this report [i.e., DOE/RW-0006, Rev. 9 (March 1993)]. The inventories for 1993 and the projections through 2030 are taken from ref. 1.

^bCapsules contain either strontium (⁹⁰Sr-⁹⁰Y) fluoride or cesium (¹³⁷Cs-^{137m}Ba) chloride.

^cGlass is waste form for SRS and WVDP. Glass/ceramic is waste form for INEL. Glass is most likely waste form for HANF.

^dThe projections for liquid, sludge, salt cake, and slurry at HANF do not include vitrification starting in 2005, as material balances for these processes have not been finalized.

^eThis thermal power is from the decay of radionuclides in a mixture of neutralized acidic liquid, alkaline liquid, alkaline sludge, and zeolite representing the blended waste for vitrification.

Table 2.9. Significant revisions and changes in the current values for HLW compared to the values in the previous year^{a,b}

Waste characteristics	Previous report values ^a	Significant revisions and changes	Updated values ^b	Explanation
<i>Savannah River Site</i>				
Volume and radioactivity (liquid, sludge, salt cake, and precipitate)	See Tables 2.4 and 2.5	None	See Tables 2.4 and 2.5	No major revisions. Changes are explained by changes in planned facility (e.g., DWPF) operations and the decay of radionuclides
<i>Idaho National Engineering Laboratory</i>				
Volume and radioactivity (liquid and calcine)	See Tables 2.4 and 2.5	None	See Tables 2.4 and 2.5	No major revisions. Changes are explained by changes in planned facility (e.g., ICPP) operations and the decay of radionuclides
<i>Hanford Site</i>				
Chemical composition of current and future HLW (liquid, sludge, salt cake, and slurry)	See Table 2.15	Decrease in phosphates in single-shell tanks	See Table 2.15	Adjustments made for quantities of phosphates discharged to ground during the 1950s and 1960s
Radionuclide composition of current HLW (liquid, sludge, salt cake, slurry, and capsules)	See Table 2.16	Modifications to ¹³⁷ Cs and ^{137m} Ba activity	See Table 2.16	Revisions made to the activity of ¹³⁷ Cs in tanks to properly reflect earlier (1986) revisions made for capsules as a result of calorimetry measurements
		Redistribution of ⁹⁰ Sr, ⁹⁰ Y, ⁹⁹ Tc, isotopes of plutonium, and ²⁴¹ Am		Revisions made to reflect analytical sample results of waste in double-shell tanks
		Modification of isotopes of plutonium in slurry		Revisions made to reflect measured plutonium recovery at the fuel reprocessing facility and tank sample results

Table 2.9 (continued)

Waste characteristics	Previous report values ^a	Significant revisions and changes	Updated values ^b	Explanation
<i>West Valley Demonstration Project</i>				
Volume and radioactivity (acid liquid, alkaline liquid, sludge, and zeolite)	See Tables 2.2, 2.4–2.8, 2.17, and 2.21	None	See Tables 2.2, 2.4–2.8, 2.17, and 2.21	Updated data from continuing pre-vitrification waste processing
	See Tables 2.8 and 2.21	New waste category (alkaline slurry)	See Tables 2.8 and 2.21	The alkaline slurry represents blended waste for vitrification. This blend is the combination of neutralized acid waste, alkaline liquid, alkaline sludge, and zeolite

^aData are for December 31, 1992. See tables and text cited in Chapter 2 of U.S. Department of Energy, *Integrated Data Base for 1993: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 9 (March 1994).

^bData are for December 31, 1993, as reported in this document (DOE/RW-0006, Rev. 10).

Table 2.10. Representative chemical composition of current and future HLW at SRS^a

Liquid		Sludge		Salt cake		Precipitate ^b		Glass	
Component	Wt %	Component	Wt %	Component	Wt %	Component	Wt %	Component	Wt %
Ag	Trace	Fe(OH) ₃	11.8	NaNO ₃	65.4	K(C ₆ H ₅) ₄ B	9.0	SiO ₂	45.6
Hg	Trace	MnO ₂	2.0	NaNO ₂	0.9	NaNO ₃	0.7	Na ₂ O	11.0
Pb	Trace	UO ₂ (OH) ₂	1.3	NaOH	3.4	Others	1.8	B ₂ O ₃	10.3
U	Trace	Al(OH) ₃	13.7	NaAl(OH) ₄	7.8	H ₂ O	88.5	Fe ₂ O ₃	7.0
F ⁻	0.003	AlO(OH)	5.2	Na ₂ CO ₃	2.7			Al ₂ O ₃	4.0
Fe	Trace	CaCO ₃	1.5	Na ₂ SO ₄	9.4		100.0	K ₂ O	3.6
Cl ⁻	0.023	CaSO ₄	0.2	Na ₃ PO ₄	Trace			Li ₂ O	3.2
OH ⁻	1.63	CaC ₂ O ₄	0.2	NaF	0.2			FeO	3.1
NO ₂ ⁻	1.10	Ni(OH) ₂	0.8	Na ₂ C ₂ O ₄	0.1			U ₃ O ₈	2.2
NO ₃ ⁻	9.63	HgO	0.4	Insolubles	3.7			MnO	2.0
Al(OH) ₄ ⁻	4.54	SiO ₂	0.2	H ₂ O	6.4			Others	8.0
CO ₃ ²⁻	0.72	ThO ₂	1.8						
CrO ₄ ²⁻	0.014	Ce(OH) ₃	0.2		100.0				100.0
SO ₄ ²⁻	0.22	ZrO(OH) ₂	0.2						
PO ₄ ³⁻	0.12	Cr(OH) ₃	0.2						
NH ₄ ⁺	Trace	Mg(OH) ₂	0.2						
Na ⁺	11.0	NaNO ₃	1.1						
H ₂ O	71.0	NaOH	1.3						
		Zeolite	1.5						
	100.0	Others	1.2						
		H ₂ O	55.0						
			100.0						
Density (25°C), g/mL	1.1		1.4		1.9		1.05		2.85

^aTaken from ref. 1(c).^bPrecipitate (non-Newtonian fluid) from the in-tank precipitation process.

Table 2.11. Representative radionuclide composition of current (end of 1993) HLW forms and future (to be generated in 1996) HLW glass at SRS^a

Radionuclide	Radioactivity, Ci					
	Liquid	Sludge	Salt cake	Precipitate	Total ^b	Glass ^c
⁹⁰ Sr	7.46E+05	1.19E+08	1.19E+06	1.79E+03	1.21E+08	2.00E+05
⁹⁰ Y	7.46E+05	1.19E+08	1.19E+06	1.79E+03	1.21E+08	1.98E+05
⁹⁹ Tc	1.68E+04	1.14E+04	2.78E+03		3.10E+04	2.90E+01
¹⁰⁶ Ru	2.30E+04	9.44E+04	8.84E+02		1.18E+05	
¹⁰⁶ Rh	2.30E+04	9.44E+04	8.84E+02		1.18E+05	
¹²⁵ Sb	5.31E+04	1.32E+05	1.29E+03		1.86E+05	6.39E+00
¹³⁷ Cs	4.26E+07	8.25E+07	5.62E+07	7.27E+04	1.81E+08	2.75E+06
^{137m} Ba	3.91E+07	7.59E+07	5.17E+07	6.69E+04	1.67E+08	2.53E+06
¹⁴⁴ Ce	1.86E+04	4.00E+05	4.43E+02		4.19E+05	
¹⁴⁴ Pr	1.86E+04	4.00E+05	4.43E+02		4.19E+05	
¹⁴⁷ Pm	5.51E+05	1.37E+07	1.32E+05	7.26E+00	1.44E+07	4.42E+02
²³³ U		1.06E+02			1.06E+02	1.90E-02
²³⁴ U		3.02E+01			3.02E+01	
²³⁵ U		1.70E+00			1.70E+00	2.00E-02
²³⁶ U		4.88E+00			4.88E+00	
²³⁸ U		5.30E+01			5.30E+01	4.30E-02
²³⁷ Np		7.01E+01			7.01E+01	
²³⁸ Pu		1.96E+06			1.96E+06	6.60E+02
²³⁹ Pu		3.66E+04			3.66E+04	3.50E+01
²⁴⁰ Pu		1.66E+04			1.66E+04	2.30E+01
²⁴¹ Pu		1.50E+06			1.50E+06	1.30E+02
²⁴² Pu		2.76E+01			2.76E+01	3.30E-02
²⁴⁴ Cm		1.40E+04			1.40E+04	1.70E+03
Total	8.39E+07	4.15E+08	1.10E+08	1.43E+05	6.09E+08	5.68E+06
Specific activity, ^d Ci/L	1.37E+00	2.98E+01	2.05E+00	7.66E-01	3.40E+01	6.07E+01

^aTaken or calculated from ref. 1(c).

^bLiquid, sludge, salt cake, and precipitate curies are as of December 31, 1993.

^cGlass curies are as of December 31, 1996 (the first year glass is to be generated).

^dSpecific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

Table 2.12. Representative chemical composition of current and future HLW liquid at INEL^a

Component	Composition, wt %			
	Zirconium fluoride	Sodium bearing	Nonfluoride	Fluorinel
Al	1.3	0.8–1.6	1.51	0.742
B	0.15	0.005–0.01	0.003	0.241
Ca		0.03–0.2	0.27	
Cl ⁻		0.06–0.1	0.023	
Cd			1.42	
Cr			0.036	0.0087
F ⁻	3.4	0.005–0.06	0.032	5.99
Fe	0.04	0.05–0.09	0.19	0.023
H ⁺	1.12	0.03–0.15	0.12	0.18
K	1.12	0.03–0.15	0.33	
Mg			0.062	
Mn			0.048	0.0004
Na	0.12	2.1–4.0	1.31	
Ni			0.016	0.0049
NO ₃ ⁻	13.7	19.4–23.3	23.1	11.47
SO ₄ ²⁻		0.33–0.5	0.65	1.52
Zr	2.47			3.80
H ₂ O	76.6	76.6–69.2	70.9	76.0
	100.0	100.0	100.0	100.0
Density, g/mL	1.2	1.2–1.3	1.2	1.2

^aTaken from U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 1 (December 1985).

Table 2.13. Representative chemical composition of current and future HLW calcine at INEL^a

Component	Composition, wt %				
	Alumina	Zirconium fluoride	Zirconium-sodium blend	Stainless steel sulfate	Fluorinel-sodium blend
Al ₂ O ₃	82.0–95.0	13.0–17.0	10.0–16.0	4.4	6.5–7.5
Al ₂ (SO ₄) ₃				81.0	
B ₂ O ₃	0.5–2.0	3.0–4.0	2.0–3.0		3.0–3.2
CaO		2.0–4.0	13.0–17.0		3.3–3.6
CaF ₂		50.0–56.0	33.0–39.0		46.0–49.0
Cd					6.0–6.5
Cr ₂ O ₃				2.0	0.05
Fe ₂ O ₃				7.0	0.2–0.3
Na ₂ O	1.3		6.0–8.0		10.0–15.0
NiO				0.9	0.02–0.03
NO ₃ ⁻	5.0–9.0	0.5–2.0	7.0–9.5		10.0–15.0
SO ₄ ²⁻					
ZrO ₂		21.0–27.0	16.0–19.0		19.0–20.0
Miscellaneous	0.5–1.5	0.5–1.5	0.5–1.5	4.4	
Fission products and actinides	0.2–1.0	0.2–1.0	0.2–1.0	0.2–1.0	0.2–1.0
Density, g/mL	1.1	1.4	1.8	1.2	1.4

^aTaken from U.S. Department of Energy, *Spent Fuel And Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 1 (December 1985).

**Table 2.14. Representative radionuclide composition
of current HLW at INEL^a**

Radionuclide	Radioactivity, Ci	
	Liquid	Calcine
⁹⁰ Sr	5.88E+05	1.16E+07
⁹⁰ Y	5.88E+05	1.16E+07
¹⁰⁶ Ru	3.33E+03	1.97E+04
¹⁰⁶ Rh	3.33E+03	1.97E+04
¹³⁴ Cs	1.52E+04	1.90E+05
¹³⁷ Cs	7.00E+05	1.33E+07
^{137m} Ba	6.63E+05	1.26E+07
¹⁴⁴ Ce	2.37E+04	1.23E+05
¹⁴⁴ Pr	2.37E+04	1.23E+05
¹⁴⁷ Pm		2.37E+05
¹⁵⁴ Eu	4.67E+03	6.73E+04
Total	2.61E+06	4.99E+07
Specific activity, ^b Ci/L	0.38	13.37

^aTaken from ref. 1(b). Curies as of December 31, 1993. Similar values for actinide nuclides are not available.

^bSpecific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

Table 2.15. Representative chemical and respective mass composition (t) of current and future HLW at HANF^a

Chemical component	Single-shell tank wastes				Double-shell tank wastes	
	Liquid	Sludge	Salt cake	Total	Soluble	Insoluble
Ag ⁺					3.11E-01	1.38E+00
Al(OH) ₄ ⁻	1.08E+03	6.25E+02	1.25E+03	2.96E+03	4.29E+03	
Al ³⁺		1.99E+03		1.99E+03		6.78E+01
As ⁵⁺					7.67E-01	4.98E-01
B ³⁺					5.19E-01	9.94E-01
Ba ²⁺					7.86E-01	3.09E+00
Be ²⁺					8.13E-02	7.61E-03
Bi ³⁺		2.61E+02		2.61E+02	2.21E+00	
Ca ²⁺		1.28E+02		1.28E+02	1.03E+01	1.15E+01
Cd ²⁺		3.84E+00		3.84E+00	1.59E-01	6.01E+00
Ce ³⁺		2.35E+02		2.35E+02	2.26E-02	3.04E+00
Cl ⁻		4.00E+01		4.00E+01	2.63E+02	1.49E+00
CO ₃ ²⁻	9.37E+01	1.15E+03	4.13E+02	1.66E+03	1.73E+03	5.83E+01
Cr ³⁺		8.63E+01		8.63E+01		3.44E+01
CrO ₄ ²⁻	5.06E+01			5.06E+01	9.05E+01	
Cu ²⁺					1.70E-01	7.46E-01
F ⁻	1.18E+01	8.00E+02		8.12E+02	3.39E+02	1.91E+01
Fe(CN) ₆ ⁴⁻		3.22E+02		3.22E+02		
Fe ³⁺		6.27E+02		6.27E+02	7.98E+00	1.42E+02
Hg ⁺		9.00E-01		9.00E-01	5.84E-02	
K ⁺					5.25E+02	2.02E+01
La ⁺					2.19E-02	2.10E+01
Li ⁺					5.77E-03	2.46E-02
Mg ²⁺					9.35E-01	1.10E+01
Mn ⁴⁺		1.20E+02		1.20E+02	7.67E+00	1.80E+01
Mo ⁶⁺					4.85E+00	8.01E-01
Na ⁺	5.54E+03	1.58E+04	3.39E+04	5.52E+04	1.05E+04	2.30E+02
Nd ³⁺						1.20E+01
Ni ²⁺		1.78E+02		1.78E+02	4.07E+00	6.57E+00
NO ₂ ⁻	3.00E+03	2.00E+03	1.53E+03	6.53E+03	2.93E+03	8.42E+00
NO ₃ ⁻	4.32E+03	1.48E+04	8.03E+04	9.94E+04	7.33E+03	3.91E+01
OH ⁻	7.45E+02	4.22E+03	8.51E+02	5.82E+03	1.79E+03	1.25E+02
Pb ⁴⁺					1.83E+00	3.28E+00
PO ₄ ³⁻	2.03E+02	3.89E+03	6.43E+02	4.74E+03	2.05E+02	2.16E+01

Table 2.15 (continued)

Chemical component	Single-shell tank wastes				Double-shell tank wastes	
	Liquid	Sludge	Salt cake	Total	Soluble	Insoluble
SiO ₃ ²⁻		1.21E+03		1.21E+03	1.53E+01	2.14E+02
SO ₄ ²⁺		5.01E+02	1.15E+03	1.65E+03	3.74E+02	6.68E+00
Sr		3.60E+01		3.60E+01		
TOC ^b	4.73E+02			4.73E+02	9.30E+02	6.84E+01
UO ₃ ²⁺					3.46E+00	2.68E+01
V ⁵⁺					6.20E-02	1.88E-01
W ⁴⁺		1.44E+01		1.44E+01	7.47E-01	
Zn ²⁺					3.38E+00	9.45E-01
Zr ⁴⁺		2.46E+02		2.46E+02	4.30E-01	2.77E+02
Subtotal	6.52E+03	4.93E+04	1.20E+05	1.76E+05	3.14E+04	1.51E+03
H ₂ O	4.80E+03	2.62E+04	1.40E+04	4.50E+04	7.19E+04	
Total	1.13E+04	7.55E+04	1.34E+05	2.21E+05	1.03E+05	

^aTaken from ref. 1(a).^bTotal organic carbon.

Table 2.16. Representative radionuclide composition (Ci) of current HLW at HANF^a

Radionuclide	Liquid	Sludge	Salt cake	Slurry	Capsules	
					⁹⁰ Sr- ⁹⁰ Y	¹³⁷ Cs- ^{137m} Ba
¹⁴ C	2.23E+03		2.00E+03	1.12E+03		
⁵⁵ Fe				1.30E+04		
⁵⁹ Ni				3.04E+01		
⁶⁰ Co		2.82E+03		2.30E+05		
⁶³ Ni		3.06E+05		3.52E+03		
⁷⁹ Se				6.30E+01		
⁸⁹ Sr				3.13E-08		
⁹⁰ Sr	4.07E+05	4.85E+07	2.14E+06	1.14E+07	2.36E+07	
⁹⁰ Y	4.07E+05	4.85E+07	2.14E+06	1.14E+07	2.36E+07	
⁹¹ Y				4.70E-06		
⁹³ Zr		9.70E+03		3.03E+02		
^{93m} Nb		8.28E+03		1.29E+02		
⁹⁵ Zr				7.23E-05		
⁹⁵ Nb				1.60E-04		
^{95m} Nb				5.33E-07		
⁹⁹ Tc	1.79E+04			1.42E+04		
¹⁰³ Ru				1.32E-12		
^{103m} Rh				1.19E-12		
¹⁰⁶ Ru		4.94E+00		1.09E+05		
¹⁰⁶ Rh		4.94E+00		1.09E+05		
¹⁰⁷ Pd				8.15E+00		
^{110m} Ag				4.14E+00		
¹¹⁰ Ag				5.49E-02		
^{113m} Cd				3.31E+03		
¹¹³ Sn				5.28E-02		
^{115m} Cd				3.57E-13		
^{119m} Sn				7.09E+01		
^{121m} Sn				6.00E+01		
¹²³ Sn				1.53E-01		
^{123m} Te				4.42E-07		
¹²⁴ Sb				3.56E-10		
¹²⁵ Sb				1.84E+05		
^{125m} Te				4.50E+04		
¹²⁶ Sn				1.00E+02		
¹²⁶ Sb				1.40E+01		
^{126m} Sb				1.11E+02		
^{127m} Te				3.82E-02		
¹²⁷ Te				3.74E-02		
¹²⁹ I				2.98E-01		
¹³⁴ Cs				8.19E+04		
¹³⁵ Cs				5.66E+01		
¹³⁷ Cs	7.56E+06	1.55E+06	1.55E+06	2.88E+07		5.44E+07

Table 2.16 (continued)

Radionuclide	Liquid	Sludge	Salt cake	Slurry	Capsules	
					$^{90}\text{Sr}-^{90}\text{Y}$	$^{137}\text{Cs}-^{137\text{m}}\text{Ba}$
$^{137\text{m}}\text{Ba}$	7.15E+06	1.47E+06	1.47E+06	2.73E+07		5.15E+07
^{144}Ce				1.31E+05		
^{144}Pr				1.31E+05		
$^{144\text{m}}\text{Pr}$				1.57E+03		
^{147}Pm				3.68E+06		
^{151}Sm		6.60E+05		4.14E+05		
^{152}Eu				5.08E+02		
^{153}Gd				2.65E-02		
^{154}Eu				6.24E+04		
^{155}Eu				7.15E+04		
^{160}Tb				1.61E-08		
^{234}U				1.59E+00		
^{235}U				6.80E-02		
^{236}U				1.74E-01		
^{238}U				1.23E+00		
^{237}Np	2.76E-03			4.77E+01		
^{238}Np				3.15E-01		
^{238}Pu				1.44E+03		
^{239}Pu		1.80E+04		8.36E+03		
^{240}Pu		4.30E+03		2.39E+03		
^{241}Pu		5.07E+04		5.25E+04		
^{242}Pu				2.80E-01		
^{241}Am	7.22E+02	3.26E+04		7.05E+04		
^{242}Am				6.27E+01		
$^{242\text{m}}\text{Am}$				6.30E+01		
^{243}Am				1.01E+01		
^{242}Cm				5.26E+01		
^{244}Cm		1.51E+02		2.27E+03		
Total	1.55E+07	1.01E+08	7.31E+06	8.43E+07	4.72E+07	1.06E+08
Specific activity, ^b Ci/L	6.2E-01	2.2E+00	7.9E-02	8.6E-01	4.4E+04	4.3E+04

^aTaken from ref. 1(a). Curies as of December 31, 1993.

^bSpecific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

**Table 2.17. Chemical composition of alkaline liquid HLW
(from reprocessing via a PUREX flowsheet) at WVDP^a**

Compound	Wet basis (wt %)	Dry basis (wt %)
NaNO ₃	3.93	27.59
NaNO ₂	6.01	42.14
Na ₂ SO ₄	2.26	15.85
KNO ₃	0.47	3.32
Na ₂ CO ₃	0.93	6.55
Al(NO ₃) ₃	0.19	1.35
NaCl	0.07	0.50
NaOH	0.06	0.42
Na ₃ BO ₃	0.01	0.07
Na ₃ PO ₄	0.05	0.33
K ₂ CrO ₄	0.06	0.43
Other	0.21	1.45
Solids subtotal	14.26	100.00
H ₂ O (by difference)	85.74	0.00
Grand total	100.00	100.00

^aTaken from ref. 1(d).

**Table 2.18. Chemical composition of alkaline sludge HLW
(from reprocessing via a PUREX flowsheet) at WVDP^a**

Compound	Mass fraction
Fission products	
Ge(OH) ₃	2.0364E-06
SrSO ₄	2.2095E-03
Y(OH) ₃	1.0487E-03
Zr(OH) ₄	9.8154E-03
Ru(OH) ₄	4.6633E-03
Rh(OH) ₄	8.0437E-04
Pd(OH) ₂	3.4619E-04
AgOH	7.1274E-06
Cd(OH) ₂	1.7309E-05
In(OH) ₃	3.0546E-06
Sn(OH) ₄	2.5455E-05
Sb(OH) ₃	7.1274E-06
BaSO ₄	3.0851E-03
La(OH) ₃	1.8837E-03
Ce(OH) ₃	3.6044E-03
Pr(OH) ₃	1.7309E-03
Nd(OH) ₃	6.3230E-03
Pm(OH) ₃	1.5273E-05
Sm(OH) ₃	1.4560E-03
Eu(OH) ₃	7.6365E-05
Gd(OH) ₃	1.7309E-05
Tb(OH) ₃	3.0546E-06
Dy(OH) ₃	2.0364E-06
Subtotal	3.7147E-02
Actinides	
UO ₂ (OH) ₂	3.1432E-02
NpO ₂	3.5637E-04
PuO ₂	3.7673E-04
AmO ₂	2.7491E-04
CmO ₂	4.0728E-06
Subtotal	3.2444E-02
Others	
Fe(OH) ₃	6.7242E-01
FePO ₄	6.4666E-02
Al(OH) ₃	5.9585E-02
AlF ₃	6.2415E-03
MnO ₂	4.6644E-02
CaCO ₃	3.2664E-02
SiO ₂	1.2860E-02
Ni(OH) ₂	1.1078E-02
MgCO ₃	8.4103E-03
Cu(OH) ₂	3.8284E-03
Zr(OH) ₄	9.8154E-03 ^b
Zn(OH) ₂	1.3033E-03

Table 2.18 (continued)

Compound	Mass fraction
Cr(OH) ₃	6.6183E-04
Hg(OH) ₂	2.3418E-04
Subtotal	9.3041E-01
Grand total	1.0000

^aTaken from ref. 1(d).^bExcludes fission product zirconium.

**Table 2.19. Chemical composition of acid liquid HLW
(from reprocessing via a THOREX flowsheet) at WVDP^a**

Compound	Wt %	Total, kg
Th(NO ₃) ₄	36.42	31,054
Fe(NO ₃) ₃	9.92	8,462
Al(NO ₃) ₃	4.90	4,175
HNO ₃	3.29	2,805
Cr(NO ₃) ₃	2.25	1,918
Ni(NO ₃) ₂	0.93	79
H ₃ BO ₃	0.56	480
NaNO ₃	0.27	227
KNO ₃	0.22	191
Na ₂ SO ₄	0.21	180
Na ₂ SiO ₃	0.15	126
KMnO ₄	0.11	98
Nd(NO ₃) ₃	0.086	73
Mg(NO ₃) ₂	0.067	57
Na ₂ MoO ₄	0.063	54
NaCl	0.059	50
Ce(NO ₃) ₄	0.050	43
Ru(NO ₃) ₄	0.049	42
ZrO ₂	0.041	35
Ca(NO ₃) ₂	0.035	30
CsNO ₃	0.033	28
Ba(NO ₃) ₂	0.032	27
La(NO ₃) ₃	0.026	22
Pr(NO ₃) ₃	0.025	21
Sr(NO ₃) ₂	0.019	16
Y(NO ₃) ₃	0.016	14
Sm(NO ₃) ₃	0.016	14
Zr(NO ₃) ₄	0.014	12
Na ₃ PO ₄	0.014	12
NaTcO ₄	0.013	11
Rh(NO ₃) ₄	0.013	11
Zn(NO ₃) ₂	0.012	10
Pd(NO ₃) ₄	0.0094	8
UO ₂ (NO ₃) ₂	0.0070	6
RbNO ₃	0.0070	6
Na ₂ TcO ₄	0.0059	5
Co(NO ₃) ₂	0.0035	3
Na ₂ SeO ₄	0.0012	1
NaF	0.0012	1
Eu(NO ₃) ₃	0.0012	1
Np(NO ₃) ₄	0.0011	0.9
Cu(NO ₃) ₂	0.00094	0.8

Table 2.19 (continued)

Compound	Wt %	Total, kg
Sn(NO ₃) ₃	0.00082	0.7
Pa(NO ₃) ₄	0.00082	0.7
Pu(NO ₃) ₄	0.00082	0.7
Gd(NO ₃) ₃	0.00047	0.4
Cd(NO ₃) ₂	0.00035	0.3
Sb(NO ₃) ₃	0.00012	0.1
AgNO ₃	0.000094	0.08
In(NO ₃) ₃	0.000047	0.04
Ge(NO ₃) ₄	0.000023	0.02
Pm(NO ₃) ₂	0.000011	0.01
Tb(NO ₃) ₃	0.0000047	0.004
Dy(NO ₃) ₃	0.0000023	0.002
Solids	59.95	51,125
H ₂ O (by difference)	40.05	34,148
Total	100.00	85,273

^aTaken from ref. 1(d).

**Table 2.20. Representative chemical composition
of future HLW glass at WVDP^a**

Component	Wt %
Al ₂ O ₃	6.00
B ₂ O ₃	12.89
BaO	0.16
CaO	0.48
Ca ₂ O ₃	0.31
CoO	0.02
Cr ₂ O ₃	0.14
Cs ₂ O	0.08
CuO	0.03
Fe ₂ O ₃	12.02
K ₂ O	5.00
La ₂ O ₃	0.04
Li ₂ O	3.71
MgO	0.89
MnO	0.82
MoO ₃	0.04
Na ₂ O	8.00
Nd ₂ O ₃	0.14
NiO	0.25
P ₂ O ₅	1.20
PdO	0.03
Pr ₆ O ₁₁	0.04
Rh ₂ O ₃	0.02
RuO ₂	0.08
SO ₃	0.23
SiO ₂	40.98
Sm ₂ O ₃	0.03
SrO	0.02
ThO ₂	3.56
TiO ₂	0.80
UO ₃	0.63
Y ₂ O ₃	0.02
ZnO	0.02
ZrO ₂	1.32
Total	100.00
Density (25°C), g/mL	2.6

^aTaken from ref. 1(d).

Table 2.21. Representative radionuclide composition (Ci) of current HLW component materials through 1993, future blended slurry targeted for 1995, and canistered glass as of 1996^a

Radionuclide	Alkaline waste (PUREX)		Acid waste (THOREX)	Zeolite waste (Ion exchanger)	Total ^b	Alkaline slurry ^c	Glass ^d
	Liquid	Sludge	Liquid	Wet mixture			
⁹⁰ Sr		4.47E+05	4.47E+05		8.94E+05	8.52E+05	2.74E+05
⁹⁰ Y		4.47E+05	4.47E+05		8.94E+05	8.52E+05	2.74E+05
¹⁰⁶ Ru		1.78E+00			1.78E+00		
¹⁰⁶ Rh		1.78E+00			1.78E+00		
¹³⁴ Cs				1.83E+03	1.83E+03		
¹³⁵ Cs				1.56E+02	1.56E+02		
¹³⁷ Cs	9.35E+05		4.48E+05	5.34E+06	6.72E+06	6.42E+06	2.07E+06
^{137m} Ba	8.84E+05		4.23E+05	5.05E+06	6.36E+06	6.07E+06	1.96E+06
¹⁴⁷ Pm	1.17E+02				1.17E+02		
²³⁸ Pu		7.62E+03			7.62E+03		
²³⁹ Pu			2.81E+00		2.81E+00	1.59E+00	3.96E-01
²⁴¹ Pu	1.09E+03				1.09E+03		
²⁴¹ Am		9.12E+04			9.12E+04		
²⁴⁴ Cm			1.09E+01		1.09E+01	1.00E+01	3.19E+00
Total	1.82E+06	9.93E+05	1.77E+06	1.04E+07	1.50E+07	1.42E+07	4.58E+06
Specific activity, ^e Ci/L	1.04	33.1	35.4	65	9.68	15.6	57.25

^aTaken or calculated from ref. 1(d), WVDP.

^bLiquid, sludge, and zeolite curies are as of December 31, 1993.

^cAlkaline slurry represents the blended waste for vitrification. This blend is the combination of the neutralized acid waste, alkaline liquid, alkaline sludge, and zeolite. Alkaline slurry curies are as of December 31, 1995.

^dGlass curies are as of December 31, 1996, which is the first year of full glass generation.

^eSpecific activity is defined in this table to be the radioactivity of a waste type at a given time divided by the volume of that waste type at the given time.

A drum miner removing underground salt in the Waste Isolation Pilot Plant (WIPP). Courtesy of the Westinghouse Electric Corporation, WIPP Project Office, Carlsbad, New Mexico, and the MAC Technical Services Company, Albuquerque, New Mexico.

3. TRANSURANIC WASTE

3.1 INTRODUCTION

This chapter presents information on the inventories and characteristics of transuranic waste (TRUW) at various sites in the United States. TRUW is a waste category peculiar to DOE; it does not apply to wastes regulated by the NRC. DOE Order 5820.2A defines TRUW as waste that (1) is contaminated with alpha-emitting transuranium (i.e., atomic numbers greater than 92) radionuclides with half-lives greater than 20 years and (2) contains a total concentration of such radionuclides in excess of 100 nCi/g of waste at the time of assay.¹

Under an earlier definition, DOE wastes containing more than 10 nCi of TRU radionuclides per gram of waste were classified as TRUW. The change to 100 nCi of TRU radionuclides per gram of waste took place in 1984. As a result of this change, some waste that had already been classified as TRUW became potentially reclassifiable as low-level waste (LLW). Some of this waste has been so reclassified, and some is still managed as TRUW with the potential of its being reclassified as LLW at some future time.

DOE Order 5820.2A also states that heads of field elements can determine that other alpha-contaminated waste peculiar to a specific site must be managed as TRUW.¹ As a consequence of this provision, wastes containing radionuclides such as ²³³U, ²⁴¹Pu, and ²⁴⁴Cm, which do not meet the strict definition of TRU radionuclides because of atomic number or half-life, may be classified as TRUW at some sites.

TRUW is primarily generated by research and development activities, plutonium recovery, weapons manufacturing, environmental restoration, and decontamination and decommissioning (D&D) projects. Most TRUW exists in solid form (e.g., items such as protective clothing, paper trash, rags, glass, miscellaneous tools, and equipment that have become contaminated with TRU radionuclides). Some TRUWs are in liquid form (sludges) resulting from chemical processing for recovery of plutonium or other TRU elements. Prior to 1970, TRUW was disposed of on-site in shallow, landfill-type configurations. TRUW disposed of in this manner is

referred to as "buried" TRUW. In 1970, the U.S. Atomic Energy Commission (AEC), which was a predecessor to DOE, concluded that waste containing long-lived alpha-emitting radionuclides should have greater confinement from the environment. Thus, all TRUW generated since the early 1970s has been segregated from other waste types and placed in retrievable storage pending shipment and final disposal in a permanent geologic repository.² This waste is referred to as "retrievably stored" TRUW. Retrievably stored waste is contained in a variety of packagings (metal drums, wooden and metal boxes) and is stored in earth-mounded berms, concrete culverts, or other types of facilities.

TRUW packages are classified as either "contact handled" (CH) or "remote handled" (RH) depending on the radiation level at the surface of the package at the time of packaging. If this level exceeds 200 mrem/h, the package is classified as RH.

CH TRUW contains relatively small quantities of fission and activation products that produce highly penetrating radiation; typically, its emissions consist mostly of alpha particles and low-energy photons of little penetrating power. Most TRUW (more than 90% by volume) is of the CH type. RH TRUW typically contains a greater proportion of fission and activation products that produce highly penetrating radiation, and therefore produce a higher level of radiation at the surface of the package.

It is estimated that as much as 50 to 60% of TRUW is mixed waste, meaning that it contains, in addition to radioactive constituents, hazardous constituents defined and regulated in accordance with the Resource Conservation and Recovery Act (RCRA). Examples of mixed waste are radionuclide-contaminated spent solvents, discarded materials contaminated with both solvents and radioactive materials, scintillation fluids, and discarded contaminated lead shielding. Mixed TRUW must be managed to comply with the applicable hazardous waste regulations (e.g., RCRA) as well as those applying to radioactive TRUW only. Some TRUW may be contaminated with hazardous materials defined by other regulations. DOE is currently developing strategies for

identifying and managing TRUW containing hazardous contaminants defined by regulations other than RCRA.

Under existing arrangements, retrievably stored TRUW is the responsibility of the DOE/EM Office of Waste Management (EM-30). It is planned that the retrievably stored TRUW and newly generated TRUW from defense-related activities will be shipped to the Waste Isolation Pilot Plant (WIPP) for disposal. Prior to the start of these shipments, it is planned that tests will be conducted over approximately the next 4 years to ensure that the wastes to be shipped to WIPP and the criteria for their emplacement at WIPP will meet all applicable federal and state requirements for TRUW and mixed TRUW. If the test phase is successful, the retrievable TRUW inventory will be disposed of in WIPP over approximately the next 20 years.

Buried TRUW and TRUW generated from site remediation activities and D&D activities are the responsibility of the Office of Environmental Restoration (EM-40). The disposition of TRUW in these categories is uncertain at this time.

3.2 TRUW INVENTORIES

3.2.1 Sources of Data

Quantitative information contained in this chapter is derived from data furnished by the DOE sites through annual data calls, as described later in this section. As programs and plans evolve or change, modifications or additions will be made to the data and other information in this chapter. It is expected that the quality and accuracy of the data will improve with each annual revision of this document, thus improving the usefulness of the data for program planning and decision purposes.

Early TRUW inventory practices were not as stringent as those of today in regard to requirements for waste identification, categorization, and segregation. Consequently, the early inventory data are based largely on process knowledge and on various studies and summaries related to site-specific practices.³ As these efforts continue and TRUW is further characterized by radioassay, significant revisions in the estimated overall quantities of TRUW are anticipated.

3.2.2 Site Locations—Summarized Volumes and Radioactivity

TRUW management activities (generation, retrievable storage, etc.) are performed at six major and fourteen minor sites. The major sites, from the standpoint of

TRUW quantities, are (1) the Hanford Site (HANF), (2) Idaho National Engineering Laboratory (INEL), (3) Los Alamos National Laboratory (LANL), (4) Oak Ridge National Laboratory (ORNL), (5) Rocky Flats Plant (RFP), and (6) the Savannah River Site (SRS). HANF and RFP no longer generate TRUW as part of weapons production processes but do generate TRUW as part of environmental restoration (cleanup) activities. The 14 minor sites are (1) Ames Laboratory (AMES), (2) Argonne National Laboratory—East (ANL-E), (3) Bettis Atomic Power Laboratory (BAPL), (4) Knolls Atomic Power Laboratory (KAPL), (5) Lawrence Berkeley Laboratory (LBL), (6) Lawrence Livermore National Laboratory (LLNL), (7) Mound Laboratory (MOUND), (8) Nevada Test Site (NTS), (9) Paducah Gaseous Diffusion Plant (PAD), (10) Pantex Plant (PANT), (11) Sandia National Laboratory (SNL/NM), (12) Santa Susana Field Laboratory (SSFL) [also referred to as the Energy Technology Engineering Center (ETEC)], (13) University of Missouri (MURR), and (14) West Valley Demonstration Project (WVDP). Figure 3.1 shows the locations of the sites that store the largest quantities of TRUW and gives an approximate indication of the relative volumes of TRUW stored at each site. Figure 3.2 shows the volumes of CH and RH retrievably stored TRUW at the major sites and clearly shows that the preponderance of TRUW volume is in the CH category. Figure 3.3 shows the decayed radioactivities of retrievably stored CH and RH TRUW at the major sites as of December 31, 1993.

3.2.3 Development of Detailed Inventory Data

Last year's IDB described recent changes in the manner in which TRUW data were collected, reviewed, and used.⁴ This year, the data collection process for the IDB was adjusted somewhat to allow for the priority collection of data for the WIPP Baseline Inventory Report.

3.2.3.1 Site data submittal process

All of the quantitative TRUW data in the IDB are ultimately derived from the site data submittals. The sites supply volumes, radionuclide compositions, and curies of each radionuclide added in each year of TRUW accumulation. This is done for each TRUW type (CH stored, RH stored, CH buried, and RH buried). The annual radioactivities in the site submittals are on an as-stored basis; that is, they represent the curies of each radionuclide added each year at the end of the year in which the waste was placed in storage. The data are entered by the sites on standardized forms. The complete set of TRUW site data submittals for this year's IDB is listed as ref. 5 (Sect. 3.6). In a few cases, it was found necessary to use last year's

submittal to the IDB because no submittal was received this year.

3.2.3.2 Site data review and modification

The site data submittals for TRUW were reviewed to make certain, insofar as possible, that the data supplied met the requirements of completeness and consistency. The data review process included modifying the formats of the data so that they could be easily converted to input data files for use in the decay calculations.

3.2.3.3 As-stored volumes and radioactivities

Tables 3.1 through 3.3 summarize a small portion of the information in the site submittals. These tables show the volumes and cumulative as-stored (undecayed) radioactivities of retrievably stored CH and RH TRUW at each site in 5-year increments from 1970 to 1990 and at the end of 1993. Table 3.2 shows total radioactivities (i.e., all radionuclides included), and Table 3.3 shows TRU radioactivity (i.e., only TRU radionuclides included).

3.2.3.4 Calculation of annual decayed radioactivities

As described in last year's IDB report, a computer code converts the annual as-stored radioactivities to annual decayed radioactivities and accumulates these quantities to produce tables showing decayed grams, curies, and watts on a year-by-year, site-by-site, and radionuclide-by-radionuclide basis. Annual added volumes and cumulative volumes are also shown. Volumes are assumed to be unaffected by decay.

In a number of cases, the site-submitted data were not sufficiently detailed to permit the desired decay calculations. The difficulty most frequently encountered was that radionuclide compositions were not adequately specified on a radionuclide-by-radionuclide basis. In some cases, data conversion codes were used to convert site-supplied input data to the radionuclide-specific forms required for decay calculations. These codes were used as follows:

1. Where the site-supplied data called for mixtures of fission products but did not give quantitative composition data for such mixtures, the assumption was made that the isotopic composition was the same as that specified by Hanford in its submittal to last year's (Rev. 9) IDB report.
2. Certain parent fission products are always accompanied by short-lived daughters. Short-lived daughter fission products are added in cases where the

site submittal shows the parent but does not specifically show the daughter and it is clear that the daughter must be present. For example, if a site shows 100 Ci of ^{90}Sr but does not show any ^{90}Y , it is assumed that the 100 Ci is the total activity of parent and daughter and the input is changed to 50 Ci ^{90}Sr and 50 Ci ^{90}Y . Other fission product parent-daughter combinations are handled in the same manner, using the appropriate curie ratio for each combination.

3.2.4 Results of Inventory Calculations

3.2.4.1 Retrievably stored wastes

Tables 3.4 and 3.5 show the cumulative decayed radioactivities of retrievably stored CH and RH TRUWs for each of the sites by 5-year increments from 1970 through 1990 and at the end of 1993. These tables are analogous to Tables 3.2 and 3.3, except that in Tables 3.4 and 3.5 the radioactivities are on a decayed basis; that is, they take into account the processes of radioactive decay and ingrowth of radioactive daughters. As before, Table 3.4 shows total radioactivities (all radionuclides included), and Table 3.5 shows only the radioactivities of TRU radionuclides. As previously stated, it is assumed throughout the tables that volumes of TRUW are not affected by radioactive decay.

Tables 3.6 and 3.7 summarize the total system inventories (i.e., all sites combined) of retrievably stored CH and RH TRUWs at DOE sites for the end of each year from 1970 to 1993. The cumulative masses, radioactivities, and thermal powers shown in these tables are decayed values. The difference between Tables 3.6 and 3.7 is that the masses, radioactivities, and thermal powers in Table 3.6 are based on all the radionuclides in the waste, whereas the quantities shown in Table 3.7 include only the contributions of the TRU radionuclides; daughters of TRU nuclides are not included in Table 3.7 unless they themselves are TRU radionuclides.

3.2.4.2 Buried TRUW

Buried TRUW volumes and radioactivities are shown in Tables 3.8 through 3.12. These are based on data provided in the site submittals. The form of the site-submitted data for buried waste is identical to that of the retrievably stored waste except that no distinction is made between CH and RH buried wastes. The buried waste tables (Tables 3.8 through 3.12) are analogous in form and information content to the retrievably stored waste tables (Tables 3.1 through 3.7) and follow the same general sequence. Table 3.8 shows as-stored volumes by sites and time periods. Tables 3.9 and 3.10 show cumulative as-

stored total and TRU-only radioactivities by sites and time periods. Tables 3.11 and 3.12 show cumulative decayed total and TRU-only radioactivities. In these tables, "total" radioactivity means that all radionuclides are included, and "TRU-only" radioactivity means that only TRU nuclides are included.

3.2.4.3 Contaminated soil

Over the years, many of the older buried waste containers have developed leaks and contaminated the adjacent soil. Also, at some sites, soil has become contaminated by liquid spills or has been used as an ion-exchange medium for dilute liquid waste streams. It is difficult to make accurate estimates of the actual quantity of contaminated soil. The data reported by the sites are shown in Table 3.13. Additional characterization efforts will be required to reduce the uncertainties in these data.

3.3 ESTIMATED MIXED WASTE CONTENT OF TRUW

The sites were requested to submit estimates of the volumes of retrievably stored CH and RH TRUWs that might fall into the category of mixed TRUWs. These estimates were requested for three time periods: 1970–1986, 1987–1993, and 1994. Table 3.14 summarizes the site-submitted estimates of these volumes.

3.4 PROJECTED FUTURE QUANTITIES OF TRUW

Table 3.15 shows the data submitted by the sites for estimated future volumes of TRUW generation. The sites were not requested to estimate the radioactivities or isotopic compositions of these wastes, since it was felt that there would be little basis for such estimates. The estimated volumes are given in terms of average annual rates (m^3/year) for seven time periods from 1994 to 2020. An effort was made to obtain estimated rates in three

categories: (1) general operations, (2) D&D, and (3) remedial action. The estimated effect of volume-reduction processes was also requested; however, little information on this was available.

3.5 TRUW DISPOSAL

The goals of the DOE TRUW Program are to terminate interim storage and achieve permanent disposal of all DOE TRUW.⁶ One of the major efforts in this direction is the WIPP project. As stated in Public Law 96–164,⁷ the WIPP project was to be constructed "... as a defense activity of the DOE for the purpose of providing a research and development facility to demonstrate the safe disposal of radioactive waste resulting from defense activities and programs of the United States." Construction of the facility is now essentially complete, and WIPP is now the only facility specifically designed for isolation of TRUW. It is designed to emplace about 175,000 m^3 of TRUW 650 m below ground in a mined salt formation.

Waste received at WIPP must meet the WIPP waste acceptance criteria and associated quality assurance requirements specified in WIPP/DOE-069.⁸ A number of other approvals remain to be completed before DOE can begin disposal operations at the facility. As previously stated, a test program of approximately 4 years will be conducted to ensure that the wastes to be shipped to WIPP, and their emplacement at WIPP, will comply with all applicable federal and state regulations. If the test phase is successful and all necessary approvals are obtained, it is planned that shipment and emplacement of wastes will begin and will continue through approximately the year 2018.

In 1993, the WIPP Legislative Land Withdrawal Act was passed, confirming congressional intent to have DOE continue with development and permitting of the facility. Since then, the DOE has stated its intent to accelerate processes leading to the start of waste disposal operations at the WIPP.

3.6 REFERENCES

1. U.S. Department of Energy, *Radioactive Waste Management*, DOE Order 5820.2A, Washington, D.C. (Sept. 26, 1988).
2. K. S. Hollingsworth, *Policy Statement Regarding Solid Waste Burial*, AEC Directive IAD No. 0511-21, Washington, D.C. (Mar. 20, 1970).

3. U.S. Department of Energy, *Defense Waste Management Plan for Buried Transuranic-Contaminated Waste, Transuranic-Contaminated Soil, and Difficult-to-Certify Transuranic Waste*, DOE/DP-0044, Washington, D.C. (June 1987).
4. U.S. Department of Energy, *Integrated Data Base for 1993: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 9, Oak Ridge National Laboratory, Oak Ridge, Tennessee (March 1994).
5. DOE site TRUW data submittal attachments, submitted to the IDB Program during September-December 1994. The following TRUW submittals were received and reviewed by MACTEC and the IDB Program before analysis and integration. Preceding each submittal is the site (in parentheses) to which it refers.
 - a. (AMES) Kay M. Lampe Hannasch, Ames Laboratory, Ames, Iowa, correspondence to James E. Fletcher, DOE Chicago Operations Office, Argonne, Illinois, "Data Requests for TRU Waste, WIPP Baseline Inventory, IDB Request," dated Sept. 28, 1994.
 - b. (ANL-E) Michael A. Sodaro, Argonne National Laboratory, Argonne, Illinois, correspondence to Jeff Williams, DOE Carlsbad Area Office, Argonne, Illinois, "WIPP TRU Baseline Inventory Report and Integrated Database Forecasts," dated Sept. 30, 1994.
 - c. (ANL-W) No submittal provided.
 - d. (ETEC) G. G. Gaylord, Rockwell International Corporation, Canoga Park, California, correspondence to Mark L. Matthews, DOE Carlsbad Area Office, Carlsbad, New Mexico, "TRU Inventory at ETEC," 94ETEC-DRF-1667, dated Oct. 31, 1994.
 - e. (HANF) R. D. Wojtasek, Westinghouse Hanford Company, Richland, Washington, correspondence to Lise Wachter, Martin Marietta Energy Systems, Inc., HAZWRAP, Oliver Springs, Tennessee, "Request for Office of Waste Management, Waste Information Update," 9305688B R1, dated Aug. 30, 1993. Also, F. M. Coony, Westinghouse Hanford Company, Richland, Washington, correspondence to E. W. Krieger, MAC Technical Services Company, Albuquerque, New Mexico, transmitting information on TRUW added to HANF inventory during CY 1993, dated Dec. 7, 1994.
 - f. (INEL) Joel T. Case, DOE Idaho Operations Office, Idaho Falls, Idaho, correspondence to Jim Teek, Advance Sciences, Inc., Albuquerque, New Mexico, "Integrated Data Base (IDB) TRU Waste 1994 Data Call," OPE-WM 94-308, dated Oct. 6, 1994.
 - g. (LANL) Davis Christensen, Los Alamos National Laboratory, Los Alamos, New Mexico, correspondence to Mark L. Matthews, DOE Carlsbad Area Office, Carlsbad, New Mexico, "WIPP Transuranic Waste Baseline Inventory Report," CST14-94-061, Nov. 1, 1994.
 - h. (LBL) Tim Wan, University of California, Berkeley, California, correspondence to Jeff Williams, DOE Carlsbad Area Office, Carlsbad, New Mexico, "Data Package for the Waste Isolation Pilot plant TRU Waste Baseline Inventory Report," HW-94-342, dated Sept. 13, 1994.
 - i. (LLNL) Roy Kearns, DOE Oakland Operations Office, Oakland, California, correspondence to Jeff Williams, DOE Carlsbad Area Office, Carlsbad, New Mexico, "Waste Isolation Pilot Plant Transuranic Integrated Database for Lawrence Livermore," 94W399/5484.a.13, dated Oct. 18, 1994.
 - j. (MOUND) Raymond J. Finney, EG&G Mound Applied Technologies, Miamisburg, Ohio, correspondence to Robert S. Rothman, DOE Miamisburg Area Office, Miamisburg, Ohio, "Response to the Waste Isolation Pilot Plant (WIPP) Transuranic Waste Baseline Inventory Report (WTWBIR) Data Package," dated Sept. 27, 1994.

- k. (MURR) W. Derek Pickett, University of Missouri, Columbia, Missouri, correspondence to Jim Teek, Advanced Sciences, Inc., Albuquerque, New Mexico, transmitting MURR TRUW information and data for the WIPP TRUW Baseline Inventory Report and the IDB report (Rev. 10), dated Sept. 29, 1994.
 - l. (NR sites—BAPL) E. D. Shollenberger, DOE Pittsburgh Naval Reactors Office, West Mifflin, Pennsylvania, correspondence to Mark L. Matthews, DOE Carlsbad Area Office, Carlsbad, New Mexico, "Waste Isolation Pilot Project Transuranic Waste (TRU) Baseline Inventory Report and Updated Integrated Database TRU Information for the Bettis Atomic Power Laboratory," dated Oct. 21, 1994.
 - m. (NTS) Joseph M. Ginanni, DOE Nevada Operations Office, Las Vegas, Nevada, correspondence to Jerry Klein, Oak Ridge National Laboratory, Oak Ridge, Tennessee; Jim Teak, Advance Sciences, Inc., Albuquerque, New Mexico; and Jeff Williams, DOE Carlsbad Area Office, Carlsbad, New Mexico, "Nevada Test Site Transuranic and Mixed Transuranic Inventory Data for the 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," dated Oct. 14, 1994.
 - n. (ORNL) P. E. Arakawa, Oak Ridge National Laboratory, Oak Ridge, Tennessee, correspondence to Mac Roddy, DOE Oak Ridge Operations Office, Oak Ridge, Tennessee, "Complete Review and Revision of Data Package for the WIPP Transuranic Waste Baseline Inventory Report (WTWBIR)," dated Nov. 2, 1994.
 - o. (PAD) No submittal provided.
 - p. (PANT) D. L. Heim, DOE Amarillo Area Office, Amarillo, Texas, correspondence to Jeff Williams, DOE Carlsbad Area Office, Carlsbad, New Mexico, "WIPP Transuranic (TRU) Waste Baseline Inventory Report and Integrated Database Report," dated Sept. 28, 1994.
 - q. (RFP) G. A. O'Leary, EG&G Rocky Flats Inc., Golden, Colorado, correspondence to Paul Drez, Drez and Associates, Albuquerque, New Mexico, "Transmittal of the Rocky Flats Environmental Technology Site (RFETS) Data Forms for the Waste Isolation Pilot Plant (WIPP) Transuranic (TRU) Waste Baseline Inventory Report (WTWBIR)—GAO-039-94," 94-RF-10526, dated Oct. 13, 1994.
 - r. (SNL/NM) No cover letter provided with site data submittal.
 - s. (SRS) S. J. Mentrup, Westinghouse Savannah River Company, Aiken, South Carolina, correspondence to Stan Massingill, DOE Savannah River Operations Office, Aiken, South Carolina, "SRS Data Package for WIPP TRU Waste Baseline Inventory Report (U)," SWE-SWE-94-0550, dated Oct. 12, 1994.
 - t. (WVDP) P. S. Klanian, West Valley Nuclear Services Company, Inc., West Valley, New York, correspondence to Jeff Williams, DOE Carlsbad Area Office, Carlsbad, New Mexico, "Data Package for WIPP Transuranic Waste Baseline Inventory Report (WTWBIR)," dated Nov. 14, 1994.
6. U.S. Department of Energy, *Long Range Master Plan for Defense Transuranic Waste Program*, DOE/WIPP 88-028, Carlsbad, New Mexico (December 1988).
 7. U.S. Congress, Department of Energy National Security and Military Application of Nuclear Energy Authorization Act of 1980, Pub. L. 96-164 (1980).
 8. U.S. Department of Energy, *TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, WIPP/DOE-069, Rev. 4, Carlsbad, New Mexico (December 1991).

Fig. 3.2. Retrievably stored TRUW volumes at the end of 1993, by site.

Fig. 3.3. Retrievably stored TRUW decayed radioactivity at the end of 1993, by site.

Table 3.1. Summary of retrievably stored TRUW by sites: cumulative as-stored volumes

Site name	Site acronym	Cumulative volume at end of calendar year, m ³					
		1970	1975	1980	1985	1990	1993
<i>Contact handled</i>							
Ames Laboratory	AMES	0.0	0.0	0.0	0.0	0.0	0.0
Argonne National Laboratory-East	ANL-E	0.0	0.0	0.0	0.0	25.5	29.1
Energy Technology Engineering Center	ETEC	0.0	0.0	0.0	0.0	1.9	1.9
Hanford Site	HANF	745.2	5,541.6	10,086.3	14,668.9	15,282.3	15,608.9
Idaho National Engineering Laboratory	INEL	1,420.0	28,356.0	42,341.0	57,615.0	64,774.0	64,774.0
Knolls Atomic Power Laboratory	KAPL	0.0	0.0	0.0	0.0	0.0	0.0
Lawrence Berkeley Laboratory	LBL	0.0	0.0	0.0	0.4	0.8	0.9
Lawrence Livermore National Laboratory	LLNL	0.0	0.0	0.0	0.0	194.5	235.0
Los Alamos National Laboratory	LANL	0.0	3,352.3	5,963.6	8,800.5	10,357.3	10,810.9
Mound	MOUND	0.0	1.7	4.7	7.7	10.7	11.9
Nevada Test Site	NTS	0.0	34.9	177.9	550.2	606.8	607.1
Oak Ridge National Laboratory	ORNL	12.6	541.0	726.7	901.4	1,049.6	2,015.2
Paducah Gaseous Diffusion Plant	PAD	0.0	0.0	0.0	0.0	4.3	4.3
Pantex Plant	PANT	0.0	0.0	0.0	0.0	0.0	0.6
Rocky Flats Plant	RFP	0.0	0.0	0.0	0.0	952.0	1,040.0
Sandia National Laboratory/New Mexico	SNL/NM	0.0	0.0	0.0	0.0	0.0	0.9
Savannah River Site	SRS	0.0	603.5	1,752.3	3,849.4	7,334.7	8,925.9
University of Missouri	MURR	0.0	0.0	0.0	0.0	0.0	0.1
West Valley Demonstration Project	WVDP	0.0	0.0	0.0	0.0	0.0	49.1
Total		2,177.8	38,431.0	61,052.5	86,393.5	100,594.4	104,115.8
<i>Remote handled</i>							
Ames Laboratory	AMES	0.0	0.0	0.0	0.0	0.0	0.0
Argonne National Laboratory-East	ANL-E	0.0	0.0	0.0	0.0	0.0	1.7
Energy Technology Engineering Center	ETEC	0.0	0.0	0.0	0.0	0.0	0.0
Hanford Site	HANF	10.3	127.8	194.9	198.2	201.0	201.0
Idaho National Engineering Laboratory	INEL	0.0	0.0	17.6	48.8	73.8	79.8
Knolls Atomic Power Laboratory	KAPL	0.0	0.0	0.0	0.0	0.0	2.4
Lawrence Berkeley Laboratory	LBL	0.0	0.0	0.0	0.0	0.0	0.0
Lawrence Livermore National Laboratory	LLNL	0.0	0.0	0.0	0.0	0.0	0.0
Los Alamos National Laboratory	LANL	0.0	0.0	7.9	27.4	27.4	91.3
Mound	MOUND	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.1 (continued)

Site name	Site acronym	Cumulative volume at end of calendar year, m ³					
		1970	1975	1980	1985	1990	1993
Remote handled (continued)							
Nevada Test Site	NTS	0.0	0.2	0.6	5.3	5.3	5.3
Oak Ridge National Laboratory	ORNL	1.7	221.3	361.2	440.3	540.6	563.9
Paducah Gaseous Diffusion Plant	PAD	0.0	0.0	0.0	0.0	0.0	0.0
Pantex Plant	PANT	0.0	0.0	0.0	0.0	0.0	0.0
Rocky Flats Plant	RFP	0.0	0.0	0.0	0.0	0.0	0.0
Sandia National Laboratory/New Mexico	SNL/NM	0.0	0.0	0.0	0.0	0.0	0.9
Savannah River Site	SRS	0.0	0.0	0.0	0.0	0.0	0.0
University of Missouri	MURR	0.0	0.0	0.0	0.0	0.0	0.0
West Valley Demonstration Project	WVDP	0.0	0.0	0.0	0.0	0.0	427.0
Total		12.0	349.3	582.2	720.0	540.6	1,373.3

Table 3.2. Summary of retrievably stored TRUW by sites: cumulative as-stored radioactivity (all radionuclides)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
<i>Contact handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.12	0.13
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.01
Hanford Site	HANF	1.05	19.61	191.49	278.45	325.62	331.57
Idaho National Engineering Laboratory	INEL	4.22	126.46	255.92	405.07	496.42	496.46
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.93	2.24
Los Alamos National Laboratory	LANL	0.00	49.18	108.46	151.01	212.92	218.96
Mound	MOUND	0.00	0.15	0.39	0.63	0.88	0.98
Nevada Test Site	NTS	0.00	0.25	1.12	3.30	4.00	4.00
Oak Ridge National Laboratory	ORNL	0.05	12.48	17.80	98.19	99.65	103.57
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.11
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	48.66	93.59
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	277.35	376.09	575.83	654.14	664.48
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.03	0.05	0.05
Total		5.32	485.48	951.27	1,512.50	1,843.38	1,916.14
<i>Remote handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.01
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	27.09	55.69	471.47	479.90	481.88	481.88
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.49	4.93	10.53	10.64
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.11
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.96	3.43	3.45	14.90
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.2 (continued)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
Remote handled (continued)							
Nevada Test Site	NTS	0.00	0.00	0.04	0.25	0.25	0.25
Oak Ridge National Laboratory	ORNL	0.00	0.60	0.76	0.98	167.24	178.13
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		27.09	56.30	473.72	489.48	663.36	685.92

Table 3.3. Summary of retrievably stored TRUW by sites: cumulative as-stored radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
<i>Contact handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.04	0.05
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.19	3.22	106.81	119.34	123.87	124.82
Idaho National Engineering Laboratory	INEL	1.52	50.87	122.85	183.83	205.34	205.35
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.15	0.35
Los Alamos National Laboratory	LANL	0.00	48.66	104.85	144.69	206.42	212.47
Mound	MOUND	0.00	0.15	0.39	0.63	0.88	0.98
Nevada Test Site	NTS	0.00	0.24	0.97	3.01	3.29	3.29
Oak Ridge National Laboratory	ORNL	0.01	6.28	6.59	9.89	10.01	10.73
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.11
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	12.73	28.06
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	250.87	335.90	505.74	549.61	558.85
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		1.72	360.30	678.36	967.12	1,112.35	1,145.05
<i>Remote handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.02	0.19	0.41	0.52	0.56	0.56
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.01	0.03	0.10	0.10
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.04	0.09	0.09	0.23
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.3 (continued)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
Remote handled (continued)							
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.02	0.03	0.05	1.06	1.12
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.02	0.21	0.49	0.69	1.81	2.01

Table 3.4. Summary of retrievably stored TRUW by sites: cumulative decayed radioactivity (all radionuclides)

Site name	Site acronym	Cumulative decayed radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
<i>Contact handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory--East	ANL-E	0.00	0.00	0.00	0.00	0.11	0.11
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.01
Hanford Site	HANF	1.05	18.23	183.76	244.40	229.40	218.06
Idaho National Engineering Laboratory	INEL	4.22	120.86	230.01	348.66	393.67	366.95
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.89	2.06
Los Alamos National Laboratory	LANL	0.00	48.71	102.16	140.90	195.36	198.40
Mound	MOUND	0.00	0.15	0.38	0.61	0.83	0.91
Nevada Test Site	NTS	0.00	0.26	1.11	3.26	3.86	3.78
Oak Ridge National Laboratory	ORNL	0.05	11.26	19.60	94.42	78.82	74.09
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.11
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	47.04	85.49
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	269.15	351.45	527.25	571.85	561.52
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.03	0.05	0.04
Total		5.32	468.62	888.47	1,359.53	1,521.88	1,511.54
<i>Remote handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory--East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.02
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	27.09	28.85	293.19	64.16	45.02	38.44
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.58	7.03	9.10	7.79
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.10
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.88	0.73	0.36	11.80
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.4 (continued)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
Remote handled (continued)							
Nevada Test Site	NTS	0.00	0.00	0.04	0.23	0.19	0.17
Oak Ridge National Laboratory	ORNL	0.00	0.53	0.51	0.60	295.02	290.20
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		27.09	29.38	295.20	72.75	349.69	348.53

Table 3.5. Summary of retrievably stored TRUW by sites: cumulative decayed radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative decayed radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
<i>Contact handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.04	0.05
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.19	3.25	107.01	116.77	118.79	118.24
Idaho National Engineering Laboratory	INEL	1.52	50.91	122.40	181.58	201.41	200.38
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.15	0.35
Los Alamos National Laboratory	LANL	0.00	48.36	101.55	137.44	194.68	197.92
Mound	MOUND	0.00	0.15	0.38	0.61	0.83	0.91
Nevada Test Site	NTS	0.00	0.24	0.96	3.00	3.27	3.27
Oak Ridge National Laboratory	ORNL	0.01	6.14	6.27	9.45	9.83	10.65
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.11
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	12.77	28.27
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	243.64	318.77	473.72	499.52	497.85
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		1.72	352.69	657.35	922.56	1,041.30	1,058.01
<i>Remote handled</i>							
Ames Laboratory	AMES	0.00	0.00	0.00	0.00	0.00	0.00
Argonne National Laboratory-East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Center	ETEC	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.02	0.20	0.44	0.60	0.67	0.70
Idaho National Engineering Laboratory	INEL	0.00	0.00	0.01	0.03	0.10	0.10
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.04	0.09	0.09	0.23
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.5 (continued)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci					
		1970	1975	1980	1985	1990	1993
Remote handled (continued)							
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.02	0.03	0.05	1.04	1.07
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00
Pantex Plant	PANT	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	0.00	0.00	0.00	0.00	0.00	0.00
University of Missouri	MURR	0.00	0.00	0.00	0.00	0.00	0.00
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.02	0.22	0.52	0.76	1.91	2.10

Table 3.6. Retrievably stored TRUW inventories and decayed characteristics,
total of all sites, all radionuclides included

End of calendar year	Volume (m ³)		Total mass ^a (kg)		Radioactivity (10 ³ Ci)		Thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Contact handled</i>								
1970	2,177.8	2,177.8	47.1	47.1	5.32	5.32	0.06	0.06
1971	8,955.7	11,133.4	331.3	378.4	233.12	238.26	7.28	7.34
1972	7,542.4	18,675.8	1,087.9	1,466.3	69.46	305.13	1.66	8.95
1973	7,120.4	25,796.2	131.8	1,598.1	29.88	331.29	0.46	9.34
1974	5,746.9	31,543.1	3,950.9	5,549.1	69.27	396.17	1.64	10.91
1975	6,887.8	38,430.9	885.6	6,434.6	78.44	468.62	0.94	11.77
1976	2,464.9	40,895.7	4,374.6	10,809.2	48.80	509.33	1.19	12.88
1977	5,651.9	46,547.6	730.3	11,539.5	64.83	565.33	1.39	14.18
1978	4,016.0	50,563.7	192.1	11,731.6	67.58	622.07	1.58	15.66
1979	5,421.1	55,984.7	3,403.2	15,134.8	91.29	707.17	1.77	17.35
1980	5,067.7	61,052.4	4,611.1	19,745.9	193.29	888.47	4.62	21.86
1981	5,255.1	66,307.5	1,105.3	20,851.2	100.30	973.81	2.16	23.88
1982	4,967.6	71,275.1	1,082.9	21,934.2	102.40	1,059.86	2.38	26.11
1983	4,634.3	75,909.3	1,238.3	23,172.4	84.72	1,126.81	2.03	27.95
1984	5,045.9	80,955.2	734.0	23,906.4	154.89	1,265.86	1.31	29.07
1985	5,438.2	86,393.5	307.7	24,214.1	118.93	1,359.53	1.72	30.61
1986	5,337.0	91,730.5	375.8	24,589.9	114.44	1,439.14	1.30	31.68
1987	3,147.9	94,878.3	466.7	25,056.7	75.36	1,473.21	1.22	32.66
1988	2,631.6	97,509.9	294.6	25,351.2	52.01	1,491.59	0.97	33.42
1989	1,698.2	99,208.1	231.6	25,582.9	44.67	1,506.22	0.65	33.87
1990	1,386.4	100,594.4	209.1	25,792.0	44.38	1,521.88	0.61	34.30
1991	1,717.2	102,311.7	155.5	25,947.5	35.31	1,528.99	0.60	34.71
1992	361.4	102,673.0	96.4	26,043.9	26.16	1,527.58	0.25	34.78
1993	1,442.8	104,115.9	125.6	26,169.5	11.29	1,511.54	0.22	34.81
<i>Remote handled</i>								
1970	12.0	12.0	29.6	29.6	27.09	27.09	0.32	0.32
1971	15.9	27.8	22.5	52.1	7.85	29.95	0.09	0.36
1972	94.9	122.8	12.1	64.2	2.86	28.48	0.03	0.34
1973	59.8	182.5	0.5	64.7	7.73	32.42	0.04	0.34
1974	41.1	223.6	0.8	65.4	5.88	31.46	0.02	0.31
1975	125.7	349.3	1.4	66.8	4.88	29.38	0.05	0.31
1976	76.6	425.9	2.7	69.5	5.25	30.00	0.02	0.29
1977	56.6	482.5	2.1	71.6	14.35	38.75	0.16	0.41
1978	49.4	531.9	2.9	74.5	1.12	34.05	0.00	0.35
1979	23.1	555.0	8.1	82.5	234.91	265.11	1.10	1.41
1980	27.1	582.1	3.7	86.2	161.78	295.20	0.69	1.47
1981	33.2	615.4	9.5	95.7	5.13	164.14	0.05	0.88
1982	33.1	648.4	2.9	98.6	3.33	115.24	0.02	0.64
1983	34.2	682.6	15.6	114.2	3.80	92.69	0.01	0.52
1984	20.8	703.5	12.1	126.2	0.78	77.57	0.01	0.44
1985	16.5	720.0	3.1	129.3	2.73	72.75	0.01	0.40
1986	18.8	738.8	2.4	131.6	1.39	66.14	0.01	0.37
1987	88.8	827.6	6,456.0	6,587.6	19.45	97.62	0.04	0.46
1988	5.2	832.8	3.5	6,591.2	4.12	98.46	0.01	0.45
1989	3.3	836.1	153,569.2 ^b	160,160.4 ^b	144.29	355.44	0.40	1.43
1990	12.0	848.1	4,625.7	164,786.1 ^b	4.64	349.69	0.01	1.39
1991	55.9	903.9	6,475.8	171,261.9 ^b	6.12	349.21	0.02	1.38

Table 3.6 (continued)

End of calendar year	Volume (m ³)		Total mass ^a (kg)		Radioactivity (10 ³ Ci)		Thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Remote handled (continued)</i>								
1992	435.9	1,339.9	5,088.1	176,350.0 ^b	4.89	347.22	0.01	1.36
1993	33.3	1,373.2	2.2	176,352.3 ^b	11.56	348.53	0.04	1.34
<i>Total</i>								
1970	2,189.7	2,189.7	76.7	76.7	32.41	32.41	0.38	0.38
1971	8,971.5	11,161.3	353.8	430.5	240.98	268.21	7.37	7.70
1972	7,637.3	18,798.5	1,100.0	1,530.5	72.32	333.61	1.70	9.29
1973	7,180.2	25,978.7	132.3	1,662.8	37.60	363.70	0.49	9.67
1974	5,788.0	31,766.7	3,951.7	5,614.5	75.15	427.63	1.66	11.21
1975	7,013.5	38,780.2	8,87.0	6,501.4	83.32	497.99	1.00	12.08
1976	2,541.5	41,321.6	4,377.2	10,878.7	54.05	539.34	1.22	13.17
1977	5,708.5	47,030.1	732.4	11,611.1	79.18	604.08	1.55	14.58
1978	4,065.4	51,095.6	195.0	11,806.1	68.70	656.12	1.59	16.01
1979	5,444.2	56,539.7	3,411.3	15,217.4	326.20	972.28	2.87	18.76
1980	5,094.8	61,634.5	4,614.8	19,832.1	355.08	1,183.66	5.32	23.33
1981	5,288.3	66,922.9	1,114.8	20,946.9	105.42	1,137.95	2.20	24.76
1982	5,000.6	71,923.5	1,085.8	22,032.7	105.73	1,175.10	2.40	26.75
1983	4,668.5	76,592.0	1,253.9	23,286.6	88.52	1,219.51	2.04	28.47
1984	5,066.8	81,658.7	746.0	24,032.6	155.67	1,343.43	1.32	29.51
1985	5,454.8	87,113.5	310.7	24,343.4	121.66	1,432.28	1.73	31.01
1986	5,355.7	92,469.2	378.2	24,721.6	115.83	1,505.28	1.32	32.05
1987	3,236.7	95,705.9	6,922.7	31,644.3	94.81	1,570.83	1.26	33.12
1988	2,636.8	98,342.6	298.1	31,942.4	56.13	1,590.06	0.98	33.87
1989	1,701.5	100,044.1	153,800.8 ^b	185,743.2 ^b	188.96	1,861.65	1.05	35.31
1990	1,398.4	101,442.5	4,834.8	190,578.0 ^b	49.01	1,871.57	0.63	35.69
1991 ^c	1,773.1	103,215.6	6,631.3	197,209.4 ^b	41.42	1,878.20	0.62	36.09
1992	797.3	104,012.9	5,184.5	202,393.9 ^b	31.05	1,874.81	0.27	36.13
1993	1,476.1	105,489.0	127.9	202,521.8 ^b	22.86	1,860.07	0.26	36.16

^aMass means mass of radionuclides, not of total waste.

^bSite-supplied data show an anomalously large mass (153,569 kg) of radionuclides added to RH TRUW in 1989. An effort is being made to resolve this. Cumulative masses for 1989 and subsequent years should be regarded as subject to revision.

^cSRS CH waste data are not available for individual years prior to 1991 but are included in totals for years 1991 and 1992.

Table 3.7. Retrievably stored TRUW inventories and decayed characteristics, total of all sites, only TRU radionuclides included^a

End of calendar year	Volume (m ³)		TRU mass ^b (kg)		TRU radioactivity (10 ³ Ci)		TRU thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Contact handled</i>								
1970	2,177.8	2,177.8	8.3	8.3	1.72	1.72	0.06	0.06
1971	8,955.7	11,133.4	39.3	47.6	219.37	221.09	7.26	7.31
1972	7,542.4	18,675.8	39.8	87.4	49.88	269.32	1.65	8.91
1973	7,120.4	25,796.2	40.0	127.4	12.09	279.51	0.39	9.24
1974	5,746.9	31,543.1	51.6	179.1	48.79	326.41	1.61	10.78
1975	6,887.8	38,430.9	77.6	256.7	28.46	352.69	0.93	11.64
1976	2,464.9	40,895.7	37.0	293.6	35.34	385.80	1.16	12.73
1977	5,651.9	46,547.6	64.6	358.2	41.65	425.01	1.37	14.02
1978	4,016.0	50,563.7	61.6	419.8	47.91	470.27	1.58	15.51
1979	5,421.1	55,984.7	122.8	542.6	53.31	520.67	1.75	17.16
1980	5,067.7	61,052.4	158.1	700.7	139.85	657.35	4.61	21.66
1981	5,255.1	66,307.5	154.4	855.0	65.52	718.78	2.15	23.68
1982	4,967.6	71,275.1	186.4	1,041.4	70.37	784.73	2.31	25.83
1983	4,634.3	75,909.3	165.0	1,206.4	61.74	841.67	2.02	27.70
1984	5,045.9	80,955.2	218.4	1,424.8	40.19	876.73	1.30	28.83
1985	5,438.2	86,393.5	242.6	1,667.4	50.93	922.56	1.65	30.31
1986	5,337.0	91,730.5	234.6	1,902.0	37.81	955.15	1.22	31.35
1987	3,147.9	94,878.3	155.7	2,057.7	37.04	986.94	1.20	32.38
1988	2,631.6	97,509.9	288.6	2,346.4	30.59	1,012.20	0.97	33.17
1989	1,698.2	99,208.1	221.0	2,567.4	20.63	1,027.47	0.65	33.65
1990	1,386.4	100,594.4	199.7	2,767.1	19.17	1,041.30	0.61	34.08
1991 ^c	1,717.2	102,311.7	142.7	2,909.8	18.89	1,054.86	0.60	34.50
1992	361.4	102,673.0	52.5	2,962.3	7.69	1,057.21	0.25	34.57
1993	1,442.8	104,115.9	95.1	3,057.3	6.12	1,058.01	0.20	34.61
<i>Remote handled</i>								
1970	12.0	12.0	0.3	0.3	0.02	0.02	0.00	0.00
1971	15.9	27.8	0.2	0.5	0.02	0.05	0.00	0.00
1972	94.9	122.8	1.1	1.6	0.09	0.14	0.00	0.00
1973	59.8	182.5	0.3	1.9	0.03	0.17	0.00	0.01
1974	41.1	223.6	0.2	2.1	0.01	0.19	0.00	0.01
1975	125.7	349.3	0.3	2.4	0.03	0.22	0.00	0.01
1976	76.6	425.9	0.5	2.9	0.05	0.27	0.00	0.01

Table 3.7 (continued)

End of calendar year	Volume (m ³)		TRU mass ^b (kg)		TRU radioactivity (10 ³ Ci)		TRU thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Remote handled (continued)</i>								
1977	56.6	482.5	0.6	3.5	0.06	0.33	0.00	0.01
1978	49.4	531.9	0.5	4.0	0.04	0.37	0.00	0.01
1979	23.1	555.0	1.1	5.1	0.09	0.47	0.00	0.01
1980	27.1	582.1	0.5	5.6	0.04	0.52	0.00	0.02
1981	33.2	615.4	0.7	6.3	0.05	0.58	0.00	0.02
1982	33.1	648.4	0.4	6.7	0.03	0.62	0.00	0.02
1983	34.2	682.6	0.6	7.3	0.07	0.70	0.00	0.02
1984	20.8	703.5	0.4	7.7	0.03	0.74	0.00	0.02
1985	16.5	720.0	0.2	7.9	0.01	0.76	0.00	0.02
1986	18.8	738.8	0.2	8.0	0.01	0.78	0.00	0.02
1987	88.8	827.6	0.7	8.7	0.13	0.92	0.00	0.03
1988	5.2	832.8	0.2	8.9	0.02	0.95	0.00	0.03
1989	3.3	836.1	2.5	11.4	0.88	1.84	0.03	0.06
1990	12.0	848.1	0.1	11.5	0.08	1.91	0.00	0.06
1991	55.9	903.9	0.1	11.6	0.04	1.95	0.00	0.06
1992	435.9	1,339.9	0.1	11.7	0.03	1.97	0.00	0.06
1993	33.3	1,373.2	2.2	13.9	0.13	2.10	0.00	0.07
<i>Total</i>								
1970	2,189.7	2,189.7	8.5	8.5	1.74	1.74	0.06	0.06
1971	8,971.5	11,161.3	39.5	48.1	219.39	221.13	7.26	7.32
1972	7,637.3	18,798.5	40.9	89.0	49.97	269.46	1.65	8.91
1973	7,180.2	25,978.7	40.4	129.4	12.12	279.69	0.40	9.24
1974	5,788.0	31,766.7	51.8	181.2	48.80	326.60	1.61	10.79
1975	7,013.5	38,780.2	77.9	259.1	28.48	352.91	0.93	11.65
1976	2,541.5	41,321.6	37.5	296.6	35.39	386.07	1.17	12.74
1977	5,708.5	47,030.1	65.2	361.7	41.71	425.34	1.37	14.03
1978	4,065.4	51,095.6	62.0	423.8	47.96	470.65	1.58	15.52
1979	5,444.2	56,539.7	123.9	547.7	53.40	521.14	1.75	17.18
1980	5,094.8	61,634.5	158.6	706.3	139.89	657.87	4.61	21.68
1981	5,288.3	66,922.9	155.1	861.3	65.57	719.37	2.15	23.69
1982	5,000.6	71,923.5	186.8	1,048.1	70.41	785.35	2.31	25.85
1983	4,668.5	76,592.0	165.6	1,213.7	61.81	842.37	2.02	27.72

Table 3.7 (continued)

End of calendar year	Volume (m ³)		TRU mass ^b (kg)		TRU radioactivity (10 ³ Ci)		TRU thermal power (10 ³ W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
<i>Total (continued)</i>								
1984	5,066.8	81,658.7	218.8	1,432.5	40.22	877.47	1.30	28.85
1985	5,454.8	87,113.5	242.8	1,675.3	50.95	923.32	1.65	30.33
1986	5,355.7	92,469.2	234.7	1,910.0	37.82	955.93	1.22	31.37
1987	3,236.7	95,705.9	156.4	2,066.4	37.17	987.86	1.21	32.41
1988	2,636.8	98,342.6	288.8	2,355.3	30.61	1,013.15	0.97	33.20
1989	1,701.5	100,044.1	223.5	2,578.8	21.51	1,029.31	0.68	33.71
1990	1,398.4	101,442.5	199.8	2,778.6	19.24	1,043.21	0.61	34.14
1991 ^c	1,773.1	103,215.6	142.8	2,921.4	18.93	1,056.80	0.60	34.57
1992	797.3	104,012.9	52.5	2,973.9	7.72	1,059.18	0.25	34.64
1993	1,476.1	105,489.0	97.2	3,071.2	6.25	1,060.11	0.20	34.68

^aRadioactive daughters of TRU radionuclides are not included.

^bTRU mass means mass of TRU radionuclides, not of total waste.

^cSRS CH waste data not available for individual years prior to 1991 but is included in totals for years 1991 and 1992.

Table 3.8. Summary of buried TRUW by sites: cumulative as-stored volumes

Site name	Site acronym	Cumulative volume at end of calendar year, m ³									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1993
Argonne National Laboratory–East	ANL–E	0	0	0	0	0	0	0	0	0	0
Energy Technology Engineering Center	ETEC	0	0	0	0	0	0	0	0	0	0
Hanford Site	HANF	779	6,159	16,333	35,509	47,932	63,624	63,629	63,629	63,629	63,629 ^a
Idaho National Engineering Laboratory	INEL	0	0	1,789	10,539	26,299	57,119	57,119	57,119	57,119	57,119
Knolls Atomic Power Laboratory	KAPL	0	0	0	0	0	0	0	0	0	0
Lawrence Berkeley Laboratory	LBL	0	0	0	0	0	0	0	0	0	0
Lawrence Livermore National Laboratory	LLNL	0	0	0	0	0	0	0	0	0	0
Los Alamos National Laboratory	LANL	0	0	0	0	0	0	0	0	0	0
Mound	MOUND	0	0	0	0	0	0	0	0	0	0
Nevada Test Site	NTS	0	0	0	0	0	0	0	0	0	0
Oak Ridge National Laboratory	ORNL	0	0	c	c	c	41	176	176	176	176
Paducah Gaseous Diffusion Plant	PAD	0	0	0	0	0	0	0	0	0	0
Rocky Flats Plant	RFP	0	0	0	0	0	0	0	0	0	0
Sandia National Laboratory/ New Mexico	SNL/NM	0	0	0	0.14	0.85	1.33	1.33	1.33	1.33	1.33
Savannah River Site	SRS	b	b	b	b	b	b	4,874	4,874	4,874	4,874
West Valley Demonstration Project	WVDP	0	0	0	0	0	709	1,353	1,353	1,353	1,353
Total ^d		779	6,159	18,122	46,048	74,232	121,494	127,152	127,152	127,152	127,152

^aReference 4 states that upon retrieval of this waste, a significant amount of the soil will become contaminated and will increase the volume of waste. The estimated waste and associated contaminated soil volume is 109,000 m³. Quantities shown for Hanford are based on their submittal of Aug. 30, 1993.

^bNo year-by-year breakdown available for these years. SRS shows 4,874 m³ as the total volume buried from 1952 through 1974.

^cUnknown amounts were buried prior to 1970 and are not included in totals.

^dTotals do not include approximately 9,500 m³ of TRUW injected by hydrofracture at ORNL. This was included in last year's totals.

Table 3.9. Summary of buried TRUW by sites: cumulative as-stored radioactivity (all radionuclides)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1993
Argonne National Laboratory–East	ANL–E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site ^a	HANF	0.56	13.89	170.14	231.13	242.85	601.02	601.67	601.68	601.68	601.68
Idaho National Engineering Laboratory	INEL	0.00	0.00	b	11.20	58.33	248.83	248.83	248.83	248.83	248.83
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.00	0.00	0.00	0.00	0.01	0.24	0.24	0.24	0.24
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/ New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	c	c	c	c	c	c	33.67	33.67	33.67	33.67
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	438.00	652.00	652.00	652.00	652.00
Total ^d		0.56	13.89	170.14	242.33	301.18	1,287.86	1,536.41	1,536.42	1,536.42	1,536.42

^aData for HANF are based on their submittal of Aug. 30, 1993 (Rev. 9 IDB data).

^bUnknown.

^cSRS data submittal showed 33,670 Ci of TRU radionuclides buried from 1952 through 1974. The curies of fission products and other non-TRU radionuclides associated with this waste were listed as unknown.

^dDoes not include about 680,000 Ci deposited by hydrofracture at ORNL. Last year's table included this material.

Table 3.10. Summary of buried TRUW by sites: cumulative as-stored radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative as-stored radioactivity at end of calendar year, 10 ³ Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1993
Argonne National Laboratory--East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.10	2.37	103.41	110.90	112.64	114.45	114.45	114.45	114.45	114.45
Idaho National Engineering Laboratory	INEL	a	a	a	a	a	a	a	a	a	a
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL ^b	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.10	0.10	0.10
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/ New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	c	c	c	c	c	c	33.67	33.67	33.67	33.67
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	438.00	652.00	652.00	652.00	652.00
Total		0.10	2.37	103.41	110.90	112.64	114.46	148.22	148.22	148.22	148.22

^aINEL did not give isotopic compositions, so radioactivity for TRU radionuclides cannot be determined. See Table 3.9 for data on a total radioactivity basis.

^bQuantities shown for ORNL include ²⁴⁴Cm, which is considered a TRU radionuclide at ORNL. If ²⁴⁴Cm is omitted, the totals are reduced by 0.08 10³ Ci/year.

^cSRS did not give data on a year-by-year basis. Cumulative curies from 1952 through 1974 were given for TRU radionuclides only.

Table 3.11. Summary of buried TRUW by sites: decayed radioactivity (all radionuclides)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10 ³ Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1993
Argonne National Laboratory--East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.56	13.40	161.70	189.75	177.37	452.07	308.59	256.77	218.37	173.41
Idaho National Engineering Laboratory	INEL	a	a	a	a	a	a	a	a	a	a
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.00	0.00	0.00	0.00	0.01	23.22	20.67	660.96	543.20
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/ New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	b	b	b	b	b	b	33.67	32.60	31.70	30.50
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.56	13.40	161.70	189.75	177.37	452.08	365.48	310.04	911.03	747.11

^aINEL data did not include any isotopic compositions, so no decay calculations could be made.

^bSRS gave cumulative radioactivity as of 1974 on an as-stored basis for TRU radionuclides only. The reduction in activity shown from 1975 through 1993 is essentially all due to the decay of ²³⁸Pu.

Table 3.12. Summary of buried TRUW by sites: decayed radioactivity (TRU radionuclides only)

Site name	Site acronym	Cumulative radioactivity at end of calendar year, 10 ³ Ci									
		1945	1950	1955	1960	1965	1970	1975	1980	1985	1993
Argonne National Laboratory--East	ANL-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy Technology Engineering Laboratory	ETEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hanford Site	HANF	0.10	2.38	102.95	107.53	106.50	105.61	102.95	100.32	97.72	93.80
Idaho National Engineering Laboratory	INEL	a	a	a	a	a	a	a	a	a	a
Knolls Atomic Power Laboratory	KAPL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Berkeley Laboratory	LBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lawrence Livermore National Laboratory	LLNL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Los Alamos National Laboratory	LANL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mound	MOUND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nevada Test Site	NTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oak Ridge National Laboratory	ORNL	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02
Paducah Gaseous Diffusion Plant	PAD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rocky Flats Plant	RFP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandia National Laboratory/ New Mexico	SNL/NM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Savannah River Site	SRS	b	b	b	b	b	b	33.67	32.60	31.70	30.50
West Valley Demonstration Project	WVDP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.10	2.38	102.95	107.53	106.50	105.61	136.64	132.94	129.44	124.32

^aNo data available.

^bSRS gave radioactivity data on a cumulative basis as of 1974. Data after 1974 are the same as in Table 3.11 because SRS gave radioactivity of buried waste for TRU radionuclides only.

Table 3.13. Volumes and radioactivities of TRU-contaminated soil

Site	Soil contaminated with solid TRUW		Soil contaminated with liquid TRUW	
	Volume (m ³)	Radioactivity (Ci)	Volume (m ³)	Radioactivity (Ci)
ANL-E	0	0	0	0
ETEC	0	0	0	0
HANF	a	a	32,000	80,591
INEL	b	b	b	b
KAPL	0	0	0	0
LANL	c	d	c	d
LBL	0	0	0	0
LLNL	0	0	0	0
MOUND	c	c	c	c
NTS	c	c	b	b
ORNL	c	c	c	c
PAD	b	b	b	b
RFP	2	40	b	b
SNL/NM	c	c	c	c
SRS	0	0	0	0
WVDP	e	e	e	e

^aIncluded in buried TRUW.^bListed in submittal as N/A (not applicable).^cUnknown.^dPartial data submitted.^eNo data submitted.

Table 3.14. Mixed TRUW volumes^a

Site	Category	Mixed CH TRU volume, m ³			Mixed RH TRU volume, m ³		
		1970–1986	1987–1993	1994	1970–1986	1987–1993	1994
AMES	Mixed	0	0	0	0	0	0
	Suspect mixed	0	0	0.3	0	0	0
ANL–E	Mixed	b		0	b		0
	Suspect mixed	b		0	b		0
BAPL ^c							
ETEC	Mixed	0	0.2	0	0	0	0
	Suspect mixed	0	0	0	0	0	0
HANF	Mixed	0	170.6	5.9	0	1.4	27.1
	Suspect mixed	193	0	0	4.46	0	0
INEL	Mixed	36,400	2,420	0	29.9	17.5	0
	Suspect mixed	0	0	0	0	7.4	0
KAPL ^d							
LANL ^e	Mixed	0	619.1	225	0	0	10
	Suspect mixed	6,796.3	0	0	2.10	0	0
LBL ^f							
LLNL	Mixed	b	7.93	0.62	0	0	0
	Suspect mixed	b	0	0	0	0	0
MOUND ^e	Mixed	0	1,020	0			
	Suspect mixed						
MURR	Mixed	0	0.06	0.02	0	0	0
NTS	Mixed	570	1.9	0	5.3	0	0
	Suspect mixed						
ORNL	Mixed	176	6.8	62.5	231	26.2	8.3
	Suspect mixed	752	110	d	225	9.8	0
PAD ^e	Mixed	4.34	g	g	g	g	g
	Suspect mixed						
RFP ^h	Mixed	110	773	23	g	g	g
	Suspect mixed	b	g	g	g	g	g
SNL/NM ⁱ	Mixed	b	0	0	0	0	0
	Suspect mixed	0	0	0	0	0	0
SRS	Mixed	0	166.9	55.1	b	b	0
	Suspect mixed	4,805	1,440	0	b	b	0

Table 3.14 (continued)

Site	Category	Mixed CH TRU volume, m ³			Mixed RH TRU volume, m ³		
		1970–1986	1987–1993	1994	1970–1986	1987–1993	1994
WVDP	Mixed	2.08	0	0	0	0	0
	Suspect mixed	9.78	20.0	b	10.5	0	0

^aCompiled from Table 4 of site submittals. The quantities shown in each column represent the total volume of a given waste type generated during the period indicated at the top of the column.

^bUnknown.

^cNo data submitted for this table.

^dKAPL estimated their TRUW contains about 10% LLW and 5% mixed waste.

^eData are from previous submittal for Rev. 9 IDB report.

^fLBL reports that they do not generate or store TRU mixed waste.

^gNot applicable.

^hThere is no remote-handled TRUW at RFP.

ⁱSNL/NM appended the following notes to their Table 4 submittal:

1. Includes only TRU waste included in SNL/NM's Disposal Request process.
2. With regard to instruction footnote c of Table 4: TRU material, which may be mixed and may be remote-handled material, is in storage in Technical Area V (TA-V) and the Manzano Site Structures. The years the material was generated or placed in storage is unknown. The material in TA-V is approximately 1 m³ and is listed in the 180-day report, although it may not be categorized as waste under SNL/NM policy current at the time of this report. A recent inventory found two 55-gal containers of TRU material in the Manzanos, one contact-handled and one remote-handled. The material may be mixed and also may not yet be officially categorized as waste. None of this Manzano material was included in TRU estimates for the 180-day report. There is no activity information for the material at TA-V or the Manzanos. The TRU material at TA-V and the Manzanos has not been entered into the Disposal Request process. To be consistent with SNL/NM's approach for input into this report, no material that has not been entered into the Disposal Request process is included in the values listed in Table 4, "Mixed TRU waste and non-mixed TRU waste volumes (m³)."
3. The estimated waste generation for 1993 for environmental restoration waste containing TRU contaminated with RCRA constituents was estimated in Table 2-4, "Projection of mixed waste to be generated by DOE environmental restoration activities (in cubic meters)," Volume 1: *U.S. Department of Energy Interim Mixed Waste Inventory Report: Waste Streams, Treatment Capacities, and Technologies*, DOE/NBM-1100, April 1993, as being 1 m³. A more recent estimate puts 1993 CH TRU mixed (RCRA) environmental restoration waste generation at zero. (See Table 5, "Future generated TRU solid waste volumes—average annual.") The amount of TRU mixed operational or D&D waste in 1993 is unknown. Therefore, the volume of CH TRU waste contaminated with RCRA constituents in 1993 is unknown.
4. The amount of contact-handled non-mixed TRU waste to be generated by Dec. 31, 1993, is unknown.
5. An unknown amount of remote-handled non-mixed TRU waste has been generated in 1993 to date and it is not known what additional amounts will be generated by Dec. 31, 1993.

Table 3.15. Projected future TRUW volumes generated annually^a

Site	Waste type	Projected volumes generated, m ³ /year						
		1994	1995–1996	1997–2000	2001–2005	2006–2010	2011–2015	2016–2020
AMES	CH	0.03	0.03	b	b	b	b	b
	RH	0	0	0	0	0	0	0
ANL-E	CH	12.8	12.8	5.9	5.9	5.9	5.9	5.9
	RH	1.7	1.7	1.7	1.7	1.7	1.7	1.7
BAPL	CH	0	13.3	18.1	4.9	0	0	0
	RH	0	0.26	0.18	0.06	0	0	0
ETEC	CH	0	5.2	0	0	0	0	0
	RH	0	0	0	0	0	0	0
HANF ^c	CH	169	484	224	1,182	1,417	1,417	1,417
	RH	29	161	149	1,394	2,221	2,221	2,221
INEL	CH	0	0	0	0	0	0	0
	RH	6	6	6	6	6	6	6
KAPL	CH	d	d	d	d	d	d	d
	RH	0.6	0.6	0.8	1.0	1.0	1.0	1.0
LANL	CH	425	425	550	550	550	550	550
	RH	20	10	10	10	10	10	10
LBL	CH	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	RH	0	0	0	0	0	0	0
LLNL	CH	24.6	93	93	93	93	93	93
	RH	0	0	0	0	0	0	0
MOUND	CH	d	d	d	d	d	d	d
	RH	d	d	d	d	d	d	d
NTS	CH	b	b	b	b	b	b	b
	RH	b	b	b	b	b	b	b
ORNL	CH	63.5	55	20.3	20	20	20	20
	RH	8.3	25	25	20	12.4	12.4	12
PAD	CH	d	d	d	d	d	d	d
	RH	d	d	d	d	d	d	d
RFP	CH	58.2	112.2	27.2	68.8	215	212	179
	RH	e	e	e	e	e	e	e
SNL/NM	CH	0	6	1	1	1	1	1
	RH	e	e	e	e	e	e	e
SRS ^f	CH	636	719	2,057	2,572	2,572	2,572	2,572
	RH	2.6	2.6	5.1	6.4	6.4	6.4	6.4

Table 3.15 (continued)

Site	Waste type	Projected volumes generated, m ³ /year						
		1994	1995–1996	1997–2000	2001–2005	2006–2010	2011–2015	2016–2020
WVDP	CH	b	b	b	b	b	b	b
	RH	b	b	b	b	b	b	b

^aCompiled from Table 5 of site submittals.

^bUnknown.

^cQuantities are based on Hanford submittal to WIPP Baseline Inventory Report.

^dNo estimates given.

^eNo RH waste at this site.

^fD&D and remedial action waste unknown in all periods.

Operations personnel stacking containers of low-level radioactive waste into one of the storage tents located on the West Valley Demonstration Project site. *Courtesy of the West Valley Nuclear Services Company, Inc., West Valley Demonstration Project, West Valley, New York.*

4. LOW-LEVEL WASTE

4.1 INTRODUCTION

As used in this chapter, LLW has the same meaning as in The Low-Level Waste Policy Act (Pub. L. 95-573, Dec. 22, 1980). Namely, LLW is radioactive waste not classified as high-level radioactive waste, transuranic waste (TRUW), spent nuclear fuel (SNF), or by-product material specified as uranium or thorium tailings and waste. The naturally occurring or accelerator-produced radioactive material that is disposed of at DOE burial or commercial disposal sites is included in the inventories given, but they are not treated as separate entities in this chapter. Tailings (viz., mill tailings) are considered in Chapters 5 and 6. Another waste classification not delineated in this chapter is "mixed" low-level waste (MLLW) that contains both chemically hazardous and radioactive constituents (see Chapter 8). Specific definitions of these waste types (as defined by DOE Order 5820.2A) are given in the glossary of this report. DOE generates LLW through its defense activities, uranium enrichment operations, naval nuclear propulsion program, and various R&D activities. The data for DOE sites represent a summary of information obtained from each site.¹

Disposal of LLW at commercial sites accounted for about 31% of the LLW disposed during 1993 (see Fig. 4.1). Commercially disposed LLW is generally divided into five categories: academic, government, industrial, medical, and utility.² The academic category includes university hospitals and university medical and nonmedical research facilities. The government category includes state and non-DOE federal agencies. The industrial category is comprised of private entities such as R&D companies, manufacturers, nondestructive-testing operations, mining works, fuel fabrication facilities, and radiopharmaceutical manufacturers. The medical category includes hospitals and clinics, research facilities, and private medical offices. The utility category includes commercial nuclear reactors. In revisions 1-8 of the IDB report, commercially disposed waste was reported by fuel cycle and industrial/institutional (I/I) type activities.

However, to achieve more consistency with other reporting agencies, the five categories described are used.

Some LLW is also generated by DOE environmental restoration programs (see Chapter 6). Other LLW will be generated in future years by nonroutine D&D operations. Waste from past commercial D&D operations is included with the commercial waste disposal portion in this chapter since it has not been reported separately. However, projections of D&D waste are not included here but, instead, are discussed in Chapter 7.

The categorization of LLW according to DOE and commercial activities permits a comparison of the radioactivity levels and volumes of waste arising from each of these major sources (Figs. 4.1 and 4.2). Summary data on LLW (DOE and commercial) are given in Table 4.1. Historical and projected data by year for DOE LLW are presented in Table 4.2. In Table 4.3, similar data are shown for commercial LLW disposal.

4.2 DOE LLW

4.2.1 Inventories at DOE LLW Disposal Sites

An abridged picture of DOE LLW activities through 1993 is given in Figs. 4.1-4.4, as well as Tables 4.1, 4.2, and 4.4-4.17. Prior to October 1979, some LLW generated by DOE contractors was shipped to commercial disposal sites. Currently, LLW generated by DOE activities is generally buried at DOE sites (Figs. 4.3 and 4.4). A summary of historical additions, cumulative volumes, and cumulative undecayed radioactivity for solid LLW buried at all DOE sites through 1993 is presented in Tables 4.1, 4.2, 4.4-4.6, 4.11, and 4.12. Summaries of DOE site-generated LLW volumes and activities are presented in Tables 4.7 and 4.8, respectively. Tables 4.9 and 4.10 provide summary volume and activity data concerning LLW stored at DOE sites. The data in these tables are derived from questionnaires obtained from DOE sites.¹

Small quantities of DOE LLW have been disposed of by dumping the LLW into the sea or by hydrofracture.³ Table 4.13 shows the estimated quantity and radioactivity of LLW disposed of by these methods. Dumping of LLW into the sea was halted by the United States in 1970, and hydrofracture was terminated in 1983.

An estimate of DOE land usage for LLW burial is given in Table 4.14.

4.2.2 Characterization of LLW at DOE Sites

Based on information reported in ref. 1, summaries of radionuclide and physical characteristics for DOE LLW are reported in Tables 4.5–4.12. Summaries of representative radionuclide characteristics for generated, stored, and buried LLW at DOE sites are provided in Table 4.5. Representative radionuclide compositions for the buried waste types have been developed⁴ and are given in Table C.3 of Appendix C. Summaries of physical characteristics for generated, stored, and buried wastes are given in Table 4.6. Site-specific volume and activity information for generated, stored, and buried LLW is included in Tables 4.7–4.12.

Most of the DOE wastes that were dumped into the sea (see Table 4.13) were incorporated into cement matrix material and packaged in steel drums (55- or 80-gal capacity).

Hydrofracture was developed at ORNL for the permanent disposal of locally generated, low-level (approximately 0.25 Ci/L) liquid waste concentrates.⁵ Waste was mixed with a blend of cement and other additives, and the resulting grout was injected into shale at a depth of 200 to 300 m. The injected grout hardened into thin, horizontal sheets several hundred meters wide.

Significant changes in DOE LLW inventory and characteristics data from that reported in the 1993 edition (1992 data) of this report are summarized in Table 4.15.

4.2.3 DOE LLW Disposal Sites

A digest of data on the current status of land usage at DOE sites with active LLW disposal areas is shown in Table 4.14 (data from refs. 1, 3, and 6–8). Most of the DOE site land usage information currently reported in Table 4.12 is based on data given in ref. 1 with land usage factors taken from ref. 3.

As previously discussed, the LLW ocean disposal sites have not been used for disposal purposes since 1970. All of the liquid LLW that had been held in long-term storage at ORNL was disposed of during 1982 and 1983 using the new hydrofracture facility.

4.2.4 DOE LLW Projections

An assumption used in this report is that the level of DOE waste burial activities will remain constant through 2030. Beginning in 1994, the volume and undecayed radioactivity added each year to each active LLW disposal area are assumed to remain constant through 2030 at the values projected for 1994. These volumes and activities are split into waste types using the radionuclide categories given in Tables 4.5, 4.11, and 4.12. The radioactivity (by waste type) is decayed from the year of addition through 2030 using the representative compositions given in Table C.3 of Appendix C.

Projections for burial of DOE LLW are presented in Tables 4.2, 4.16, and 4.17. Table 4.16 summarizes DOE LLW excluding saltstone. Table 4.17 summarizes projections of saltstone, an LLW by-product from the solidification of HLW at SRS. This saltstone (see Fig. 2.5 and Table C.5 of Appendix C) is to be stored in concrete vaults at SRS. Grout-immobilized LLW derived from processing double-shell waste at Hanford (see Fig. 2.7 in Chapter 2) is excluded from the projections in Table 4.2 because the schedule and formulation for immobilization are not yet firmly defined.

4.3 COMMERCIAL LLW

4.3.1 Inventories at Commercial LLW Disposal Sites

There are six commercial shallow-land disposal sites for LLW (Figs. 4.2, 4.5, and 4.6), but only two are currently in operation. Commercial operations at the Maxey Flats, West Valley, and Sheffield sites have been halted. In addition, acceptance of LLW at Beatty stopped as of December 31, 1992. Until 1986, a second NRC-licensed burial ground at West Valley continued to receive wastes generated on-site from cleanup and water treatment operations. However, disposal operations at the WVDP have been suspended since 1986 pending the preparation of an environmental impact statement (EIS) report for the West Valley site closure. The historical data for annual additions and inventories of volume and radioactivity (undecayed) at each commercial disposal site through the end of 1993 are listed in Tables 4.18 and 4.19, respectively (compiled from refs. 3, 7, 9–12). The volumes are depicted in Figs. 4.2, 4.5, and 4.6. Sources of the historical reported data through 1984 are given in ref. 3, and those through 1992 are given in ref. 7. Quantities of LLW shipped to disposal sites during 1993

are listed in Table 4.20 on a state-by-state basis.⁹ Table 4.3 is a summary of historical and projected volumes and radioactivity (decayed) for commercial LLW. Projections are made only through 1995 because of uncertainties in commercial disposal facilities operations. Not included in Table 4.3 are the drums of cemented LLW to be generated by the WVDP as a result of the vitrification of HLW. This LLW from the WVDP is described in Table C.7 of Appendix C.

4.3.2 Characterization of LLW at Commercial Disposal Sites

All of the LLW accepted for commercial disposal is categorized as Class A, B, or C in compliance with NRC specifications.¹³ The LLW that exceeds these specifications is currently in storage at the generator site or at a DOE site which has accepted it for study (see Sect. 4.3.3). A calculated representative radionuclide composition for disposed commercial LLW is given in Table C.4 of Appendix C. This composition is periodically updated to reflect changes in waste management practices and in the regulations governing LLW disposal.

4.3.3 Greater-Than-Class-C Low-Level Waste (GTCC LLW)

In 1980, federal law made each state responsible for providing the disposal capacity for LLW generated within its borders, except for certain waste generated by the federal government.¹⁴ In 10 CFR Part 61 (ref. 13), the NRC codifies disposal requirements for three classes of LLW, as mentioned above, generally suitable for near-surface disposal, namely, Class A, B, and C (with Class C waste requiring the most rigorous disposal specifications). Waste with concentrations above Class C limits for certain short- and long-lived radionuclides (i.e., GTCC LLW) was found not generally suitable for near-surface disposal, except on a case-by-case evaluation of the waste and the proposed disposal method by NRC or state licensing agency. The Low-Level Radioactive Waste Policy Amendments Act (LLRWPA)¹⁵ made the states responsible for the disposal of Classes A, B, and C LLW and made the federal government (viz., DOE) responsible for disposal of GTCC LLW. The law also required that GTCC LLW generated by licensees of NRC be disposed of in a facility licensed by NRC. The projected amounts of GTCC LLW are uncertain, both because of regulatory uncertainties affecting the definition of HLW (i.e., a clearly defined all-inclusive list of wastes considered HLW may include more than those described in Chapter 2) and because of the lack of information on the sources, volumes, and characteristics of GTCC LLW.¹⁶

In May 1989, NRC promulgated a rule that requires disposal of GTCC LLW in a deep geologic repository unless disposal elsewhere has been approved by NRC. The rule as amended states: "Waste that is not generally acceptable for near-surface disposal is waste for which form and disposal methods must be different and, in general, more stringent than those specified for Class C waste. In the absence of specific requirements in this part, such waste must be disposed of in a geologic repository as defined in Part 60 of this chapter unless proposals for disposal of such waste in a disposal site licensed pursuant to this part are approved by the Commission."¹⁷ A disposal facility (other than a deep geologic repository) for GTCC LLW will probably not be available for several decades because of the complexities of siting and NRC licensing. A generic description of estimated sources and forms of GTCC LLW is presented in Table C.6 of Appendix C.

DOE recently revised an earlier study to provide information about estimates of present and future GTCC LLW to the year 2035 (2055 in some instances). Information garnered during the study¹⁸ includes identification of generators, waste form characteristics, volumes, and radionuclide activities. The study categorizes GTCC LLW as (1) nuclear utilities waste, (2) sealed sources wastes, (3) DOE-held potential GTCC LLW, and (4) other generator waste. Various scenarios for data projection were used: (a) unpackaged volumes; (b) packaged volumes based on the application of packaging factors to the unpackaged volumes; and (c) concentration averaging, mixing or blending of similar materials with different radionuclide concentrations, values applied to the packaged volumes. Each of the three scenarios is treated for three cases: low, base, and high.

Based on base-case projections of after-concentration-averaged-packaged waste to the year 2035, the study determined that the largest volume of GTCC wastes (approximately 53%) is generated by nuclear power plants. The "other" generator waste category contributes approximately 31% of the total GTCC LLW volume projected to the year 2035. Sealed sources are about 16% of the total projected volume of GTCC LLW. A summary of historical and projected cumulative volume and radioactivity for GTCC LLW is presented in Table 4.21.

4.3.4 Commercial LLW Disposal Sites

Three commercial LLW disposal sites in the eastern United States (Maxey Flats, Sheffield, and West Valley) have been closed to further use. Additionally, reception of LLW at Beatty stopped as of December 31, 1992. Only a small amount of on-site generated LLW from site cleanup is occasionally buried at Maxey Flats. The closure of the

eastern three commercial LLW disposal sites resulted in increasing volumes of LLW being shipped to the operating sites. The increase prompted South Carolina to impose an upper limit on the volume of LLW that could be accepted at Barnwell. Eventually, a general concern developed that the responsibility for LLW disposal should not rest with only a few states and that a coordinated national plan was needed. As described previously, the LLRWPA¹⁴ was passed in 1980, making each state responsible for its own LLW and encouraging formation of regional interstate compacts to deal with the disposal problem. The Act provided that any compact approved by Congress could restrict access to its LLW disposal facility to member states after January 1, 1986. However, by 1984, it became evident that no new regional disposal facilities would be operating by the end of 1985. This gave rise to new legislation, the LLRWPA¹⁵, which continued to encourage interstate compact formation while requiring that nonsited (i.e., without an operating disposal site) states and compacts meet specific milestones, leading to the operation of new regional facilities by January 1, 1993. Additionally, the LLRWPA established rates and limits of acceptance at the three commercial disposal sites in operation, as well as space allocations for utility wastes. The utilities were required to meet certain waste volume reductions during a 7-year transition period, which was provided to allow for the opening of new LLW disposal sites under state compact arrangements.

However, no new regional facilities were in operation as of January 1, 1993. Barnwell continued to receive out-of-region waste until June 30, 1994. Since this date, Barnwell has received only Southeast Compact Waste and is scheduled to remain open until December 31, 1995. If a new North Carolina facility opens earlier than this date, then Barnwell will close. As of December 31, 1992, the disposal facility at Richland, Washington, allowed access only to members of the Northwest and Rocky Mountain compacts. The Richland facility is projected to remain open into the next century.^{9,19}

4.4 REFERENCES

1. U.S. Department of Energy site LLW data submittals (Attachment 4) submitted to the IDB Program during July–October 1994. The following LLW submittals were received, reviewed, analyzed, and integrated by the IDB Program. Preceding each submittal is the site (in parentheses) to which it refers.
 - a. (AMES) Lowell K. Mathison, Ames Laboratory, Ames, Iowa, correspondence to James E. Fletcher, DOE Chicago Operations Office, Ames Laboratory Management Office, Argonne, Illinois, submitting Ames Laboratory TSCA MLLW information, dated July 13, 1994.

During 1993, Barnwell received about 76% of the total volume of commercial LLW shipped for burial. The site at Richland, Washington, received about 24% (see Table 4.18). Chem-Nuclear Systems, Inc., operates the Barnwell disposal site, and U.S. Ecology, Inc., operates the disposal site at Richland. The land usage at existing commercial disposal sites is summarized in Table 4.14. Information reported for these commercial sites is based on data provided by state health and environmental control agencies (refs. 3, 6, 8, and 11).

Table 4.22 provides a breakdown of waste received at commercial sites in 1993 by category (academic, government, industrial, medical, or utility LLW).

4.3.5 Commercial LLW Projections

This report presents summary information for disposed commercial waste. Historical volume, radioactivity, and thermal power data through 1979 are taken from an earlier version of this report (DOE/RW-0006, Rev. 8). After 1979, the source term for commercial LLW in Table C.4 of Appendix C is used to decay the annual waste additions to the commercial sites.

Projections for disposed commercial LLW are made only through 1995 because of uncertainties in current facility operations and the availability of future sites. Projections (1994–1995) are made for Barnwell and Richland and are based on refs. 9 and 19. Historical and projected volume, radioactivity, and thermal power for disposed commercial LLW are presented in Table 4.3.

Because of timing uncertainties, projected decommissioning wastes are not included in the projections of this chapter. Rather, decommissioning waste projections are reported separately in Chapter 7. Former DOE facilities that will be affected by environmental restoration activities are discussed in Chapter 6 and are also excluded from the projected values in this chapter.

- b. (ANL-E) Michael A. Sodaro, Argonne National Laboratory, Argonne, Illinois, correspondence to A. L. Taboas, DOE Argonne Area Office, Argonne, Illinois, "Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," dated July 22, 1994.
- c. (ANL-W) See ref. 1(h).
- d. (BNL) Carson L. Nealy, DOE Brookhaven Area Office, Upton, New York, correspondence to Jerry A. Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Brookhaven National Laboratory's (BNL) Response to the 1994 Integrated Data Base Information Request," dated July 20, 1994.
- e. (FNAL) J. Donald Cossairt, Fermi National Accelerator Laboratory, Batavia, Illinois, correspondence to Andrew E. Mravca, DOE Batavia Area Office, Batavia, Illinois, "DOE Site Low-Level Waste Information Request for 1994 Integrated Data Base (IDB) Report (DOE/RW-0006, Rev. 10)," dated Aug. 23, 1994.
- f. (FEMP) Bob Giessel, Fernald Environmental Management Project, telephone conversation with A. S. Icenhour, IDB Program, ORNL, Oak Ridge, Tennessee, Aug. 7, 1994.
- g. (HANF) F. M. Coony, Westinghouse Hanford Company, Richland, Washington, correspondence to A. S. Icenhour, IDB Program, ORNL, Oak Ridge, Tennessee, "1994 LLW Update to Integrated Data Base," dated Aug. 15, 1994.
- h. (INEL) R. R. Piscitella, EG&G Idaho, Inc., Idaho Falls, Idaho, correspondence to J. A. Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Idaho National Engineering Laboratory (INEL) Input to Integrated Data Base (DOE/RW-0006, Rev. 10)," RRP-35-94, dated Sept. 29, 1994.
- i. (ITRI) Joe L. Mauderly, Lovelace Biomedical and Environmental Research Institute, Inc., Albuquerque, New Mexico, correspondence to George K. Laskar, DOE Kirtland Area Office, Albuquerque, New Mexico, "ITRI 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," dated Aug. 11, 1994.
- j. (K-25) Jeff Wilson, K-25 Site, Oak Ridge, Tennessee, correspondence to Stephen Storch, IDB Program, ORNL, Oak Ridge, Tennessee, dated Oct. 12, 1994.
- k. (KCP) Margaret E. Stockdale, DOE Kansas City Area Office, Kansas City, Missouri, correspondence to Jerry Klein, IDB Program, ORNL, Oak Ridge, Tennessee, dated Aug. 12, 1994.
- l. (LANL) I-Li Chen, Los Alamos National Laboratory, Los Alamos, New Mexico, correspondence to Jerry Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Waste Information IDB Report," CST-7G-94-366, dated July 6, 1994.
- m. (LBL) Kam Tung, Lawrence Berkeley Laboratory, Berkeley, California, correspondence to Jerry A. Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Submission of Data for the 1994 Integrated Data Base Annual Report," HW-94-257, dated July 1, 1994.
- n. (LLNL) No submittal correspondence provided with data attachment.
- o. (MOUND) Raymond J. Finney, EG&G Mound Applied Technologies, Miamisburg, Ohio, correspondence to Robert S. Rothman, DOE Miamisburg Area Office, Miamisburg, Ohio, "Data Request in Support of the 1994 Integrated Data Base Report," dated Aug. 24, 1994.
- p. (NR sites/KAPL) A. R. Seepo, DOE Schenectady Naval Reactors Office, Schenectady, New York, correspondence to Jerry Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report," REC&SD:GJV#94-53, dated July 21, 1994.

- q. (NR sites/BAPL/NRF) E. D. Shollenberger, DOE Pittsburgh Naval Reactors Office, West Mifflin, Pennsylvania, correspondence to Jerry Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Radioactive Waste Data for the 1994 Integrated Data Base Report," dated July 28, 1994.
- r. (NTS) Carlos Gonzales, Reynolds Electrical and Engineering Company, Las Vegas, Nevada, correspondence to Alan Icenhour, IDB Program, ORNL, Oak Ridge, Tennessee, dated Aug. 12, 1994.
- s. (ORISE) No submittal correspondence provided with data attachment.
- t. (ORNL) No submittal correspondence provided with data attachment.
- u. (PAD) Carol Tippin, Martin Marietta Energy Systems, Inc., Paducah, Kentucky, correspondence to Stephen Storch, IDB Program, ORNL, Oak Ridge, Tennessee, transmitting updated PAD LLW information, dated July 29, 1994.
- v. (PANT) Jeffrey Jarry, Battelle, Amarillo, Texas, correspondence to Alan Icenhour, IDB Program, ORNL, Oak Ridge, Tennessee, dated July 20, 1994.
- w. (PINELLAS) Gary C. Schmidtke, Albuquerque Operations Office, Pinellas Area Office, Largo, Florida, correspondence to Jerry Klein, IDB Program, ORNL, Oak Ridge, Tennessee, dated Aug. 2, 1994.
- x. (PORTS) Gary Conner, Martin Marietta Energy Systems, Inc., Portsmouth, Ohio, correspondence to J. A. Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report," ERWM-1168-94-205, dated Aug. 25, 1994.
- y. (PPPL) Milton D. Johnson, Princeton Area Office, Princeton, New Jersey, correspondence to Jerry Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10): Princeton Plasma Physics Laboratory," dated Aug. 3, 1994.
- z. (RFP) Paul Cote and Mary Vargas, DOE Rocky Flats Office, Golden, Colorado, correspondences to Jerry A. Klein, IDB Program, ORNL, Oak Ridge, Tennessee, 94-DOE-07365 and 94-DOE-07496, submitting RFP LLW information, dated July 19, 1994.
- aa. (SLAC) Kevin Hartnett, DOE Oakland Operations Office, correspondence to Mathew Zenkovich, DOE/EM Office of Program Integration, Technical Analysis Division, Washington, D.C., "Data Request in Support of the 1994 Integrated Data Base Report," dated Sept. 21, 1994.
- ab. (SNL/CA) Sarah C. K. O'Connor, Sandia National Laboratory/California, correspondence to Alan Icenhour, IDB Program, ORNL, Oak Ridge, Tennessee, "Department of Energy Site Request for 1994 Integrated Data Base Report," dated Aug. 30, 1994.
- ac. (SNL/NM) Maureen J. Lincoln, Sandia National Laboratory/New Mexico, Albuquerque, New Mexico, correspondence to Ted Pietrok, DOE Kirtland Area Office, Albuquerque, New Mexico, "IDB Data Base Updated," dated July 15, 1994.
- ad. (SRS) H. F. Daugherty, Westinghouse Savannah River Company, Aiken, South Carolina, correspondence to Michael G. O'Rear, DOE Savannah River Operations Office, Aiken, South Carolina, "Information Request for 1994 Integrated Data Base (IDB) Report," SWE-SWD-94-0217, dated Aug. 23, 1994.
- ae. (Y-12) N. E. Leonetti, Y-12 Plant, Oak Ridge, Tennessee, correspondence to J. A. Klein, IDB Program, ORNL, Oak Ridge, Tennessee, "Deliverable, Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," dated July 15, 1994.

2. R. L. Fuchs, "1993 State-by-State Assessment of Low-Level Radioactive Wastes Received at Commercial Disposal Sites," DOE/LLW-205, Idaho National Engineering Laboratory, Idaho Falls, Idaho (September 1994).
3. U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 1, Oak Ridge National Laboratory, Oak Ridge, Tennessee (December 1985).
4. C. W. Forsberg, W. L. Carter, and A. H. Kibbey, *Flowsheets and Source Terms for Radioactive Waste Projections*, ORNL/TM-8462, Oak Ridge National Laboratory, Oak Ridge, Tennessee (March 1985).
5. U.S. Energy Research and Development Administration, Environmental Statement, *Radioactive Waste Facilities*, WASH-1532 (Draft), Oak Ridge National Laboratory, Oak Ridge, Tennessee (January 1974).
6. Virgil R. Autry, South Carolina Department of Health and Environmental Control, Columbia, South Carolina, letter to A. S. Icenhour, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated May 18, 1994.
7. U.S. Department of Energy, *Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 9, Oak Ridge National Laboratory, Oak Ridge, Tennessee (March 1994).
8. John Vaden, Nevada Division of Health, letter to A. S. Icenhour, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Mar. 26, 1993.
9. M. R. Winberg, EG&G Idaho, Inc., National Low-Level Waste Management Program, Idaho Falls, Idaho, letter to A. S. Icenhour, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Transmittal of Data Requested for Integrated Data Base Report-MRW-10-94," dated Sept. 14, 1994.
10. T. J. Rowland, U.S. Department of Energy, West Valley Project Office, West Valley, New York, letter to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update to the DOE 1992 Integrated Data Base Report," dated Apr. 1, 1992.
11. D. Mills, Commonwealth of Kentucky, Department for Environmental Protection, Frankfort, Kentucky, letter to A. H. Kibbey, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Feb. 5, 1990.
12. U.S. Department of Energy, National Low-Level Radioactive Waste Management Program, *The 1989 State-By-State Assessment of Low-Level Radioactive Wastes Shipped to Commercial Disposal Sites*, DOE/LLW-88, EG&G Idaho, Inc., Idaho Falls, Idaho (December 1990).
13. U.S. Nuclear Regulatory Commission, "Licensing Requirements for Land Disposal of Radioactive Wastes," *Code of Federal Regulations*, Title 10, Part 61, Jan. 1, 1994.
14. U.S. Congress, The Low-Level Radioactive Waste Policy Act, Pub. L. 95-573, Dec. 22, 1980.
15. U.S. Congress, The Low-Level Radioactive Waste Policy Amendments Act of 1985, Pub. L. 99-240, Jan. 15, 1986.
16. U.S. Department of Energy, *Recommendations for Management of Greater-than-Class-C Low-Level Radioactive Waste*, DOE/NE-0077 (February 1987).
17. U.S. Nuclear Regulatory Commission, amendments to 10 CFR Part 61, "Disposal of Radioactive Wastes," final rule, *Fed. Regist.* 54(100), 22578-83 (May 25, 1989).
18. Lockheed Idaho Technologies Company, *Greater-Than-Class-C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics*, DOE/LLW-114, Rev. 1, Idaho Falls, Idaho (September 1994).

19. U.S. Department of Energy, Office of Environmental Restoration and Waste Management, *Report to Congress in Response to Public Law 99-240, 1992 Annual Report on Low-Level Radioactive Waste Management Progress* (final draft), May 1993.

Fig. 4.1. Volume and radioactivity of LLW disposed at commercial and DOE facilities during 1993.

Fig. 4.2. Total volume of LLW disposed through 1993.

Fig. 4.3. Total volume of DOE LLW disposed through 1993.

Fig. 4.4. Locations and total volumes of DOE LLW disposed through 1993.

Fig. 4.5. Total volume of commercial LLW disposed through 1993.

Fig. 4.6. Locations and total volumes of commercial LLW disposed through 1993.

Table 4.1. A summary of characteristics for buried/disposed LLW as of December 31, 1993

Category	Volume (10 ³ m ³)		Radioactivity (10 ³ Ci)		Thermal power (W)	
	Annual ^a	Cumulative	Annual	Cumulative	Annual	Cumulative
DOE sites	50.5	2,911	894	13,147	3,263	20,398
Commercial sites	22.4	1,495	643	5,709	3,252	21,627
Total buried/ disposed LLW	72.9	4,406	1,537	18,856	6,515	42,025

^aAddition during 1993.

Table 4.2. Historical and projected volume, radioactivity, and thermal power of buried DOE LLW^a

End of calendar year	Volume (10 ³ m ³)		Radioactivity (10 ³ Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative ^b	Annual	Cumulative
1990	60.0	2,759	545	13,516	2,013	17,844
1991	53.6	2,812	717	13,277	2,788	18,220
1992	48.3	2,860	1,078	13,401	4,947	20,741
1993	50.5	2,911	894	13,147	3,263	20,398
1994	44.2	2,955	756	12,993	3,073	21,143
1995	44.2	2,999	756	12,906	3,073	22,066
1996	69.3	3,068	757	12,847	3,076	23,009
1997	117.2	3,186	759	12,807	3,080	23,928
1998	131.3	3,317	777	12,796	3,122	24,849
1999	146.2	3,463	769	12,785	3,103	25,708
2000	116.7	3,579	763	12,775	3,089	26,510
2001	131.3	3,710	756	12,765	3,073	27,260
2002	131.3	3,841	759	12,764	3,081	27,983
2003	132.6	3,975	764	12,775	3,091	28,687
2004	44.2	4,019	756	12,780	3,073	29,342
2005	131.3	4,150	756	12,792	3,073	29,974
2006	131.2	4,281	761	12,815	3,084	30,596
2007	88.0	4,368	757	12,838	3,076	31,188
2008	88.0	4,457	756	12,864	3,073	31,757
2009	87.7	4,545	756	12,894	3,073	32,309
2010	57.5	4,602	756	12,927	3,073	32,842
2011	64.3	4,666	756	12,963	3,073	33,359
2012	85.3	4,750	757	13,004	3,074	33,866
2013	131.3	4,885	763	13,055	3,088	34,374
2014	95.9	4,979	758	13,102	3,078	34,858
2015	87.7	5,063	756	13,150	3,073	35,322
2016	131.3	5,197	756	13,199	3,073	35,774
2017	131.3	5,331	756	13,251	3,073	36,216
2018	131.3	5,455	756	13,305	3,073	36,648
2019	87.7	5,550	756	13,358	3,073	37,067
2020	87.7	5,634	756	13,416	3,074	37,480
2021	44.2	5,678	756	13,472	3,073	37,879
2022	44.2	5,722	756	13,531	3,073	38,270
2023	44.2	5,766	756	13,590	3,073	38,652
2024	44.2	5,811	756	13,649	3,073	39,025
2025	44.2	5,855	756	13,709	3,073	39,390
2026	44.2	5,899	756	13,770	3,073	39,748
2027	44.2	5,943	756	13,832	3,073	40,098
2028	44.2	5,987	756	13,893	3,073	40,440
2029	44.2	6,031	756	13,955	3,073	40,775
2030	44.2	6,076	756	14,017	3,073	41,104

^aSummation of values in Tables 4.16 (buried DOE LLW, except SRS saltstone) and 4.17 (LLW saltstone at SRS).

^bThe radioactivity added each year for each waste type is decayed as described in the footnotes of Tables 4.16 and 4.17.

Table 4.3. Historical and projected volume, radioactivity, and thermal power of commercial LLW shipped for disposal^a

End of calendar year	Volume (10 ³ m ³)		Radioactivity (10 ³ Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative ^b	Annual	Cumulative
1990	32.4	1,384	549	4,979	2,774	16,457
1991	38.8	1,423	800	5,272	4,044	18,424
1992	49.4	1,472	1,000	5,708	5,057	21,117
1993	22.4	1,495	643	5,709	3,252	21,627
1994 ^c	16.2	1,511	211	5,301	1,069	20,016
1995	12.0	1,523	139	4,916	703	18,419

^aIncludes LLW disposed of at the following commercial sites: Beatty, Nevada; West Valley, New York; Maxey Flats, Kentucky; Richland, Washington; Sheffield, Illinois; and Barnwell, South Carolina.

^bThe radioactivity through 1979 was decayed using a multiple source term methodology (see Tables 4.3 and 4.20–4.25 of Rev. 8 of this report for a description of this method). After 1979, the radioactivity is decayed from the year of addition using the representative compositions given in Table C.4 of Appendix C.

^cProjections were made based on disposal operations at Richland, Washington and Barnwell, South Carolina, as described in Sect. 4.3.5. Projections were made only through 1995 because of large uncertainties in commercial disposal facility operations.

Table 4.4. Historical annual additions and total volume of LLW buried at DOE sites^a

Year	Volume of waste buried annually, 10 ³ m ³									Total annual addition	Total cumulative volume
	FEMP	HANF	INEL	LANL	NTS	ORNL	SRS	Y-12 ^b	All other ^c		
1975 ^d	309.3	352.0	84.6	131.6	8.3	181.5	269.1	58.4	83.9	1,478.9	1,479
1976	14.4	4.1	6.2	8.8	0.0	3.8	8.1	2.7	0.9	49.0	1,528
1977	2.8	10.7	6.6	3.6	0.5	2.4	14.7	1.5	1.1	43.9	1,572
1978	1.9	9.8	5.9	7.5	10.0	2.0	15.5	1.4	3.2	57.2	1,629
1979	1.6	17.5	5.3	4.9	15.8	2.1	18.2	1.1	1.1	67.6	1,697
1980	1.3	10.4	5.1	4.8	13.3	2.0	19.6	1.4	0.7	58.6	1,755
1981	1.5	12.8	3.1	5.5	21.1	1.4	20.1	1.2	1.6	68.3	1,824
1982	2.8	11.7	3.2	4.5	57.0	1.3	22.4	2.2	2.0	107.1	1,931
1983	3.4	17.9	5.5	3.2	12.1	1.8	26.7	3.4	1.7	75.7	2,006
1984	3.5	18.8	3.9	5.4	36.0	2.2	26.1	7.2	10.6	113.7	2,120
1985	0.7	17.0	3.1	6.7	41.7	2.2	30.5	18.7	2.1	122.7	2,243
1986	0	21.1	3.4	4.5	27.9	1.8	30.1	15.0	1.0	104.8	2,348
1987	0	20.3	3.0	3.7	81.1	0.5	28.2	16.2	1.0	154.0	2,501
1988	0	16.8	2.0	4.3	39.1	0.6	30.2	10.6	1.0	104.6	2,606
1989	0	13.7	1.3	6.4	35.0	1.3	26.8	5.7	2.3	92.5	2,699
1990	0	13.4	1.8	4.5	9.1	0.3	26.6	4.4	0.0	60.1	2,759
1991	0	10.6	1.3	5.8	11.6	0.2	23.8	0.3	0.0	53.6	2,812
1992	0	10.9	0.8	2.3	20.1	1.1	13.0	0.0	0.0	48.2	2,860
1993	0	12.1	0.9	2.7	18.6	0.8	15.3	0.1	0.0	50.5	2,911
Total	343.2	601.6	147.0	220.7	458.4	209.3	665.0	151.3	114.2	2,911	

^aNo TRUW included; data from refs. 1 and 7. Slight differences in values shown and those actually reported result from round-off and truncation of numbers.

^bLand disposal of LLW at Y-12 was terminated as of July 1, 1991. A single exception was made in 1993 when waste was placed in the Bear Creek Burial Ground walk-in pits.

^cIncludes contributions from AMES, BNL, K-25, LLNL, PAD, PANT, PORTS, and SNL/NM. See Tables 4.5, 4.6, 4.11, and 4.12 for breakdown of 1993 accumulation.

^dValues for 1975 are cumulative volumes to this date (ref. 3).

Table 4.5. Summary of radionuclide characteristics for LLW at DOE sites^a

Waste type	Radionuclide characteristic ^b	Volume, m ³			Activity, Ci			
		1993	Cumulative ^c	1994 (projected)	1993	Total undecayed ^d	Total decayed ^e	1994 (projected)
Generated on-site	Uranium/thorium	12,381	f	4,109	4	f	f	4
	Fission product	14,986	f	12,417	52,900	f	f	52,749
	Induced activity	2,933	f	2,236	464,049	f	f	406,111
	Tritium	1,548	f	1,351	45,341	f	f	40,572
	Alpha	5,040	f	4,793	4,051	f	f	881
	Other	4,527	f	9,469	184,818	f	f	450,007
	Total	41,415	f	34,375	751,163	f	f	950,324
Stored	Uranium/thorium	7,500	72,180	1,956	3	1,924	g	1
	Fission product	867	49,478	1,827	1,688	546,739	g	8,605
	Induced activity	896	3,401	997	211,207	234,801	g	91,207
	Tritium	410	2,395	455	36,549	132,632	g	34,471
	Alpha	3,325	9,763	2,857	11	127	g	5
	Other	1,983	18,449	5,512	97,315	952,949	g	270,002
	Total	14,981	155,666	13,604	346,773	1,869,172	g	404,291
Buried	Uranium/thorium	22,208	1,112,166	21,484	235	38,719	50,022	729
	Fission product	21,040	1,038,148	15,502	761,150	10,889,517	5,461,098	534,308
	Induced activity	1,884	224,603	715	2,190	6,250,604	138,969	2,021
	Tritium	1,820	56,211	1,442	39,165	15,510,808	6,888,246	38,979
	Alpha	2,054	327,813	3,270	4,065	69,348	44,533	69
	Other	1,457	152,235	1,771	87,475	12,527,178	564,429	180,000
	Total	50,463	2,911,177	44,184	894,280	45,286,174	13,147,297	756,106

^aBased on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bRadionuclide characteristics:

- uranium/thorium—those waste materials in which the principal hazard results from naturally occurring uranium and thorium isotopes. The hazard from all other radioactive contaminants should be insignificant. Examples of these wastes include depleted uranium, natural uranium ore, and slightly enriched uranium. These wastes do not include uranium mill tailings (see Chapters 5 and 6).
- fission product—waste materials that are contaminated with beta-gamma-emitting radionuclides which originate as a result of fission processes. Primary examples are ¹³⁷Cs and ⁹⁰Sr.

(Footnotes continued on next page.)

Table 4.5 (continued)

- induced activity—waste materials that are contaminated with beta-gamma-emitting radioisotopes which are generated through neutron activation. Of major concern is ^{60}Co .
- tritium—waste materials in which the principal hazard results from tritium (^3H).
- alpha—waste materials contaminated with alpha-emitting radionuclides not listed under U/Th or low levels (<100 nCi/g) of TRU isotopes.
- other—unknown or not defined materials.

^cFrom beginning of operations through 1993.

^dSum of annual additions without decay.

^eDecayed from time of addition using an isotope generation/depletion code.

^fNot applicable [i.e., generation is taken to be an intensive quantity (amount/year) and is not additive; whereas stored and buried are extensive quantities (amounts) and are additive].

^gInformation not available.

Table 4.6. Summary of physical characteristics for LLW at DOE sites^a

Waste type	Physical characteristic ^b	Volume, m ³			Activity, Ci		
		1993	Cumulative ^c	1994 (projected)	1993	Total gross ^d	1994 (projected)
Generated on-site	Biological	285	e	317	2,608	e	6,343
	Contaminated equipment	3,531	e	3,347	665,714	e	846,445
	Decontamination debris	4,814	e	5,870	704	e	986
	Dry solids	18,611	e	16,256	76,312	e	87,642
	Solidified sludge	745	e	843	1,657	e	3,673
	Other	13,429	e	7,742	4,168	e	5,235
	Total	41,415	e	34,375	751,163	e	950,324
Stored	Biological	167	939	200	1,361	13,441	3,806
	Contaminated equipment	852	42,248	1,986	109,538	877,888	267,317
	Decontamination debris	2,021	9,164	2,909	607	1,180	852
	Dry solids	4,338	46,332	4,429	20,046	680,334	36,518
	Solidified sludge	639	26,081	738	1,657	1,665	3,583
	Other	6,964	30,902	3,342	213,564	294,664	92,215
	Total	14,981	155,666	13,604	346,773	1,869,172	404,291
Buried	Biological	117	f	122	1,247	f	2,537
	Contaminated equipment	8,783	f	6,324	104,780	f	170,480
	Decontamination debris	7,313	f	10,292	193	f	213
	Dry solids	27,663	f	24,200	785,388	f	579,902
	Solidified sludge	106	f	197	2	f	90
	Other	6,481	f	3,049	2,670	f	2,884
	Total	50,463	2,911,177	44,184	894,280	45,286,174	756,106

^aBased on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bPhysical characteristics: (1) biological (sewage sludge, animal carcasses, excreta, etc.); (2) contaminated equipment (components, maintenance wastes, etc.); (3) decontamination debris (wastes resulting from decontamination and decommissioning efforts, construction debris, etc.); (4) dry solids (normal plant wastes, blotting paper, combustible materials, etc.); (5) solidified sludge (any wastes solidified from a process sludge such as evaporator bottoms solidification, solidification of precipitated salts, etc.); and (6) other (materials which are outside of the above categories).

^cFrom beginning of operations through 1993.

^dSum of annual additions without decay.

^eNot applicable [i.e., generation is taken to be an intensive quantity (amount/year) and is not additive; whereas stored and buried are extensive quantities (amounts) and are additive].

^fInformation not available.

Table 4.7. Breakdown of volumes of LLW generated during 1993 at DOE sites by radionuclide characteristic^a

DOE site ^b	Volume, m ³						Total
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other ^c	
AMES	3	0	1	0	0	0	4
ANL-E	0	0	0	0	0	95	95
ANL-W	d	d	d	d	d	d	d
BNL	5	13	25	25	2	0	70
FEMP	e	e	e	e	e	e	e
FNAL	0	0	118	1	0	0	119
HANF	1,285	2,303	39	185	c	0	3,812
INEL	64	385	6	<1	15	1,749	2,218
ITRI	<<1	2	10	19	<1	<<1	31
K-25	0	0	0	0	0	1,498	1,498
KCP	0	0	0	0	0	<1	<1
LANL	1,503	107	193	138	738	13	2,692
LBL	0	0	15	4	0	17	35
LLNL	110	0	0	50	91	7	258
MOUND	0	0	0	250	2,200	0	2,450
NR sites ^f	372	252	1,320	0	36	3	1,983
NTS	0	44	0	0	0	0	44
ORISE	4	2	0	2	8	11	26
ORNL	100	964	182	5	17	60	1,327
PAD	476	0	0	0	0	269	744
PANT	0	0	0	0	0	368	368
PINELLAS	0	0	0	26	0	0	26
PORTS	1,691	<<1	0	0	0	0	1,691
PPPL	0	0	82	3	0	37	122
RFP	56	0	0	0	1,065	0	1,120
SLAC	0	0	88	0	0	0	88
SNL/CA	1	0	0	18	0	<1	19
SNL/NM	18	14	20	37	<<1	6	95
SRS	305	10,900	835	786	868	396	14,090
Y-12	6,390	0	0	0	0	0	6,390
Total	12,381	14,986	2,933	1,548	5,040	4,527	41,415

^aBased on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bRadionuclide characteristics are described in footnote b of Table 4.5.

^cUnknown or mixture.

^dData for ANL-W are included with INEL data.

^eThis site is now included in the DOE Environmental Restoration Program. In future updates of this report, information on waste generated from environmental restoration activities at this site will be provided in Chapter 6.

^fNaval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.8. Breakdown of activity of LLW generated during 1993 at DOE sites by radionuclide characteristic^a

DOE site ^b	Activity, Ci						Total
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other ^c	
AMES	<<1	0	<<1	0	0	0	<<1
ANL-E	0	0	0	0	0	2	2
ANL-W	d	d	d	d	d	d	d
BNL	<<1	10	<<1	2	<1	0	12
FEMP	e	e	e	e	e	e	e
FNAL	0	0	<1	<<1	0	0	<1
HANF	<1	50,722	1	3,008	c	0	53,732
INEL	1	23	1	16	1	184,800	184,842
ITRI	<<1	<<1	1	1	<<1	<<1	2
K-25	0	0	0	0	0	c	c
KCP	0	0	0	0	0	<<1	<<1
LANL	<1	5	2,093	2,452	4	0	4,554
LBL	0	0	<<1	1,200	0	1	1,201
LLNL	2	0	0	2	<1	<1	5
MOUND	0	0	0	1,000	<1	0	1,000
NR sites ^f	<1	3	461,730	0	<1	0	461,733
NTS	0	<<1	0	0	0	0	<<1
ORISE	<<1	<<1	0	<<1	c	<<1	<<1
ORNL	1	1,689	20	<<1	<1	<1	1,710
PAD	<<1	<<1	0	0	<<1	c	<<1
PANT	<<1	0	0	14	0	0	14
PINELLAS	0	0	0	31,615	0	0	31,615
PORTS	c	<<1	0	0	0	0	<<1
PPPL	0	0	<<1	460	0	<<1	460
RFP	<1	0	0	0	5	0	6
SLAC	0	0	199	0	0	0	199
SNL/CA	<<1	0	0	2,500	0	10	2,510
SNL/NM	<<1	<<1	<<1	10	<<1	2	12
SRS	<<1	447	5	3,060	4,040	3	7,555
Y-12	c	0	0	0	0	0	c
Total	4	52,900	464,049	45,341	4,051	184,818	751,163

^aBased on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bRadionuclide characteristics are described in footnote b of Table 4.5.

^cUnknown or mixture.

^dData for ANL-W are included with INEL data.

^eThis site is now included in the DOE Environmental Restoration Program. In future updates of this report, information on waste generated from environmental restoration activities at this site will be provided in Chapter 6.

^fNaval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.9. Breakdown of cumulative volumes of LLW stored at DOE sites by radionuclide characteristic^a

DOE site ^b	Volume, m ³						Total
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other ^c	
AMES	14	0	0	0	0	0	14
ANL-E	0	0	0	0	0	420	420
ANL-W	d	d	d	d	d	d	d
BNL	e	e	e	e	e	e	e
FEMP	e	e	e	e	e	e	e
FNAL	0	0	166	5	0	0	170
HANF	63	24	53	2	f	0	143
INEL	346	2,063	30	2	78	9,402	11,921
ITRI	<<1	1	6	12	<1	<<1	20
K-25	0	0	0	0	0	5,594	5,594
KCP	2	0	0	0	0	7	9
LANL	0	0	0	0	0	0	0
LBL	0	0	300	11	0	41	351
LLNL	315	140	4	135	216	15	825
MOUND	<1	0	0	2,100	2,000	7	4,107
NR sites ^g	0	0	0	0	0	0	0
NTS	730	0	0	0	<1	0	730
ORISE	0	0	0	0	8	0	8
ORNL	1,386	46,540	1,544	15	3,168	6	52,659
PAD	897	0	0	0	0	2,658	3,555
PANT	0	0	0	0	0	232	232
PINELLAS	0	0	0	32	0	0	32
PORTS	49,494	<<1	0	0	0	0	49,494
PPPL	0	0	330	1	0	36	367
RFP	457	0	0	0	4,165	0	4,622
SLAC	0	0	70	0	0	6	76
SNL/CA	5	0	0	36	0	<1	41
SNL/NM	29	79	138	44	<<1	25	315
SRS	342	631	760	0	128	0	1,861
Y-12	18,100	0	0	0	0	0	18,100
Total	72,180	49,478	3,401	2,395	9,763	18,449	155,666

^aFrom beginning of operations through 1993. Based on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bRadionuclide characteristics are described in footnote b of Table 4.5.

^cUnknown or mixture.

^dData for ANL-W are included with INEL data.

^eThis site is now included in the DOE Environmental Restoration Program. In future updates of this report, information on waste stored from environmental restoration activities at this site will be provided in Chapter 6.

^fUnknown. Contributions included in reported categories.

^gNaval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.10. Breakdown of total gross activity of LLW stored at DOE sites by radionuclide characteristic

DOE site ^b	Total gross activity, Ci ^a						Total
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other ^c	
AMES	<<1	0	0	0	0	0	<<1
ANL-E	0	0	0	0	0	8	8
ANL-W	d	d	d	d	d	d	d
BNL	c	c	c	c	c	c	c
FEMP	e	e	e	e	e	e	e
FNAL	0	0	<1	<<1	0	0	<1
HANF	0	204,900	<1	210	f	0	205,110
INEL	<<1	118	3	84	7	952,200	952,411
ITRI	<<1	<<1	<<1	<1	<<1	<<1	<1
K-25	0	0	0	0	0	c	c
KCP	<<1	0	0	0	0	724	724
LANL	0	0	0	0	0	0	0
LBL	0	0	<1	12,600	0	1	12,601
LLNL	4	110	<1	14,152	3	2	14,272
MOUND	<<1	0	0	70,000	2	<<1	70,002
NR sites ^g	0	0	0	0	0	0	0
NTS	292	0	0	0	<1	0	292
ORISE	0	0	0	0	c	0	c
ORNL	1,620	341,600	394	0	95	<<1	343,709
PAD	<<1	<<1	0	0	<<1	c	<<1
PANT	<1	0	0	5	0	0	6
PINELLAS	0	0	0	32,979	0	0	32,979
PORTS	c	<<1	0	0	0	0	<<1
PPPL	0	0	4	<<1	0	<<1	4
RFP	2	0	0	0	21	0	23
SLAC	0	0	399	0	0	<<1	399
SNL/CA	<<1	0	0	2,570	0	10	2,580
SNL/NM	1	10	<<1	32	<<1	5	48
SRS	4	<1	234,000	0	<<1	0	234,004
Y-12	c	0	0	0	0	0	c
Total	1,924	546,739	234,801	132,632	127	952,949	1,869,172

^aSum of annual additions without decay, from beginning of operations through 1993. Based on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bRadionuclide characteristics are described in footnote b of Table 4.5.

^cUnknown or mixture.

^dData for ANL-W are included with INEL data.

^eThis site is now included in the DOE Environmental Restoration Program. In future updates of this report, information on waste stored from environmental restoration activities at this site will be provided in Chapter 6.

^fUnknown. Contributions included in reported categories.

^gNaval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.11. Breakdown of cumulative volumes of LLW buried at DOE sites by radionuclide characteristic^a

DOE site ^b	Volume, m ³						Total
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other ^c	
AMES	200	0	0	0	0	0	200
ANL-E	0	0	0	0	0	0	0
ANL-W	0	0	0	0	0	0	0
BNL	0	0	5	832	0	3	839
FEMP	337,548	0	0	0	0	5,670	343,218
FNAL	0	0	0	0	0	0	0
HANF	229,927	245,797	121,584	4,302	d	0	601,610
INEL	4,226	25,500	374	20	964	116,000	147,084
ITRI	0	0	0	0	0	0	0
K-25	81,048	0	0	0	0	0	81,048
KCP	0	0	0	0	0	0	0
LANL	65,470	11,659	10,455	3,496	129,552	84	220,716
LBL	0	0	0	0	0	0	0
LLNL ^e	9,102	<<1	<<1	0	0	0	9,102
MOUND	0	0	0	0	0	0	0
NR sites ^f	0	0	0	0	0	0	0
NTS	119,487	216,855	12,859	8,677	91,181	9,376	458,435
ORISE	0	0	0	0	0	0	0
ORNL	19,118	123,950	34,215	3,806	13,050	15,130	209,268
PAD	7,613	0	0	0	0	0	7,613
PANT	121	0	0	13	0	0	134
PINELLAS	0	0	0	0	0	0	0
PORTS	12,110	0	0	0	0	0	12,110
PPPL	0	0	0	0	0	0	0
RFP	0	0	0	0	0	0	0
SLAC	0	0	0	0	0	0	0
SNL/CA	0	0	0	0	0	0	0
SNL/NM	3,178	7	33	<1	<<1	<<1	3,218
SRS	71,675	414,381	45,079	35,066	93,066	5,972	665,239
Y-12	151,343	0	0	0	0	0	151,343
Total	1,112,166	1,038,148	224,603	56,211	327,813	152,235	2,911,177

^aFrom beginning of operations through 1993. Based on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bRadionuclide characteristics are described in footnote b of Table 4.5.

^cUnknown or mixture.

^dUnknown. Contributions included in reported categories.

^eNo wastes are buried on the LLNL site. The inventory reported is for wastes buried at the Site 300 Area, an explosives disposal area located off, but near, LLNL.

^fNaval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.12. Breakdown of total gross activity of LLW buried at DOE sites by radionuclide characteristic

DOE site ^b	Total gross activity, Ci ^a						Total
	Uranium/ thorium	Fission product	Induced activity	Tritium	Alpha	Other ^c	
AMES	<1	0	0	0	0	0	<1
ANL-E	0	0	0	0	0	0	0
ANL-W	0	0	0	0	0	0	0
BNL	0	0	2	3	0	1	5
FEMP	2,610	0	0	0	0	1,804	4,414
FNAL	0	0	0	0	0	0	0
HANF	661	9,674,681	81,792	457,136	d	0	10,214,271
INEL	45	1,523	36	1,076	9	11,920,000	11,922,689
ITRI	0	0	0	0	0	0	0
K-25	59	0	0	0	0	0	59
KCP	0	0	0	0	0	0	0
LANL	264	17,907	420,304	1,056,162	4,531	0	1,499,168
LBL	0	0	0	0	0	0	0
LLNL ^e	13	<<1	<<1	0	0	0	13
MOUND	0	0	0	0	0	0	0
NR sites ^f	0	0	0	0	0	0	0
NTS	2,581	90,323	7,095	9,288,576	54,766	361,329	9,804,670
ORISE	0	0	0	0	0	0	0
ORNL	1,349	384,316	853,848	12,239	754	41	1,252,547
PAD	20,396	3	0	0	0	0	20,399
PANT	8	0	<<1	<1	0	<1	8
PINELLAS	0	0	0	0	0	0	0
PORTS	26	0	0	0	0	0	26
PPPL	0	0	0	0	0	0	0
RFP	0	0	0	0	0	0	0
SLAC	0	0	0	0	0	0	0
SNL/CA	0	0	0	0	0	0	0
SNL/NM	12	611	5,493	2,984	3	4	9,107
SRS	294	720,153	4,882,034	4,692,632	9,285	243,999	10,548,397
Y-12	10,400	0	0	0	0	0	10,400
Total	38,719	10,889,517	6,250,604	15,510,808	69,348	12,527,178	45,286,174

^aSum of annual additions without decay, from beginning of operations through 1993. Based on DOE site information provided in ref. 1. Totals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

^bRadionuclide characteristics are described in footnote b of Table 4.5.

^cUnknown or mixture.

^dUnknown. Contributions included in reported categories.

^eNo wastes are buried on the LLNL site. The inventory reported is for wastes buried at the Site 300 Area, an explosives disposal area located off, but near, LLNL.

^fNaval reactors (NR) sites include KAPL, BAPL, and NRF.

Table 4.13. DOE LLW disposed by methods other than shallow-land burial^a

Site	Location	Site use (year)	Waste containers buried ^b	Undecayed radioactive content (Ci)
<i>Atlantic Ocean</i>				
Atlantic	38°30'N 72°06'W	1951–1956; 1959–1962	14,300	74,400 ^c
Atlantic	37°50'N 70°35'W	1957–1959	14,500	2,100
Massachusetts Bay	42°25'N 70°35'W	1952–1959	4,008	2,440
Cape Henry	36°56'N 74°23'W	1949–1967	843	87
Central Atlantic	36°20'N/ 43°49'N 45°00'W	1959–1960	432	480
Subtotal			34,083	79,507
<i>Pacific Ocean</i>				
Farallon Islands (Subsite A)	37°38'N 123°08'W	1951–1953	3,500	1,100
Farallon Islands (Subsite B)	37°37'N 123°17'W	1946–1950; 1954–1956	44,000	13,400
Santa Cruz Basin	33°40'N 119°40'W	1946–1962	3,114	108
Cape Scot	50°56'N 136°03'W 52°25'N 140°12'W	1958–1969	360	124
San Diego	32°00'N 121°30'W	1959–1962	4,415	34
Subtotal (oceans)			55,389	14,766
Total			89,472	94,273
<i>Hydrofracture facility</i>				
ORNL	Bedded Conasauga shale underlying the ORNL site	1959–1965 1966–1980 ^d 1982 ^e 1983 ^e	Small experimental amounts 8.0 × 10 ³ m ³ of grout 3.8 × 10 ³ m ³ of grout 5.5 × 10 ³ m ³ of grout	600,000 200,000 500,000
Total			17.3 × 10 ³ m ³	1,300,000

^aRadioactivity is given at time of burial. Data taken from Table 4.5 of ref. 3.^bEstimated number of containers.^cIncludes approximately 33,000 Ci of induced activity associated with the U.S.S. Seawolf reactor vessel.^dRetired after 18 injections.^eNew facility started up with four injections in 1982 and completed campaign with seven injections in 1983.

Table 4.14. Status of land usage at LLW burial and disposal sites^a

Site	Site size (ha)	Estimated total usable area ^b (ha)	Estimated area utilized through 1993 (ha) ^b
DOE (burial sites)			
HANF ^c	145,040	385	155
INEL	230,510	38.2	32.3
K-25 ^d	607	e	e
LANL	11,137	37.1	17.4
NTS ^f	349,661	820	174.2
ORNL	1,174	26	7
SNL/NM ^d	1,141	0.27	e
SRS	84,175	91.1	67.9
Total	823,445	>1,398	>454
Commercial (disposal sites)			
West Valley, NY (Closed Mar. 11, 1975) ^g	8.9	7.2	3.8
Maxey Flats, KY (Closed Dec. 27, 1977)	102	<51	10.4
Sheffield, IL (Closed Apr. 8, 1978)	8.9	8.1	8.1
Barnwell, SC ^h	121	44.5	36.6
Beatty, NV ⁱ	32	18.6	15.7
Richland, WA	40	29.5	11.9
Total	313	159	86.5
Grand total	823,758	~1,557	>541

^aNote: 1 acre = 0.4047 ha, and 1 ha = 10,000 m².

^bDOE usable area and area utilized (except where noted) are generally taken from ref. 1. Comparable commercial values (except where noted) are taken from ref. 7.

^cUtilized land value is for the 200-Area only; in addition, the closed 100- and 300-Area burial grounds include a total of 16.8 ha.

^dCurrently no active disposal operations at this site.

^eInformation not available, or unknown.

^fThis pertains to the radioactive waste management site in Area 5 and Area 3 of the NTS. The availability of land that could be used for shallow-land burial is not clearly defined because of the classified nature of the site and the abundance of land.

^gWVDP LLW was buried on-site in the noncommercial NRC disposal area from 1982 until late 1986. No waste was buried at West Valley from 1987–1993 (see Table 4.18).

^hBased on information provided in ref. 6. Anticipated closure date for this site is December 31, 1995.

ⁱBased on ref. 8.

Table 4.15. Significant revisions and changes in the current values for LLW compared to the values in the previous year

Burial/ disposal site	DOE/RW-0006, Rev. 9 (1993) Table No.	DOE/RW-0006, Rev. 10 (1994) Table No.	Significant revision or net change	Explanation
DOE/Hanford	4.1, 4.2, 4.4, 4.5, 4.6, 4.9, 4.10, and 4.14	4.1, 4.2, 4.4, 4.5, 4.6, 4.11, 4.12, and 4.16	Total volume and radioactivity buried at Hanford has increased	Revision of historical data
DOE	N/A	4.9 and 4.10	Added tables reporting data for stored DOE LLW	Stored data were included to provide data similar to that presented for generated and buried LLW
DOE	4.19 and 4.20	4.21	GTCC LLW data updated and incorporated into Rev. 10, Table 4.21	Recent revision of GTCC LLW report allowed update

Table 4.16. Historical and projected volume, radioactivity, and thermal power characteristics of buried DOE LLW, except SRS saltstone

End of calendar year	Volume ^{a,b} (10 ³ m ³)		Radioactivity ^{a,b} (10 ³ Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1990	60.0	2,759	545	13,516	2,013	17,844
1991	53.6	2,812	717	13,277	2,788	18,220
1992	48.3	2,860	1,078	13,401	4,947	2,074
1993	50.5	2,911	894	13,147	3,263	20,398
1994	44.2	2,955	756	12,993	3,073	21,143
1995	44.2	2,999	756	12,906	3,073	22,066
1996	44.2	3,043	756	12,846	3,073	23,006
1997	44.2	3,088	756	12,803	3,073	23,918
1998	44.2	3,132	756	12,770	3,073	24,790
1999	44.2	3,176	756	12,746	3,073	25,618
2000	44.2	3,220	756	12,729	3,073	26,405
2001	44.2	3,264	756	12,719	3,073	27,155
2002	44.2	3,308	756	12,715	3,073	27,871
2003	44.2	3,353	756	12,718	3,073	28,557
2004	44.2	3,397	756	12,725	3,073	29,215
2005	44.2	3,441	756	12,738	3,073	29,849
2006	44.2	3,485	756	12,756	3,073	30,460
2007	44.2	3,529	756	12,778	3,073	31,050
2008	44.2	3,574	756	12,805	3,073	31,621
2009	44.2	3,618	756	12,835	3,073	32,174
2010	44.2	3,662	756	12,869	3,073	32,710
2011	44.2	3,706	756	12,907	3,073	33,230
2012	44.2	3,750	756	12,947	3,073	33,736
2013	44.2	3,795	756	12,991	3,073	34,228
2014	44.2	3,839	756	13,036	3,073	34,707
2015	44.2	3,883	756	13,085	3,073	35,173
2016	44.2	3,927	756	13,135	3,073	35,628
2017	44.2	3,971	756	13,188	3,073	36,071
2018	44.2	4,015	756	13,242	3,073	36,504
2019	44.2	4,060	756	13,297	3,073	36,926
2020	44.2	4,104	756	13,354	3,073	37,338
2021	44.2	4,148	756	13,412	3,073	37,741
2022	44.2	4,192	756	13,472	3,073	38,135
2023	44.2	4,236	756	13,532	3,073	38,520
2024	44.2	4,281	756	13,593	3,073	38,896
2025	44.2	4,325	756	13,654	3,073	39,264
2026	44.2	4,369	756	13,716	3,073	39,625
2027	44.2	4,413	756	13,779	3,073	39,977
2028	44.2	4,457	756	13,842	3,073	40,322
2029	44.2	4,501	756	13,905	3,073	40,660
2030	44.2	4,546	756	13,968	3,073	40,991

^aHistorical (beginning of operations through 1992) annual values of volume and radioactivity (by waste type) for each site are from ref. 7. Similar values for 1993 are from ref. 1. See Tables 4.4, 4.5, 4.11, and 4.12 for more detail. Radioactivity (by waste type) is decayed from the year of addition using the representative compositions given in Table C.3 of Appendix C.

^bBeginning in 1994, the volume and radioactivity added each year are assumed to remain constant through 2030 at the 1994 values projected (ref. 1) by each site.

Table 4.17. Projected volume, radioactivity, and thermal power characteristics of DOE LLW saltstone at SRS^a

End of calendar year	Volume (10 ³ m ³)		Radioactivity ^b (10 ³ Ci)		Thermal power (W)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1994	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.0	0.0	0.0	0.0	0.0	0.0
1996	25.1	25.1	1.1	1.1	2.5	2.5
1997	73.0	98.0	3.2	4.3	7.4	9.9
1998	87.1	185.0	21.4	25.8	49.2	59.2
1999	102.0	287.0	13.2	39.0	30.4	89.6
2000	72.5	359.0	6.9	45.9	15.8	105.0
2001	87.1	446.0	0.0	45.6	0.0	105.0
2002	87.1	533.0	3.3	48.9	7.6	112.0
2003	88.4	622.0	7.8	56.7	17.9	130.0
2004	0.0	622.0	0.0	55.4	0.0	127.0
2005	87.1	709.0	0.0	54.4	0.0	125.0
2006	87.0	796.0	4.7	59.0	10.8	136.0
2007	43.8	839.0	1.3	60.3	2.9	138.0
2008	43.8	883.0	0.0	59.4	0.0	136.0
2009	43.5	927.0	0.0	58.9	0.0	135.0
2010	13.3	940.0	0.0	57.6	0.0	132.0
2011	20.1	960.0	0.0	56.3	0.0	129.0
2012	41.1	1,000.0	0.5	56.8	1.2	130.0
2013	87.1	1,090.0	6.7	63.5	15.3	146.0
2014	51.7	1,140.0	2.2	65.6	5.0	151.0
2015	43.5	1,180.0	0.0	65.1	0.0	149.0
2016	87.1	1,270.0	0.0	63.6	0.0	146.0
2017	87.1	1,360.0	0.0	63.2	0.0	145.0
2018	87.1	1,440.0	0.0	62.8	0.0	144.0
2019	43.5	1,490.0	0.0	61.4	0.0	141.0
2020	43.5	1,530.0	0.4	61.7	0.9	142.0
2021	0.0	1,530.0	0.0	60.3	0.0	138.0
2022	0.0	1,530.0	0.0	59.0	0.0	135.0
2023	0.0	1,530.0	0.0	57.6	0.0	132.0
2024	0.0	1,530.0	0.0	56.3	0.0	129.0
2025	0.0	1,530.0	0.0	55.1	0.0	126.0
2026	0.0	1,530.0	0.0	53.8	0.0	123.0
2027	0.0	1,530.0	0.0	52.6	0.0	121.0
2028	0.0	1,530.0	0.0	51.4	0.0	118.0
2029	0.0	1,530.0	0.0	50.2	0.0	115.0
2030	0.0	1,530.0	0.0	49.1	0.0	113.0

^aTaken from ref. 1 of Chapter 2.

^bRadionuclide composition as a function of time is given in Table C.5 of Appendix C.

Table 4.18. Historical annual additions and total volume of LLW at commercial disposal sites^a

Year	Volume, m ³						Annual total	Cumulative total
	Beatty ^b	West Valley ^c	Maxey Flats ^d	Richland	Sheffield ^e	Barnwell		
1962	1,861						1,861	1,861
1963	3,512	127	2,206				5,845	7,706
1964	2,836	5,940	3,872				12,648	20,354
1965	1,988	5,192	5,753	668			13,601	33,955
1966	3,533	3,951	5,557	2,402			15,443	49,398
1967	3,206	7,475	7,820	773	2,527		21,801	71,199
1968	3,576	3,490	8,178	1,359	2,713		19,316	90,515
1969	4,526	4,099	10,354	438	2,012		21,429	111,944
1970	5,152	4,906	12,521	423	2,825		25,827	137,771
1971	4,916	7,002	13,173	584	4,430	1,171	31,276	169,047
1972	4,301	9,045	15,578	654	5,956	3,757	39,291	208,338
1973	4,076	7,535	10,074	1,033	8,524	15,839	47,081	255,419
1974	4,103	8,866	8,898	1,411	12,373	18,244	53,895	309,314
1975	4,943	2,243	17,098	1,500	14,116	18,072	57,972	367,286
1976	3,864	427	13,775	2,867	13,480	40,227	74,640	441,926
1977	4,742	351	423	2,718	17,643	45,663	71,540	513,466
1978	8,874	144		7,422	1,735	61,554	79,729	593,195
1979	6,491	138		12,185		63,861	82,675	675,870
1980	12,717	141		24,819		54,723 ^f	92,400	768,270
1981	3,351	216		40,732		39,427 ^f	83,726	851,996
1982	1,505	632		39,606		34,779	76,522	928,518
1983	1,111	1,284		40,458		35,132	77,985	1,006,503
1984	2,067	966		38,481		34,879	76,393	1,082,896
1985	1,388	809		40,135		34,389	76,721	1,159,617
1986	2,668	2,095		18,833		29,612	53,208	1,212,825
1987	9,414			15,765		27,060	52,239	1,265,064
1988	2,645			11,430		26,391	40,466	1,305,530
1989	3,291			11,562		31,242	46,095	1,351,625
1990	1,684			8,362		22,315	32,361	1,383,986
1991	4,539			11,872		22,368	38,779	1,422,765
1992	14,575			11,271		23,518	49,364	1,472,129
1993				5,288		17,145	22,433	1,494,562
Total	137,455	77,074	135,280	355,051	88,334	701,368		1,494,562

^aFor a summary of historical additions (1962–1984), see Table 4.6 in ref. 3. For Beatty, Richland, and Barnwell, the additions for 1985–1992 are from Table 4.16 in ref. 7. Information for 1993 is taken from ref. 9.

^bBeatty ceased accepting LLW December 31, 1992.

^cWest Valley includes a commercial state-licensed facility which opened Nov. 18, 1963, and closed Mar. 11, 1975, and an NRC-licensed facility (for on-site fuel reprocessing wastes) which opened in 1966 and continued to receive only on-site-generated LLW associated with water treatment and site cleanup until late 1986. This license is in abeyance. Disposal operations at the West Valley Demonstration Project (WVDP) have been suspended pending the preparation of an EIS report for the West Valley site closure. The WVDP began in 1982. The LLW volumes reported for 1982 through 1986 are for the WVDP only and are taken from ref. 7. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 7).

^dClosed Dec. 27, 1977. Small perturbations in waste volumes have occurred during site cleanup operations (ref. 11) but are not included here since they are inconsequential.

^eClosed Apr. 8, 1978. No additional operations have taken place at the site.

^fThese values exclude almost 19,000 m³ (approximately 14,506 in 1980 and approximately 4,279 in 1981) of very low-level-activity settling pond sludge that was not counted against the annual quota.

Table 4.19. Historical annual additions and total undecayed radioactivity of LLW at commercial disposal sites^a

Year	Radioactivity, Ci						Annual total	Cumulative total
	Beatty ^b	West Valley ^c	Maxey Flats ^d	Richland	Sheffield ^e	Barnwell		
1962	f						f	f
1963	5,690	100	22,556				28,346	28,346
1964	6,477	10,400	147,218				164,095	192,441
1965	6,377	22,600	63,828	144			92,949	285,390
1966	11,974	35,400	52,737	1,606			101,717	387,107
1967	10,894	123,100	23,273	5,378	3,850		166,495	553,602
1968	6,808	10,600	45,577	64,432	2,381		129,798	683,400
1969	9,761	36,000	31,028	55,964	2,192		134,945	818,345
1970	12,304	91,900	46,969	52,820	5,427		209,420	1,027,765
1971	4,316	436,700	720,146	23,916	7,895	4,151	1,197,124	2,224,889
1972	5,228	131,300	217,351	31,809	4,857	13,575	404,120	2,629,009
1973	5,704	346,000	118,359	57,037	2,834	48,212	578,146	3,207,155
1974	23,904	6,600	143,656	12,773	3,229	13,557	203,719	3,410,874
1975	18,388	11,600	289,570	113,341	6,103	17,428	456,430	3,867,304
1976	4,493	1,200	211,359	104,306	7,744	90,205	419,307	4,286,611
1977	23,811	900	267,063	7,465	11,147	390,121	700,507	4,987,118
1978	5,685	700		235,548	2,547	652,061	896,541	5,883,659
1979	8,897	400		164,787		314,938	489,022	6,372,681
1980	148,312	300		41,031		143,502	333,145	6,705,826
1981	52,214	229		43,905		183,744	280,092	6,985,918
1982	80,929	293		59,007		273,962	414,191	7,400,109
1983	1,356	255		120,534		383,450	505,595	7,905,704
1984	544	25		215,286		385,079	600,934	8,506,638
1985	453	39		287,849		460,571	748,912	9,255,550
1986	672	13		115,591		116,108	232,384	9,487,934
1987	3,353	0		42,734		211,026	257,113	9,745,047
1988	8,690	0		32,067		218,901	259,658	10,004,705
1989	42,678	0		99,056		725,164	866,898	10,871,603
1990	11,323	0		92,985		444,277	548,585	11,420,188
1991	29,679	0		158,784		611,348	799,811	12,219,999
1992	90,206	0		93,923		815,974	1,000,103	13,220,102
1993				31,422		611,785	643,207	13,863,309
Total	641,120	1,266,654	2,400,690	2,365,500	60,206	7,129,139		13,863,309

^aFor a summary of historical additions (1962–1984), see Table 4.6 in ref. 3. For Beatty, Richland, and Barnwell, the additions for 1985–1992 are from Table 4.17 in ref. 7. Information for 1993 is taken from ref. 9.

^bBeatty ceased accepting LLW December 31, 1992.

^cWest Valley includes a commercial state-licensed facility which opened Nov. 18, 1963, and closed Mar. 11, 1975, and an NRC-licensed facility (for on-site fuel reprocessing wastes) which opened in 1966 and continued to receive only on-site-generated LLW associated with water treatment and site cleanup until late 1986. This license is in abeyance. Disposal operations at the West Valley Demonstration Project (WVDP) have been suspended pending the preparation of an EIS report for the West Valley site closure. The WVDP began in 1982. The LLW radioactivity values reported for 1982 through 1986 are for the WVDP only and are taken from ref. 7. Since the beginning of 1987, LLW generated at the WVDP is stored on-site in engineered facilities pending final disposal (ref. 7).

^dClosed Dec. 27, 1977.

^eClosed Apr. 8, 1978.

^fReported as 296 kg of source material (as defined in Title 10, Code of Federal Regulations, Part 40).

Table 4.20. Distribution of total volume and radioactivity, by state, of LLW shipped to commercial disposal sites in 1993^a

State	Volume (m ³)	Radioactivity (Ci)	State	Volume (m ³)	Radioactivity (Ci)
Alabama	370.31	67,948.69	Nebraska	333.24	1,063.39
Alaska	12.67	<0.10	Nevada	0.00	0.00
Arizona	230.86	680.37	New Hampshire	0.00	0.00
Arkansas	81.84	4,859.67	New Jersey	596.85	8,586.93
California	560.81	10,914.48	New Mexico	0.34	<0.10
Colorado	1,094.72	30,006.56	New York	1,461.82	41,642.86
Connecticut	413.49	5,378.42	North Carolina	1,048.54	2,502.42
Delaware	14.16	45.08	North Dakota	0.11	17.61
District of Columbia	0.01	<0.10	Ohio	189.08	2,370.30
Florida	354.73	13,052.40	Oklahoma	5.53	623.37
Georgia	374.70	218,851.17	Oregon	2,826.86	331.03
Hawaii	66.87	2.94	Pennsylvania	1,376.89	84,346.95
Idaho	9.17	2.12	Puerto Rico	0.00	0.00
Illinois	1,883.53	37,718.31	Rhode Island	0.00	0.00
Indiana	27.39	6.75	South Carolina	1,075.54	20,962.56
Iowa	56.84	51,341.87	South Dakota	0.25	<0.10
Kansas	77.20	1,440.23	Tennessee	2,397.28	242.67
Kentucky	13.26	514.10	Texas	277.55	6,605.34
Louisiana	202.78	255.27	Utah	184.73	0.36
Maine	0.00	0.00	Vermont	131.19	739.80
Maryland	321.80	5,019.37	Virgin Islands	0.00	0.00
Massachusetts	706.92	18,011.84	Virginia	2,053.63	3,304.79
Michigan	0.00	0.00	Washington	1,092.85	1,077.60
Minnesota	143.19	1,449.65	West Virginia	0.76	5.53
Mississippi	208.75	493.33	Wisconsin	63.02	345.09
Missouri	90.31	444.13	Wyoming	0.00	0.00
Montana	0.00	0.00			
			Total	22,432.37	643,206.81

^aData provided by EG&G, Idaho (ref. 9) and is published in ref. 2.

Table 4.21. Historical and projected cumulative volume and radioactivity summary of commercial GTCC LLW^a

Category	1993 ^b			2035 ^{c,d}		
	Volume (m ³)		Radioactivity (Ci)	Volume (m ³)		Radioactivity (Ci)
	Unpackaged	ACA packaged ^e		Unpackaged	ACA packaged	
Nuclear utility wastes						
• BWR operations	3.20	1.10	28,200	105.2	36.7	1,155,517
• PWR operations	2.82	0.12	18,300	77.7	10.0	573,510
LWR operations total	6.02	1.22	46,500	182.9	46.7	1,729,027
• BWR decommissioning	6.26	14.48	757,000	115.4	188.8	3,270,412
• PWR decommissioning	3.98	10.32	3,086,500	398.9	570.9	30,548,517
LWR decommissioning total	10.24	24.80	3,843,500	514.3	759.7	33,818,929
Nuclear utility total	16.26	26.02	3,890,000	697.2	806.4	35,547,956
Sealed sources						
• General license	0.007	0.474	1,119	0.123	8.09	18,440
• Specific license	0.125	38.22	354,000	0.87	234	1,560,000
Sealed sources total	0.13	38.69	355,119	0.99	242	1,578,440
DOE-held potential GTCC waste	0	0	0	0	0	0
Other generator waste ^f	46.9	74.2	2,738	235	465	12,680
Total	63.3	138.9	4,247,857	933	1,513	37,139,076

^aBased on the INEL study of ref. 18. Projected data reported represent base-case scenario projections.

^bReported cumulative inventory as of December 31, 1993.

^cProjected cumulative inventory for end of CY 2035.

^dReference 18 also projects quantities of nuclear utility GTCC LLW by the end of CY 2055. For the base case, these include an unpackaged volume of 1,144 m³, an after-concentration-averaged (ACA) packaged volume of 1,347 m³, and an associated radioactivity of 88,400,000 Ci.

^eACA packaged waste. This is the packaged volume of waste that is classified as GTCC LLW, after all other waste has been classified as Class A, B, or C LLW using concentration-averaging practices.

^fIncludes contributions from ¹⁴C users, irradiation laboratories, sealed source manufacturers, a nuclear fuel fabrication facility, and a university reactor.

Table 4.22. Breakdown of 1993 low-level radioactive waste by type, volume, and activity received by commercial disposal sites^a

Commercial site	Type of waste	Volume (m ³)	Radioactivity (Ci)
Barnwell	Academic	294	99
	Government	2,165	28,644
	Industrial	4,778	2,015
	Medical	139	20
	Utility	9,769	581,007
		<hr/> 17,145	<hr/> 611,785
Richland	Academic	51	12
	Government	540	21
	Industrial	3,065	23
	Medical	7	2
	Utility	1,625	31,364
		<hr/> 5,288	<hr/> 31,422

^aBased on ref. 9.

A uranium mill tailings pond at the Panna Maria site in Karnes County, Texas. Courtesy of the U.S. Department of Energy, Energy Information Administration, Washington, D.C.

5. URANIUM MILL TAILINGS FROM COMMERCIAL OPERATIONS

5.1 INTRODUCTION

Uranium mill tailings are the residual wastes of milled ore that remain after the uranium has been recovered. Mill tailings at licensed sites and those that will be produced to meet future uranium requirements are "commercial" mill tailings, the subject of this chapter. Tailings resulting from uranium milled for defense purposes are not included. Existing tailings at sites that are no longer licensed are classified as "inactive" mill tailings. Inactive tailings are administered under the remedial action projects discussed in Chapter 6.

Mill tailings are generated during the process of extracting uranium from the ore fed to the mill. Uranium mills use either an acid leach or an alkaline leach process to recover uranium, depending on the ore's chemical characteristics. Currently, all U.S. mills use the acid leach process. Mill tailings from both processes consist of slurries of sands and clay-like particles called slimes; the tailings slurries are pumped to tailings impoundment ponds for disposal.

U.S. uranium production from conventional milling has declined since 1980; as a consequence, the quantity of mill tailings generated each year has declined (see Table 5.1). During 1993, there was no uranium production from conventional mills, therefore no new mill tailings were generated. At the end of 1993, six mills were on standby status. The location of each of these mills is indicated on the map shown in Fig. 5.1. The small utilization of U.S. uranium mill capacity can be attributed, in large part, to nuclear power plant cancellations and deferments. Since the late 1970s, these have led to lower uranium demand which, in turn, has contributed to lower uranium prices and a steady decline in domestic uranium mining. In addition, cost increases for domestic uranium mining and milling have led to increased reliance on imports of lower cost uranium.

In the 46-year history of U.S. uranium production, 1993 was the only year with no production from conventional milling of ore. Nonconventional concentrate production in 1993 also decreased to about 1,400 t U_3O_8 , or 30% below 1992 production.^{1,2} Nonconventional

concentrate production includes by-product processing from the mining of phosphate ore as well as the processing of in situ leach mining solutions, heap-leach solutions, mine water, and other solutions from reclamation activities. In situ leaching (ISL) technology has been increasingly applied in recent years in mining operations. Of the total \$80/kg-U uranium reserves estimated by the Energy Information Administration (EIA), the amount for which ISL is the proposed mining method has increased from 39% in 1992 to 42% in 1993. Because ISL mining generally is successful at lower costs compared with conventional mining methods, it could gain even wider use in the near future. ISL and by-product production methods do not generate mill tailings. Residual wastes from nonconventional methods are not considered in this chapter.

The volumes of historical and projected cumulative mill tailings through the year 2005 are shown in Fig. 5.2. This graph is based on the data reported in Table 5.1. The estimates of projected domestic tailings are based on U.S. production of uranium found in projections from ref. 3.

5.2 INVENTORIES

The status of the licensed mills, including their estimated commercial and government-related tailings inventories at the end of 1993, is shown in Table 5.2 (data based on refs. 1-12). For each mill, the amount of tailings generated depends on the amount of ore processed, the ore-feed grade (U_3O_8 assay), and the percentage of U_3O_8 recovered. Table 5.3 lists the annual milling rate, ore grade, and U_3O_8 recovery. The associated mill tailings generated through 1993 are 189.5×10^6 t (118.6×10^6 m³). There were no additions to the tailings pile during 1993.

5.3 WASTE CHARACTERIZATION

Because the amount of uranium (by weight) extracted from the ore during milling is relatively small, the dry

weight of the tailings produced is nearly equal to the dry weight of the ore processed. Dry tailings typically are composed of 70 to 80 wt % sand-sized particles and 20 to 30 wt % finer-sized particles. Acid leaching is preferred for ores with low lime content (12% or less). Those with high lime content require excessive quantities of acid for neutralization and, for economic reasons, are best treated by alkaline leaching. In either leach process, most of the uranium is dissolved, together with the other materials present in the ore (e.g., iron, aluminum, and other impurities). After the ore is leached, the uranium-laden leach liquor is removed from the tailings solids by decantation. After thorough washing, the tailings are pumped as a slurry to a tailings pond. The waste liquid accompanying the tailings solids to the disposal pond is approximately 1 to 1.5 times the weight of the processed ore. Typical characteristics of the tailings solids and liquid are outlined in Table 5.4 (ref. 8).

In August 1986, the EPA issued its final rules on ^{222}Rn emissions from tailings piles.⁷ Mill owners have 6 years (subject to certain extensions) to phase out the use of large, existing tailings piles. New tailings piles must be contained in small [i.e., less than 16 ha (40 acres)] impoundments or disposed of by continuous dewatering and burial with no more than 4 ha (10 acres) uncovered at any one time.

5.4 PROJECTIONS

An average tailings density of 1.6 t/m³ was used to calculate mill-tailings volumes resulting from the milling of uranium ore mined by open-pit and underground operations. The quantity of material produced is based on projections of uranium production as reported in the EIA publication, *World Nuclear Outlook 1994*, DOE/EIA-0436(94). These projections were based on uranium requirements associated with the "DOE/EIA 1994 low-case (no-new-orders) scenario" and assumed a 2-year lead time from the mining/milling of uranium to its use as a reactor fuel.

The volumes of tailings generated from 1994 through 2010 are estimated based on production schedules for conventional mine/mill operations expected to be operational in this period. Most of the U.S. production is projected to come from nonconventional extraction operations (in situ, by-product, etc.). Imports and U.S. inventory drawdowns, which are projected to make up over 80% of U.S. requirements through 2005, will not add to U.S. tailings buildup.

5.5 REFERENCES

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Fig. 5.1. Locations of uranium mills on standby status at the end of 1993.

Fig. 5.2. Historical and projected cumulative volume of commercial mill tailings.

Table 5.1. Historical and projected volume of uranium mill tailings^{a,b}

End of calendar year	Volume (10 ⁶ m ³)	
	Annual	Cumulative
Prior to 1978		68.0
1978	7.9	75.8
1979	9.1	84.9
1980	9.5	94.4
1981	8.2	102.7
1982	5.0	107.7
1983	3.4	111.1
1984	2.5	113.6
1985	1.0	114.6
1986	0.7	115.4
1987	0.8	116.2
1988	0.7	116.9
1989	0.7	117.6
1990	0.4	118.0
1991	0.4	118.4
1992	0.2	118.6
1993	0.0	118.6
1994	<0.1	118.6
1995	0.0	118.6
1996	<0.1	118.6
1997	<0.1	118.7
1998	<0.1	118.7
1999	<0.1	118.8
2000	0.1	118.9
2001	0.2	119.1
2002	0.3	119.4
2003	0.5	119.9
2004	0.5	120.4
2005	0.5	120.9
2006	0.5	121.4
2007	0.5	121.9
2008	0.5	122.4
2009	0.4	122.8
2010	0.3	123.1

^aProjections of domestic tailings are generated from estimates of U.S. uranium production under current market conditions described in ref. 3, which is the Lower Reference Case (now referred to by DOE/EIA as the Mid Case).

^bSources: Prior to 1984—U.S. Department of Energy, Grand Junction Project Office data files. From 1984 through 1993—Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey."

Table 5.2. Status of conventional uranium mill sites at the end of 1993^a

Location	Operator	Rated capacity ^b (t/d ore)	Status		Tailings storage area (ha) ^d	Total tailings		
			Operations ^b	Tailings ^c		Volume ^e (10 ⁶ m ³)	Mass (10 ⁶ t)	Government portion ^f (10 ⁶ t)
Colorado								
Canon City	Cotter	1,090	Shut down, 1987		54R ^g	1.3	2.0R	0.3
Uravan	Umetco Minerals	1,180 ^h	Decommissioning	Partially stabilized	44	5.9	9.5	5.2
Subtotal		1,090			98R	7.2	11.5R	5.5
New Mexico								
Cebolleta	Sohio Western Mining	1,450 ^h	Decommissioned, 1986	i	73	1.2	1.9	0
Church Rock	United Nuclear	2,720 ^h	Decommissioned, 1986	i	83	2.0	3.2	0
Grants	Anaconda	5,440 ^h	Decommissioned, 1987	Partially stabilized	199	13.6	21.7	8.0
Grants	Quivira Mining	6,350	Shut down, 1985	Fenced	142	18.8	30.1	9.1
Grants	Homestake Mining	3,080 ^h	Decommissioning	Unstabilized	105	12.7	20.2R	10.4
Marquez	Bokum Resources	1,820 ^h	New (on standby)	Never operated	0	0	0	0
Subtotal		6,350			602	48.3	77.1R	27.5
South Dakota								
Edgemont	Tennessee Valley Authority	680 ^h	Decommissioned, 1983	Partially stabilized	50	1.2	1.8	1.5
Subtotal		0			50	1.2	1.8	1.5
Texas								
Falls City	Continental Oil/ Pioneer Nuclear	3,080 ^h	Decommissioned, 1981	i	89	6.5	10.5	0
Hobson	Rio Grande Resources	2,720	Decommissioning	i	101	3.9	5.9	0
Ray Point (Felder Facility)	Exxon	1,000 ^h	Decommissioned, 1973 ^j	Stabilized ^k	18	0.2	0.4 ^l	0
Subtotal		2,720			208	10.6	16.8	0

Table 5.2 (continued)

Location	Operator	Rated capacity ^b (t/d ore)	Status		Tailings storage area (ha) ^d	Total tailings		
			Operations ^b	Tailings ^c		Volume ^c (10 ⁶ m ³)	Mass (10 ⁶ t)	Government portion ^f (10 ⁶ t)
Utah								
Blanding	Umetco/Energy Fuels Nuclear	1,810	Shut down, 1990	Partially stabilized	135	1.9	3.2	0
La Sal	Rio Algom	680	Decommissioning	i	14	2.2	3.5	0
Moab	Atlas	1,270 ^h	Decommissioning	Unstabilized	>80	6.0	9.6	5.4
Hanksville	Plateau Resources	910	New (on standby)	Never operated	28	0	0	0
Subtotal		3,400			>257	10.1	16.3	5.4
Washington								
Ford	Dawn Mining	410	Shut down, 1982	Wood chip covering	43	1.8	2.8	1.1
Wellpinit	Western Nuclear	1,810 ^h	Decommissioning	i	17	1.6	2.6	0
Subtotal		410			60	3.4	5.4	1.1
Wyoming								
Gas Hills	American Nuclear	860 ^h	Decommissioned, 1988	Unstabilized	52	3.3	5.4R	2.0R
Gas Hills	Pathfinder	2,540 ^h	Decommissioning	Unstabilized	55	6.6	10.6	2.6R
Jeffrey City	Western Nuclear	1,540 ^h	Decommissioned, 1988	Interim stabilization	34	4.4	7.0	3.0
Natrona	Umetco	1,270 ^h	Decommissioned, 1987	Unstabilized	70	4.6	7.3	1.9
Powder River	Exxon	2,900 ^h	Decommissioned, 1984	Partially stabilized	81	6.4	10.3	0
Powder River	Rocky Mountain Energy	1,810 ^h	Decommissioned, 1987	Unstabilized	61	2.7	4.3	0
Shirley Basin	Pathfinder	1,630	Decommissioning	i	94	4.7	7.4	0
Shirley Basin	Petrotomics	1,360 ^h	Decommissioned, 1985	Unstabilized	65	3.9	6.3	0.7
Red Desert	Minerals Exploration/ Union Energy Mining	2,720	Shut down, May 1983	Partially stabilized	121	1.3	2.1	0
Subtotal		4,350			633	37.9	60.7R	10.2R
1990 total for all sites ^{b,m,n}		18,320 ^o			i	118.6	189.5R	51.2R ^p

^aData based on refs. 1-12. Note: subtotals and totals may not equal sum of components because of independent rounding. Ray Point, Texas (Felder Facility), site was stabilized during 1987 by Exxon Corporation. Historical data are revised based on detailed study of milling data from the Grand Junction Project Office and EIA files. The values shown include all tailings.

Table 5.2 (continued)

^bFrom refs. 1, 5, and 9. Values rounded to nearest 10 t.

^cOn Aug. 15, 1986, EPA issued its final rules on ²²²Rn emissions from tailings piles. Mill owners have 6 years (subject to certain extensions) to phase out the use of large existing tailings piles. New tailings piles may be contained in small impoundments (less than 16 ha) or disposed of continuously by dewatering and burial (i.e., no more than 4 ha are uncovered at any one time). See ref. 7.

^dFrom refs. 6 and 12; 1 ha = 10,000 m² or approximately 2.5 acres.

^eCalculated from reported mass using density = 1.6 t/m³.

^fFrom ref. 5, Table 8.0. These tailings are from government contracts only and are included in the "Total tailings" column.

^gR = revised.

^hEstimates provided are not included in the total. See column labeled "Operations" under "Status" for reason.

ⁱNot available.

^jFrom ref. 9.

^kFrom ref. 11.

^lFrom ref. 10.

^mThese values are cumulative totals that may not equal sum of components due to independent rounding. For annual totals see Table 5.3.

ⁿFrom ref. 1.

^oMills reported as permanently closed on Form EIA-858 for 1993. This is not the same as decommissioned, according to industry contacts.

^pTotal at the end of government-contracted deliveries in 1970 (ref. 5).

Table 5.3. Uranium ore processed, U_3O_8 recovery rate, and tailings generated through 1993^{a,b}

End of calendar year	Ore processed		U_3O_8		Tailings generated	
	Mass ^c (10 ⁶ t)	Grade (% U_3O_8)	Recovery from ore (%)	Product ^d (10 ³ t)	Mass ^e (10 ⁶ t)	Volume ^f (10 ⁶ m ³)
Prior to 1978	g	g	g	g	108.8	68.0
1978	12.5	0.134	91	15.6	12.6	7.9
1979	14.6	0.113	91	15.3	14.5	9.1
1980	15.3	0.118	93	17.2	15.2	9.5
1981	13.2	0.115	94	14.5	13.2	8.2
1982	7.9	0.119	96	9.9	8.1	5.0
1983	5.4	0.128	97	7.0	5.4	3.4
1984	3.9	0.112	95	4.4	4.0	2.5
1985	1.6	0.161	96	2.8	1.6	1.0
1986	1.2	0.338	97	4.0	1.2	0.7
1987	1.3	0.284	96	3.8	1.3	0.8
1988	1.1	0.288	95	3.2	1.1	0.7
1989	1.1	0.323	95	3.7	1.0	0.7
1990	0.7	0.293	94	2.1	0.7	0.4
1991	0.6	0.188	92	1.2	0.6	0.4
1992	0.2	0.229	96	0.6	0.2	0.2
1993	0.0	0.000	0	0.0	0.0	0.0
Total ^h					189.5R ⁱ	118.6

^aSources: Prior to 1984—U.S. Department of Energy, Grand Junction Area Office data files.
1984–1993—Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey."

^bThis table has been revised based on a detailed study of milling data from the Grand Junction Project Office and EIA files. The values shown include all tailings.

^cBefore in-process inventory adjustments.

^dConventional U_3O_8 concentrate production.

^eIncludes adjustments to ore-fed amounts for annual mill circuit inventory changes and uranium concentrate production.

^fCalculated assuming that the average density of tailings is 1.6 t/m³ (metric tons per cubic meter).

^gNot available.

^hTotals may not equal sum of components due to independent rounding.

ⁱR = revised.

Table 5.4. Typical characteristics of uranium mill tailings^a

Tailings component	Particle size (μm)	Chemical composition	Radioactivity characteristics
Sands	75 to 500	SiO_2 with <1% complex silicates of Al, Fe, Mg, Ca, Na, K, Se, Mn, Ni, Mo, Zn, U, and V; also metallic oxides	0.004 to 0.01% U_3O_8 ^b Acid leaching: ^c 26 to 100 pCi $^{226}\text{Ra}/\text{g}$; 70 to 600 pCi $^{230}\text{Th}/\text{g}$
Slimes	45 to 75	Small amounts of SiO_2 but mostly very complex clay-like silicates of Na, Ca, Mn, Mg, Al, and Fe; also metallic oxides	U_3O_8 and ^{226}Ra are almost twice the concentration present in the sands Acid leaching: ^c 150 to 400 pCi $^{226}\text{Ra}/\text{g}$; 70 to 600 pCi $^{230}\text{Th}/\text{g}$
Liquids	d	Acid leaching: pH 1.2 to 2.0; Na^+ , NH_4^+ , SO_4^{-2} , Cl^- , and PO_4^{-3} ; dissolved solids up to 1% Alkaline leaching: pH 10 to 10.5; CO_3^{-2} and HCO_3^- ; dissolved solids ~10%	Acid leaching: 0.001 to 0.01% U 20 to 7,500 pCi $^{226}\text{Ra}/\text{L}$; 2,000 to 22,000 pCi $^{230}\text{Th}/\text{L}$ Alkaline leaching: 200 pCi $^{226}\text{Ra}/\text{L}$; essentially no ^{230}Th (insoluble)

^aAdapted from information in ref. 8.^b U_3O_8 content is higher for acid leaching than for alkaline leaching.^cSeparate analyses of sands and slimes from the alkaline leaching process are not available. However, total ^{226}Ra and ^{230}Th contents of up to 600 pCi/g (of each) have been reported for the combined sands and slimes.^dParticle size does not apply. Up to 70% of the liquid may be recycled. Recycle potential is greater in the alkaline process.

Remediation of the Pompton Plains Railroad Siding in Pequannock, New Jersey, under the Formerly Utilized Sites Remedial Action Program.
Courtesy of the U.S. Department of Energy, Office of the Deputy Assistant Secretary for Environmental Restoration, Washington, D.C.

6. ENVIRONMENTAL RESTORATION PROGRAM WASTES

6.1 INTRODUCTION

The fundamental goal of the DOE Office of Environmental Restoration (DOE/EM-40, or simply EM-40) is to ensure that the risks to the environment and human health and safety posed by inactive and surplus facilities and sites are either eliminated or reduced to prescribed, safe levels. These facilities contain radioactive and chemically hazardous contaminants as a result of previous activities conducted by DOE and its predecessor agencies. Although this goal encompasses all requirements prescribed by applicable federal, state, and local environmental statutes and regulatory requirements, it is not limited to regulatory compliance. DOE's paramount concerns are maintaining and improving human health and safety and protecting the environment.

The DOE environmental restoration program includes a bias for action to expedite actual cleanup wherever and whenever possible. However, major actions are currently being undertaken at only a limited number of sites because most sites are in the assessment phase to determine the nature and extent of contamination that must be addressed. Closures and interim remedial actions are being undertaken at several sites to address more immediate concerns and bring them into compliance with federal and state environmental laws and regulations. Full remediation will follow assessment efforts, and, after cleanup is completed, these sites will continue to be monitored.

Environmental restoration efforts are proceeding in two major areas: remedial action (RA) and decontamination and decommissioning (D&D). These activities include cleanup of facilities and areas that supported defense-related activities (such as nuclear weapon component fabrication) and nondefense, civilian nuclear power activities (such as the development of heat sources for the space program and the operation of small test reactors).

RAs are concerned with all aspects of the assessment and cleanup of inactive sites at which releases of radioactive and chemically hazardous substances have occurred. These actions are not only limited to those areas directly impacted by the release but also include additional

areas to which contaminants may have migrated (e.g., to ground water). A number of DOE installations are on the EPA National Priorities List. RAs include site discovery, preliminary assessment, and site inspection; site characterization, analysis of cleanup alternatives, and selection of remedy; cleanup and site closure; and site compliance monitoring. Although such activities may deal with storage tanks, buildings, and structures, most are concerned with contaminated environmental media such as soil, sediment, and ground water.

The principal regulatory requirements for RAs are derived from the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Activities may further be subject to requirements associated with compliance with the National Environmental Policy Act (NEPA) as well as to additional regulatory requirements imposed by the states. Other requirements are set forth in various DOE Orders and standards and other guidance documents.

D&D activities are primarily concerned with the safekeeping of surplus nuclear facilities following shutdown and for either their ensuing decontamination for reuse or their complete dismantlement. Such tasks include surveillance and maintenance, assessment and characterization, environmental review, engineering, specific D&D operations, and project closeout. Most D&D activities are concerned with facilities such as reactors, hot cells, processing plants, storage tanks, and other structures from which, in general, few releases to the environment have occurred. Approximately 500 contaminated facilities are currently included in the EM-40 inventory for future action. The objectives of D&D activities are to decontaminate these facilities and to eliminate any potential hazards to public health and the environment.

D&D activities are carried out under the authority of the Atomic Energy Act (AEA) and with requirements set forth in various DOE Orders and standards and other guidance documents. In addition, the provisions of RCRA and CERCLA may apply also to those facilities from which there either has been a release or there is a potential for

release to the environment. State requirements may also apply in certain instances. Only those D&D activities at facilities currently in the EM-40 program are addressed in this chapter.

Because many RA and D&D sites are still in the assessment phase, it is very difficult to project the volumes and types of waste that may be generated. Moreover, detailed information on the specific cleanup activities that may be applied to various contamination problems is not yet available; therefore, the quantity of resultant waste that might be generated cannot be reliably determined. In fact, the plans for many sites are not yet to a stage at which even the broad category of response that will be taken is known. For example, the decision whether a given contaminated area, such as a waste pit, is to be excavated or stabilized in place is not typically made until after (1) the nature of the problem has been adequately defined, (2) various response alternatives and related impacts have been evaluated in considerable detail, and (3) other agencies (such as the EPA, the impacted state, and the local community) have had a chance to comment on the preferred alternative. Materials regarded as waste would be generated only if the waste pit were excavated; no waste would be generated if the pit were capped in place.

DOE is currently undertaking several initiatives to determine the volumes and types of waste that may be generated during future environmental restoration activities. These studies have not yet been completed to a point at which realistic waste projections can be made; these results should be available within the next few years. Hence, environmental restoration waste volumes are not provided in this report. However, the volumes of contaminated solid environmental media are known at most sites, and these volumes are included in Sect. 6.3.

6.2 OFFICE OF ENVIRONMENTAL RESTORATION

Environmental restoration activities under the auspices of EM-40 are managed by three program offices: Southwestern Area Programs (EM-45), Northwestern Area Programs (EM-44), and Eastern Area Programs (EM-42). Each office manages both remedial and D&D activities. Activities are divided into 17 major projects to assist in the planning, oversight, and performance-tracking of environmental restoration activities (see Fig. 6.1).

6.2.1 Southwestern Area Programs

The Southwestern Area Programs include all EM-40 activities managed through the DOE Nevada and

Albuquerque operations offices, the Grand Junction Projects Office, and the Rocky Flats Office. Activities managed by the Nevada Operations Office include remediation of a number of locations at the Nevada Test Site (NTS) and at off-site areas where nuclear tests and related activities were conducted. Environmental restoration activities at NTS involve cleanup of areas of contamination from above-ground and underground nuclear weapons testing. Off-site locations include Amchitka Island, Alaska; the Rio Blanco and Rulison Test sites in Colorado; the Gnome and Gasbuggy Test sites in New Mexico; the Salmon Test Site in Mississippi; and the Shoal and Central Nevada Test sites in Nevada.

The Albuquerque Operations Office activities are managed as five separate projects. Environmental restoration activities at Albuquerque Laboratories include RAs at the South Valley Superfund Site, Sandia National Laboratories—New Mexico (SNL/NM), Los Alamos National Laboratory (LANL), and the Inhalation Toxicology Research Institute (ITRI) (all of which are located in New Mexico), and at Sandia National Laboratories—California (SNL/CA). These laboratories were used for various defense-related R&D activities. Environmental restoration activities at Albuquerque Production Facilities include RAs at the Pantex, Kansas City, Pinellas, and Mound plants. These plants, which are located in Texas, Missouri, Florida, and Ohio, respectively, were used in the production of nuclear materials for defense activities.

The Albuquerque Operations Office is responsible also for implementing the Uranium Mill Tailings Remedial Action Program (UMTRAP), which was authorized in 1978, and involves the stabilization and control of (a) 24 inactive uranium-processing sites and associated vicinity properties located in 10 states and 2 Indian tribal lands and (b) vicinity properties associated with the Edgemont, South Dakota, inactive uranium mill, which is currently owned by the Tennessee Valley Authority (see Fig. 6.2). All of the sites are located in the western United States, except for one in Canonsburg, Pennsylvania. Currently, two Albuquerque projects oversee work for UMTRAP: Uranium Mill Tailing Remedial Action (UMTRA) Surface and UMTRA Ground-Water Assessment and Remediation. RAs have been completed at 13 of the 24 inactive uranium-processing sites under the UMTRA Surface Project.¹

The fifth project managed by the Albuquerque Operations Office consists of three sites being remediated by the Grand Junction Projects Office. This projects office is responsible for directing RA activities for tailings remediation and for surface and ground-water cleanup at the Monticello Mill Tailings Site in Utah, the Grand

Junction Projects Office Site in Colorado, and at a site in Oxnard, California.

The Rocky Flats Plant (RFP) in Colorado was formerly a nuclear weapons manufacturing facility; the mission of this facility is currently transition, environmental restoration, and waste management. Recently, RFP was renamed the Rocky Flats Environmental Technology Site (RFETS). Storage and disposal of hazardous, radioactive, and mixed wastes occurred on-site in the past when the facility was operational. Off-site areas that may require remediation include two reservoirs and surrounding land areas. These areas may have received contaminated effluent and sediments originating from the plant.

6.2.2 Northwestern Area Programs

The Northwestern Area Programs include all EM-40 activities managed through the DOE Idaho, Richland, Oakland, and Chicago operations offices. Environmental restoration activities managed by the Idaho Operations Office are limited to cleanup of facilities and areas at the Idaho National Engineering Laboratory (INEL), which was established in 1949 as a site where nuclear reactors, support facilities, and equipment could be safely built, tested, and operated to evaluate various options for the use of nuclear power as a means to generate electricity. INEL is currently one of DOE's principal centers for nuclear energy research and development (R&D). These activities have resulted in the contamination of soil, structures, and ground water within the site.

The Richland Operations Office manages environmental restoration activities at the Hanford Site (HANF) in the state of Washington. HANF has been involved in a large number of nuclear production activities since the early 1940s. More than 1,100 waste sites have been identified, most of which have resulted from the on-site storage or soil-column disposal of low-level radioactive, hazardous, and mixed wastes. More than 100 surplus facilities contaminated with radioactivity are scheduled for D&D. These facilities include nine former production reactors, as well as chemical process buildings and ancillary structures. Remediation of HANF includes constructing a disposal facility to receive cleanup wastes, as well as closing underground storage tanks and other RCRA units.

The Oakland Operations Office is responsible for managing environmental restoration activities at seven different sites in California. These sites were primarily associated with nuclear weapons programs and other nuclear and energy research activities supported by the Department. Those installations with an ongoing EM-40 program include Lawrence Livermore National Laboratory

(LLNL), Lawrence Berkeley Laboratory (LBL), Stanford Linear Accelerator Center (SLAC), General Atomics (GA) Site, Laboratory for Energy-Related Health Research (LEHR), General Electric Vallecitos Nuclear Center (GEVNC), and the DOE portion of the Santa Susana Field Laboratory (SSFL), known as the Energy Technology Engineering Center (ETEC). Activities at these sites have resulted in the contamination of facilities, soil, and ground water with a wide range of radioactive and chemically hazardous substances. Restoration activities include remediation of soil and ground-water contamination and D&D of surplus inactive buildings.

The Chicago Operations Office manages two EM-40 projects: the Chicago and Battelle Columbus laboratories. The primary mission of Chicago Laboratories is energy research, development, and demonstration. Environmental restoration activities are being performed under this project at 5 R&D laboratories: Argonne National Laboratory-East (ANL-E), Illinois (including Site A/Plot M, which was formerly a portion of ANL-E); Argonne National Laboratory-West (ANL-W), Idaho; Brookhaven National Laboratory (BNL), New York; Princeton Plasma Physics Laboratory (PPPL), New Jersey; and Ames (AMES) Laboratory, Iowa. RAs at these sites include remediation of soil and ground-water contamination, disposal sites, and underground storage tanks. Environmental restoration activities are also being conducted at the Reactive Metals, Inc. (RMI), site in Ohio. RA activities at this site involve the cleanup of a former metals-extrusion plant that became contaminated as a result of the processing of radioactive materials (principally uranium). In addition to the activities at these six sites, activities included in the Chicago Laboratories Program encompass the D&D of two retired nuclear reactors (at Hallam, Nebraska, and Piqua, Ohio) and processing facilities at the Separations Process Research Unit located at the Knolls Atomic Power Laboratory (KAPL) in the state of New York. Environmental restoration activities at Battelle Columbus Laboratories in Ohio include the D&D of 15 contaminated buildings and surrounding soils that were previously used for government-sponsored nuclear research.

6.2.3 Eastern Area Programs

The Eastern Area Programs include all EM-40 activities managed through the DOE Oak Ridge and Savannah River operations offices and the Fernald Field Office. The Oak Ridge Operations Office manages environmental restoration activities at installations in the vicinity of Oak Ridge, Tennessee, including ORNL, the K-25 Site, and the Y-12 Plant. The Oak Ridge Operations Office is also responsible for environmental restoration

and waste management activities at the Portsmouth Gaseous Diffusion Plant (PORTS) in Ohio and the Paducah Gaseous Diffusion Plant (PAD) in Kentucky. These facilities provided enriched uranium for use in production reactors for defense purposes. Previous activities at these sites have resulted in contamination of soils, surface water, ground water, and various structures. The primary contaminant at most of these sites is uranium.

The Oak Ridge Operations Office also manages the Formerly Utilized Sites Remedial Action Program (FUSRAP), which is primarily concerned with the cleanup of sites that were formerly used to support the activities of the Manhattan Engineer District, established for the Manhattan Project, and the Atomic Energy Commission (AEC). Private firms and institutions were contracted by the federal government in the 1940s and 1950s to develop processes and perform research on radioactive materials. The storage and processing of uranium and thorium ores, concentrates, and residues were often involved. Although these sites were cleaned up to formerly acceptable levels, FUSRAP was established in 1974 to identify, reevaluate; and, if necessary, remediate these sites. Currently, 44 sites have been identified in 14 states; 12 of these sites have already been remediated (see Fig. 6.3). Most FUSRAP sites are in the eastern half of the country.¹

The Oak Ridge Operations Office also manages environmental restoration activities being conducted by the Weldon Spring Site Office, which is responsible for the cleanup of a former uranium processing plant in Missouri. Environmental restoration activities at this site include the D&D of the chemical plant processing buildings, remedial action of the raffinate pits and quarry, restoration of contaminated vicinity properties, construction and operation of two water treatment plants and waste-processing facilities, and disposal of all waste generated by site cleanup activities.

The Savannah River Operations Office manages environmental restoration at the Savannah River Site (SRS) in South Carolina. The site's nuclear production reactors have not operated since 1988, although start-up tests were conducted on the K-Reactor in 1991. This reactor is currently in cold standby status. Much of the site's current mission is environmental restoration and waste management. Its historical mission of producing nuclear materials for defense purposes has resulted in the generation of a significant quantity of radioactive, hazardous, and mixed wastes, which were disposed of on-site. Soil and ground-water contamination has resulted from contaminants migrating from seepage and settling basins, unlined disposal pits, waste piles, burial grounds, and underground storage tanks. D&D activities are currently under way at several reactor areas; remedial

action activities are ongoing at burial grounds, tanks, pits, basins, and areas having ground-water contamination.

The Fernald Area Office is responsible for implementing the Fernald Environmental Management Project (FEMP) in Ohio. This site was the location of the former Feed Materials Production Center, whose mission was to produce feed materials (principally uranium) for nuclear reactor fuel as part of the nation's defense program. The mission of this project is now environmental restoration and waste management. Previous activities at this site resulted in the contamination of structures, soil, surface water, and ground water. The major contaminants are primarily uranium and radium.

6.3 ENVIRONMENTAL RESTORATION WASTE CHARACTERISTICS

The volumes and types of wastes associated with DOE environmental restoration activities are a direct result of the remedy chosen. Waste associated with remediation of contaminated environmental media would occur only when such media are exhumed. For example, no waste would be produced at a site for which an in situ remedy was selected, such as capping an area containing contaminated soil. If a minimal remedial action were selected (e.g., pumping and treating a small pocket of contaminated ground water followed by construction of lateral barriers to minimize future migration), the site would have relatively small waste volumes. However, if large volumes of contaminated environmental media were removed, treated to provide a more suitable waste form for disposal, and then disposed of in an engineered facility, the site would have very large waste volumes.

Environmental restoration wastes are different from those associated with processing operations in that they generally have much lower concentrations of radioactive and chemically hazardous substances. Much of the material requiring remediation is a consequence of past activities such as spills, waste disposal, and environmental releases such as liquid discharges to drainage basins. In addition, operations within structures resulted in the contamination of equipment, walls, and floors from routine material-handling activities and from off-normal incidents such as spills and equipment failure. D&D of these facilities will result in wastes such as wipes, concrete, metal, personal protective clothing, and decontamination solvents that have generally low concentrations of radioactive and chemical contaminants.

Environmental restoration wastes also differ from those resulting from processing operations in that they are generally highly heterogeneous both in physical form and

chemical constituency. For example, remediation of an abandoned waste pit could require the exhumation of all materials previously placed into the pit for disposal. This effort could involve any possible imaginable combination of objects ranging from small pieces of equipment and drums to entire vehicles such as trucks and forklifts. In addition, a full spectrum of contaminants could be associated with these previously disposed materials including those associated with ordnance operations, processing of uranium and thorium ores and concentrates, and the operation of nuclear reactors and associated chemical processing plants. This potential variety is in contrast to waste streams associated with processing activities that have relatively consistent chemical and physical properties.

Because most DOE environmental restoration projects are in the assessment phase of the remedy-selection process, it is not possible to make definitive projections of wastes that will result from these projects. For this reason, such estimates are not included here. Rather, the volumes of radioactively contaminated solid media associated with the various environmental restoration sites are provided. These volumes are based on historical knowledge, monitoring information, and field-characterization results. These volumes are given in Table 6.1 for radioactively contaminated soil (including sediment and sludge) and in Table 6.2 for radioactively contaminated debris such as metal, concrete, brick, and wood. The actual waste volumes that will result from cleanup of some sites may be significantly lower than those given in these two tables, especially for those sites for which minimal RAs are selected. Such minimal activities will likely occur at major DOE installations located in remote areas of the country. In addition, decontamination of metallic items such as hot-cell liners, tanks, and processing equipment could allow for unrestricted release of these items, which would reduce the volume of material requiring disposal.

The volumes of radioactively contaminated media given in Tables 6.1 and 6.2 are limited to solid materials (i.e., contaminated liquids such as surface-water impoundments and ground water are not included). These data are based on currently available information encompassing those projects for which characterization activities have proceeded to a point which allows for preparation of realistic volume estimates. Some projects have not yet initiated field-characterization activities, and historical records are not available in sufficient detail to allow for volume estimates to be made. The volume estimates for such sites will be larger than those shown in these two tables because not all of the potentially contaminated media would have been addressed.

An intensive effort is currently under way to better define waste management requirements for implementing

the DOE environmental restoration program. A data collection program was initiated in late 1993 to develop "cradle-to-grave" contaminated media/waste information to allow for better planning of waste treatment and disposal capacity needs.² This effort includes collecting data on all waste types that may result from future environmental restoration activities including radioactive, sanitary, demolition, and hazardous wastes as regulated by RCRA and the Toxic Substances Control Act (TSCA). The results of this data collection program are currently being compiled. Once this data base is fully populated, more complete waste estimates can be made. Such estimates will be included in future revisions of this report as they become available.

Three major radioactive waste classes are associated with environmental restoration activities: LLW, TRU waste (TRUW), and 11e(2) by-product material. As defined in DOE Order 5820.2A, LLW is waste that contains radioactivity and is not classified as HLW, TRUW, spent nuclear fuel, or 11e(2) by-product material. Environmental restoration activities will not generate any HLW or spent nuclear fuel. TRUW is waste contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and at concentrations greater than 100 nCi/g at the time of assay. As defined in Sect. 11e(2) of the AEA of 1954 (P.L. 83-703, as amended), 11e(2) by-product material is tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. In addition to radioactive contaminants, these wastes can also be contaminated with hazardous constituents as regulated by RCRA or TSCA; such wastes are considered mixed wastes. Thus, a total of six waste classes are relevant for radioactively contaminated material resulting from environmental restoration activities: LLW, mixed LLW (MLLW), TRUW, mixed TRUW (MTRUW), 11e(2) by-product material, and mixed 11e(2) by-product material.

The relative volumes of these six waste classes for contaminated soil and solid debris for environmental restoration sites are shown in Figs. 6.4 and 6.5, respectively. The two waste classes that constitute the largest volumes of radioactively contaminated soil are LLW and 11e(2) by-product material. The large volume of soil designated as LLW is mainly associated with three sites: NTS, LANL, and HANF. Together, these three sites account for over 80% of the soil in this waste class. The actual amount of contaminated soil at these three sites that will eventually be handled as waste is highly uncertain because remedy-selection decisions have yet to be made. The large volume of 11e(2) by-product material is mainly the result of the large volume of waste associated with uranium mill tailings being remediated under UMTRAP.

The volume of radioactively contaminated debris is a very small fraction of that associated with soil. The total volume of contaminated debris is approximately 3,500,000 m³; the total volume of contaminated soil is approximately 72,000,000 m³. Most of this debris is classified as LLW (see Fig. 6.5), which accounts for about 76% of the total volume of radioactively contaminated debris. As with the volume estimates provided for soil, the total amount of debris that will be handled as waste could be lower than that given here if a significant fraction of this debris (e.g., metallic items) can be decontaminated to allow for reuse.

Since environmental restoration information is currently in the initial stages of being compiled at a number of sites, much of the information included in Tables 6.1 and 6.2 is preliminary. In addition, these tables include information only for sites currently in the EM-40 program for which data are available. That is, zero volumes may be reported for areas of a site at which characterization activities have not been initiated, thus resulting in an underestimate of the total volume of radioactively contaminated media. Conversely, overly conservative assumptions may be incorporated into some estimates to ensure adequate sizing of treatment and disposal facilities. These uncertainties will continue to be reduced with time as characterization and engineering studies become available to refine these volume estimates.

The information contained in this chapter is limited to radioactively contaminated environmental media and wastes, consistent with the scope of this report. The volume estimates given in Tables 6.1 and 6.2 are limited to solid materials; liquids, such as contaminated surface water and ground water; and liquid wastes currently in

storage, are not included. It should not be concluded that sites for which no (or minimal) volumes are given in Tables 6.1 and 6.2 have no waste management concerns. Environmental restoration activities at such sites could generate hazardous wastes as regulated by RCRA and TSCA, as well as large volumes of sanitary and demolition wastes. Also, additional characterization activities at these sites may identify areas of radioactive contamination requiring remediation in the future. As it becomes available, such information will be included in future updates of this report.

The volumes of radioactively contaminated soil and debris given in Tables 6.1 and 6.2 are limited to those sites and facilities currently in the EM-40 program. These data are summed across all elements of a site including environmental media, wastes currently in storage, and radioactively contaminated materials that could result from future D&D activities. At a number of sites, wastes generated as a result of EM-40 RA and D&D activities have been transferred to the Office of Waste Management (EM-30) for treatment, storage, and disposal. These wastes are no longer being managed by EM-40 and are therefore not included in this chapter. MLLW currently in storage at EM-40 sites and that projected to be generated in the future are provided in Chapter 8 of this report.

The DOE Office of Facility Transition (EM-60) is currently preparing a detailed inventory of all facilities that may eventually be transferred to the Office of Environmental Management (EM-1). As facilities are transferred to EM-1, environmental restoration and waste management information will be developed and included in future updates of this report.

6.4 REFERENCES

1. U.S. Department of Energy, *Environmental Management 1994, Progress and Plans of the Environmental Restoration and Waste Management Program*, DOE/EM-0119, Washington, D.C. (February 1994).
2. R. P. Whitfield, U.S. Department of Energy, Deputy Assistant Secretary for Environmental Restoration, Washington, D.C., letter to distribution, "Contaminated Media/Waste Data Call Guidance," dated Oct. 8, 1993.

Fig. 6.1. Locations of site offices that manage the major projects of the DOE environmental restoration program.

Fig. 6.2. Locations and status of UMTRAP sites.

Fig. 6.3. Locations and status of FUSRAP sites.

**ENVIRONMENTAL RESTORATION WASTES
(RADIOACTIVELY CONTAMINATED SOILS)**

Fig. 6.4. Estimated volumes of radioactively contaminated soils associated with environmental restoration projects.

**ENVIRONMENTAL RESTORATION WASTES
(RADIOACTIVELY CONTAMINATED DEBRIS)**

Fig. 6.5. Estimated volumes of radioactively contaminated debris associated with environmental restoration projects.

Table 6.1. Estimated volumes of radioactively contaminated soils associated with environmental restoration projects^{a,b}

Environmental restoration program	Waste volume, m ³					
	LLW	MLLW	11e(2) by-product ^c	Mixed 11e(2) by-product	TRUW	Total
<i>Southwestern Area Programs</i>						
Albuquerque Laboratories						
Inhalation Toxicology Research Institute	9,000					9,000
Los Alamos National Laboratory	8,300,000	1,200,000			93,000 ^d	9,600,000
Sandia National Laboratories/California						0
Sandia National Laboratories/New Mexico	15,000	52,000				67,000
South Valley Superfund Site						0
Albuquerque Production Facilities						
Kansas City Plant						0
Mound Plant	140,000	17,000				150,000
Pantex Plant						0
Pinellas Plant						0
Grand Junction Projects Office						
Grand Junction Projects Office Site			35,000	46		35,000
Monticello Remedial Action Project ^e			2,200,000			2,200,000
Nevada Operations Office						
Nevada Test Site	14,000,000	460				14,000,000
Nevada off-site locations ^f	9,500	21,000				30,000
Rocky Flats Plant	360	270,000				270,000
Uranium Mill Tailings Remedial Action Project			32,000,000			32,000,000
Southwestern Area total	23,000,000	1,500,000	34,000,000	46	93,000	58,000,000
<i>Northwestern Area Programs</i>						
Battelle Columbus Laboratories	640	24			390	1,000
Chicago Laboratories						
Ames Laboratory	360	240				600
Argonne National Laboratory-East	8,700	19,000				27,000
Argonne National Laboratory-West	1					1
Brookhaven National Laboratory	23,000	3,500				26,000
Hallam Site						0
Piqua Site						0
Princeton Plasma Physics Laboratory						0

Table 6.1 (continued)

Environmental restoration program	Waste volume, m ³					Total
	LLW	M LLW	11c(2) by-product ^c	Mixed 11c(2) by-product	TRUW	
Chicago Laboratories (continued)						
Reactive Metals, Inc., Site	24,000	3,500				27,000
Separations Process Research Unit	14,000				36	14,000
Site A/Plot M ^g	4,500	500				5,000
Hanford Site ^h	3,100,000	760,000				3,900,000
Idaho National Engineering Laboratory	280,000	200,000			170,000	660,000
Oakland Operations Office						
General Atomics Site						0
General Electric Vallecitos Nuclear Center						0
Laboratory for Energy-Related Health Research	620					620
Lawrence Berkeley Laboratory						0
Lawrence Livermore National Laboratory						0
Santa Susana Field Laboratory						0
Stanford Linear Accelerator Center						0
Northwestern Area total	3,500,000	990,000			170,000	4,600,000
<i>Eastern Area Programs</i>						
Fernald Environmental Management Project	1,500,000	75,000				1,600,000
Formerly Utilized Sites Remedial Action Project						
Missouri sites	210,000		500,000			720,000
New Jersey sites	54,000	24,000 ⁱ	390,000			460,000
New York sites	9,400	12,000	430,000			450,000
Other sites	91,000	7,200	28,000			130,000
Oak Ridge Laboratories and Production Facilities						
K-25 Site	3,300	1,700				5,000
Oak Ridge National Laboratory	43,000	32,000			500	76,000
Oak Ridge Reservation (off-site) ^j	100,000					100,000
Paducah Gaseous Diffusion Plant	1,800	520,000				530,000
Portsmouth Gaseous Diffusion Plant	7,700	2,200				9,900
Y-12 Plant	960	340,000				340,000
Savannah River Site	1,400,000	1,200,000			990,000	3,600,000
Weldon Spring Site Remedial Action Project			520,000	3,100		530,000

Table 6.1 (continued)

Environmental restoration program	Waste volume, m ³					Total
	LLW	M LLW	11e(2) by-product ^c	Mixed 11e(2) by-product	TRUW	
Eastern Area total	3,400,000	2,200,000	1,900,000	3,100	1,000,000	8,600,000
Grand total	30,000,000	4,800,000	36,000,000	3,200	1,300,000	72,000,000

^aEstimated as of December 31, 1993. Includes contaminated soil, sediment, and sludge. Blank entries mean there are no radioactively contaminated soils for the indicated waste class. The quantity of containerized mixed waste currently in storage as a result of environmental restoration activities is not included here, but is provided in Chapter 8 of this report.

^bThese volume estimates represent the quantity of in-place contaminated materials; the waste volumes resulting from remedial action activities may be larger or smaller depending on the selected remedy and treatment technology utilized. Waste volumes resulting from minimal remedial actions such as capping, monitoring, and certain in situ remedies will be quite small. All values are preliminary and are being updated as site characterization activities proceed. Values are given to two significant figures unless information was reported to only one significant figure. Some totals may not equal sum of components due to independent rounding.

^cBy-product material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (P.L. 83-703), as amended.

^dMixed TRUW.

^eIncludes contaminated debris, which will be managed in the same manner as contaminated soil.

^fConsists of Amchitka Island, Alaska; the Rio Blanco and Rulison Test sites in Colorado; the Gnome and Gasbuggy Test sites in New Mexico; the Salmon Test Site in Mississippi; and the Shoal and Central Nevada Test sites in Nevada.

^gEstimate is very preliminary and includes contaminated debris.

^hDoes not include contaminated soil at the 200 Area of the Hanford Site, which is currently planned to be capped in place. A small percentage of the radioactively contaminated soil at the Hanford Site may be TRUW.

ⁱLow-level mixed waste soil currently in bulk storage at the Middlesex Site. This storage pile is covered with a tarp.

^jIncludes contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of the Y-12 Plant, the K-25 Site, and Oak Ridge National Laboratory.

Table 6.2. Estimated volumes of radioactively contaminated debris associated with environmental restoration projects^{a,b}

Environmental restoration program	Waste volume, m ³					Total
	LLW	M LLW	11e(2) by-product ^c	Mixed 11e(2) by-product	TRUW	
<i>Southwestern Area Programs</i>						
Albuquerque Laboratories						
Inhalation Toxicology Research Institute	44					44
Los Alamos National Laboratory	9,800	1,600				11,000
Sandia National Laboratories/California						0
Sandia National Laboratories/New Mexico	2,600					2,600
South Valley Superfund Site						0
Albuquerque Production Facilities						
Kansas City Plant						0
Mound Plant	28,000					28,000
Pantex Plant						0
Pinellas Plant						0
Grand Junction Projects Office						
Grand Junction Projects Office Site			2,100	38		2,200
Monticello Remedial Action Project ^d						0
Nevada Operations Office						
Nevada Test Site	3,800	290				4,100
Nevada off-site locations ^c						0
Rocky Flats Plant						0
Uranium Mill Tailings Remedial Action Project			340,000			340,000
Southwestern Area total	44,000	1,900	340,000	38		390,000
<i>Northwestern Area Programs</i>						
Battelle Columbus Laboratories	4,200					4,200
Chicago Laboratories						
Ames Laboratory	110	3				110
Argonne National Laboratory-East	4,000	120,000			190	130,000
Argonne National Laboratory-West	150					150
Brookhaven National Laboratory	33	360			6.9	400
Hallam Site						0
Piqua Site						0
Princeton Plasma Physics Laboratory						0

Table 6.2 (continued)

Environmental restoration program	Waste volume, m ³					Total
	LLW	M LLW	11e(2) by-product ^c	Mixed 11e(2) by-product	TRUW	
Chicago Laboratories (continued)						
Reactive Metals, Inc., Site	4,400	4				4,400
Separations Process Research Unit	1,400	1.6				1,400
Site A/Plot M ^f						0
Hanford Site ^g	2,300,000	120,000				2,500,000
Idaho National Engineering Laboratory	23,000	2,700				26,000
Oakland Operations Office						
General Atomics Site	730	15				750
General Electric Vallecitos Nuclear Center					17	17
Laboratory for Energy-Related Health Research	390					390
Lawrence Berkeley Laboratory	9,400					9,400
Lawrence Livermore National Laboratory						0
Santa Susana Field Laboratory	1,000					1,000
Stanford Linear Accelerator Center						0
Northwestern Area total	2,400,000	250,000			210	2,600,000
<i>Eastern Area Programs</i>						
Fernald Environmental Management Project	100,000	84,000				180,000
Formerly Utilized Sites Remedial Action Project						
Missouri sites	130		17,000			17,000
New Jersey sites	6		65			71
New York sites	5,100	3,000	1,100			9,200
Other sites	690					690
Oak Ridge Laboratories and Production Facilities						
K-25 Site	57,000	1,700				59,000
Oak Ridge National Laboratory	26,000	1,700			510	28,000
Oak Ridge Reservation (off-site) ^h						0
Paducah Gaseous Diffusion Plant	100	16,000				16,000
Portsmouth Gaseous Diffusion Plant	54,000	970				55,000
Y-12 Plant	490	5,200				5,700
Savannah River Site	88	620				710
Weldon Spring Site Remedial Action Project			120,000			120,000

Table 6.2 (continued)

Environmental restoration program	Waste volume, m ³					Total
	LLW	M LLW	11e(2) by-product ^c	Mixed 11e(2) by-product	TRUW	
Eastern Area total	250,000	110,000	140,000		510	500,000
Grand total	2,700,000	370,000	490,000	38	720	3,500,000

^aEstimated as of December 31, 1993. Includes contaminated metal, concrete, brick, wood, and other similar materials. Blank entries mean there are no radioactively contaminated debris for the indicated waste class. The quantity of containerized mixed waste currently in storage as a result of environmental restoration activities is not included here, but is provided in Chapter 8 of this report.

^bThese volume estimates represent the quantity of in-place contaminated materials; the waste volumes resulting from remedial action activities may be larger or smaller depending on the selected remedy and treatment technology utilized. Waste volumes resulting from minimal remedial actions such as capping, monitoring, and certain in situ remedies will be quite small. All values are preliminary and are being updated as site characterization activities proceed. Values are given to two significant figures unless information was reported to only one significant figure. Some totals may not equal sum of components due to independent rounding.

^cBy-product material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (P.L. 83-703), as amended.

^dContaminated debris will be managed in the same manner as contaminated soil. The volume debris associated with remediation of the Monticello Uranium Mill Tailings Site and vicinity properties is included with the contaminated soil volume given in Table 6.1.

^eConsists of Amchitka Island, Alaska; the Rio Blanco and Rulison Test sites in Colorado; the Gnome and Gasbuggy Test sites in New Mexico; the Salmon Test Site in Mississippi; and the Shoal and Central Nevada Test sites in Nevada.

^fContaminated debris volume is included with the contaminated soil volume given in Table 6.1.

^gA small percentage of the radioactively contaminated debris at the Hanford Site may be TRUW.

^hIncludes contaminated areas in the vicinity of Oak Ridge, Tennessee, beyond the boundaries of the Y-12 Plant, the K-25 Site, and Oak Ridge National Laboratory.

A 19-ft-thick, 110-ton segment of the prestressed concrete reactor vessel (primary containment system) being removed for disposal as radioactive waste from the Fort St. Vrain high-temperature, gas-cooled reactor. Courtesy of the Public Service Company of Colorado, Denver, Colorado.

7. COMMERCIAL DECOMMISSIONING WASTES

7.1 INTRODUCTION

At the end of their useful life, commercial nuclear facilities must be shut down and decommissioned. This chapter considers the radioactive wastes from the decontamination and decommissioning (D&D) of commercial power reactors and supporting fuel cycle facilities (viz., uranium conversion, enrichment, fuel fabrication, and fuel reprocessing). As described in ref. 1, the U.S. Nuclear Regulatory Commission (NRC) has defined the three major alternative classifications for decommissioning nuclear facilities:

- DECON—“ . . . the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations.”
- SAFSTOR—“ . . . the alternative in which the nuclear facility is placed and maintained in such condition that the nuclear facility can be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use.”
- ENTOMB—“ . . . the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombment structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level permitting the unrestricted release of property.” (This alternative would be allowable for nuclear facilities contaminated with relatively short-lived radionuclides such that all contaminants would decay to levels permissible for unrestricted use within a period on the order of 100 years.)

Table 7.1 lists the major power reactors that have undergone some mode of decommissioning to date (data from refs. 2 and 3). A comprehensive listing of all types of

domestic reactors that have been shut down or dismantled is provided in ref. 2. Those fuel cycle facilities that have been permanently shut down as of the end of 1993 are listed in Table 7.2.

Several studies have been made of the D&D of commercial LWRs and their supporting fuel cycle facilities. Most notable were those prepared and documented by Battelle Pacific Northwest Laboratory (PNL) for the NRC. These included decommissioning analyses for a reference BWR and PWR, documented in refs. 4–6 and refs. 7–9, respectively. Recently, PNL prepared and issued draft revised decommissioning analyses for both the reference BWR (ref. 10) and reference PWR (ref. 11). These analyses include estimates of the radioactive wastes from D&D, which include LLW (Class A, B, and C) and some greater-than-Class-C (GTCC) wastes.

Table 7.3 summarizes projections of radioactive wastes from decommissioning reference LWRs and their supporting fuel cycle facilities (data from refs. 10–15). Most of the waste estimates reported assume a 40-year facility operating life. In practice, the operating lifetime can vary significantly, depending on the extent to which facility equipment is periodically upgraded or retrofitted. Not shown in Table 7.3 are the radioactive wastes that will result from the decommissioning of research, training, and test reactors.^{16–17} However, the quantities of these wastes are not expected to be significant because such reactors are much smaller than commercial power reactors.

7.2 WASTE CHARACTERIZATION

Radioactive waste from LWR decommissioning can be grouped into three major categories:^{5,8} (1) neutron-activated wastes, (2) contaminated wastes, and (3) miscellaneous wastes.

Neutron-activated materials include the reactor vessel and its internal components (e.g., core shroud, core support assemblies, and control-rod guide tubes) and the inner portion of the biological shield. Contaminated materials include much of the piping and equipment in the

reactor containment, fuel-handling, and auxiliary control buildings. In addition, some concrete surfaces of these buildings are expected to be radioactive and will require removal. The miscellaneous radioactive waste category includes both "wet" and "dry" solids. Wet waste materials result from the processing of chemical decontamination solutions and contaminated water and include spent ion-exchange resins, cartridge filters, and evaporator and concentrator bottoms. Dry radioactive wastes include discarded contaminated items such as rags and wipes, tools, and protective clothing.

Many reactor items with surface contamination can be decontaminated,¹⁸ thereby rendering most of the material nonradioactive and producing a smaller, more concentrated volume of waste containing the radioactivity. Waste decontamination requires the appropriate technology and a defined level of radioactivity at which the contamination level is regarded as acceptable. Depending on available technology and minimum regulatory level definition, actual quantities of wastes from reactor and fuel cycle facility decommissioning could vary significantly from projected amounts currently reported.

LWR decommissioning operations collect LLW and a small volume of high-activity wastes from the neutron activation of internal parts of the reactor core. Under NRC rules, some of these neutron activation wastes would be classified as GTCC LLW. Some GTCC wastes contain significant concentrations of ⁶⁰Co and long-lived, nontransuranic radioisotopes, such as ⁵⁹Ni, ⁶³Ni, and ⁹⁴Nb. These isotopes are produced by the long-term irradiation (neutron activation) of the stainless steel and other alloys that comprise reactor-core structural components. Because the method of waste disposal for these reactor internals is different from LLW disposal, GTCC wastes are reported separately. Under current NRC regulations,¹⁹⁻²⁰ these wastes are considered not generally acceptable for shallow-land disposal. Such wastes must be put into a federal geologic repository unless the NRC approves an alternative disposal in a licensed site. High-activity activation wastes from the DECON decommissioning of LWRs are estimated to make up less than 1% of the total radioactive waste volume, but contain more than 95% of the radioactivity.⁵⁸ Most of this radioactivity is in a single reactor component, the stainless steel core shroud that surrounds the reactor fuel.

In recent years, analyses have been made of radioactive wastes from the Shippingport Station D&D and of neutron-activated metal components (GTCC materials) from the internals of other reactors. Waste characterization assessments from studies such as refs. 21 and 22 have thus far indicated the following properties of reactor decommissioning materials:

- All reactor decommissioning materials, except the pressure vessel internals, have the potential for being disposed of as Class-A LLW.
- Fission products and TRU radionuclides are absent.
- Most radioactivity results from neutron-activated products, of which ⁶⁰Co is the principal contributor.

7.3 INVENTORIES AND PROJECTIONS

7.3.1 Commercial Power Reactors

A schedule of historical and projected commercial power LWR shutdowns, based on refs. 2 and 23, is given in Table 7.4. Projections of shutdown capacity listed are based on estimated reactor lifetimes. Actual reactor decommissioning schedules may be significantly different from those indicated in this report if any of the following are implemented:

- reactors are upgraded to extend their operating lifetimes,
- significant radioactivity decay time is allowed before D&D operations begin, or
- the last core of spent nuclear fuel is required to remain on-site for a minimum period (possibly several years) before shipment.

Table 7.5 reports quantities of actual wastes shipped from reactor sites that either have completed or are undergoing DECON (dismantlement). Completed DECON projects include the Elk River BWR; the Pathfinder BWR; the sodium reactor experiment at Santa Susana, California; and the Shippingport Station. Specific decommissioning waste characteristics for Elk River, Santa Susana, and Shippingport are given in Tables 7.5, 7.6, and 7.8, respectively, of the previous edition of this report.²⁴

Projected volumes and undecayed radioactivity levels of wastes from decommissioning alternatives considered for reference model LWRs are summarized in Table 7.6. The volume estimates given in this table reflect revisions reported by PNL in updated LWR decommissioning analyses recently performed for the NRC.¹⁰⁻¹¹ These revised estimates reflect significant reductions from the quantities previously reported in earlier PNL studies.⁴⁻⁹ The reductions are the result mainly of a large decline in the projected quantities of radioactively contaminated concrete debris resulting from DECON activities and to packaging assumptions that resulted in higher packaging densities for LLW, compared with the earlier PNL studies.

The estimated cumulative volume, decayed radioactivity, and thermal power of radioactive wastes from decommissioning commercial power LWRs shut down during the period 1994–2030 are provided in Table 7.7. These waste projections are based on the results of the PNL reference reactor studies (Table 7.6) and represent additional quantities to those previously reported in Chapter 4 for commercial LLW. This approach is taken because the timing associated with future commercial power reactor D&D activities is uncertain over the long term. Projected waste data shown in Table 7.7 are based on the projected LWR shutdown schedule given in Table 7.4 and decommissioning waste source terms developed from Table 7.6 and refs. 4–11. (The source terms are described in Appendix C.) The projections of Table 7.7 reflect a delayed DECON scenario, which assumes a 10-year period for decommissioning, beginning 6 years after reactor shutdown to allow sufficient preparation for D&D operations and cooling time for the last batch of SNF from the reactor's core. It is further assumed that the D&D wastes will be shipped to a disposal site in equal volumes during each of the 4 years that the facility will be dismantled. (For comparison, it should be noted that the period for disassembly and decontamination used in the PNL studies of refs. 10 and 11 was 1.7 years following the emptying of the SNF pool, not 4 years.)

Radioactive waste inventories and projections are being compiled for several ongoing or recently completed commercial reactor decommissioning projects. Alphabetically listed, the reactors include Dresden–Unit 1 BWR, Fort St Vrain HTGR, Humboldt Bay–Unit 3 BWR, Indian Point–Unit 1 PWR, La Crosse BWR, Pathfinder BWR (project completed in 1993), Rancho Seco PWR, San Onofre–Unit 1 PWR, Saxton PWR, Shoreham BWR, Three Mile Island (TMI)–Unit 2 PWR, and Yankee Rowe PWR. Major highlights of the D&D activities at each of these reactor sites follows.

A summary of projected radioactive materials from the SAFSTOR decommissioning of the Dresden–Unit 1 BWR station is given in Table 7.8 (data from ref. 25). These estimates are based on the *Dresden–Unit 1 Decommissioning Plan and Environmental Report*, which was issued by the Commonwealth Edison Company. Commonwealth Edison plans to place the Unit 1 station in a SAFSTOR condition until Dresden–Units 2 and 3 are ready for decommissioning. If an extended-life program for Units 2 and 3 is not initiated, then current utility plans call for all three Dresden units to be decommissioned by dismantling; this will begin in 2017.

Actual inventories (through 1993) of wastes from D&D activities at the Fort St. Vrain HTGR are reported in Table 7.9 (data from ref. 26). In August 1989, the 330-MW(e) Fort St. Vrain reactor was shut down to replace an

inoperable control rod. During this forced outage, stress cracking of the feed-water ring headers to the steam generators was noted and thus resulted in a decision to permanently cease reactor operations. The DECON option was selected as the mode of decommissioning. During 1993, the top head of the prestressed concrete reactor vessel (PCRVR) was removed and sectioned.²⁷ Projections of total wastes from DECON of the Fort St. Vrain reactor are reported in Table 7.10 (data from refs. 28 and 29).

Projections of wastes from decommissioning the 65-MW(e) Humboldt Bay–Unit 3 BWR are reported in Table 7.11 (data from ref. 30). Projections for the Humboldt Bay BWR include wastes from completely dismantling the reactor following a SAFSTOR period of 30 years (i.e., SAFSTOR with delayed DECON).

Table 7.12 (data from ref. 31) reports projections of wastes from the Indian Point–Unit 1 reactor. This 265-MW(e) PWR was shut down in 1974 and later placed in SAFSTOR. The projections of Table 7.12 pertain to a case of dismantlement (DECON) of the Unit 1 station upon completion of its SAFSTOR phase, which will occur when Unit 2 (PWR) is finally shut down.

The La Crosse BWR was shut down in 1987 and placed in SAFSTOR in 1991. Current plans are to dismantle the reactor after a SAFSTOR period of 30 to 50 years. Projected volumes and associated activities of annual waste shipments from this reactor during this period are given in Table 7.13 (data from ref. 32).

The 66-MW(e) Pathfinder BWR was placed in the SAFSTOR mode following its shutdown in 1967. Dismantling the reactor (DECON) began in 1990 and was completed during 1993. In 1991, the reactor vessel was lifted out of the containment building and shipped via rail to the commercial LLW disposal site near Richland, Washington. Inventories of the radioactive wastes disposed from the completed Pathfinder D&D activities are given in Table 7.14 (data from ref. 33).

The 918-MW(e) Rancho Seco PWR was permanently shut down in 1989. Table 7.15 (data from ref. 34) lists projected volumes of wastes from the dismantlement of this reactor following a SAFSTOR period of about 20 years.

The San Onofre–Unit 1 PWR was shut down in 1992. Estimates of wastes from decommissioning this 436-MW(e) reactor are given in Table 7.16 (data from ref. 35). These projections are reported for a case of DECON following a SAFSTOR period of about 20 years. Dismantlement of San Onofre–Unit 1 is projected to start in 2013.

The Saxton Nuclear Experimental Reactor is a 3-MW(e) PWR that was placed in SAFSTOR following its shutdown in 1972. A three-phase decommissioning effort

(DECON) was begun in 1986. Phase 1 consisted of the removal of groundwater from reactor support structures and was completed in 1987. Phase 2 involved the decontamination, final survey, and demolition of all structures except the containment vessel (reactor building); this phase was completed in 1992. The final phase will decommission the containment vessel and restore the site for unrestricted use. This phase is scheduled to be completed in 2000. A summary of projected waste volumes from Saxton decommissioning is provided in Table 7.17 (data from ref. 36).

The 820-MW(e) Shoreham BWR underwent low-power tests until 1989, when the plant's owner, Long Island Lighting Company, agreed to sell the plant to the state of New York for decommissioning. A proposed decommissioning plan³⁷ for the Shoreham plant has been approved by the NRC.³⁸ Prompt decontamination and dismantling (DECON) of the Shoreham BWR began in 1992, and these activities are proceeding. Projections of decommissioning wastes are reported in Table 7.18 (data from ref. 39).

Inventories of wastes shipped from the TMI-Unit 2 PWR are summarized in Table 7.19 (data from ref. 40). Removal of core debris from the damaged reactor was begun in January 1986 and completed in April 1990. This resulted in a shipment of 155.9 t of core debris to INEL for R&D testing and storage. TMI-Unit 2 is currently in the Post Defueling Monitored Storage (PDMS) mode after completing preparation activities in December 1993. Criteria for initiating and implementing the PDMS phase were approved through an NRC review of a licensing change request.⁴⁰

The 167-MW(e) Yankee Rowe PWR was shut down in 1992, and projections of wastes from its decommissioning are reported in Table 7.20 (data from ref. 41). These projections are reported for two major phases of project decommissioning: component removal (1993–1994), which includes removal of the reactor vessel internal components and steam generator; and final decommissioning phase (2003–2005), which includes the remainder of the reactor's components and general plant inventories.⁴¹

Currently, the total impact of wastes from D&D activities at commercial reactor sites has been small. However, as the projected schedule of Table 7.4 suggests, the impact will become more significant after the year 2000, when more of the older reactors complete their campaign of operation.

7.3.2 Supporting Fuel Cycle Facilities

Table 7.2 lists major facilities that once provided UF_6 conversion, enrichment, fuel fabrication, and fuel reprocessing services for the commercial nuclear fuel cycle. Details of the radioactive waste inventories and projections associated with decommissioning each of these facilities are given below.

Inventories and projections of wastes from decommissioning activities at the Cimarron (Oklahoma) Fuel Fabrication Facility are provided in Table 7.21 (data from ref. 42). Decontamination work at this fabrication plant is scheduled to be completed during 1995. Shut down since 1975, this facility is comprised of two former fabrication plants, one for uranium fuel and one for mixed-oxide fuel.

Table 7.22 (data from ref. 43) presents a summary of the waste inventories and projections from activities at the West Valley Demonstration Project (WVDP), formerly a commercial fuel reprocessing facility. Since startup of this project in 1982, more than 70% of the cell surface areas of the original process building have been decontaminated and released for project reuse.

7.3.3 Noncommercial Facilities

Significant quantities of radioactive wastes have and will also be produced from decommissioning noncommercial facilities. These include wastes from D&D activities performed at various DOE installations, discussed in Chapter 6, and submarine power reactor D&D activities performed for the U.S. Department of Defense. During a period spanning 20 to 30 years, about 100 nuclear-powered submarines of the U.S. Navy may be removed from service and consigned to permanent disposal after removal of the SNF. Current plans are to dispose of the submarine reactor compartments by land burial at the Hanford Site. Each reactor compartment contains about 1000 t of metal, and it is estimated that about 4 ha (10 acres) will be required to bury 100 reactor compartments.⁴⁴ At the end of 1993, 68 submarines had been taken out of active service. In 35 of these submarines, the reactor compartment was first defueled, then later removed, and disposed of at Hanford. (LLW disposed from these activities is included in the DOE site inventories reported in Chapter 4.) The remaining 33 submarines with reactor compartments were being held in protective storage.²

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Table 7.1. List of U.S. civilian reactors shut down or dismantled as of December 31, 1993^a

[Reactors of 10-MW(th) capacity or greater]							
Reactor facility	Location	Reactor type	Capacity rating		Year of permanent shutdown	Decommissioning alternative selected	Present status of decommissioning alternative
			MW(e)	MW(th)			
Boiling Nuclear Superheater Power Station (BONUS)	Punta Higuera, PR	Boiling-water	37	50	1968	ENTOMB	ENTOMB
Carolinas-Virginia Tube Reactor (CVTR)	Parr, SC	Pressure-tube, heavy-water	17	64	1967	SAFSTOR	SAFSTOR
Dresden Nuclear Power Station—Unit 1	Morris, IL	Boiling-water	200	700	1978	SAFSTOR	SAFSTOR preparation ^b
Elk River Power Station	Elk River, MN	Boiling-water	22	58	1968	DECON	DECON completed ^c
Enrico Fermi—Unit 1	Lagoon Beach, MI	Sodium-cooled, fast	61	200	1972	SAFSTOR	SAFSTOR
ESADA/GE Vallecitos Experimental Superheat Reactor (Empire States Atomic Development Associates and General Electric Company)	Pleasanton, CA	Light-water, moderated	NE ^d	17	1967	SAFSTOR	SAFSTOR
Fort St. Vrain Reactor	Platteville, CO	High-temperature, gas-cooled	330	842	1989	DECON	DECON in progress ^c
General Electric Testing Reactor	Pleasanton, CA	Tank	NE	50	1977	SAFSTOR	SAFSTOR
Hallam Nuclear Power Facility	Hallam, NE	Sodium-cooled, graphite-moderated	75	240	1964	ENTOMB	ENTOMB
Humboldt Bay Power Plant—Unit 3	Eureka, CA	Boiling-water	65	242	1976	SAFSTOR	SAFSTOR ^f
Indian Point Station—Unit 1	Buchanan, NY	Pressurized-water	265	615	1974	SAFSTOR ^g	SAFSTOR

Table 7.1 (continued)

Reactor facility	Location	Reactor type	Capacity rating		Year of permanent shutdown	Decommissioning alternative selected	Present status of decommissioning alternative
			MW(e)	MW(th)			
La Crosse Nuclear Generating Station	Genoa, WI	Boiling-water	48	165	1987	SAFSTOR	SAFSTOR ^h
Pathfinder Atomic Plant	Sioux Falls, SD	Boiling-water	66	192	1967	DECON	DECON ⁱ
Peach Bottom Power Station--Unit 1	Peach Bottom, PA	High-temperature, gas-cooled	40	115	1974	SAFSTOR	SAFSTOR
Piqua Nuclear Power Facility	Piqua, OH	Organic-cooled and moderated	11	46	1966	ENTOMB	ENTOMB
Plum Brook Reactor	Sandusky, OH	Tank	NE	60	1974	SAFSTOR	SAFSTOR
Rancho Seco	Clay Station, CA	Pressurized-water	918	2,915	1989	SAFSTOR	SAFSTOR preparation ^j
San Onofre--Unit 1	San Clemente, CA	Pressurized-water	436	1,347	1992	SAFSTOR	SAFSTOR preparation ^k
Saxton Nuclear Experimental Reactor Project	Saxton, PA	Pressurized-water	3	24	1972	SAFSTOR	DECON in progress ^l
Shippingport Power Station	Shippingport, PA	Pressurized-water	72	236	1982	DECON	DECON completed ^m
Shoreham Reactor	Brookhaven, NY	Boiling-water	820	2,436	1989	DECON	DECON in progress ⁿ
Sodium Reactor Experiment	Santa Susana, CA	Sodium-cooled, graphite-moderated	10	30	1964	DECON	DECON completed ^o
Southwest Experimental Fast Oxide Reactor (SEFOR)	Strickler, AR	Sodium-cooled, fast	NE	20	1972	SAFSTOR	SAFSTOR
Three Mile Island--Unit 2 Reactor	Londonderry Township, PA	Pressurized-water	926	2,770	1979	p	p
Trojan--Unit 1	Prescott, OR	Pressurized-water	1,130	3,411	1992	TBD	TBD

Table 7.1 (continued)

Reactor facility	Location	Reactor type	Capacity rating		Year of permanent shutdown	Decommissioning alternative selected	Present status of decommissioning alternative
			MW(e)	MW(th)			
Vallecitos Boiling-Water Reactor (VBWR)	Pleasanton, CA	Boiling-water	5	33	1963	SAFSTOR	SAFSTOR
Westinghouse Testing Reactor (WTR)	Waltz Mill, PA	Tank	NE	60	1962	SAFSTOR	SAFSTOR
Yankee Rowe—Unit 1 ^q	Rowe, MA	Pressurized-water	167	600	1991	SAFSTOR	SAFSTOR preparation

^aAdapted from refs. 2 and 3.

^bEstimates of decommissioning wastes are reported in Table 7.8.

^cDecommissioning wastes are reported in Table 7.5 of the previous edition of this report (DOE/RW-0006, Rev. 9).

^dNE = no electricity generated by reactor before it was shut down.

^eEstimates of decommissioning wastes are reported in Table 7.10. Actual inventories recovered are reported in Table 7.9.

^fEstimates of decommissioning wastes are reported in Table 7.11.

^gEstimates of decommissioning wastes are reported in Table 7.12.

^hEstimates of decommissioning wastes are reported in Table 7.13.

ⁱEstimates of decommissioning wastes are reported in Table 7.14.

^jDecommissioning wastes are reported in Table 7.15.

^kDecommissioning wastes are reported in Table 7.16.

^lDECON of the Saxton facility started in 1986. Estimates of decommissioning wastes are given in Table 7.17.

^mDecommissioning wastes are reported in Table 7.8 of the previous edition of this report (DOE/RW-0006, Rev. 9).

ⁿDECON of the Shoreham plant started in 1992. Estimates of decommissioning wastes are reported in Table 7.18.

^oDecommissioning wastes are reported in Table 7.6 of the previous edition of this report (DOE/RW-0006, Rev. 9).

PTMI—Unit 2 has completed defueling and decontamination in selected areas. The plant will be placed in a long-term monitored storage mode and will be decommissioned when

TMI—Unit 1 is dismantled. Inventories of decontamination wastes are reported in Table 7.19.

^qDecommissioning wastes are reported in Table 7.20.

Table 7.2. List of U.S. nuclear fuel cycle facilities shut down or being decommissioned as of December 31, 1993^a

Facility	Type of installation	Location	Rated capacity	Period of operation	Decommissioning objectives or status
Sequoyah Fuels Corporation Plant	Nuclear fuel conversion plant	Gore, OK	9,090 MTU/year	1970–1993	Complete dismantlement by 2002–2004
Oak Ridge Gaseous Diffusion Plant (K-25 Site)	Uranium enrichment plant	Oak Ridge, TN	7,700 t SWU/year	1945–1985	TBD
Cimarron Fuel Fabrication Facility	Nuclear fuel fabrication plant ^b	Crescent, OK	300 MTU/year	1965–1975	Anticipated completion in 1995
West Valley Demonstration Project	Nuclear fuel reprocessing plant	West Valley, NY	300 MTIHM/year	1966–1972	Proceeding ^c

^aExcludes uranium mining and milling facilities being decommissioned. These are indicated in Table 5.2 of Chapter 5.

^bThis facility was comprised of a uranium fuel fabrication plant and a mixed-oxide fuel fabrication plant. The uranium fuel fabrication plant operated from 1965 to 1975 and had a rated capacity of 300 MTU/year. The mixed-oxide fuel fabrication plant operated from 1969 to 1975 and had a rated plutonium product (PuO₂) capacity of 0.5 t/year.

^cMore than 70% of the cell surface areas of the original process building have been decontaminated and released for project reuse.

Table 7.3. Projections of radioactive wastes from decommissioning reference commercial power reactors and fuel cycle facilities^a

Fuel cycle facility	Capacity	Operation		Decommissioning alternative	Waste volume, m ³	
		Period	Lifetime (years)		LLW ^b	GTCC ^c
Boiling-water reactor	1,155 MW(e)		40 ^d	DECON	14,275	7
Pressurized-water reactor	1,175 MW(e)		40 ^d	DECON	6,981	11
Uranium conversion plant (solvent extraction process)	10,000 MTIHM/year		40	DECON	1,260	0
Uranium enrichment plants (gaseous diffusion plants)						
• K-25 site	7,700,000 kg SWU/year	1945–1985	40	DECON	212,466 ^e	0
• Paducah site	11,300,000 kg SWU/year	1954–2005	51	DECON	662,414	0
• Portsmouth site	8,300,000 kg SWU/year	1956–2005	49	DECON	630,093	0
Fuel fabrication plant	1,000 MTIHM/year		40	DECON	1,090	0

^aBased on information reported in refs. 10–15.^bClass-A, Class-B, and Class-C LLW.^cGreater-than-Class-C LLW.^dReactor operations assume a 75%-capacity factor.^eIncludes some liquids (1,849 m³), but mostly solids (mainly in the form of metal equipment and scrap, roofing and construction debris, sludge, and other materials).

Table 7.4. Schedule of actual and projected final shutdown dates for commercial light-water reactors^{a,b}

Calendar year of shutdown	BWR		PWR		Total LWR	
	No.	MW(e)	No.	MW(e)	No.	MW(e)
1963	1	5			1	5
1967	1	66	1	17	2	83
1968	2	39			2	39
1972			1	3	1	3
1974			1	265	1	265
1976	1	65			1	65
1978	1	200			1	200
1979			1	926 ^c	1	926
1982			1	72	1	72
1987	1	48	1	48		
1989	1	820	1	918	2	1,738
1991			1	167	1	167
1992			2	1,566	2	1,566
1993	0	0	0	0	0	0
Actual totals through 1993	8	1,243	9	3,934	17	5,177
2000	1	67			1	67
2007			3	1,892	3	1,892
2008	3	2,691	2	1,346	5	4,037
2009	1	610	1	470	2	1,080
2010	3	1,956	2	1,175	5	3,131
2011			1	755	1	755
2012	2	1,161	1	781	3	1,942
2013	4	3,376	9	7,596	13	10,972
2014	7	5,506	6	4,711	13	10,217
2015			2	1,843	2	1,843
2016	2	1,832	6	5,225	8	7,057
2017			2	1,875	2	1,875
2018	1	770	2	1,706	3	2,476
2020			3	3,163	3	3,163
2021			4	4,176	4	4,176
2022	2	2,183			2	2,183
2023	1	1,100	2	1,968	3	3,068
2024	4	4,195	3	3,470	7	7,665
2025	2	1,991	5	5,815	7	7,806
2026	4	4,175	4	3,909	8	8,084
2027			4	4,741	4	4,741
2028			3	3,421	3	3,421
2029	1	1,055	1	1,114	2	2,169
2030			4	4,620	4	4,620
Projected totals (1994–2030)	38	32,668	70	65,772	108	98,440

^aData from refs. 2 and 23. Historical data (prior to 1994) are based on ref. 2. Projected shutdown dates are based on utility-projected dates for reactor retirement reported in Table 4 of ref. 23.

^bYears in which no reactor shutdown is expected are eliminated.

^cShutdown of Three Mile Island–Unit 2 nuclear power plant due to an accident. Upon completion of the present cleanup campaign, the plant will be placed in a monitored storage mode and will be decommissioned when TMI–Unit 1 is dismantled.

Table 7.5. Quantities of shipped LLW from completed and ongoing reactor DECON decommissioning projects^a

Reactor	Type ^b	Rated capacity [MW(e)]	Year of permanent shutdown	Lifetime electrical generation [MW(e)-years]	Volume of LLW shipped (m ³)
Elk River	BWR	22	1968	58	3,377
Fort St. Vrain ^c	HTGR	330	1989	490	1,519
Pathfinder	BWR	66	1967	16	562 ^d
Santa Susana	SCGM	10	1964	4	3,863
Shippingport	PWR	72	1982	842	6,056
Three Mile Island—Unit 2 ^c	PWR	926	1979	232	9,146
Yankee Rowe	PWR	167	1992	4,030	503 ^e
Total		1,593		5,672	25,026

^aInformation as of December 31, 1993, unless indicated otherwise.

^bAbbreviations used: BWR—boiling-water reactor; HTGR—high-temperature, gas-cooled reactor; SCGM—sodium-cooled, graphite-moderated reactor; and PWR—pressurized water reactor.

^cDECON for this reactor is still in progress.

^dVolume of LLW disposed was 303 m³.

^eAs of June 30, 1994.

Table 7.6. Revised estimates of disposal volumes for radioactive wastes from decommissioning alternatives considered for reference LWRs^{a,b}

Decommissioning alternative ^c	Post-shutdown period ^d (years)	Estimated disposal volume, m ³				
		Total	Class-A LLW	Class-B LLW	Class-C LLW	GTCC LLW ^e
Reference boiling-water reactor [1155 MW(e)]						
DECON	6.3	14,282	13,903	332	40	7
SAFSTOR 1	60	1,117	738	332	40	7
SAFSTOR 2	60	14,282	13,903	332	40	7
ENTOMB 1	60	490	483	0	0	7
ENTOMB 2	60	1,139	760	332	40	7
ENTOMB 3	300	490	483	0	0	7
Reference pressurized-water reactor [1175 MW(e)]						
DECON	8.6	6,992	6,797	154	30	11
SAFSTOR 1	60	763	568	154	30	11
SAFSTOR 2	60	6,992	6,797	154	30	11
ENTOMB 1	60	305	294	0	0	11
ENTOMB 2	60	754	559	154	30	11
ENTOMB 3	300	305	294	0	0	11

^aAdapted from refs. 10 and 11. Before final shutdown, each reactor is assumed to have operated for 40 years with a capacity factor of 0.75.

^bThe classifications listed for LLW are based on the limiting concentrations of long- and short-lived radionuclides given in Tables 1 and 2 of 10 CFR Part 61.55.

^cAs indicated in refs. 10 and 11, the decommissioning alternatives listed have the following major features: DECON—assumes a period of plant safe storage until the SNF inventory has sufficiently decayed and been completely removed. This is followed by dismantlement of the radioactive portions of the plant; SAFSTOR 1—assumes extended safe storage (<60 years) without any fuel in the reactor storage pool, followed by decontamination and dismantlement of the radioactive portions of the plant and that only the reactor pressure vessel and BWR sacrificial shield or PWR bioshield require disposal as LLW; SAFSTOR 2—same as SAFSTOR 1 except that all radioactive materials are assumed to still exceed unrestricted release levels. No volume reduction from DECON results; ENTOMB 1—assumes no removal of reactor pressure vessel and BWR sacrificial shield or PWR bioshield as these will decay to unrestricted levels; ENTOMB 2—assumes removal of reactor pressure vessel and BWR sacrificial shield or PWR bioshield is required during preparations for entombment to assure license termination within 60 years after final shutdown; and ENTOMB 3—allows for 300 years of radioactive decay after which the reactor pressure vessel and BWR sacrificial shield or PWR bioshield will have decayed to unrestricted release levels.

^dCovers the period of time starting from final reactor shutdown to the completion of plant decommissioning activities.

^eRevised estimates of quantities of GTCC wastes from LWR decommissioning were also recently developed by Lockheed Idaho Technologies Company and are reported in ref. 22. A summary of all GTCC waste estimates reported in ref. 22 is given in Chapter 4.

Table 7.7. Projections of cumulative volume, radioactivity, and thermal power of wastes from decommissioning commercial light-water reactors shut down during 1994–2030^{a,b,c}

Waste type	Volume (m ³)	Activity (Ci)	Thermal power (W)
<i>Boiling-water reactors</i>			
Class-A LLW	393,232	35,532	209
Class-B LLW	9,390	110,992	652
Class-C LLW	1,131	299,466	984
Subtotals	403,753	445,990	1,845
Greater-than-Class-C LLW ^d	194	16,760,009	80,974
Totals for D&D of BWRs	403,947	17,205,999	82,819
<i>Pressurized-water reactors</i>			
Class-A LLW	380,470	137,527	727
Class-B LLW	8,622	170,167	1,538
Class-C LLW	1,680	165,309	1,106
Subtotals	390,772	473,003	3,371
Greater-than-Class-C LLW ^d	616	25,437,189	125,684
Totals for D&D of PWRs	391,388	25,910,192	129,055
<i>Total light-water reactors</i>			
Total LLW	794,525	918,993	5,216
Greater-than-Class-C LLW	810	42,197,198	206,658
Totals for D&D of LWRs	795,335	43,116,191	211,874

^aThe projections in this table are based on a decommissioning scenario (delayed DECON) that spans a total period of 10 years following final reactor shutdown. This scenario assumes an initial 6-year period is needed for spent nuclear fuel from the reactor's last core to sufficiently cool to permit its transfer either to DOE or to a dry on-site storage facility. Active dismantlement of the reactor is assumed to begin following the completion of fuel removal and to take 4 additional years, with radioactive wastes being collected equally over each of the 4 years. In terms of numerical significance, the number of digits used to report these projections are greater than justified. However, this procedure is used for bookkeeping purposes to ensure consistency in the numerical totals reported. Since these projections are based on the reactor shutdown dates reported in ref. 23 and the source terms developed from refs. 4–11 (see Appendix C), each reported number is significant to no more than three figures.

^bThis table refers only to reactors yet to be decommissioned. Historical reactor D&D wastes are included in the institutional/industrial (I/I) waste inventories reported in Chapter 4.

^cThe projections reported for volume, activity, and thermal power are the cumulative levels of wastes from reactor D&D activities (delayed DECON) during the period 1994–2040. For the scenario described in footnote a, the year 2040 is the last year in which wastes are collected from reactors shut down in the year 2030.

^dIncludes contributions from core shroud and other internal core components.

Table 7.8. Projected characteristics of radioactive wastes from Dresden—Unit 1 decommissioning activities^{a,b,c}

Waste category	Reactor component(s)	Volume (m ³)
Radioactive materials	Reactor vessel and internals: ^d	
	Reactor vessel	11
	Bioshield sand and concrete	239
	Thermal shield	2
	Instrumentation support tubes	1
	Bottom core support structure	1
	Other ^e	5
	Subtotal	259
	Solidified decontamination solvents	655
	Reactor station components and materials ^f	6,214
	Total	7,128
Radioactive hazardous materials	Asbestos insulation on contaminated piping and components	409
	Grand total	7,537

^aBased on ref. 25.

^bThe 200-MW(e) Dresden BWR began operation in 1960 and generated about 1,800 MW(e)-years of (gross) electrical energy before it was shut down in 1978. The projections of this table pertain to wastes from the dismantlement of the reactor following a SAFSTOR period of about 30 years.

^cThese projections do not include 32 m³ of LLW from SAFSTOR preparation activities (e.g., materials from cleaning spent fuel pool surfaces, miscellaneous sumps, and other contaminated areas; filters from chemical cleaning system; and miscellaneous dry active trash).

^dThe greatest source of radioactivity in the Dresden containment building is in the reactor vessel and internals. This activity results from neutron activation products in the vessel and shield materials. When the reactor was shut down in 1978, the estimated activity for the vessel and internals was 4,029,000 Ci. By the year 2017, when dismantling of the reactor is to begin, this activity is projected to drop to a level of about 16,000 Ci.

^eOther reactor internal components include steam deflector support, top grid assembly, bottom support grid, control rod guide tubes, and reactor vessel cladding.

^fReactor station components and materials include piping, valves, pumps, heat exchangers, building concrete, and structural steel.

Table 7.9. Actual radioactive waste disposal from the decommissioning of the Fort St. Vrain HTGR^{a,b}

Year	Irradiated hardware			Dry active waste		
	No. of shipments	Volume ^c (m ³)	Activity (Ci)	No. of shipments	Volume ^c (m ³)	Activity (Ci)
1991	6	29.1	8,083.80	20	13.3	1.81
1992 ^d	64	365.8	32,678.49	6	13.4	7.88
1993	113	981.9	26,385.91	7	115.1	8.54
Total	183	1,376.8	67,148.20	33	141.8	18.23

^aBased on ref. 26. Includes shipments made by Public Service Company of Colorado and decommissioning contractor and waste processors subsequent to volume reduction.

^bTracking of volume by individual components and/or system is not performed because of mixing of components from various waste streams, void spaces, etc.

^cActual disposal volume which therefore includes void space, filler volume, package volume, etc.

^dNRC Decommissioning Order for Fort St. Vrain became effective on December 8, 1992. Prior to that date, decommissioning activities performed were considered to be early dismantlement.

**Table 7.10. Projected characteristics of wastes from DECON
(dismantling) of the Fort St. Vrain HTGR^{a,b}**

Reactor component(s)/waste	Burial volume (m ³)	Activity (Ci)	Projected LLW class
<i>Prestressed concrete reactor vessel (PCRV) system</i>			
PCRV concrete	1,174.94	c	A
Control rod drives (CRDs)	97.81	c	A
CRD absorber strings	18.81	c	C
CRD metal clad reflector	4.04	c	C
Boronated stainless steel rods	845.27	c	B
Top cover plates	1.59	c	A
Top head kaowool ^d and liner	13.32	c	A
Core barrel	21.97	c	A
Core support blocks	41.09	c	A
Core support floor kaowool, plates, and liner	6.94	c	A
Metal clad reflector blocks (non-CRD)	28.67	c	C
Dummy fuel blocks	168.28	c	A
Graphite reflector blocks	237.65	c	A, B
Silica insulation blocks	14.27	c	A
Large permeable reflectors	709.32	c	B
Reflector keys	0.57	c	A
Metal shell for large side reflector	0.58	c	A
Radial cover plate, kaowool, and PCRV liner	55.57	c	A
Region constraint devices	1.42	c	C
Helium purification and regeneration system	30.87	c	A
Helium circulators	4.01	c	A
Steam generators	269.02	c	A, B
PCRV system total	3,746.01	1.30E+6	
<i>Material handling, treatment, and storage (MHTS) systems</i>			
Fuel handling machine	63.33	c	A
Fuel storage wells	28.48	c	A
Equipment storage wells	2.98	c	A
Auxiliary transfer cask	19.52	c	A
Hot service facility	10.98	c	A
MHTS systems total	125.29	3.88E-2	
<i>Decontamination and waste (DW) systems</i>			
Decontamination	9.57	c	A
Radioactive liquid waste	9.15	c	A
Radioactive gas waste	32.93	c	A
Dry activated and other wastes	153.34	c	A
DW total	204.99	1.33E-4	
Fort St. Vrain HTGR total	4,076.29	1.30E+6	

^aBased on refs. 28 and 29. This table represents the projected radioactive waste disposal volume for the entire DECON project (projected completion in early 1996).

^bThe 330-MW(e) Fort St. Vrain HTGR operated from 1979 until 1989, generating about 490 MW(e)-years of (gross) electrical energy.

^cInformation is not available.

^dKaowool is an insulation material.

Table 7.11. Projected burial volumes of radioactive wastes from SAFSTOR (mothballing/delayed dismantling) of Humboldt Bay—Unit 3 BWR^{a,b,c}

D&D activity/reactor component	Volume (m ³)
Spent fuel racks	28.3
Nuclear steam supply system removal	
Reactor vessel	66.8 ^d
Reactor vessel internals	19.1 ^e
Other components ^f	17.0
Removal of major equipment	
Asbestos removal program	116.1
Main condensers	24.6
Main turbine/generator	36.4
Disposal of contaminated plant systems	
Condensate system	65.5
Electrical system	30.6
High-pressure steam and feedwater systems	66.7
Radwaste collection and treatment systems	49.2
Reactor cleanup and shutdown	38.8
Turbine system	415.3
Other systems ^g	74.8
Decontamination of site buildings	
Refueling building	216.7
Turbine building	21.3
Yard piping and soil	211.4
Other ^h	14.7
Disposal of contaminated solid waste	16.4
Process liquid waste ⁱ	27.3
Disposal of modified plant seismic and off-gas systems as a result of 1986–1991 capital improvements	20.8
Total	1,577.8

^aBased on the information reported in ref. 30.

^bThe 65-MW(e) Humboldt Bay—Unit 3 BWR operated from 1963 until 1976, generating 545 MW(e)-years of (net) electrical energy. The plant was placed in a SAFSTOR mode in 1988. The projections in this table assume delayed dismantling (DECON) of the reactor begins after a SAFSTOR dormancy period of 30 years. At this time (2018), the current inventory of spent fuel at the site will have been shipped to a federal repository when the latter is available.

^cExcept where noted, the volumes reported represent estimates for packaged Class-A LLW.

^dIncludes 14.8 m³ of Class-B LLW.

^eIncludes 5.8 m³ of Class-B LLW and 13.3 m³ of Class-C LLW.

^fIncludes removed control rod drive mechanism and inner core instrumentation.

^gIncludes contaminated control rod drive hydraulics, extraction drains and vents, gaseous radwaste, yard piping, seismic equipment, and heating, ventilating, and air-conditioning equipment.

^hIncludes contaminated buildings for hot machine shop and calibration equipment, radwaste treatment, and equipment storage.

ⁱClass-B LLW.

**Table 7.12. Projected volumes of wastes from Indian Point–Unit 1
PWR decommissioning activities^{a,b,c}**

Reactor component(s)	Container (type and number)		
	LSA boxes	Cask liners	Total
Contaminated piping, valves, equipment, and concrete	2,440	0	2,440
Spent nuclear fuel racks	9	0	9
Reactor internals	7	13	20
Reactor vessel	52	0	52
Total containers	2,508	13	2,521
External volume (m ³) of each container (box or liner)	4.694	3.341	
Total container volume (m ³)	11,774	43	11,817

^aBased on ref. 31.

^bThe 265-MW(e) Indian Point–Unit 1 PWR began operation in 1962 and generated about 1,440 MW(e)-years of (gross) electrical energy before it was shut down in 1974. The projections in this table pertain to wastes from the dismantlement of the reactor following a SAFSTOR period of about 40 years.

^cAll Unit 1 systems shared with Unit 2 are credited to Unit 1 waste volume. Significant volume reductions from smelting and off-site decontamination are not factored into estimate. Total induced activity in vessel and vessel internals is approximately 25,000 Ci, projected in year 2013. About 90% of this induced activity is due to ⁶³Ni and about 9% is due to ⁶⁰Co.

Table 7.13. Inventories and projections of low-level radioactive wastes from La Crosse BWR decommissioning activities^{a,b}

Calendar year(s)	Decommissioning mode	Average annual quantity of waste shipped to burial site ^{c,d}	
		Volume (m ³ /year)	Activity (Ci/year)
1988	SAFSTOR	4.62	70.3
1989 ^e	SAFSTOR	6.74	32.12
1990 ^e	SAFSTOR	4.59	0.74
1991 ^e	SAFSTOR	5.46	0.32
1992 ^e	SAFSTOR	2.61	0.44
1993 ^e	SAFSTOR	3.31	0.24
Totals (through 1993)	SAFSTOR	27.33	104.16 ^f
1994	SAFSTOR	44.9	1.6
1995–1998	SAFSTOR	0.0	0.0
1999–2003	SAFSTOR	6.5	13
2004–2008	SAFSTOR	4.9	7
2009–2013	SAFSTOR	3.6	5
2014–2020	SAFSTOR	0.0	0.0
2021–2025	DECON	103.0	>280
Projected totals (1994–2025)	SAFSTOR/DECON	634.9	>1,526.6 ^f
Historical and projected totals (1988–2025)	SAFSTOR/DECON	662.2	>1,630.8 ^f

^aBased on the information reported in ref. 32.

^bThe 48-MW(e) La Crosse BWR began operation in 1968 and generated 462 MW(e)-years of (gross) electrical energy until it was shut down in April 1987. The reactor was placed in SAFSTOR in 1991. The data in this table are based on a SAFSTOR period of 30 years.

^cDuring the SAFSTOR period, the principal types of radioactive solid waste which will be processed and shipped to a suitable disposal facility will be low-level radioactive wastes principally with radioactivity content less than Class C (10 CFR Part 61) wastes. These wastes will include (1) dry active wastes (DAW), normally Class A, unstable; (2) dewatered spent demineralizer resins and filtration media, normally Class A or B, stable; and (3) contaminated or irradiated plant system components, normally Class B or C, stable.

^dContributions from activated core components and structural materials are not included. Volume estimates of these materials are currently not available; however, a preliminary activity estimate of 9,960 Ci has been made for these activated materials for year 2021, when the reactor will be ready for dismantlement.

^eVolume of waste for this year reflects significant reductions due to treatment. Waste shipments for this year contained DAW and contaminated metal, which were either decontaminated, supercompacted, or both by two Oak Ridge waste treatment companies (Quadrex Recycle Center and SEG).

^fValues are decayed to the time of burial.

Table 7.14. Characteristics of disposed radioactive wastes associated with decommissioning the Pathfinder BWR^{a,b}

Reactor component(s)/waste	Volume ^c (m ³)	Mass (t)	Activity (Ci)
Reactor vessel ^d	113	280.5	560.92
Bioshield	e	e	e
Recirculation pumps and motors (3)	e	e	e
Contaminated concrete	e	e	e
Dry active waste ^f	170.4	635.5	0.557
Liquids	0	0	0
Asbestos	20	17	0.0001
Total	303.4	1,208	561.50

^aBased on ref. 33. All material is low-specific-activity LLW.

^bThe 66-MW(e) Pathfinder BWR began operation in 1964 and had generated about 140,000 MW(e)-hours of electrical energy when it was shut down in 1967.

^cThese numbers represent the disposal volume of radioactive waste shipped.

^dIncludes reactor pressure vessel, internal components, control rod drive blades, gravel, grout, and routine shipping (Type A) packaging components.

^eThese components were recycled and are therefore not included in the disposal inventory. Estimates of component quantities shipped are reported in Table 7.18 of the 1993 Integrated Data Base report (ref. 24).

^fIncludes piping, valves, conduits, cables, sand, wires, steel, shield blocks, grating, lights, filters, plastic, paper, and wood.

Table 7.15. Projected volumes of wastes from Rancho Seco PWR decommissioning activities^{a,b,c}

Reactor component(s)/waste	Volume (m ³)
Spent nuclear fuel racks	359
Reactor vessel	212
Reactor vessel internals	156
Primary system components and piping	1,336
Total for reactor vessel and components	2,063
Secondary and radwaste systems	2,625
Contaminated structures	468
Processed liquid waste	98
Dry active waste	397
Grand total	5,651

^aBased on ref. 34 (extracted from a 1991 decommissioning cost study prepared by TLG Engineering, Inc.).

^bThe 918-MW(e) Rancho Seco-Unit 1 PWR was shut down in 1989. The reactor operated from 1974 until 1989, generating 5,277.3 MW(e)-years of (gross) electrical energy.

^cThe projections in this table pertain to wastes from dismantlement of the reactor following a SAFSTOR period of about 20 years.

Table 7.16. Projected volumes of wastes from San Onofre-Unit 1 PWR decommissioning activities^{a,b}

Activity/reactor facility component or type of waste	Waste volume, m ³				
	Class A	Class B	Class C	GTCC	Total
Annual SAFSTOR maintenance					
Dry activated waste ^c	121.12				121.12
Spent fuel racks	14.39				14.39
Nuclear steam supply system (NSSS) removal					
Reactor coolant piping	86.04				86.04
Pressurizer quench tank	12.94				12.94
Reactor coolant system pumps and motors	49.28				49.28
Pressurizer	56.64				56.64
Steam generators	367.54				367.54
Control rod drive mechanism and incore instrumentation	48.20				48.20
Vessel internals	22.26	13.06	30.81	20.25	86.38
Reactor vessel	147.15	51.94			199.09
NSSS total	790.05	65.00	30.81	20.25	906.11
Plant systems					
Auxiliary feedwater	92.12				92.12
Containment ventilation	42.45				42.45
Contaminated electrical equipment	79.27				79.27
Feedwater sampling	90.28				90.28
Feedwater	338.48				338.48
Gaseous radwaste	54.46				54.46
Letdown demineralizer	3.82				3.82
Letdown and residual heat removal	42.48				42.48
Liquid radwaste	37.72				37.72
Post-accident sampling	5.35				5.35
Pressurizer and relief tank	0.20				0.20
Radwaste drain system	5.21				5.21
Reactor coolant pump seal water system	13.71				13.71
Reactor cool system	3.12				3.12
Reactor cool system sampling system	13.06				13.06
Safety injection	85.70				85.70
Spent fuel cooling	11.98				11.98
Chemical volume and control system	23.93				23.93
Plant systems total	943.34				943.34
Site buildings					
Reactor sphere and enclosure	249.27				249.27
Auxiliary additions	2.04				2.04
Contaminated soil	724.96				724.96
Fuel storage	21.69				21.69
Miscellaneous contaminated buildings	18.49				18.49
Radwaste	13.45				13.45
Reactor auxiliary	5.89				5.89
Storage building	1.42				1.42
Site buildings total	1,037.21				1,037.21

Table 7.16 (continued)

Activity/reactor facility component or type of waste	Waste volume, m ³				
	Class A	Class B	Class C	GTCC	Total
Final waste liquid processing		40.24			40.24
Mixed waste		16.68			16.68
Totals	2,922.79	105.24	30.81	20.25	3,079.09

^aBased on ref. 35. Projections in this table pertain to wastes from reactor dismantlement (DECON) following a SAFSTOR period of 20 years. San Onofre–Unit 1 will be dismantled beginning in 2013.

^bThe 436-MW(e) San Onofre–Unit 1 PWR began operation in 1967 and generated about 6,045 MW(e)-years of (gross) electrical energy before it was shut down in 1992.

^cIncludes 83.94 m³ of dry, activated waste (including protective worker clothing) generated during the latter phase of decommissioning.

Table 7.17. Projected volumes of wastes from Saxton PWR decommissioning activities^{a,b,c}

Reactor component(s)/waste	Volume (m ³)
Auxiliary system piping and valves	28.32
Containment vessel sump pumps	0.85
Containment ventilation equipment	16.99
Contaminated and activated concrete of containment vessel	229.37
Contaminated soil ^d	1,590.27
Cooling heat exchangers	16.99
Demineralizers	4.25
Discharge tank drain pumps	0.85
General valves, controllers, and instrumentation	42.48
Low-level waste from disposal operations	33.98
Pressurizer	7.26
Primary coolant pump	2.83
Primary piping	5.66
Reactor vessel, head, and internals	39.64
Relief valve discharge tank	4.25
Safety injection pumps	1.42
Shutdown cooling pumps	0.85
Steam generator	8.43
Total volume	2,034.69

^aBased on the information reported in ref. 36.

^bThe 3-MW(e) Saxton PWR was shut down in 1972 and placed in SAFSTOR. Work on dismantling the reactor site started in 1986. This facility operated from 1961 until 1971, generating 10.4 MW(e)-years of (gross) electrical energy.

^cActivity data are unknown at this time. Saxton reactor decommissioning waste characteristics are still being reviewed, and additional information will be provided in this table in future reports.

^dContaminated soil (radioactive waste, 5–100 pCi/g) is currently (in 1994) being shipped to Envirocare of Utah, Inc.

Table 7.18. Characteristics of wastes from Shoreham BWR decommissioning activities^{a,b}

(Unless otherwise indicated, all wastes are projected to be LLW Class A)

Category	Containers		Mass (t)	Shipment volume ^c (m ³)	Radioactivity (Ci)	Burial volume (m ³)
	Number	Type				
Items shipped to volume reduction facilities for processing prior to burial ^d						
Reactor recirculation system	e	e	e	e	e	e
Control rod drive system ^f	e	e	e	e	e	e
Residual heat removal system	e	e	e	e	e	e
Core spray system	e	e	e	e	e	e
Reactor water cleanup system	e	e	e	e	e	e
Fuel pool cleanup system	e	e	e	e	e	e
Condensate and demineralizer system	e	e	e	e	e	e
Process sampling system	e	e	e	e	e	e
SNF rack and accessories	e	e	e	e	e	e
Process and dry activated wastes	e	e	e	e	e	e
Demineralizer system and resins/filters	e	e	e	e	e	e
Liquid radwaste system	e	e	e	e	e	e
Mirror insulation	e	e	e	e	e	e
Total	210	g	1,836.93	6,329.38	6.97	61.15
Items shipped directly to burial site (Barnwell)						
Reactor internals ^h						
Control rod blades and drives						
Total	51	i	96.90	79.62	675.79	79.62
Laundry (recycled) ^j	588		125.35	765.91	0.28	0
Miscellaneous equipment (recycled) ^k	87		269.86	598.24	0.23	0
Grand total	936		2,329.06	7,773.15	683.27	140.77

^aBased on ref. 39. As of December 31, 1993.^bThe 820-MW(e) Shoreham BWR underwent low-power tests until 1989, when the Long Island Lighting Company agreed to sell the plant to the state of New York for decommissioning. A total of 865 MW(e)-hours of (gross) electrical energy were generated during the low power tests.^cPrior to treatment and burial.^dVolume reduction facilities include SEG and Quadrex.^eInformation unavailable.^fExcludes control rod blades and drives.^gContainer type: sea land containers, boxes, and high-integrity containers (HICs).^hIncludes some incore instruments, which are projected to be Class B LLW.ⁱCasks and boxes.^jCleaned by Interstate Nuclear Services and recycled.^kEquipment shipped to various reactor sites for salvaging. Such equipment includes traversing incore probe drives and detectors, reactor pressure vessel segments, control rod drives, steam relief valves, local power range monitors, intermediate range monitors, source range monitors, and recirculation pump components.

Table 7.19. Characteristics of wastes from decontamination activities at the Three Mile Island—Unit 2 reactor site^{a,b}

Type of waste	Mass shipped (t)	Total waste shipped from TMI (August 1979 through December 1993)	
		Packaged volume (m ³)	Shipment activity ^c (Ci)
Spent nuclear fuel/core debris ^d	155.9	123.9	6,911,513
Low-level and other wastes ^e			
Dry, activated waste (DAW) ^f		7,423.0	726.4
Wet and solidified waste ^g		320.3	7,787.5
Submerged demineralizer system (SDS) ^h		58.2	673,877.7
EPICOR II system liners ⁱ			
First generation		125.7	77,750
Second generation		947.3	5,066.9
Defueling water cleanup system (DWCS) ^j		8.45	5,886.3
Off-site deconable scrap		138.9	4
Totals	155.9	9,145.75	7,682,611.8

^aThree Mile Island (TMI—Unit 2) is a PWR reactor with the following characteristics: rated capacity—926 MW(e); mass of fuel in core before accident—82 MTIHM; and number of fuel assemblies before accident—177. The reactor began operation in 1978 and generated 231.6 MW(e)-years of (gross) electrical energy before being permanently shut down by an accident in March 1979.

^bBased on information reported in ref. 40.

^cThese activities represent the cumulative sum of curies reported at the time of waste shipment. The values reported are not corrected for decay after the time of shipment.

^dDefueling of the reactor started in January 1986. Fuel-debris shipments were completed in April 1990.

^eOther wastes include those regarded as "abnormal" because their classification is currently uncertain.

^fDry, activated wastes are dry wastes packaged in drums, boxes, and high-integrity containers.

^gIncludes solidified miscellaneous liquids and miscellaneous resin liners and filters from TMI—Unit 2 systems.

^hResin liners and filters from the SDS (for water treatment).

ⁱResin liners and filters from the EPICOR II system that use organic ion-exchange resins and inorganic zeolite media. These include processing high-integrity containers (HICs). The EPICOR II system is a special type of filtering system used at the TMI—Unit 2 site in the final stages of decontaminating large volumes of contaminated water.

^jResin liners and filters from the DWCS that use inorganic zeolite media. These are primarily processing HICs.

Table 7.20. Projected characteristics of wastes from Yankee Rowe
PWR decommissioning activities^{a,b}

Reactor component	Volume (m ³)	Radioactivity ^c (Ci)
<i>Component Removal Project (1993–1994)</i>		
Main coolant pumps (4)	8.8	11
Pressurizer	19.3	3
Reactor vessel internal components	87.0	132,600
Steam generators (4)	197.0	1,300
Miscellaneous waste	191.0	370
Total (1993–1994)	503.1	134,284
<i>Final decommissioning (2003–2005)</i>		
Building inventory	444.3	<1
General plant inventory	2,095.5	<500
Reactor core baffle ^d	2.1	1,020,000
Reactor vessel	192.2	4,700
Miscellaneous waste	471.0	<50
Total (2003–2005)	3,205.1	1,025,251
Total (1993–2005)	3,708.2	1,159,535

^aBased on ref. 41.

^bThe 167-MW(e) Yankee Rowe–Unit 1 PWR began operation in 1960 and generated about 4,030 MW(e)-years of (gross) electrical energy before it was shut down in 1992.

^cAs of January 1, 1994.

^dThe reactor core baffle, the component directly adjacent to the reactor core, was highly activated during plant operations. The baffle's radioactivity exceeds 10 CFR Part 61.55 Class-C LLW requirements for near-surface disposal. DOE is responsible for the disposal of GTCC materials.

Table 7.21. Characteristics of wastes from decommissioning activities at the Cimarron Fuel Fabrication Facility^a

Project area	Type of waste	Total waste removed from Cimarron through December 1993 ^b		Projected waste volume remaining ^c (m ³)
		Volume (m ³)	Activity (Ci)	
Burial ground	LLW (LSA) ^d	1,833.10	5.37	0
Mixed-oxide fuel plant	TRUW	259.34	10.87	0
	LLW (LSA)	463.88	3.25	0
Uranium fuel plant areas				
a. Uranium fuel plant	LLW (LSA)	2,198.76	3.65	12-24
b. North Field	LLW (LSA)	630.19	0.33	0
Liquid process waste evaporation ponds				
a. Mixed-oxide plant pond	LLW (LSA)	104.30	0.000009	0
b. Uranium plant pond	LLW (LSA)	183.73	0.23	0
Sanitary lagoon piping and manholes	LLW (LSA)	1,559.23	2.93	0
Project totals	TRUW	259.34	10.87	0
	LLW (LSA)	6,973.19	15.76	12-24
Total waste		7,232.53	26.63	12-24

^aBased on the information provided in ref. 42.

^bThe LLW inventories are included in the commercial disposal site inventories of Chapter 4. No waste shipments were made from the site during 1993.

^cDecontamination work is anticipated to be completed during 1995. More than 95% of the estimated decontamination requirement has been completed.

^dLSA = low-specific-activity waste.

**Table 7.22 Inventories and projections of wastes from various activities
at the West Valley Demonstration Project^{a,b}**

Waste description	Total wastes as of December 31, 1993 ^c	Projected total wastes upon completion of the project
Spent nuclear fuel remaining ^d		
Mass, MTIHM	27	27
Number of fuel assemblies	125	125
High-level waste generated from reprocessing operations (1966–1972) ^e		
Volume, m ³	1,990 ^f	2408
Activity, Ci ^h	14,972,000	13,200,000 ⁱ
Transuranic waste generated from presolidification activities and HLW vitrification		
Volume, m ³		
Contact-handled	51	j
Remote-handled	427	j
Activity, Ci		
Contact-handled	j	j
Remote-handled	j	j
Low-level waste generated from presolidification activities and HLW vitrification		
Buried waste (1982–86) volume, m ³	5,786	5,786
Buried waste (1982–86) activity, Ci ^h	625	j
Stored waste volume, m ³	12,881	j
Stored waste activity, Ci ^h	k	k
Low-level waste incorporated in cement by radwaste treatment system ^l		
Stored waste volume, m ³	4,252	j
Stored waste activity, Ci ^h	j	j
Low-level waste from postsolidification D&D after HLW vitrification		
Volume, m ³	0	4,771
Activity, Ci ^h	0	j
Total low-level summary (buried and stored wastes)		
Volume, m ³	22,919	j
Activity, Ci ^h	j	j

^aBased on data reported in ref. 43.

^bAt the West Valley Demonstration Project (WVDP) site, Nuclear Fuel Services, Inc., operated a reprocessing plant with a rated capacity of 300 MTIHM/year. During its operation from 1966 to 1972, about 640 MTHM of spent nuclear fuel were reprocessed.

^cWastes generated after 1987 are regarded as stored, not buried or disposed.

^dAt the end of 1993, 125 fuel assemblies (representing 27 MTIHM of spent nuclear fuel) still remained in storage at the WVDP. These assemblies are owned by DOE. The return shipment of all commercially owned spent fuel (625 fuel assemblies) to the owner utilities was completed by the end of 1986. The current SNF inventory at the WVDP consists of 85 BWR assemblies (11.7 MTIHM) and 40 PWR assemblies (15.3 MTIHM).

(Footnotes continued on next page.)

Table 7.22 (continued)

^cCurrently, HLW at the WVDP site is stored in two underground steel tanks. Eventually, this waste will be vitrified and about 300 canisters of glass will be produced. It is assumed that each canister will contain 0.80 m³ of glass.

^fWaste form is liquid, sludge, and zeolite.

^gGlass is the waste form.

^hPrincipal nuclides include ²⁴¹Am, ²⁴¹Pu, ¹³⁷Cs, ⁹⁹Tc, ⁹⁰Sr, and ⁶³Ni.

ⁱDecayed activity for 1998.

^jUnknown.

^kInformation currently unavailable. This information will be updated in future updates of this report to include estimated total activity for containerized wastes as the information becomes available.

^lComprised of Class A and Class C LLW. See Table C.7 of Appendix C.

A chemical operator attaching a hose from the unloading station of the Y-12 Plant Head End Waste Treatment Facility to a 300-gal Tuff Tank containing liquid mixed low-level waste. *Courtesy of Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.*

8. MIXED LOW-LEVEL WASTE

8.1 INTRODUCTION

This chapter reports estimated inventories and generation rates of mixed low-level waste (MLLW) from DOE-site and commercial operations. MLLW includes mixtures of low-level radioactive materials and (chemically and/or physically) hazardous wastes. Typically, MLLW at DOE sites includes a variety of contaminated materials, including air filters, cleaning materials, engine oils and grease, paint residues, photographic materials, soils, building materials, and plant equipment being decommissioned. Mixed wastes include other types of radioactive wastes. All high-level wastes (HLWs) are regarded as mixed and are discussed in Chapter 2. Mixed transuranic wastes (MTRUWs) are not included in this chapter, but they are included in the TRUW inventories and projections of Chapter 3.

The radioactive components of mixed wastes are subject to the Atomic Energy Act (AEA), as amended,¹ which, for government sources, is administered by DOE, and, for commercial sources, by NRC (unless a state has obtained agreement-state status). In general, the hazardous components of most mixed wastes are subject to either of two federal statutes that are administered by the U.S. Environmental Protection Agency (EPA) (unless a state has obtained an authorization status): (1) the Resource Conservation and Recovery Act (RCRA), as amended,² and (2) the Toxic Substances Control Act (TSCA).³ Some mixed wastes, particularly spent engine oils, are regulated by state laws. The treatment, handling, and disposal of RCRA- and TSCA-regulated mixed wastes are subject to the regulations of the EPA^{4,5} and NRC (or the authorized and agreement states), or DOE. Table 8.1 (data from ref. 6) lists those states and territories designated by EPA as having mixed waste authorization.

In this report, MLLW is considered separately from the purely radioactive LLW, which is discussed in Chapter 4. This section reports MLLW inventories and projections for two major groups of MLLW. The first comprises wastes containing hazardous components that are RCRA- and/or state-regulated, including RCRA-/state-regulated wastes that are also subject to TSCA. The summary

information reported for these RCRA-/state-regulated wastes are based on the DOE Mixed Waste Inventory Report (MWIR),⁷ which is required by the Federal Facility Compliance Act (FFCA).⁸ Wastes whose hazardous components are regulated by TSCA comprise the second group of MLLW; inventories and projections of this group are reported in this chapter. Information for the TSCA-regulated wastes was recently provided to the IDB Program by DOE sites.

Unless otherwise noted, the inventories and projections reported for MLLW are separate from those reported for strictly radioactive LLW in Chapter 4. Inventories of MLLW currently stored at DOE sites are being thoroughly characterized. As a result, the waste at some sites could require reclassification, thereby causing significant changes in the inventories that reflect current data.

The FFCA amends RCRA to require (among other things) that DOE develop a Site Treatment Plan (STP) for each site which generates, stores, or treats MLLW. Specifically, Sect. 3021(b) of RCRA, as amended by the FFCA, requires that DOE prepare STPs for developing the technologies and capacities needed to treat MLLWs according to the standards required by EPA in Sect. 3004(m) of RCRA. All STPs are required to be in place by October 1995. These STPs could significantly impact future projections of MLLWs reported in this document for DOE sites.

8.2 WASTE CHARACTERIZATION

MLLWs stored at DOE sites have several common features: (1) such wastes have different blends of hazardous (chemical and/or physical) and radioactive components that dictate precautionary measures; (2) several processes may be involved in generating these wastes; and (3) various methods can be used to treat and prepare these wastes for storage. In recent years, EPA has adopted new toxicity-characteristic leaching procedures (TCLPs) for identifying some hazardous components of these wastes. Representative data on the chemical and

radionuclide compositions of MLLWs will be reported as more detailed site information becomes available.

In this chapter, inventories and annual generation rates of MLLW information are expressed in terms of physical and hazardous categories. RCRA-/state-regulated waste from DOE activities is generally classified into four physical/chemical categories: liquids, solids, specific waste forms, and final waste forms. TSCA-regulated waste from DOE activities is classified into four physical categories: solid, liquid, gas, and sludge, and two hazard categories: PCB and asbestos. MLLW from commercial activities is classified by hazardous categories.

8.3 SUMMARY OF DOE MLLW

Cumulative mass inventories and generation rates are reported in this chapter for most of the DOE sites listed in Table D.3, Appendix D. The rates are based on (a) RCRA-/state-regulated waste information reported in the MWIR⁷ and (b) DOE site information on TSCA-regulated wastes.⁹ Some generation rates may vary from current inventory additions because the generation levels reported do not reflect treatment that may take place before the waste is placed in interim storage. DOE site inventories and generation rates are given in both mass [kilograms (kg)] and volume [cubic meters (m³)] units. Until recently, many DOE sites tracked and reported their mixed waste streams in mass units. However, for disposal considerations, DOE is requiring these sites to report their mixed waste inventories and generation rates in units of disposal volume.

A breakdown of the MLLW volume inventory by site is graphically described in Fig. 8.1, and a breakdown of the volume-generation level by site is shown in Fig. 8.2. The current total volume inventory of MLLW at DOE sites is about 190,720 m³. About 49,340 m³ of MLLW are estimated to be generated during the period 1993 through 1997.

Summary cumulative inventories and projected cumulative generation for MLLW from DOE site operations are reported in Tables 8.2–8.5. For each site, information is reported for RCRA-/state-regulated wastes based on the MWIR⁷ and for TSCA-regulated wastes based on DOE site information submitted.⁹ Cumulative inventories of MLLW in interim storage are reported on a mass and volume basis in Tables 8.2 and 8.3, respectively. Projected 5-year mass generation and volume generation of these wastes from DOE site activities are given in Tables 8.4 and 8.5, respectively.

Detailed characteristics of RCRA-/state-regulated wastes from site operations are described in Tables 8.6–8.8 (adapted from refs. 7 and 10). The MWIR

documents inventories and generation levels for a wide range of categories of RCRA-/state-regulated wastes. These categories are based on various physical and chemical groupings and are described in Table 8.6 (adapted from ref. 10). Cumulative mass and volume inventories for these physical/chemical groups are given for each site in Table 8.7 and for the DOE complex in Table 8.8. Projected cumulative 5-year generation levels for each category are given in Table 8.9.

Detailed characteristics of TSCA-regulated MLLW from DOE site operations are reported by physical category (solid, liquid, gas, and sludge) in Tables 8.10–8.13 and by TSCA hazard category [polychlorinated biphenyls (PCBs), asbestos, and other specified materials] in Tables 8.14–8.17.

Cumulative 1993 mass inventories and volume inventories are given in the physical category tables for the TSCA-regulated wastes (Tables 8.10 and 8.11, respectively). Annual mass generation and volume generation of these wastes for 1993 are reported in Tables 8.12 and 8.13, respectively.

The hazardous category tables for TSCA-regulated wastes include information on PCB wastes and asbestos. Other MLLWs regulated by TSCA at each site are also indicated. PCBs are a group of synthetic organic chemicals once widely used in electrical equipment, special hydraulic systems, heat-transfer systems, and other industrial products. They are currently considered a possible carcinogen. Asbestos is a group of magnesium silicate compounds that are mixed with varying amounts of calcium and iron silicates. They are fibrous, noncombustible minerals that have been previously used in the manufacture of many fireproofing and insulating materials. However, such compounds have been found to produce long-term carcinogenic effects; consequently, their use is being phased out.

Cumulative 1993 mass and volume inventories are reported in the hazardous category tables for TSCA-regulated wastes (Tables 8.14 and 8.15, respectively). Annual mass generation and volume generation of these wastes for 1993 are reported in Tables 8.16 and 8.17, respectively.

Historical and annual projections of DOE-site MLLW are reported in Tables 8.18 and 8.19. These tables report annual mass data (Table 8.18) and annual volume data (Table 8.19) on generated TSCA-regulated MLLW from DOE site activities, based on ref. 9.

8.4 SPECIFIC DOE SITE MLLW

This section highlights the major ground rules and assumptions associated with the DOE site TSCA MLLW

information reported in Tables 8.2–8.5 and Tables 8.7–8.19. Most of the information reported in the subsections that follow describes the TSCA MLLW inventory, generation, and projection ground rules and assumptions documented in the specific DOE site submittals of ref. 9. Corresponding site information associated with RCRA-/state-regulated waste data are reported in the MWIR (ref. 7).

8.4.1 Ames Laboratory (AMES)

Materials containing radioactively contaminated asbestos comprise the TSCA MLLW inventories and projections for AMES in Tables 8.2, 8.3, 8.10, 8.11, 8.14, 8.15, 8.18, and 8.19. The inventories represent cumulative levels from 1986.

8.4.2 Argonne National Laboratory–East (ANL–E)

As of the end of 1993, ANL–E had no TSCA MLLW inventory. However, projections are reported in Tables 8.18 and 8.19. These projections assume that 200 kg of waste generated at the site will be packaged in a 55-gal (0.21-m³) drum.

8.4.3 Brookhaven National Laboratory (BNL)

Solid wastes, consisting of mostly PCBs and small quantities of asbestos, comprise the BNL TSCA MLLW inventories reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. These inventories represent cumulative levels from 1990. Projected wastes reported in Tables 8.18 and 8.19 assume a slight decrease in annual generation because of the phasing out of equipment and materials containing PCBs and asbestos.

8.4.4 Energy Technology Engineering Center (ETEC)

TSCA MLLW inventories reported for ETEC in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 represent levels accumulated during 1993. Projections are reported for generated mass in Table 8.18 and for generated volume in Table 8.19. These projections pertain to quantities of asbestos-containing floor tiles, which are scheduled to be removed during D&D activities.

8.4.5 Fernald Environmental Management Project (FEMP)

Information for this site is not available.

8.4.6 Grand Junction Projects Office (GJPO)

GJPO TSCA MLLWs are comprised of radioactive PCBs. Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 report cumulative inventories of these wastes from 1990. Projections reported in Tables 8.18 and 8.19 apply to wastes from the remediation of radioactive PCB ballasts. It is assumed that this remediation will subsequently decrease each year.

8.4.7 Hanford Site (HANF)

PCB wastes comprise the TSCA MLLW inventories reported for HANF in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. These inventories represent cumulative levels from 1987. Site projections reported in Tables 8.18 and 8.19 are based on assumed densities of 1,500 kg/m³ for soils and 1,000 kg/m³ for other waste.

8.4.8 Idaho National Engineering Laboratory (INEL)

TSCA MLLW inventories reported for INEL in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 include contributions from ANL–W. The year from which these inventories accumulated is not known. No projections of TSCA MLLW are available for Tables 8.18 and 8.19, however, it is anticipated that quantities of radioactive PCBs and asbestos will be generated on the INEL reservation in the future.

8.4.9 K-25 Site

For the K-25 Site, TSCA MLLW inventories are reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. These inventories represent cumulative levels from 1945. Quantities of TSCA MLLW generated during 1993 consist mainly of contributions from PCB capacitors and are reported in Tables 8.12, 8.13, 8.16, and 8.17. The volume inventory data reported are based on an assumed density of 1,440 kg/m³. Projections of TSCA MLLW to be generated at the K-25 Site are reported in Tables 8.18 and 8.19. Volume generation data are based on an assumed density of 800 kg/m³.

8.4.10 Lawrence Berkeley Laboratory (LBL)

LBL TSCA MLLW inventories, representing cumulative levels from 1988, are reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. Current inventories are comprised of mostly PCBs and some asbestos. The mass projections reported for LBL in Table 8.18 were estimated from site-reported volume projections (Table 8.19) by assuming an average waste density of 500 kg/m³.

Generation of radioactive PCB equipment and asbestos is sporadic and dependent upon decommissioning schedules. Estimates of 1994 and 1995 LBL generation levels reflect quantities of asbestos from glove boxes.

8.4.11 Lawrence Livermore National Laboratory (LLNL)

Inventories of TSCA-regulated MLLW at LLNL are reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. These quantities represent cumulative levels from 1990. No TSCA MLLW is projected from future LLNL activities. Current inventories resulted from either the removal of PCB-containing transformers from service or from renovation/closure of buildings containing asbestos.

8.4.12 Los Alamos National Laboratory (LANL)

Inventories of TSCA MLLW at LANL reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 represent cumulative levels from 1970. These reported inventories are based on limited records kept of asbestos and PCB wastes during the early operating years. A significant increase occurred during 1993 from the addition of contaminated equipment to the asbestos inventory.

8.4.13 Mound Plant (MOUND)

TSCA MLLWs are not routinely generated at MOUND. TSCA MLLW inventories reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 are cumulative levels of asbestos from 1947. After 1994, no major generation of either PCB or asbestos wastes are anticipated. Projections reported in Tables 8.18 and 8.19 assume a generation rate of two 55-gal drums per year of radioactively contaminated asbestos pipe covers and/or floor tiles.

8.4.14 Naval Reactor (NR) Sites

Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 report the total inventories of several NR sites, including contributions from the Bettis Atomic Power Laboratory (BAPL), the Knolls, Kesselring (KESS), and Windsor (WIND) sites of the Knolls Atomic Power Laboratory (KAPL); and the INEL Naval Reactors Facility (NRF). The levels reported in these tables reflect cumulative quantities from as early as 1987. Projected wastes reported for NR sites in Tables 8.18 and 8.19 are anticipated to result from a variety of site activities, including D&D, plant lay-up, ship defueling, and asbestos removal/replacement.

8.4.15 Oak Ridge National Laboratory (ORNL)

Inventories of TSCA MLLW at ORNL reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 are cumulative levels from 1968. Site generation projections reported in Tables 8.18 and 8.19 pertain to radioactivity contaminated asbestos.

8.4.16 Paducah Gaseous Diffusion Plant (PAD)

The PAD site TSCA MLLW inventories reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 are cumulative levels from 1980. Projections reported for generated TSCA wastes in Tables 8.18 and 8.19 are based on the following assumptions:

- a routine waste generation of 608 m³/year;
- the mass of a 55-gal (0.21-m³) drum is 159 kg;
- generation levels resulting from routine site activities, environmental restoration activities, and engineering project activities;
- reported quantities apply to waste solids and liquids, not sludges; and
- reported quantities exclude wastes contaminated by both PCBs and RCRA hazardous materials.

8.4.17 Portsmouth Gaseous Diffusion Plant (PORTS)

At PORTS, TSCA-regulated MLLW is comprised of both PCBs and asbestos. Inventories of these wastes represent cumulative levels from 1954, and are reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. Projections of generated TSCA wastes from PORTS site activities are reported in Tables 8.18 and 8.19. These forecasts are based on annual historical data and reflect a 10% reduction/year to account for waste minimization.

8.4.18 Rocky Flats Plant (RFP)

Both radioactive PCBs and asbestos are included in the RFP TSCA MLLW inventories reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. These inventories represent cumulative levels from 1987. Projections reported in Tables 8.18 and 8.19 are based on separate assumptions pertaining to PCBs and asbestos. PCB generation rates assume that historical PCB spill sites will be funded for remediation during the years 1995–2000, and that these sites will contain only low-level radioactivity. Asbestos generation rates assume funding for asbestos abatement projects, no significant changes in regulations affecting encapsulation and abatement, and increases in waste generation from building transition and D&D activities.

8.4.19 Sandia National Laboratory/New Mexico (SNL/NM)

Radioactive asbestos comprises the SNL/NM TSCA MLLW inventories reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15. These inventories are levels cumulative from 1989. Future TSCA MLLWs cannot be estimated at this time. These wastes are expected to be mostly asbestos from building D&D activities. Some older SNL/NM buildings slated for D&D are known to contain radiologically contaminated asbestos. PCBs are expected to comprise a much smaller portion of future-generated SNL/NM TSCA MLLW.

8.4.20 Savannah River Site (SRS)

SRS TSCA MLLW inventories reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 represent cumulative levels from 1986. Most of the SRS TSCA wastes are asbestos materials whose mass was estimated from site-reported volume data using an assumed density of 500 kg/m³. This density was also used to estimate the TSCA MLLW mass generation rates reported in Tables 8.12, 8.16, and 8.18. The projections reported in Tables 8.18 and 8.19 assume that 15% of forecasted asbestos generation rates will be also be contaminated as LLW.

8.4.21 West Valley Demonstration Project (WVDP)

TSCA MLLW inventories reported for WVDP in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 are cumulative quantities of PCBs and asbestos from 1982. Projections reported in Tables 8.18 and 8.19 do not include PCBs because of forecasting uncertainties. The estimates reported for asbestos generation are based on actual generation levels achieved during January–June 1994.

8.4.22 Y-12 Plant (Y-12)

Y-12 Plant TSCA MLLW inventories reported in Tables 8.2, 8.3, 8.10, 8.11, 8.14, and 8.15 represent cumulative levels from 1982. These wastes are PCBs regulated by TSCA. The inventories reported show significant reductions because the site now has the ability to separate quantities of RCRA-regulated wastes from TSCA-regulated wastes. (Previous estimates of TSCA MLLW at Y-12 included contributions from RCRA-regulated wastes). Contributions from asbestos are not reported because asbestos is considered to be a sanitary waste at the Y-12 Plant. Waste volumes reported were estimated from site reported waste mass information using an assumed density of 1,500 kg/m³ for solids and 1,000 kg/m³ for liquids. In Tables 8.10–8.13, the quantity

of generated sludge cannot be broken out and, therefore, is included in the solid or liquid data given in these tables. For Tables 8.18 and 8.19, projected TSCA MLLW generation rates for the Y-12 Plant are based on 1993 generation levels.

8.5 COMMERCIAL MLLW

In recent years, the NRC and EPA co-sponsored a survey study to compile a national profile of the volumes, characteristics, and treatability of commercially generated MLLW. Such a profile was designed to provide the following:

- states and compacts with information to assist in planning and developing adequate disposal capacity for low-level radioactive waste, including MLLW, as mandated by the Low-Level Radioactive Waste Policy Amendments Act;¹¹
- private developers with a clearer idea of the characteristics and volumes of mixed waste and the technical capability and capacity needed to treat this waste; and
- a reliable national data base of the volumes, characteristics, and treatability of commercial mixed waste.

In addition, the data were collected to provide a basis for possible federal actions that would effectively manage and regulate the treatment and disposal of mixed waste. Results from this investigation are documented in ref. 12 and summarized in this report.

The study identified the types and volumes of MLLW generated from five groups of facilities: nuclear utilities, medical facilities, academic institutions, industrial facilities, and NRC-licensed government facilities. The study selected a random sample of 1,323 facilities out of a total target population of 2,936 facilities. Data from the 1,016 completed mixed waste survey questionnaires (77% response rate) received and the use of appropriate weighting factors indicate that approximately 3,950 m³ of MLLW—of which 72% was liquid scintillation fluids—were generated in the United States in 1990.

The study divided the MLLW into several hazardous stream categories, including the following:

- Liquid scintillation fluids from laboratory counting activities.
- Waste oil from various pumps, equipment, and maintenance activities.

- Chlorinated or fluorinated organics and chlorinated fluorocarbons, including sludges and contaminated filters from dry cleaning, refrigeration, degreasing, and decontamination operations. Chloroform and a number of pesticides are also included.
- Other organics, including miscellaneous solvents, reagents, expired products, and other organic compounds (or materials like rags, wipes, etc., contaminated with such) from research and manufacturing activities, experimental procedures, and laboratory and process equipment cleaning.
- Lead wastes, including lead shielding and lead solutions for research and industrial facilities.
- Mercury wastes, including equipment and debris contaminated with mercury.
- Chromate wastes, including chromium-contaminated solutions for research, maintenance, and waste treatment (ion exchange) operations.
- Cadmium wastes from decontamination activities.
- Aqueous corrosive wastes, including inorganic acids, or, in some instances, bases from cleanup and decontamination activities.
- Other hazardous materials, including materials (a) either not readily assignable to any one of the previous categories or (b) containing a number of different hazardous materials.

Summaries of estimated generation rates, amounts in storage, and amounts treated for each of the five facility categories and each of the hazardous waste stream categories are shown in Tables 8.20 and 8.21, respectively (data from ref. 12). Upper and lower bounds were also set for the volume of mixed waste that is untreatable under current technologies by making the simplifying assumption that liquid scintillation fluids, oil, nonhalogenated organics, and corrosive wastes are treatable. Deducting their total contribution from the estimated total mixed waste generation rate leaves residues of about 524 m³. This upper bound for untreatable mixed waste is about 13% of the estimated 1990 national generation rate of 3,950 m³. However, it was noted that the capacity to treat *all* of the so-called treatable mixed waste may not be available.

8.6 REFERENCES

1. U.S. Congress, Atomic Energy Act of 1954, Pub. L. 83-703, Aug. 15, 1954.
2. U.S. Congress, Resource Conservation and Recovery Act of 1976, Pub. L. 94-580, Oct. 21, 1976, as amended by the Hazardous and Solid Waste Amendments Acts of 1984, Pub. L. 98-616, Nov. 9, 1984.
3. U.S. Congress, Toxic Substances Control Act of 1976, Pub. L. 94-469, Oct. 11, 1976.
4. U.S. Environmental Protection Agency, "Identification and Listing of Hazardous Waste," *Code of Federal Regulations*, 40 CFR Parts 260-271 (1986).
5. U.S. Environmental Protection Agency, "Subchapter R—Toxic Substances Control Act," *Code of Federal Regulations*, 40 CFR Parts 700-799 (1988).
6. Betsy Owen, Science Applications International Corporation, Germantown, Maryland, facsimile to S. N. Storch, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated June 16, 1994, containing the updated respective EPA mixed waste authorization statuses for states and U.S. territories as of April 30, 1994.
7. U.S. Department of Energy, Office of Environmental Management, *Mixed Waste Inventory Report Data Base System*, Phase II, Rev. 1, personal computer software, MS-DOS 3.3, 50 MB disk, Washington, D.C. (May 1994).
8. U.S. Congress, Federal Facility Compliance Act of 1992, Pub. L. 102-386, Oct. 6, 1992.

9. DOE site TSCA-regulated MLLW data submittal attachments, submitted to the IDB Program during July–December 1994. The following TSCA MLLW submittals were received and reviewed by the IDB Program before analysis and integration. Preceding each submittal is the site (in parentheses) to which it refers.
 - a. (AMES) Lowell K. Mathison, Ames Laboratory, Ames, Iowa, correspondence to James E. Fletcher, DOE Chicago Operations Office, Ames Laboratory Management Office, Argonne, Illinois, submitting Ames Laboratory TSCA MLLW information, dated July 13, 1994.
 - b. (ANL-E) Michael A. Sodaro, Argonne National Laboratory, Argonne, Illinois, correspondence to A. L. Taboas, DOE Argonne Area Office, Argonne, Illinois, "Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," dated July 22, 1994.
 - c. (ANL-W) See reference for INEL.
 - d. (BNL) Carson L. Nealy, DOE Brookhaven Area Office, Upton, New York, correspondence to Jerry A. Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Brookhaven National Laboratory's (BNL) Response to the 1994 Integrated Data Base Information Request," dated July 20, 1994.
 - e. (ETEC) Kevin Hartnett, DOE Oakland Operations Office, Oakland, California, correspondence to Mathew Zenkovich, DOE/EM Office of Program Integration, Technical Analysis Division, "Data Request in Support of 1994 Integrated Data Base Report," dated Aug. 11, 1994.
 - f. (FNAL) J. Donald Cossairt, Fermi National Accelerator Laboratory, Batavia, Illinois, correspondence to Andrew E. Mravca, DOE Batavia Area Office, Batavia, Illinois, "DOE Site Low-Level Waste Information Request for 1994 Integrated Data Base (IDB) Report (DOE/RW-0006, Rev. 10)," dated Aug. 23, 1994.
 - g. (FEMP) No submittal provided.
 - h. (GJPO) Todd VanderHoogt, DOE Grand Junction Projects Office, Grand Junction, Colorado, correspondence to Steve Storch, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Sept. 20, 1994.
 - i. (HANF) No submittal correspondence provided with data attachment.
 - j. (INEL) R. R. Piscitella, EG&G Idaho, Inc., Idaho Falls, Idaho, correspondence to J. A. Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Idaho National Engineering Laboratory (INEL) Input to Integrated Data Base (DOE/RW-0006, Rev. 10)," RRP-35-94, dated Sept. 29, 1994.
 - k. (ITRI) Joe L. Mauderly, Lovelace Biomedical and Environmental Research Institute, Inc., Albuquerque, New Mexico, correspondence to George K. Laskar, DOE Kirtland Area Office, Albuquerque, New Mexico, "ITRI 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," dated Aug. 11, 1994.
 - l. (K-25) Jeff Wilson, Martin Marietta Energy Systems, Inc., Central Waste Management Division, correspondence to Steve Storch, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, transmitting updated K-25 Site MLLW information, dated Dec. 8, 1994.
 - m. (KCP) Margaret E. Stockdale, DOE Kansas City Area Office, Kansas City, Missouri, correspondence to Jerry Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, dated Aug. 12, 1994.
 - n. (LANL) I-Li Chen, Los Alamos National Laboratory, Los Alamos, New Mexico, correspondence to Jerry Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Waste Information IDB Report," CST-7G-94-366, dated July 6, 1994.

- o. (LBL) Kam Tung, Lawrence Berkeley Laboratory, Berkeley, California, correspondence to Jerry A. Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Submission of Data for the 1994 Integrated Data Base Annual Report," HW-94-257, dated July 1, 1994.
- p. (LLNL) No submittal correspondence provided with data attachment.
- q. (MOUND) Raymond J. Finney, EG&G Mound Applied Technologies, Miamisburg, Ohio, correspondence to Robert S. Rothman, DOE Miamisburg Area Office, Miamisburg, Ohio, "Data Request in Support of the 1994 Integrated Data Base Report," dated Aug. 24, 1994.
- r. (NR sites/KAPL) A. R. Seepo, DOE Schenectady Naval Reactors Office, Schenectady, New York, correspondence to Jerry Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report," REC&SD:GJV#94-53, dated July 21, 1994.
- s. (NR sites/BAPL/NRF) E. D. Shollenberger, DOE Pittsburgh Naval Reactors Office, West Mifflin, Pennsylvania, correspondence to Jerry Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Radioactive Waste Data for the 1994 Integrated Data Base Report," dated July 28, 1994.
- t. (NTS) No submittal correspondence provided.
- u. (ORISE) No submittal correspondence provided with data attachment.
- v. (ORNL) No submittal correspondence provided with data attachment.
- w. (PAD) Carol Tippin, Martin Marietta Energy Systems, Inc., Paducah, Kentucky, correspondence to Stephen Storch, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, transmitting updated PAD TSCA MLLW information, dated July 29, 1994.
- x. (PANT) No submittal correspondence provided.
- y. (PINELLAS) No submittal correspondence provided.
- z. (PORTS) Chris Warner, Martin Marietta Energy Systems, Inc., Portsmouth, Ohio, correspondence to S. N. Storch, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, submitting PORTS TSCA MLLW information, dated Oct. 25, 1994.
- aa. (PPPL) No submittal correspondence provided.
- ab. (RFP) Paul Cote and Mary Vargas, DOE Rocky Flats Office, Golden, Colorado, correspondences to Jerry A. Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 94-DOE-07365 and 94-DOE-07496, submitting RFP TSCA MLLW information, dated July 19, 1994.
- ac. (SLAC) Kevin Hartnett, DOE Oakland Operations Office, correspondence to Mathew Zenkovich, DOE/EM Office of Program Integration, Technical Analysis Division, Washington, D.C., "Data Request in Support of the 1994 Integrated Data Base Report," dated Sept. 21, 1994.
- ad. (SNL/CA) Sarah C. K. O'Connor, Sandia National Laboratory/California, correspondence to Alan Icenhour, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Department of Energy Site Request for 1994 Integrated Data Base Report," dated Aug. 30, 1994.

- ae. (SNL/NM) Maureen J. Lincoln, Sandia National Laboratory/New Mexico, Albuquerque, New Mexico, correspondence to Ted Pietrok, DOE Kirtland Area Office, Albuquerque, New Mexico, "IDB Data Base Updated," dated July 15, 1994.
 - af. (SRS) H. F. Daugherty, Westinghouse Savannah River Company, Aiken, South Carolina, correspondence to Michael G. O'Rear, DOE Savannah River Operations Office, Aiken, South Carolina, "Information Request for 1994 Integrated Data Base (IDB) Report," SWE-SWD-94-0217, dated Aug. 23, 1994.
 - ag. (Y-12) N. E. Leonetti, Y-12 Plant, Oak Ridge, Tennessee, correspondence to J. A. Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Deliverable, Department of Energy Site Low-Level Waste Information Request for 1994 Integrated Data Base Report (DOE/RW-0006, Rev. 10)," dated July 15, 1994.
 - ah. (WVDP) P. S. Klanian, West Valley Nuclear Services Company, Inc., West Valley, New York, correspondence to J. A. Klein, IDB Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Submittal of Low-Level Waste Information for the 1994 Integrated Data Base Report," WZ:94:0123, dated Aug. 12, 1994.
- 10. U.S. Department of Energy, Office of Waste Management, *DOE Waste Treatability Groups Guidance*, final draft, Aug. 15, 1994.
 - 11. U.S. Congress, Low-Level Radioactive Waste Policy Amendments Act of 1985, Pub. L. 99-240, Jan. 15, 1986.
 - 12. J. A. Klein, et al., *National Profile on Commercially Generated Low-Level Radioactive Mixed Waste*, prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee, for U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency, NUREG/CR-5938, Oak Ridge National Laboratory-6731 (December 1992).

Fig. 8.1. Total volume inventory of all DOE MLLW. **Fig. 8.2. Projected cumulative volume generation of all DOE MLLW during 1993-1997.**

Table 8.1. Thirty-seven states and territories with EPA mixed waste authorization^a

State/territory	Effective date	State/territory	Effective date
Alabama	11/23/93	Montana	03/21/94
Arizona	01/22/93	Nebraska	12/03/88
Arkansas	05/29/90	Nevada	06/29/92
California	08/01/92	New Mexico	07/25/90
Colorado	11/07/86	New York	05/07/90
Connecticut	12/31/90	North Carolina	11/21/89
Florida	02/12/91	North Dakota	08/24/90
Georgia	09/26/88	Ohio	06/30/89
Guam	10/10/89	Oklahoma	11/27/90
Idaho	04/09/90	Oregon	05/29/90
Illinois	04/30/90	South Carolina	09/13/87
Indiana	09/30/91	South Dakota	06/17/91
Kansas	06/25/90	Tennessee	08/11/87
Kentucky	12/19/88	Texas	03/15/90
Louisiana	10/26/91	Utah	03/07/89
Michigan	12/26/89	Vermont	08/06/93
Minnesota	06/23/89	Washington	11/23/87
Mississippi	05/28/91	Wisconsin	04/24/92
Missouri	03/12/93		

^aBased on ref. 6. Information as of April 30, 1994.

Table 8.2. Cumulative mass (kg) inventories of MLLW from DOE site activities^{a,b}

Site	RCRA/state ^c	TSCA ^d	Total
AMES	750	2,600	3,350
ANL-E	e	0	e
ANL-W	8,008	e	8,008
BNL	78,394	445	78,839
ETEC	1,302,521	720	1,303,241
FEMP	e	e	e
FNAL	e	0	e
GJPO	839	10,886	11,725
HANF ^f	3,124,609 ^g	104,390	3,228,999
INEL ^h	13,275,118	633	13,275,751
ITRI	1,415	0	1,415
K-25	38,918,281	4,519,915	43,438,196
KCP	199	0	199
LANL	e	2,431,988	2,431,988
LBL	13,249	483	13,732
LLNL	203,336	929	204,265
MOUND	45,076	2,059	47,135
NR sites ⁱ	25,000	9,000	34,000
NTS	165	0	165
ORISE	e	0	e
ORNL	2,936,264	206,810	3,143,074
PAD	468,274	2,797,904	3,266,178
PANT	e	0	e
PINELLAS	0	0	0
PORTS	6,690,542	2,391,500	9,082,042
PPPL	41	0	41
RFP	e	30,080	30,080
RMI	16,478	e	16,478
SLAC	e	0	e
SNL/CA	4,425	0	4,425
SNL/NM	3,812	68	3,880
SRS	e	64,436	64,436
WVDP	34,654	6,694	41,348
Y-12	17,841,567	198,000	18,039,567
Others ^j	39,329,893	e	39,329,893
Total	124,322,908 ^k	12,779,540 ^k	137,102,448 ^k

^aMaterials may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bIn general, densities of 500 kg/m³ for compressed gases, 1,000 kg/m³ for liquids, and 1,500 kg/m³ for solids and sludges were assumed to estimate masses when site did not report mass data.

^cBased on the MWIR, ref. 7. Inventories are associated with the data indicated in Table 8.7.

^dBased on the DOE site data submittals of ref. 9. Inventories as of December 31, 1993.

^eInformation not available or unknown.

^fIncludes contributions from PNL.

^gConsists of contributions from newly generated solid waste.

^hIncludes contributions from the Naval Reactors Facility (NRF).

ⁱIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

^jIncludes contributions from Battelle Columbus Laboratories Decommissioning Project, Colonie Interim Storage Site, General Atomics facility, Laboratory for Energy-Related Health Research, Middlesex Sampling Plant (39,170,000), University of Missouri, Weldon Spring Site Remedial Action Project, and 6 naval shipyards (Charleston, South Carolina; Mare Island, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

^kExcludes contributions from sites that did not report complete mass data.

Table 8.3. Cumulative volume (m³) inventories of MLLW from DOE site activities^a

Site	RCRA/state ^b	TSCA ^c	Total
AMES	0.4	3.4	3.8
ANL-E	113.8	0	113.8
ANL-W	16.1	d	16.1
BNL	84.9	1.0	85.9
ETEC	656.6	3.2	659.8
FEMP	2,597.3	d	2,597.3
FNAL	d	0	d
GJPO	0.8	46.6	47.4
HANF ^e	3,102.0 ^f	90.0	3,192.0
INEL ^g	25,479.2	1.1	25,480.3
ITRI	3.6	0	3.6
K-25	27,434.6	3,138.3	30,572.9
KCP	0.8	0	0.8
LANL	665.4	4,016.2	4,681.6
LBL	22.0	0.6	22.6
LLNL	215.0	0.9	215.9
MOUND	76.6	8.7	85.3
NR sites ^h	36.3	18.0	54.3
NTS	0.4	0	0.4
ORISE	d	0	d
ORNL	2,698.6	1,384.0	4,082.6
PAD	596.5	3,905.7	4,502.2
PANT	133.9	0	133.9
PINELLAS	0	0	0
PORTS	9,049.8	3,826.0	12,875.8
PPPL	-0.0	0	-0.0
RFP	56,029.6	76.0	56,105.6
RMI	22.1	d	22.1
SLAC	d	0	d
SNL/CA	11.3	0	11.3
SNL/NM	65.7	0.4	66.1
SRS	6,554.4	129.6	6,684.0
WVDP	22.9	41.2	64.1
Y-12	11,904.8	138.3	12,043.1
Others ⁱ	26,295.0	d	26,295.0
Total	173,890.3	16,829.2	190,719.5

^aMaterials may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bBased on the MWIR, ref. 7. Inventories are associated with the dates in Table 8.7.

^cBased on the DOE site data submittals of ref. 9. Inventories as of December 31, 1993.

^dInformation not available or unknown.

^eIncludes contributions from PNL.

^fConsists of contributions from newly generated solid waste.

^gIncludes contributions from the Naval Reactors Facility (NRF).

^hIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

ⁱIncludes contributions from Battelle Columbus Laboratories Decommissioning Project, Colonie Interim Storage Site, General Atomics facility, Laboratory for Energy-Related Health Research, Middlesex Sampling Plant (24,480 m³), University of Missouri, Weldon Spring Remedial Action Project, and 6 naval shipyards (Charleston, South Carolina; Mare Island, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

Table 8.4. Projected 5-year (1993–1997) cumulative mass (kg) generation of MLLW from DOE site activities^{a,b}

Site	RCRA/state ^c	TSCA ^d	Total
AMES	154	300	454
ANL-E	e	125,686	125,686
ANL-W	4,848	e	4,848
BNL	27,243	5,817	33,060
ETEC	1,200,000	5,560	1,205,560
FEMP	45,367	e	45,367
FNAL	e	0	e
GJPO	422	260	682
HANF ^f	5,597,207 ^g	2,133,178	7,730,385
INEL ^h	2,834,764	e	2,834,764
ITRI	19,192	0	19,192
K-25	6,736,260	2,839,840	9,576,100
KCP	0	0	0
LANL	e	154,125	154,125
LBL	e	4,645	4,645
LLNL	1,019,830	133	1,019,963
MOUND	e	2,324	2,324
NR sites ⁱ	56,792	365,480	422,272
NTS	120	0	120
ORISE	e	0	e
ORNL	669,510	27,102	696,612
PAD	e	4,621,620	4,621,620
PANT	e	0	e
PINELLAS	0	0	0
PORTS	4,653,045	1,238,490	5,891,535
PPPL	14	0	14
RFP	e	47,794	47,794
RMI	5,445	e	5,445
SLAC	e	0	e
SNL/CA	27,333	0	27,333
SNL/NM	e	e	e
SRS	e	840,800	840,800
WVDP	18,419	5,507	23,926
Y-12	2,120,240	182,500	2,302,740
Others ^j	60,085	e	60,085
Total	25,096,286 ^k	12,601,161 ^k	37,697,447 ^k

^aSpecific site information is provided in Sect. 8.4.

^bIn general, densities of 500 kg/m³ for compressed gases, 1,000 kg/m³ for liquids, and 1,500 kg/m³ for solids and sludges were assumed to estimate masses when site did not report mass data.

^cBased on the MWIR, ref. 7. RCRA/state projections for six sites [Ames Laboratory (AMES), Argonne National Laboratory-East (ANL-E), Battelle Columbus Laboratories Decommissioning Project (BCLDP), Energy Technology Engineering Center (ETEC), Laboratory for Energy-Related Health Research (LEHR), and Savannah River Site (SRS)] include contributions from DOE environmental restoration (EM-40) wastes.

^dBased on the DOE site data submittals of ref. 9.

^eInformation not available or unknown.

^fIncludes contributions from PNL.

^gIncludes newly generated solid waste. Excludes 114,000,000 kg of process wastewater.

^hIncludes contributions from the Naval Reactors Facility (NRF).

ⁱIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

^jIncludes contributions from BCLDP, Colonie Interim Storage Site (CISS), General Atomics (GA) facility, LEHR, Middlesex Sampling Plant, University of Missouri (MURR), and Weldon Spring Site Remedial Action Project (WSSRAP), and 6 naval shipyards (Charleston, South Carolina; Mare Island, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

^kExcludes contributions from sites that did not report complete mass data.

Table 8.5. Projected 5-year (1993–1997) cumulative volume (m³) generation of MLLW from DOE site activities^a

Site	RCRA/state ^b	TSCA ^c	Total
AMES	0.2	1.1	1.3
ANL-E	2,176.4	130.9	2,307.3
ANL-W	3.9	d	3.9
BNL	27.4	11.9	39.3
ETEC	600.0	12.3	612.3
FEMP	43.0	d	43.0
FNAL	d	0	d
GJPO	0.3	0.6	0.9
HANF ^f	5,383.5 ^g	1,986.5	7,370.0
INEL ^h	2,456.1	d	2,456.1
ITRI	10.9	0	10.9
K-25	6,087.5 ^c	3,539.0	9,626.5
KCP	0.0	0	0.0
LANL	529.3	258.3	787.6
LBL	150.7	9.6	160.3
LLNL	1,075.1	0.1	1,075.2
MOUND	4.3	8.3	12.6
NR sites ⁱ	77.7	790.0	867.7
NTS	0.2	0	0.2
ORISE	d	0	d
ORNL	568.5	189.2	757.7
PAD	d	3,425.1	3,425.1
PANT	343.9	0	343.9
PINELLAS	0	0	0
PORTS	6,383.2	1,438.5	7,821.7
PPPL	~0.0	0	~0.0
RFP	3,368.7	113.7	3,482.4
RMI	7.0	d	7.0
SLAC	d	0	d
SNL/CA	72.5	0	72.5
SNL/NM	d	d	d
SRS	4,432.3	1,681.6	6,113.9
WVDP	13.5	37.0	50.5
Y-12	1,640.3	134.5	1,774.8
Others ^j	116.3	d	116.3
Total	35,572.7	13,768.2	49,340.9

^aSpecific site information is provided in Sect. 8.4.

^bBased on the MWIR, ref. 7. RCRA/state projections for six sites [Ames Laboratory (AMES), Argonne National Laboratory-East (ANL-E), Battelle Columbus Laboratories Decommissioning Project (BCLDP), Energy Technology Engineering Center (ETEC), Laboratory for Energy-Related Health Research (LEHR), and Savannah River Site (SRS)] include contributions from DOE environmental restoration (EM-40) wastes.

^cBased on the DOE site data submittals of ref. 9.

^dInformation not available or unknown.

^eSite did not report volume data in the MWIR (ref. 7). Densities of 1,000 kg/m³ for liquids and 1,500 kg/m³ for solids and sludges were used to estimate volumes.

^fIncludes contributions from PNL.

^gIncludes contributions from newly generated solid waste. Excludes 114,000 m³ of process wastewater.

^hIncludes contributions from the Naval Reactors Facility (NRF).

ⁱIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

^jIncludes contributions from BCLDP, Colonie Interim Storage Site (CISS), General Atomics (GA) facility, LEHR, Middlesex Sampling Plant, University of Missouri (MURR), Weldon Spring Remedial Action Project (WSSRAP), and 6 naval shipyards (Charleston, South Carolina; Mare Island, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).

Table 8.6. Physical/chemical form groupings used to characterize RCRA- and state-regulated MLLW from DOE activities^a

Waste group/category	Description
<i>Liquids^b</i>	
Aqueous liquids/slurries	Liquids and slurries containing less than 1% total organic carbon (TOC). They may be acidic, basic, neutral, or cyanide
Organic liquids	Liquids and slurries containing $\geq 1\%$ TOC. They may either be pure organic liquids or mixtures of aqueous and organic liquids
Unknown liquids	Bulk liquid or slurry waste which can not be further categorized as aqueous or organic because it is not known if the TOC level is less, or greater than 1%
<i>Solids^c</i>	
Inorganic process residues	Wastes that are at least 50 vol % inorganic solids, excluding soil, that do not meet the land-disposal-restricted (LDR) criteria for classification as debris. These are defined as process residues with sufficient inorganic solids content such that a minimum of approximately 20 wt % of the waste would remain as residue (i.e., ash/solids) following incineration. Examples of inorganic process residues are inorganic particulates, sludges, salt wastes, and cemented solids
Organic process residues	Wastes that are at least 50 vol % organic solids that do not meet the LDR criteria for classification as debris. These are defined as process residues with a base structure that is primarily organic. The matrix may contain some inorganic solids content such that up to approximately 20 wt % of the waste would remain as residue (i.e., ash/solids) following incineration. Examples of organic process residues are organic particulates, sludges, and chemicals
Uncategorized process residues	<p>Wastes that are at least 50 vol % solid materials, excluding soil, that do not meet the LDR criteria for classification as debris that either:</p> <ol style="list-style-type: none"> (1) lacks adequate characterization information for assignment into the inorganic process residues or the organic process residues categories, or (2) is inconsistent with the definitions for the inorganic process residues or the organic process residues categories
Soils	Wastes that are at least 50 vol % soil, including contamination from spills, etc. Soil mixed with debris is included in this category, provided soil makes up at least 50 vol % of the matrix
Inorganic debris	Wastes that meet the LDR criteria for classification as debris and are approximately 95 vol %, or more, metal or inorganic nonmetal debris. Examples of inorganic debris are metal (excluding bulk lead), concrete, glass, and brick
Organic debris	Wastes that meet the LDR criteria for classification as debris and are approximately 95 vol %, or more, organic materials. Examples of organic debris are materials constructed of plastic, rubber, wood, paper, cloth, graphite, and biological materials

Table 8.6 (continued)

Waste group/category	Description
Heterogeneous debris	Wastes that are at least 50 vol % debris materials which do not meet the criteria for assignment into either inorganic or organic debris. An example is waste that is essentially entirely debris but is not dominant (i.e., approximately 95 vol %, or more) in either inorganic or organic debris materials. Another example is waste that is at least 50 vol % debris materials with the balance being soil or solid process residues
Uncategorized debris	Wastes that meet the LDR criteria for classification as debris, however, they lack adequate characterization information for assignment as inorganic, organic, or heterogeneous debris
Unknown solids	Solid wastes for which insufficient characterization information exist to further categorize as a solid process residue, soil, or debris
<i>Specific waste forms^d</i>	
Lab packs	Wastes packaged as lab packs. Lab packs are defined as waste with inner containers of free liquids or solid chemicals surrounded by absorbents and packaged within a larger outer container. The absorbents can be solid process residues materials or debris. Examples of absorbent materials include rags, vermiculite, diatomaceous earth, and paper wipes. This category does not include lab packs of elemental liquid mercury
Reactive metals	Reactive metal wastes, which are defined as wastes meeting the criteria for classification as water-reactive or ignitable-reactive per the Third Third LDR rule (55FR 22545 and 22553). Typically, these waste streams are sodium metal or sodium metal alloys, but can also include particulate fines of aluminum, uranium, zirconium, or other pyrophoric materials. The waste may be mixed with stabilizing materials
Explosives/propellants	Wastes consisting of substances which undergo rapid chemical transformations which produce large amounts of gases and heat. The gases rapidly expand at velocities exceeding the speed of sound (due to the heat of reaction), which creates a shock wave and explosion. All waste that meets this definition is identified here, regardless of the specific physical form
Compressed gases/aerosols	Wastes meeting the criteria for classification as ignitable compressed gases per the Third Third LDR rule (55FR 22545). Typically, these are wastes consisting of pressurized gas cylinders or aerosol cans. Depressurized gas cylinders or aerosol cans would not be included in this category
Elemental mercury	Wastes that are bulk, pourable liquid mercury. The liquid mercury may be packaged in small containers within a larger container holding other materials (e.g., lab pack configuration)
Elemental lead	Wastes that contain at least 50 vol % bulk elemental lead. Examples of wastes in this category are lead bricks, sheets, and pipes. The lead may be activated or nonactivated
Beryllium waste	Wastes that are essentially beryllium dust or beryllium chips and fines that may also contain beryllium dust. This category does not include debris waste that is contaminated with beryllium dust
Batteries	Wastes consisting of lead acid, cadmium, or other batteries. The batteries may be packaged with absorbent materials (e.g., particulates, rags)

Table 8.6 (continued)

Waste group/category	Description
<i>Unknown matrix</i>	
Uncategorized matrix	Wastes for which insufficient characterization information is known to enable categorization as a liquid or solid or as one of the specific waste forms
<i>Final waste forms^c</i>	
Cement forms	Wastes that have been immobilized with grout or other cement-type binders and meet disposal criteria, including applicable LDR treatment standards
Vitrified forms	Wastes that have been immobilized via vitrification and meet disposal criteria, including applicable LDR treatment standards

^aBased on the MWIR (ref. 7) and ref. 8.

^bThis category addresses waste streams that are liquid, including pumpable slurries. Usually, slurries are considered pumpable with a total suspended/settled solids (TSS) content of up to approximately 35 to 40%.

^cThis category addresses waste with physically solid matrices, including sludges. As opposed to slurries, sludges are considered nonpumpable. Solids may be initially categorized according to the general classifications of process residues, soil, and debris.

^dThis category addresses certain waste forms that require specific treatment technologies not expected to be common with other waste forms. The waste may be inherently hazardous.

^eThis category addresses final waste forms that meet disposal criteria, including applicable LDR treatment standards.

Table 8.7. Cumulative mass and volume inventories of RCRA- and state-regulated MLLW at each DOE site^a

Site	Category ^b	Inventory		
		Date(s) ^c	Mass (kg)	Volume (m ³)
AMES	Aqueous liquids/slurries		46	0.05
	Lab packs		24	0.25
	Elemental lead		680	0.10
	AMES total	12/31/92–11/17/93	750	0.40
ANL–E	Aqueous wastewater		d	0.1
	Debris		d	27.4
	Process residues		d	28.6
	Lab packs		d	44.7
	Elemental lead		d	12.9
	Soils		d	0.1
	ANL–E total	07/01/93	d	113.8
ANL–W	Aqueous liquids/slurries		537	0.4
	Debris		1,032	5.6
	Process residues		449	3.9
	Organic liquids		9	<0.1
	Reactive metals		5,981	6.2
	ANL–W total	09/30/93	8,008	16.1
BNL	Process residues		58,615	59.8
	Lab packs		1,953	6.0
	Elemental lead		1,639	1.5
	Elemental mercury		514	0.1
	Organic liquids		15,673	17.5
	BNL total	07/31/93	78,394	84.9
ETEC	Aqueous liquids/slurries		140	0.1
	Debris		961	14.0
	Process residues		3,400	4.5
	Elemental lead		98,020	38.0
	Soils		1,200,000	600.0
	ETEC total	12/31/93	1,302,521	656.6
FEMP	Aqueous liquids/slurries		d	748.1
	Batteries		d	4.6
	Debris		d	137.6
	Process residues		d	1,500.6
	Lab packs		d	0.4
	Elemental lead		d	1.3
	Elemental mercury		d	0.6
	Organic liquids		d	196.3
	Reactive metals		d	0.6
	Soils		d	7.2
	FEMP total	12/02/93	d	2,597.3

Table 8.7 (continued)

Site	Category ^b	Inventory		
		Date(s) ^c	Mass (kg)	Volume (m ³)
FNAL	d	d	d	d
GJPO	Aqueous liquids/slurries		495	0.50
	Lab packs		40	0.05
	Organic liquids		122	0.14
	Process residues		78	0.04
	Soils		104	0.05
	GJPO total	10/13/93	839	0.78
HANF ^c	Batteries		1,240	1.2
	Debris		312,892	312.9
	Elemental lead		142,753	137.1
	Elemental mercury		1,578	1.5
	Lab packs		137,600	137.6
	Process residues		2,470,867	2,470.2
	Reactive metals		8,250	8.5
	Soils		49,221	32.8
	Unknown		208	0.2
	HANF total	12/31/92	3,124,609	3,102.0
INEL ^f	Aqueous liquids/slurries		113,174	119.2
	Debris		6,446,511	17,600.0
	Elemental lead		912,393	470.1
	Lab packs		3,062	4.7
	Organic liquids		26,849	30.3
	Process residues		3,870,668	3,528.7
	Reactive metals		692	0.9
	Soils		216,604	218.3
	Unknown		1,685,165	3,507.0
	INEL total	09/30/93	13,275,118	25,479.2
ITRI	Lab packs	11/01/93	1,415	3.6
K-25	Aqueous liquids/slurries		273,599	273.6
	Batteries		9,320	6.2
	Debris		270,141	180.1
	Elemental lead		32,127	21.4
	Elemental mercury		253,624	169.1
	Final waste forms (cement)		24,604,610	15,762.0
	Lab packs		4,558	3.0
	Organic liquids		994,375	994.4
	Process residues		12,446,693	10,005.3
	Soils		5,628	3.8
	Unknown		23,606	15.7
	K-25 total	12/31/92	38,918,281	27,434.6
KCP	Debris	12/31/92–11/09/93	199	0.8

Table 8.7 (continued)

Site	Category ^b	Inventory		
		Date(s) ^c	Mass (kg)	Volume (m ³)
LANL	Aqueous liquids/slurries		d	8.9
	Debris		d	215.7
	Elemental mercury		d	10.5
	Final waste forms (cement)		d	269.9
	Lab packs		d	20.1
	Organic liquids		d	127.8
	Process residues		d	11.7
	Unknown		d	0.8
	LANL total	12/31/92	d	665.4
LBL	Debris		290	0.8
	Elemental lead		1,271	0.7
	Elemental mercury		32	0.1
	Lab packs		9,112	16.6
	Organic liquids		2,544	3.8
	LBL total	12/31/92–12/26/93	13,249	22.0
LLNL	Debris		18,990	34.4
	Elemental lead		4,400	4.5
	Elemental mercury		9	<<0.1
	Lab packs		1,621	3.3
	Organic liquids		87,876	92.8
	Process residues		85,210	75.3
	Soils		4,680	4.2
	Unknown		550	0.5
	LLNL total	12/31/92	203,336	215.0
MOUND	Batteries		1,024	0.9
	Debris		6	<0.1
	Elemental lead		4,117	5.0
	Elemental mercury		30	<<0.1
	Lab packs		13,318	43.3
	Organic liquids		26,400	27.1
	Process residues		181	0.2
	MOUND total	12/31/92	45,076	76.6
NR sites ^g	Debris		12,943	22.5
	Elemental lead		6,814	3.7
	Lab packs		2	<<0.1
	Organic liquids		576	0.9
	Process residues		3,383	6.8
	Soils		1,282	2.4
	NR sites total	11/30/93	25,000	36.3

Table 8.7 (continued)

Site	Category ^b	Inventory		
		Date(s) ^c	Mass (kg)	Volume (m ³)
NTS	Batteries		50	0.1
	Lab packs		38	0.2
	Process residues		77	0.1
	NTS total	11/24/93	165	0.4
ORISE	d	d	d	d
ORNL	Aqueous liquids/slurries		2,620,980	2,374.2
	Batteries		884	1.6
	Debris		1,394	2.8
	Elemental mercury		1,004	1.2
	Lab packs		33,217	67.7
	Organic liquids		96,021	114.3
	Process residues		132,405	74.7
	Soils		2,485	4.1
	Unknown		47,874	58.0
	ORNL total	12/31/92	2,936,264	2,698.6
PAD	Aqueous liquids/slurries		21,991	23.8
	Batteries		6,611	16.2
	Debris		93,825	115.6
	Lab packs		1,625	2.5
	Organic liquids		273,640	337.1
	Process residues		22,891	25.8
	Unknown		47,691	75.5
	PAD total	12/01/93	468,274	596.5
PANT	Aqueous slurries		d	6.8
	Batteries		d	0.2
	Debris		d	89.5
	Elemental lead		d	0.2
	Lab packs		d	11.0
	Organic liquids		d	3.8
	Process residues		d	22.1
	Soils		d	0.1
	Unknown		d	0.2
	PANT total	07/13/93	d	133.9
PINELLAS	PINELLAS total	12/31/93	d	d
PORTS	Aqueous liquids/slurries		114,596	122.3
	Batteries		71,384	58.3
	Debris		1,150,680	3,468.2
	Elemental mercury		805	1.0
	Lab packs		11,251	15.3
	Organic liquids		300,690	279.8
	Process residues		562,297	772.0
	Reactive metals		680	0.6

Table 8.7 (continued)

Site	Category ^b	Inventory		
		Date(s) ^c	Mass (kg)	Volume (m ³)
PORTS (continued)	Soils		4,259,766	4,138.7
	Unknown		218,393	193.6
	PORTS total	02/08/93	6,690,542	9,049.8
PPPL	Lab packs	12/31/92	41	0.01
RFP	Aqueous liquids/slurries		d	45,456.1
	Beryllium dust		d	1.5
	Debris		d	503.1
	Elemental lead		d	31.9
	Lab packs		d	5.7
	Organic liquids		d	143.2
	Process residues		d	9,844.5
	Soils		d	43.6
	RFP total	01/01/92–01/04/93	d	56,029.6
RMI	Aqueous liquids/slurries		1,290	1.5
	Debris		5,849	9.7
	Organic liquids		5,083	6.8
	Process residues		4,256	4.1
	RMI total	04/22/94	16,478	22.1
SLAC	d	d	d	d
SNL/CA	Homogenous solids		191	0.9
	Lab packs		297	1.5
	Organic liquids		3,937	8.9
	SNL/CA total	10/01/93	4,425	11.3
SNL/NM	Batteries		166	0.1
	Debris		2,815	62.1
	Elemental lead		63	0.1
	Lab packs		3	0.1
	Process residues		1	<<0.1
	Reactive metals		5	<0.1
	Unknown		759	3.3
	SNL/NM total	12/31/92	3,812	65.7
SRS	Aqueous liquids/slurries		164,056	163.6
	Debris		922,578	4,129.9
	Elemental lead		264,736	276.3
	Elemental mercury		d	0.3
	Homogenous solids		d	1,834.4
	Lab packs		45	0.2
	Organic liquids		d	130.8
	Reactive metals		d	0.8
	Soils		d	18.1
	SRS total	12/31/91–09/30/93	d	6,554.4

Table 8.7 (continued)

Site	Category ^b	Inventory		
		Date(s) ^c	Mass (kg)	Volume (m ³)
WVDP	Aqueous liquids/slurries		512	0.8
	Batteries		64	0.2
	Debris		3,286	5.2
	Elemental lead		13,815	1.2
	Lab packs		169	0.7
	Organic liquids		3,985	5.5
	Process residues		12,769	9.3
	Unknown		54	<<0.1
	WVDP total	10/01/93	34,654	22.9
Y-12	Aqueous liquids/slurries		3,327	3.3
	Batteries		2,053	1.4
	Beryllium dust		3	<<0.1
	Debris		205,172	136.8
	Homogenous solids		7,466,375	4,977.6
	Organic liquids		340,688	340.7
	Reactive metals		1,303	0.9
	Soils		9,804,301	6,428.9
	Unknown		18,345	15.2
	Y-12 total	12/31/92	17,841,567	11,904.8
Others ^h	Aqueous liquids/slurries		8,309	37.8
	Batteries		2,459	4.6
	Debris		18,020	1,565.1
	Elemental lead		11,819	17.5
	Elemental mercury		195	0.4
	Lab packs		2,378	5.0
	Organic liquids		50,996	75.4
	Process residues		65,364	108.8
	Reactive metals		72	0.4
	Soils		39,170,281	24,480.2
	Others total	10/21/93–04/15/94	39,329,893	26,295.2
Grand total (DOE complex)		01/01/92–04/22/94	124,322,908 ⁱ	173,890.3

^aBased on MWIR, ref. 7.^bAs described in ref. 8.^cAs reported in the MWIR, different categories of MLLW for a site may have different inventory dates. Thus, a range of dates may be reported for a site's MLLW inventory. Each date is specified by the numbering system used for month/day/calendar year.^dInformation not available.^eIncludes contributions from PNL.^fIncludes contributions from the Naval Reactors Facility (NRF).^gIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).^hIncludes contributions from Battelle Columbus Laboratories Decommissioning Project, Colonie Interim Storage Site, General Atomics facility, Laboratory for Energy-Related Health Research, Middlesex Sampling Plant, University of Missouri, Weldon Spring Site Remedial Action Project, and 6 naval shipyards (Charleston, South Carolina; Mare Island, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Portsmouth, Maine; and Puget Sound, Washington).ⁱExcludes contributions from sites that did not report complete mass data.

Table 8.8. Cumulative mass and volume inventories, by physical/chemical matrix category, of RCRA- and state-regulated MLLW from DOE site activities^a

Category ^b	Mass (kg)	Volume (m ³)
Liquids		
Aqueous liquids/slurries	c	49,341.1
Organic liquids (aqueous, pure, and other)	c	2,937.3
Unknown	32,039.6	33.4
Solids		
Debris		
Heterogeneous	c	15,727.9
Inorganic	c	8,743.0
Organic	c	1,391.7
Uncategorized	836,590	2,777.1
Inorganic process residues	c	34,287.8
Organic process residues	c	1,040.5
Soils	c	35,982.5
Uncategorized process residues	61,471	41.5
Unknown solids	1,587,045	3,221.0
Specific waste forms		
Lab packs	c	393.6
Special wastes		
Batteries	c	95.6
Beryllium waste	c	1.5
Compressed gases	c	21.1
Explosives	9	0.1
Elemental lead	c	1,023.5
Elemental mercury	c	184.7
Reactive metals	c	19.0
Final waste forms (cement)	c	16,031.9
Uncategorized matrix	c	594.4
Grand total (DOE complex)	124,322,908^d	173,890.3

^aBased on the MWIR, ref. 7. Detailed site data for these categories are also reported in this reference.

^bAs described in Table 8.6 and refs. 7 and 8.

^cData not compiled by site.

^dExcludes contributions from sites that did not report complete mass data. See Table 8.2.

Table 8.9. Projected 5-year (1993–1997) cumulative mass and volume generation, by physical/chemical matrix category, of RCRA- and state-regulated MLLW from DOE site activities^a

Category ^b	Mass (kg)	Volume (m ³)
Liquids		
Aqueous liquids/slurries	c	2,524.6
Organic liquids (aqueous, pure, and other)	c	7,865.3
Unknown	37,800	39.3
Solids		
Debris		
Heterogeneous	c	10,634.7
Inorganic	c	588.0
Organic	c	556.2
Uncategorized	3,950	7.0
Inorganic process residues	c	6,597.7
Organic process residues	c	235.3
Soils	c	3,121.3
Uncategorized process residues	94,525	63.0
Unknown solids	8,685	9.7
Specific waste forms		
Lab packs	c	2,019.7
Special wastes		
Batteries	c	118.5
Beryllium waste	c	0.7
Compressed gases	c	9.9
Explosives	0	0
Elemental lead	c	407.5
Elemental mercury	c	38.7
Reactive metals	c	4.3
Final waste forms		
Cement	7,264	3.4
Vitrified	1,200,000	500.0
Uncategorized matrix	c	228.0
Grand total (DOE complex)	25,096,286^d	35,572.7

^aBased on the MWIR, ref. 7. Detailed site data for these categories are also reported in this reference.

^bAs described in Table 8.6 and refs. 7 and 8.

^cData not compiled by site.

^dExcludes contributions from sites that did not report complete mass data. See Table 8.4.

Table 8.10. Cumulative mass (kg) inventories through 1993, by physical category, of TSCA-regulated MLLW from DOE site activities^{a,b}

Site	Solid	Liquid	Gas ^c	Sludge	Total
AMES	2,600	0	0	0	2,600
ANL-E	0	0	0	0	0
ANL-W	d	d	d	d	d
BNL	445	0	0	0	445
ETEC	720	0	0	0	720
FEMP	e	e	e	e	e
FNAL	0	0	0	0	0
GJPO	10,886	0	0	0	10,886
HANF ^f	104,390	0	0	0	104,390
INEL ^g	68	565	0	0	633
ITRI	0	0	0	0	0
K-25	4,519,915 ^h	e	e	e	4,519,915
KCP	0	0	0	0	0
LANL	2,431,988	0	0	0	2,431,988
LBL	483	0	0	0	483
LLNL	472	434	0	23	929
MOUND	2,059	0	0	0	2,059
NR sites ⁱ	8,600	400	0	0	9,000
NTS	0	0	0	0	0
ORISE	0	0	0	0	0
ORNL	206,810	0	0	0	206,810
PAD	2,666,098	131,806	0	0	2,797,904
PANT	0	0	0	0	0
PINELLAS	0	0	0	0	0
PORTS	1,692,401	33,589	0	665,510	2,391,500
PPPL	0	0	0	0	0
RFP	25,400	4,680	0	0	30,080
SLAC	0	0	0	0	0
SNL/CA	0	0	0	0	0
SNL/NM	68	0	0	0	68
SRS	64,436	0	0	0	64,436
WVDP	6,694	0	0	0	6,694
Y-12	179,000	19,000	0	e	198,000
Total	11,923,533	190,474	0	665,533	12,779,540

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bIn general, densities of 500 kg/m³ for compressed gases, 1,000 kg/m³ for liquids, and 1,500 kg/m³ for solids and sludges were assumed to calculate masses when the site did not report mass data.

^cStored in cylinders.

^dIncluded in the INEL contributions below.

^eInformation not available or unknown.

^fIncludes contributions from PNL.

^gIncludes contributions from ANL-W and the Naval Reactors Facility (NRF).

^hIncludes contributions from liquids, gases, and sludges.

ⁱIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.11. Cumulative volume (m³) inventories through 1993, by physical category, of TSCA-regulated MLLW from DOE site activities^{a,b}

Site	Solid	Liquid	Gas ^c	Sludge	Total
AMES	3.4	0.0	0.0	0.0	3.4
ANL-E	0.0	0.0	0.0	0.0	0.0
ANL-W	d	d	d	d	d
BNL	1.0	0.0	0.0	0.0	1.0
ETEC	3.2	0.0	0.0	0.0	3.2
FEMP	e	e	e	e	e
FNAL	0.0	0.0	0.0	0.0	0.0
GJPO	46.6	0.0	0.0	0.0	46.6
HANF ^f	90.0	0.0	0.0	0.0	90.0
INEL ^g	0.2	0.9	0.0	0.0	1.1
ITRI	0.0	0.0	0.0	0.0	0.0
K-25	3,138.3 ^h	e	e	e	3,138.3
KCP	0.0	0.0	0.0	0.0	0.0
LANL	4,016.2	0.0	0.0	0.0	4,016.2
LBL	0.6	0.0	0.0	0.0	0.6
LLNL	0.5	0.4	0.0	~0	0.9
MOUND	8.7	0.0	0.0	0.0	8.7
NR sites ⁱ	17.0	1.0	0.0	0.0	18.0
NTS	0.0	0.0	0.0	0.0	0.0
ORISE	0.0	0.0	0.0	0.0	0.0
ORNL	1,384.0	0.0	0.0	0.0	1,384.0
PAD	3,762.4	143.3	0.0	0.0	3,905.7
PANT	0.0	0.0	0.0	0.0	0.0
PINELLAS	0.0	0.0	0.0	0.0	0.0
PORTS	3,318.0	50.0	0.0	458.0	3,826.0
PPPL	0.0	0.0	0.0	0.0	0.0
RFP	69.0	7.0	0.0	0.0	76.0
SLAC	0.0	0.0	0.0	0.0	0.0
SNL/CA	0.0	0.0	0.0	0.0	0.0
SNL/NM	0.4	0.0	0.0	0.0	0.4
SRS	129.6	0.0	0.0	0.0	129.6
WVDP	41.2	0.0	0.0	0.0	41.2
Y-12	119.3	19.0	0.0	g	138.3
Total	16,149.6	221.6	0.0	458.0	16,829.2

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bIn general, densities of 500 kg/m³ for compressed gases, 1,000 kg/m³ for liquids, and 1,500 kg/m³ for solids and sludges were assumed to calculate masses when the site did not report mass data.

^cStored in cylinders.

^dIncluded in the INEL contributions below.

^eInformation not available or unknown.

^fIncludes contributions from PNL.

^gIncludes contributions from ANL-W and the Naval Reactors Facility (NRF).

^hIncludes contributions from liquids, gases, and sludges.

ⁱIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.12. 1993 mass (kg) generation, by physical category, of TSCA-regulated MLLW from DOE site activities^{a,b}

Site	Solid	Liquid	Gas ^c	Sludge	Total
AMES	200	0	0	0	200
ANL-E	0	0	0	0	0
ANL-W	0	0	0	0	0
BNL	5,732	0	0	0	5,732
ETEC	360	0	0	0	360
FEMP	d	d	d	d	d
FNAL	0	0	0	0	0
GJPO	0	0	0	0	0
HANF ^e	2,578	0	0	0	2,578
INEL ^f	0	0	0	0	0
ITRI	0	0	0	0	0
K-25	218,840 ^g	d	d	d	214,840
KCP	0	0	0	0	0
LANL	21,125	0	0	0	21,125
LBL	45	0	0	0	45
LLNL	114	19	0	0	133
MOUND	0	0	0	0	0
NR sites ^h	114,687	0	0	0	114,687
NTS	0	0	0	0	0
ORISE	0	0	0	0	0
ORNL	7,520	0	0	0	7,520
PAD	291,151	51,601	0	0	342,752
PANT	0	0	0	0	0
PINELLAS	0	0	0	0	0
PORTS	352,011	16,799	0	213,170	581,980
PPPL	0	0	0	0	0
RFP	4,400	664	0	0	5,064
SLAC	0	0	0	0	0
SNL/CA	0	0	0	0	0
SNL/NM	0	0	0	0	0
SRS	18,800	0	0	0	18,800
WVDP	3,963	0	0	0	3,963
Y-12	28,700	7,800	0	f	36,500
Total	1,066,226	76,883	0	213,170	1,356,279

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bIn general, densities of 500 kg/m³ for compressed gases, 1,000 kg/m³ for liquids, and 1,500 kg/m³ for solids and sludges were assumed to calculate masses when the site did not report mass data.

^cStored in cylinders.

^dInformation not available or unknown.

^eIncludes contributions from PNL.

^fIncludes contributions from ANL-W and the Naval Reactors Facility (NRF).

^gIncludes contributions from liquids, gases, and sludges.

^hIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.13. 1993 volume (m³) generation, by physical category, of TSCA-regulated MLLW from DOE site activities^{a,b}

Site	Solid	Liquid	Gas ^c	Sludge	Total
AMES	1.0	0.0	0.0	0.0	1.0
ANL-E	0.0	0.0	0.0	0.0	0.0
ANL-W	0.0	0.0	0.0	0.0	0.0
BNL	11.5	0.0	0.0	0.0	11.5
ETEC	1.6	0.0	0.0	0.0	1.6
FEMP	d	d	d	d	d
FNAL	0.0	0.0	0.0	0.0	0.0
GJPO	0.0	0.0	0.0	0.0	0.0
HANF ^e	2.6	0.0	0.0	0.0	2.6
INEL ^f	0.0	0.0	0.0	0.0	0.0
ITRI	0.0	0.0	0.0	0.0	0.0
K-25	268.0 ^g	d	d	d	268.0
KCP	0.0	0.0	0.0	0.0	0.0
LANL	43.3	0.0	0.0	0.0	43.3
LBL	0.2	0.0	0.0	0.0	0.2
LLNL	0.1	~0	0.0	0.0	0.1
MOUND	0.0	0.0	0.0	0.0	0.0
NR sites ^h	227.9	0.0	0.0	0.0	227.9
NTS	0.0	0.0	0.0	0.0	0.0
ORISE	0.0	0.0	0.0	0.0	0.0
ORNL	27.7	0.0	0.0	0.0	27.7
PAD	717.5	53.7	0.0	0.0	771.2
PANT	0.0	0.0	0.0	0.0	0.0
PINELLAS	0.0	0.0	0.0	0.0	0.0
PORTS	507.2	22.0	0.0	91.2	620.4
PPPL	0.0	0.0	0.0	0.0	0.0
RFP	12.9	2.0	0.0	0.0	14.9
SLAC	0.0	0.0	0.0	0.0	0.0
SNL/CA	0.0	0.0	0.0	0.0	0.0
SNL/NM	0.0	0.0	0.0	0.0	0.0
SRS	37.6	0.0	0.0	0.0	37.6
WVDP	25.0	0.0	0.0	0.0	25.0
Y-12	19.1	7.8	0.0	f	26.9
Total	1,903.2	85.5	0.0	91.2	2,079.9

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bDensities of 500 kg/m³ for compressed gases, 1,000 kg/m³ for liquids, and 1,500 kg/m³ for solids and sludges were assumed to calculate masses when the site did not report mass data.

^cStored in cylinders.

^dInformation not available or unknown.

^eIncludes contributions from PNL.

^fIncludes contributions from ANL-W and the Naval Reactors Facility (NRF).

^gIncludes contributions from liquids, gases, and sludges.

^hIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.14. Cumulative mass (kg) inventories through 1993, by hazard category, of TSCA-regulated MLLW from DOE site activities^a

Site	PCB	Asbestos	Other	Total
AMES	0	2,600	0	2,600
ANL-E	0	0	0	0
ANL-W	b	b	b	b
BNL	443	2	0	445
ETEC	0	720	0	720
FEMP	c	c	c	c
FNAL	0	0	0	0
GJPO	10,886	0	0	10,886
HANF ^d	104,390	c	0	104,390
INEL ^e	633	c	0	633
ITRI	0	0	0	0
K-25	4,519,915	c	c	4,519,915
KCP	0	0	0	0
LANL	2,033,913	398,075	0	2,431,988
LBL	438	45	0	483
LLNL	461	468	0	929
MOUND	0	2,059	0	2,059
NR sites ^f	9,000	0	0	9,000
NTS	0	0	0	0
ORISE	0	0	0	0
ORNL	0	206,810	0	206,810
PAD	2,752,106	45,798	0	2,797,904
PANT	0	0	0	0
PINELLAS	0	0	0	0
PORTS	1,812,800	578,700	0	2,391,500
PPPL	0	0	0	0
RFP	13,620	16,460	0	30,080
SLAC	0	0	0	0
SNL/CA	0	0	0	0
SNL/NM	0	68	0	68
SRS	636	63,800	0	64,436
WVDP	2,573	4,121	0	6,694
Y-12	198,000	0	0	198,000
Total	11,459,814	1,319,726	0	12,779,540

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bIncluded in the INEL contributions below.

^cInformation not available or unknown.

^dIncludes contributions from PNL.

^eIncludes contributions from ANL-W and the Naval Reactors Facility (NRF).

^fIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.15. Cumulative volume (m³) inventories through 1993, by hazard category, of TSCA-regulated MLLW from DOE site activities^a

Site	PCB	Asbestos	Other	Total
AMES	0.0	3.4	0.0	3.4
ANL-E	0.0	0.0	0.0	0.0
ANL-W	b	b	b	b
BNL	1.0	~0	0.0	1.0
ETEC	0.0	3.2	0.0	3.2
FEMP	c	c	c	c
FNAL	0.0	0.0	0.0	0.0
GJPO	46.6	0.0	0.0	46.6
HANF ^d	90.0	c	0.0	90.0
INEL ^e	1.1	c	0.0	1.1
ITRI	0.0	0.0	0.0	0.0
K-25	3,138.3	c	c	3,138.3
KCP	0.0	0.0	0.0	0.0
LANL	2,123.3	1,892.9	0.0	4,016.2
LBL	0.4	0.2	0.0	0.6
LLNL	0.4	0.5	0.0	0.9
MOUND	0.0	8.7	0.0	8.7
NR sites ^f	18.0	0.0	0.0	18.0
NTS	0.0	0.0	0.0	0.0
ORISE	0.0	0.0	0.0	0.0
ORNL	0.0	1,384.0	0.0	1,384.0
PAD	3,726.0	179.7	0.0	3,905.7
PANT	0.0	0.0	0.0	0.0
PINELLAS	0.0	0.0	0.0	0.0
PORTS	3,460.0	366.0	0.0	3,826.0
PPPL	0.0	0.0	0.0	0.0
RFP	39.9	36.1	0.0	76.0
SLAC	0.0	0.0	0.0	0.0
SNL/CA	0.0	0.0	0.0	0.0
SNL/NM	0.0	0.4	0.0	0.4
SRS	2.0	127.6	0.0	129.6
WVDP	1.7	39.5	0.0	41.2
Y-12	138.3	0.0	0.0	138.3
Total	12,787.0	4,042.2	0.0	16,829.2

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bIncluded in the INEL contributions below.

^cInformation not available or unknown.

^dIncludes contributions from PNL.

^eIncludes contributions from ANL-W and the Naval Reactors Facility (NRF).

^fIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.16. 1993 mass (kg) generation, by hazard category, of TSCA-regulated MLLW from DOE site activities^a

Site	PCB	Asbestos	Other	Total
AMES	0	200	0	200
ANL-E	0	0	0	0
ANL-W	0	b	0	b
BNL	214	5,518	0	5,732
ETEC	0	360	0	360
FEMP	b	b	b	b
FNAL	0	0	0	0
GJPO	0	0	0	0
HANF ^c	2,578	b	0	2,578
INEL ^d	0	b	0	b
ITRI	0	0	0	0
K-25	214,840	b	b	214,840
KCP	0	0	0	0
LANL	11,767	9,358	0	21,125
LBL	0	45	0	45
LLNL	19	114	0	133
MOUND	0	0	0	0
NR sites ^e	0	114,687	0	114,687
NTS	0	0	0	0
ORISE	0	0	0	0
ORNL	0	7,520	0	7,520
PAD	323,416	19,336	0	342,752
PANT	0	0	0	0
PINELLAS	0	0	0	0
PORTS	369,460	212,520	0	581,980
PPPL	0	0	0	0
RFP	3,760	1,304	0	5,064
SLAC	0	0	0	0
SNL/CA	0	0	0	0
SNL/NM	0	0	0	0
SRS	0	18,800	0	18,800
WVDP	121	3,842	0	3,963
Y-12	36,500	0	0	36,500
Total	962,675	393,604	0	1,356,279

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bInformation not available or unknown.

^cIncludes contributions from PNL.

^dIncludes contributions from the Naval Reactors Facility (NRF).

^eIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.17. 1993 volume (m³) generation, by hazard category, of TSCA-regulated MLLW from DOE site activities^a

Site	PCB	Asbestos	Other	Total
AMES	0.0	1.0	0.0	1.0
ANL-E	0.0	0.0	0.0	0.0
ANL-W	0.0	b	0.0	b
BNL	0.7	10.8	0.0	11.5
ETEC	0.0	1.6	0.0	1.6
FEMP	b	b	b	b
FNAL	0.0	0.0	0.0	0.0
GJPO	0.0	0.0	0.0	0.0
HANF ^c	2.6	b	0.0	2.6
INEL ^d	0.0	b	0.0	b
ITRI	0.0	0.0	0.0	0.0
K-25	268.0	b	b	268.0
KCP	0.0	0.0	0.0	0.0
LANL	13.7	29.6	0.0	43.3
LBL	0.0	0.2	0.0	0.2
LLNL	~0	0.1	0.0	0.1
MOUND	0.0	0.0	0.0	0.0
NR sites ^c	0.0	227.9	0.0	227.9
NTS	0.0	0.0	0.0	0.0
ORISE	0.0	0.0	0.0	0.0
ORNL	0.0	27.7	0.0	27.7
PAD	685.4	85.8	0.0	771.2
PANT	0.0	0.0	0.0	0.0
PINELLAS	0.0	0.0	0.0	0.0
PORTS	530.4	90.0	0.0	620.4
PPPL	0.0	0.0	0.0	0.0
RFP	4.0	10.9	0.0	14.9
SLAC	0.0	0.0	0.0	0.0
SNL/CA	0.0	0.0	0.0	0.0
SNL/NM	0.0	0.0	0.0	0.0
SRS	0.0	37.6	0.0	37.6
WVDP	7.3	17.7	0.0	25.0
Y-12	26.9	0.0	0.0	26.9
Total	1,539.0	540.9	0.0	2,079.9

^aBased on the DOE site data submittals of ref. 9. Material may be in interim storage awaiting treatment. Specific site information is provided in Sect. 8.4.

^bInformation not available or unknown.

^cIncludes contributions from PNL.

^dIncludes contributions from the Naval Reactors Facility (NRF).

^eIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.19. Historical and projected annual volume (m³) generation rates for TSCA-regulated MLLW from DOE site activities^a

Site	1993 ^b	1994	1995	1996	1997	1998	1999–2030 ^c
AMES	1.0	<0.1	<0.1	d	d	d	d
ANL-E	0.0	52.2	78.6	<0.1	<0.1	0.0	0.0
ANL-W	0.0	d	d	d	d	d	d
BNL	11.5	0.1	0.1	0.1	<0.1	<0.1	<0.1
ETEC	1.6	7.2	1.0	2.5	d	d	d
FEMP	d	d	d	d	d	d	d
FNAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GJPO	0.0	0.4	0.1	<0.1	<0.1	<0.1	<0.1
HANF ^e	2.6	475.9	406.9	510.1	591.0	391.0	952.0
INEL ^f	0.0	d	d	d	d	d	d
ITRI	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-25	268.0	2,431.0	280.0	280.0	280.0	250.0	250.0
KCP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LANL	43.3	45.0	50.0	60.0	60.0	50.0	45.0
LBL	0.2	3.7	3.7	1.0	1.0	1.0	1.0
LLNL	0.1	0.0	0.0	0.0	0.0	0.0	0.0
MOUND	0.0	6.8	0.5	0.5	0.5	0.5	0.5
NR sites ^g	227.9	117.9	92.6	126.0	225.6	150.3	320.2
NTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ORISE	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ORNL	27.7	22.0	46.5	46.5	46.5	46.5	46.5
PAD	771.2	793.1	630.9	610.7	619.2	612.3	608.0
PANT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PINELLAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PORTS	620.4	237.9	214.1	192.7	173.4	156.1	32.1
PPPL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RFP	14.9	6.8	20.0	36.0	36.0	36.0	36.0
SLAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SNL/CA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SNL/NM	0.0	d	d	d	d	d	d
SRS	37.6	411.0	411.0	411.0	411.0	411.0	560.0
WVDP	25.0	3.0	3.0	3.0	3.0	3.0	d
Y-12	26.9	26.9	26.9	26.9	26.9	26.9	d
Total	2,079.9	4,641.0	2,266.0	2,307.1	2,474.4	2,134.8	2,851.5

^aBased on the DOE site data submittals of ref. 9. Specific site information is provided in Sect. 8.4.

^bActual data.

^cAverage annual generation rate anticipated for this period.

^dInformation not available or unknown.

^eIncludes contributions from PNL.

^fIncludes contributions from the Naval Reactors Facility (NRF).

^gIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

Table 8.18. Historical and projected annual mass (kg) generation rates for TSCA-regulated MLLW from DOE site activities^a

Site	1993 ^b	1994	1995	1996	1997	1998	1999–2030 ^c
AMES	200	50	50	d	d	d	d
ANL-E	0	50,000	75,570	58	58	0	0
ANL-W	0	d	d	d	d	d	d
BNL	5,732	25	25	20	15	10	10
ETEC	360	3,500	500	1,200	d	d	d
FEMP	d	d	d	d	d	d	d
FNAL	0	0	0	0	0	0	0
GJPO	0	170	50	20	20	10	10
HANF ^e	2,578	519,400	427,500	548,700	635,000	432,200	1,230,000
INEL ^f	0	d	d	d	d	d	d
ITRI	0	0	0	0	0	0	0
K-25	214,840	1,950,000	225,000	225,000	225,000	200,000	200,000
KCP	0	0	0	0	0	0	0
LANL	21,125	28,000	31,000	37,000	37,000	31,000	28,000
LBL	45	1,800	1,800	500	500	500	500
LLNL	133	0	0	0	0	0	0
MOUND	0	2,054	90	90	90	90	90
NR sites ^g	114,687	55,188	45,235	55,620	94,750	65,145	131,915
NTS	0	0	0	0	0	0	0
ORISE	0	0	0	0	0	0	0
ORNL	7,520	3,754	5,276	5,276	5,276	5,276	5,276
PAD	342,752	1,189,926	1,040,400	1,018,906	1,029,636	1,019,926	1,015,000
PANT	0	0	0	0	0	0	0
PINELLAS	0	0	0	0	0	0	0
PORTS	581,980	190,900	171,810	154,630	139,170	125,250	25,788
PPPL	0	0	0	0	0	0	0
RFP	5,064	1,430	2,500	19,400	19,400	19,400	19,400
SLAC	0	0	0	0	0	0	0
SNL/CA	0	0	0	0	0	0	0
SNL/NM	0	d	d	d	d	d	d
SRS	18,800	205,500	205,500	205,500	205,500	205,500	280,000
WVDP	3,963	386	386	386	386	386	d
Y-12	36,500	36,500	36,500	36,500	36,500	36,500	d
Total	1,356,279	4,238,583	2,269,192	2,308,806	2,428,301	2,141,193	2,935,989

^aBased on the DOE site data submittals of ref. 9. Specific site information is provided in Sect. 8.4.

^bActual data.

^cAverage annual generation rate anticipated for this period.

^dInformation not available or unknown.

^eIncludes contributions from PNL.

^fIncludes contributions from the Naval Reactors Facility (NRF).

^gIncludes contributions (if any) from Bettis (BAPL), Knolls (KAPL), Kesselring (KESS), and Windsor (WIND).

**Table 8.20. National commercially generated MLLW profile
volume summary, by facility category^a**

Facility category	Waste volume, m ³		
	Generated in 1990	Stored as of Dec. 31, 1990 ^b	Treated in 1990 ^c
Academic	820.7	154.2	1,581.9
Government	750.4	78.9	612.5
Industrial	1,428.0	1,197.3	1,115.1
Medical	563.6	63.1	466.3
Nuclear power plants	385.8	622.5	216.9
Total^d	3,948.5	2,116.0	3,992.6

^aBased on ref. 12.

^bThis is not the amount of mixed waste requiring disposal. Some of this waste was being accumulated for treatment.

^cTreated wastes may include mixed wastes generated in years prior to 1990.

^dTotal reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

Table 8.21. National commercially generated MLLW profile volume summary, by hazardous waste stream^a

Hazardous stream	Waste volume, m ³		
	Generated in 1990	Stored as of Dec. 31, 1990 ^b	Treated in 1990 ^c
Organics			
Liquid scintillation fluids	2,837.2	363.4	3,371.8
Waste oil	148.9	178.1	139.4
Chlorinated organics	70.9	27.0	23.2
Fluorinated organics	0	3.5	0
Chlorinated fluorocarbons (CFCs)	113.2	254.7	3.7
Other organics	274.6	117.9	258.9
Total organics ^d	3,444.8	944.6	3,797.0
Metals			
Lead	81.6	138.7	6.1
Mercury	12.5	81.1	1.5
Chromium	28.4	53.3	3.9
Cadmium	0.3	745.2	0.1
Total metals ^d	122.8	1,018.3	11.6
Aqueous corrosives	80.4	12.2	2.6
Other hazardous materials	300.5	141.0	181.4
Grand totals ^d	3,948.5	2,116.0	3,992.6

^aBased on ref. 12.

^bThis is not the amount of mixed waste requiring disposal. Some of this waste was being accumulated for treatment.

^cTreated wastes may include mixed wastes generated in years prior to 1990.

^dTotals reported in this table may not equal the sum of component entries because of round-off and truncation of numbers.

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

APPENDIX A. MISCELLANEOUS RADIOACTIVE MATERIALS

A.1 INTRODUCTION

This appendix lists year-end 1993 inventories of miscellaneous radioactive material (MRM) at six major DOE sites and one commercial site, the Babcock & Wilcox (B&W) Nuclear Environmental Services Lynchburg Technology Center site at Lynchburg, Virginia. Information on inventories at the end of calendar-year 1993 was collected by direct contact with these sites.

The types of materials covered in this appendix represent principally wastes that will probably require repository disposal but that are not covered specifically in the preceding chapters of this report. However, there may be some overlap with materials covered elsewhere in this report (particularly in Chapter 1) because much of the miscellaneous material reported by the sites consists of whole or sectioned fuel rods or assemblies that originated in commercial reactors and were used in various DOE-related experimental programs.

Damaged fuel assemblies and core debris from the Three Mile Island (TMI)-Unit 2 reactor are included in this appendix as part of the inventory at Idaho National Engineering Laboratory (INEL).

This appendix does not include spent nuclear fuels from naval reactors and defense production reactors, which are discussed briefly in Chapter 1. Also, it does not include greater-than-Class-C low-level waste (GTCC LLW), which is covered in Chapter 4.

The map of Fig. A.1 shows the current locations of MRM, and Fig. A.2 compares the masses of MRM now stored at the various sites.

A.2 INVENTORIES AND PROJECTIONS

Table A.1 summarizes the current inventories of MRM at the seven major sites. Tables A.2 through A.8 describe the separate materials at each site in more detail. The data presented in Tables A.1 through A.8 (derived from refs. 1-12) will be useful in planning for final disposal of these materials in a repository. As previously noted, some quantities of the commercially generated spent nuclear fuels reported in Tables A.2-A.8 may already be covered in Chapter 1 of this report. The spent nuclear fuel inventories reported in Tables A.2-A.8 will be reviewed to identify clearly any possible overlaps between the inventories in these tables and those reported in Chapter 1. Any spent nuclear fuel inventory overlaps identified from this investigation will be clarified in subsequent editions of this report.

Inventories of MRM stored at INEL, including materials stored at the Idaho Chemical Processing Plant (ICPP) and the Naval Reactors Facility (NRF), are given in Table A.3. The spent nuclear fuels that are included in these inventories are not scheduled for reprocessing.^{3,4}

The spent nuclear fuels now inventoried at the Savannah River Site (SRS) (Table A.8) are not currently regarded as reprocessable because of the lack of defined reprocessing schemes or required facilities. This fuel is considered by SRS to be in indefinite storage.¹¹

Recently, DOE made the decision to phase out the reprocessing of spent nuclear fuel from defense production reactors. INEL and the SRS are preparing phase-out plans. A summary of this and other DOE spent nuclear fuel not scheduled for reprocessing is given in Sect. 1.4 of this report.

A.3 REFERENCES

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12. W. D. Clark, DOE Savannah River Operations Office, Aiken, South Carolina, correspondence to Royes Salmon, Oak Ridge National Laboratory, Oak Ridge, Tennessee, "Update of Savannah River Site Miscellaneous Radioactive Materials for the 1994 Integrated Data Base Report," dated Aug. 15, 1994.

*Includes contributions from ANL-W, ICPP, NRF, and other facilities.

Fig. A.1. Locations and total masses of miscellaneous radioactive materials through 1993.

Fig. A.2. Mass of miscellaneous radioactive materials, by site, as of December 31, 1993.

Table A.1. Inventory of miscellaneous radioactive materials as of December 31, 1993, that may require geologic disposal

Storage site and location	Total candidate materials (kg)	Uranium content, kg			Total plutonium content (kg)	Total thorium content (kg)
		Total	²³⁵ U	²³³ U ^a		
Reported potential miscellaneous materials inventory						
Argonne National Laboratory–West, Idaho Falls, ID	1,179.12	1,160.84	126.00		18.282	
Idaho National Engineering Laboratory, Idaho Falls, ID	217,380	164,026	6,837.6	962.53	470.1	52,884
Los Alamos National Laboratory, Los Alamos, NM	14.91	14.91	12.78			
Lynchburg Technology Center, Lynchburg, VA	101.98	100.96	1.278		<1.016	
Oak Ridge National Laboratory, Oak Ridge, TN	1,250.98	1,250.18	797.30	279.63	0.801	
Pacific Northwest Laboratory, Richland, WA	2,303.3	2,266.7	20.9		29.7	6.9
Savannah River Site, Aiken, SC	21,783.74	13,092.33	762.46	31.16	43.21	8,648.2
Total reported	244,014	181,912	8,558.3	1,273.32	563.1	61,539

^aSome of the ²³³U waste may be certifiable as TRUW and would therefore be reported in Chapter 3 in the future.

Table A.2. Miscellaneous radioactive materials inventory at Argonne National Laboratory—West, as of December 31, 1993^a

Source of material	Composition	Description ^b	U content, kg		Total Pu content (kg)
			Total	²³⁵ U	
Radioactive Scrap and Waste Facility ^c					
Basic research—ANL	Scrap	In canister ^d	309.95	96.19	5.492
EBR-2 blanket subassembly	Scrap	In canister ^d	835.04	22.97	9.072
LMFBR test fuel	Scrap	In canister ^d	13.33	5.253	3.026
Postirradiation test on NUMEC ^e LMFBR	Scrap	In canister ^d	0.72	0.345	0.123
Sodium Loop Safety Facility	Scrap	In canister ^d	1.80	1.242	0.569
Total			1,160.84	126.00	18.282

^aSee ref. 1.

^bInformation regarding the burnup of this scrap may be available.

^cRadioactive Scrap and Waste Facility is located about 0.5 miles north of ANL—W site.

^dCanisters are retrievable and constructed of stainless steel with minimum dimensions of 8-in. OD and 5-ft length. The canister lid is gasketed and tightly screwed on, welded closed, or screwed into a canister fitted with pipe threads.

^eNuclear Uranium Materials Equipment Corporation.

Table A.3. Miscellaneous radioactive materials inventory at the Idaho National Engineering Laboratory, as of December 31, 1993^a

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Defense plus other government agency materials inventory at Idaho Chemical Processing Plant (ICPP)								
Advanced test reactor (ATR)	UAl _x fuel, Al-clad	808 assemblies 5.4 × 49.5 in.	41% (avg.)	666.7	548.4		1.82	
Gas-cooled reactor experiment (GCRE)	UO ₂ -MgO, some in pellets and some Hastelloy-clad	Two cans, one SS and one Al	NA	0.984	0.918			
Miscellaneous Al-clad fuel (ARMF, HFBR, ORR)	UAl _x fuel, Al-clad	15 plates 3.1 × 0.065 × 25.2 in.; 240 elements 2.9 × 3.2 × 24.5 in.; 17 elements 3 × 3 × 25.6 in.	NA	66.80	53.42			
Miscellaneous SS-clad fuel (APPR, BMI, GETR, SPSS, and SPEC)	UO ₂ and U metal with SS in the fuel, all SS-clad	APPR — one SS can 5 × 36 in.; BMI — three Al or SS cans 6 × 12 in.; GETR — ten SS cans 5.5 × 3.64 in.; SPEC — one Al can 4 × 24 in.	NA	9.459	6.16			
Shippingport light-water breeder reactor (LWBR)	UO ₂ ceramic fuel pellets with Th, Zr, and Ca oxides, Zr-clad; Th blanket	48 elements 10 × 103 in. in 24 SS cans 25.5 × 158 in.	NA	656.64	10.56	523.68	0.177	41,933
Shippingport LWBR (unirradiated)	UO ₂ ceramic fuel pellets with Th, Zr, and Ca oxides, Zr-clad	40 elements, Zr-clad, contained in SS cans	None	323.6		302.4		14.4

Table A.3 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Defense plus other government agency materials inventory at ICPP (continued)								
Stationary media (SM-1A)	UO ₂ in SS powder fuel, SS-clad	93 assemblies 2.9 × 2.9 × 33.6 in. in 93 SS cans 4.9 × 39 in.	5,124 (avg.)	65.759	56.648			
TORY-IIA	UO ₂ -BeO with Ca cermet	146 Al cans 4.5 × 22 in.	0.9%	48.645	45.325			
TORY-IIC	UO ₂ -Y ₂ O ₃ -ZrO ₂ -BeO ceramic pellets crushed to 0.25 × 0.06 in.	655 Al tubes 2.75 × 54 in. in 23 canisters	1.5%	58.95	55.86			
Subtotal				1,897.5	777.3	826.08	1.997	41,947
DOE/Civilian Development Programs materials inventory at ICPP								
Boiling reactor experiment No. 5 (BORAX-V)	UO ₂ with SS and 2.5% Si, SS-clad	36 assemblies 3.6 × 3.9 × 36 in.	NA	20.8	19.4			
Experimental breeder reactor-2 (EBR-2)	Fuel is U metal with 5% fissium, ^c metallic sodium bonding, SS-clad	41,951 elements 0.174 × 23.8 in. in 3,688 SS cans 2 × 25.5 in.	25,000–30,000	1,967.5	1,224.97		5.2	
Fermi reactor core-1 & 2	U-Mo alloy fuel, metallic sodium bonding, Zr-clad, some declad	214 assemblies canned in 214 Al cans 3.1 × 43 in.	2%	3,911.06	997.45		2.0	
Fermi reactor core-1 blanket	U-Mo alloy fuel, metallic sodium bonding, SS-clad	510 assemblies canned in 14 SS cans 25.5 × 158.5 in.	<1%	34,165	120		6.63	

Table A.3 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Civilian Development Programs materials inventory at ICPP (continued)								
Fort St. Vrain Reactor (FSVR)	U-Th carbide and Th carbide, pyrolytic carbon-coated particles in graphite matrix	744 assemblies 14 × 16 × 31 in.	6,000–26,000	308.33	167.648	90.139	0.752	8,316.6
Miscellaneous Al-clad (University of Washington)	UAl _x in an Al matrix	26 bundles 2.9 × 2.4 × 27 in.	0.44%	4.056	3.80			
Miscellaneous unirradiated SS-clad (ANL–W, EBR–II scrap)	U-5% fissium, ^c SS-clad	56 SS cans	None	55.7	21.64			
Miscellaneous unirradiated (ANL foils, VYCOR glass)	U-metal foils and U-metal mixed with glass	13 drums	None	38.171	34.435			
Missouri University Research Reactor (MURR)	UAl _x with SS rollers and Al in the matrix, Al-clad	56 assemblies 4 × 4.5 × 32.5 in.	20–24%	38.02	33.21			
Pathfinder	UO ₂ -B ₄ C and SS in the matrix. Some thermocouples, SS-clad	417 rods 0.9 × 79.5 in.	NA	53.406	49.242			
Peach Bottom	U-Th carbide, pyrolytic carbon- coated particles in graphite matrix with Rh and B	1,603 graphite elements 3.5 × 144 in. in 90 Al cans 4.5 × 153 in.	<1%	332.42	233.54	46.31	0.97	2,620
Pulstar (State University of New York at Buffalo)	UO ₂ pellets with Be, Zr-clad	504 fuel pins 0.474 × 26.125 in. in 24 SS cans	8,000–12,000	251.431	12.1		0.793	

Table A.3 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Civilian Development Programs materials inventory at ICPP (continued)								
Shippingport PWR—Core 1	UO ₂ -ZrO ₂ fuel with boron, Zr-clad	4 subassemblies 5.6 × 5.6 × 84.5 in.	42.6%	2.02	1.63			
Shippingport PWR—Core 2	UO ₂ -ZrO ₂ fuel with boron and some with CaO, Zr-clad	19 clusters 7.4 × 7.4 × 104.5 in.	47%	519.68	394.34		1.95	
SNAP (AI, S8DR, S8ER, S2DR, STF, SER)	U-Zr-hydride fuel, clad removed	19 Al cans 3.8 × 36 in.; 12 Al cans 2.5 × 43 in.	NA	28.8	26.8			
TRIGA (Training Reactor, Isotopes, General Atomic) stainless steel-clad	U-Zr-hydride fuel, some containing graphite, erbium, SS-clad	21 elements 3 × 3 × 37 in. in Al and SS cans; 7 rods 1.4 × 30 in. in Al cans; 263 elements 1.5 × 29 in., not canned	Varies	60.82	14.18		0.03	
TRIGA aluminum-clad	U-Zr-hydride fuel with Mo and graphite, Al-clad	570 rods 1.4 × 29 in., not canned	Varies	103.17	20.24			
Unirradiated graphite (Parka, LANL)	U-carbide fuel with ZrC, contained in graphite blocks	2,168 rods 3/4 × 52 in. and also 390 cans	None	403.26	371.97			
Unirradiated metal	U metal or U metal with Al	9 drums	None	17.34	15.95			
Vallecitos Boiling-Water Reactor (VBWR) (Geneva)	UO ₂ or UO ₂ -TiO ₂ fuel with SS, Zr, and TiO ₂ in the matrix, SS- or Al-clad	142 rods in four 6 × 36 in. Al cans	8%	12.38	2.61			
Subtotal				42,293	3,765.2	136.45	18.33	10,937

Table A.3 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE materials inventory at the Naval Reactors Facility (NRF)								
Shippingport PWR—Core 1	UO ₂ pellets, Zr-clad	Miscellaneous test specimens from blanket fuel assemblies	11,100	568	<0.5		3.4	
Shippingport PWR—Core 2	UO ₂ wafers, Zr-clad	Three modules and module sections from blanket fuel assemblies	14,273	1,028	2		8.9	
Shippingport PWR—Core 2 seed	UO ₂ wafers, Zr-clad	One seed module		11.09	7.45			
Subtotal				1,607.09	9.45		12.3	
DOE/Civilian Development Programs materials inventory at Power Burst Facility (PBF)								
PBF irradiated driver core	UO ₂ -ZrO ₂ -CaO ternary fuel pellets, SS-clad	2,425 rods 0.75 × 47.5 in. in 72 open containers	1,849	561.63	102.82			
PBF unirradiated driver core	UO ₂ -ZrO ₂ -CaO ternary fuel pellets, SS-clad	595 rods 0.75 × 47.5 in.	None	140.3	25.34			
Subtotal				701.93	128.16			
DOE/Civilian Development Program materials inventory at Test Area North (TAN)								
Connecticut Yankee Atomic Power Company (Haddam Neck)	UO ₂ , SS-clad	One 15 × 15 PWR assembly with 4 rods replaced with SS rods	32,151	378.485	5.204		3.775	

Table A.3 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Civilian Development Programs materials inventory at TAN (continued)								
Dresden	UO ₂ -Dy ₂ O ₃ fuel, Zr-clad	One complete 6 × 6 BWR assembly 5.5 × 5.5 × 134.25 in. of 36 rods and one partial assembly of 19 rods	NA	165.0	d		1.064	
Dry-rod consolidation technology ^c (DRCT)	UO ₂ fuel, Zr-clad	24 canisters 8.3 × 7.9 × 155 in. (408 fuel rods per canister)	28,124 (avg.)	21,002.7	147.36		183.29	
Engine maintenance assembly and disassembly ^f (EMAD)	UO ₂ , Zr-clad	Five 15 × 15 PWR assemblies that were not consolidated in the DRCT program	27,525	2,303.32	17.09		19.19	
H.B. Robinson	UO ₂ fuel, Zr-clad	113 rods	20,000	257.43	1.84		2.09	
Loose fuel-rod shipping basket (LFRSB) (LEU)	Variety of many different types of fuel rods	106 SS rods filled with cut-up pieces of fuel, some not canned and some clad	NA	309.354	1.759		2.627	
Loss-of-fluid test (LOFT)	UO ₂ -ZrO ₂ fuel, Zr-clad	14 assemblies and 5 one-quart SS cans of fines	500-6,400	2,201.69	89.371		2.029	
Peach Bottom	UO ₂ fuel, Zr-clad. One assembly is depleted U	2 partial assemblies, one with 47 rods and one with 46. Assemblies are 5.4 × 5.4 × 176 in.	NA	354.64	2.39		1.87	

Table A.3 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Civilian Development Programs materials inventory at TAN (continued)								
TMI—Unit 2	UO ₂ fuel, Zr-clad fuel assemblies reduced to large pieces of core debris, partial assemblies, and rubble	342 SS canisters 16-in. OD × 145.9 in.	3,176	82,399	1,820		151	
Turkey Point—3 (BCD)	UO ₂ , Zr-clad	One 15 × 15 PWR assembly with 11 rods replaced with SS rods contained in one canister	25,665	408.57	3.52		3.24	
Virginia Electric Power Company (VEPCO) (Surry)	UO ₂ fuel, Zr-clad	12 assemblies, typical 15 × 15 PWR	30,521	7,551.28	52.36		66.59	
Subtotal				117,332	2,140.89		436.765	
DOE/Civilian Development Program materials inventory at Test Reactors Area (TRA) ^g								
Canadian Deuterium Uranium Reactor (CANDU)	UO ₂ pellets, Zr-clad	8 pins (cut up, many pieces)	5,000	2.66	0.261			
Gap conductance (GAP CON) (possibly Saxton)	UO ₂ pellets, Zr-clad	20 pins	41–115	12.838	1.285			
General Electric ^h (GE)	UO ₂ pellets, Zr-clad	5 rods	NA	18.644	0.394		0.071	
Halden assemblies	UO ₂ pellets, Zr-clad	5 pins	4,000	2.313	0.233		0.005	
Halden Pu-U mixed oxide fuel assemblies	UO ₂ -PuO ₂ pellets, Zr-clad	13 rods of various sizes in 4 Al canisters	41,000	4.55	d		0.324	
Irradiation effects (IE)	UO ₂ pellets, Zr-clad	Pins	27–17,600	7.833	0.677		0.012	
LOFT lead rod (LLR)	UO ₂ pellets, Zr-clad	7 pins	36–510	3.51	0.327			

Table A.3 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM or % of initial loading)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Civilian Development Programs materials inventory at TRA (continued)								
Loss of coolant (LOC)	UO ₂ pellets, Zr-clad	60 pins	16–150	7.777	0.816		0.01	
Mitsubishi Atomic Power Industries (MAPI)	UO ₂ pellets, Zr-clad	49 rods 0.4 × 39 in., 36 enriched and 13 depleted, in 12 canisters	5,140	22.300	0.976 ⁱ			
Operational Transient (OPTRAN)	UO ₂ pellets, Zr-clad	Pins	0–15,000	19.669	0.472		0.09	
Power coolant mismatch (PCM)	UO ₂ pellets, Zr-clad	30 pins	<70	18.828	6.557			
Reactivity initiated accident (RIA)	UO ₂ pellets, Zr-clad	23 pins	0–6,090	8.989	0.504		0.013	
Saxton	UO ₂ pellets, Zr-clad	21 pins	10,400–18,253	7.607	0.66		0.025	
Severe fuel damage (SFD)	UO ₂ pellets, Zr-clad	143 pins, cut up	NA	50.867	2.711		0.15	
Thermocouple (TC)	UO ₂ pellets, Zr-clad	Pins	0–<20	6.186	0.683			
Subtotal				194.57	16.56		0.7	
Total at INEL				164,026	6,837.6	962.53	470.1	52,884

^aInformation is principally based on the INEL Spent Fuel Data Base. Items listed as “unirradiated” have not been exposed in a reactor and are not classified as spent nuclear fuel. See refs. 2–4.

^bFuel composition and cladding material where applicable. Zr = Zircaloy; SS = stainless steel.

^cFission is a mixture of nonradioactive isotopes of typical fission product elements that is added to the EBR fuel prior to irradiation.

^dDepleted.

^eMixture of EMAD and Surry fuel.

^fEMAD is a project that used Turkey Point fuel. There is also some EMAD fuel under DRCT.

^gFuels at TRA are from various reactors and, in some cases, are named for the experiment performed on the fuel rather than for the reactor from which the fuel was taken.

^hMost likely five Peach Bottom rods from fuels stored at TAN.

ⁱIn enriched rods only.

Table A.4. Miscellaneous radioactive materials inventory at the Los Alamos National Laboratory, as of December 31, 1993^a

Source of material	Composition	Container description	U content, kg			Total Pu content (kg)	Total Th content (kg)
			Total	²³⁵ U	²³³ U		
Omega West Reactor	Reactor fuel rods; SS-clad	Rods are ~0.3 in. diam × 13.5 in. length. Stored in four lead-lined casks that weigh ~17,600 kg each	7.706	6.766			
Reactor	U ₃ O ₈ in fuel rods; SS-clad	Rods are ~0.3 in. diam × ~13.5 in. length. Stored in two lead-lined casks that weigh ~17,600 kg each	7.174	5.988			
UNITREX rods	U ₃ O ₈ fuel pins	Lead-shielded container ~10 in. diam × 2.5 ft in height	0.032	0.03			
Total			14.912	12.784	0	0	0

^aSee ref. 5.

Table A.5. Miscellaneous radioactive materials inventory at the Lynchburg Technology Center, as of December 31, 1993^a

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)
				Total	²³⁵ U	
Arkansas I	UO ₂ , Zr-clad	Three full-length rods; three sectioned rods in four 4.25-in.-diam × 33-in. Al canisters	47,000	11.641	0.049	0.133
B&W Test Reactor	UO ₂ , Zr-clad	In fourteen 4.25-in.-diam × 33-in. Al canisters	Unknown ^c	0.015	0.005	<0.0005
Consolidated Edison	UO ₂ , Zr-clad	Four sectioned rods in 4.25-in.-diam × 33-in. Al canisters	29,523	10.849	0.058	0.088
Hot-cell solid waste	Miscellaneous ^d	In forty-four 80-gal drums, forty-four 55-gal drums, and one hundred and two 30-gal drums		e	e	<0.082 ^f
Oconee I	UO ₂ , Zr-clad	Twenty-three sectioned rods in twenty-six 4.25-in.-diam × 33-in. Al canisters	18,686	0.531	0.004	0.003
			24,080	2.159	0.028	0.017
			26,480	6.483	0.032	0.054
			31,160	4.275	0.041	0.037
			39,180	11.000	0.057	0.101
			50,000	8.249	0.029	0.092
	UO ₂ , Zr-clad	One full-length rod (archive fuel rod No. 15181)	50,000	2.063	0.007	0.023
	UO ₂ , Zr-clad	Five full-length rods; three sectioned rods	59,300	14.542	0.037	0.171
	UO ₂ -Gd ₂ O ₃ , Zr-clad	In four 4.25-in.-diam × 33-in. Al canisters	15,000	7.884	0.102	0.048
	Oconee II	UO ₂ , Zr-clad	Eight sectioned rods in seven 4.25-in.-diam × 33-in. Al canisters	27,500	10.711	0.105
31,000			6.412	0.057	0.057	
36,000			1.998	0.014	0.015	

Table A.5 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)
				Total	²³⁵ U	
TMI-Unit 2	UO ₂ debris	In one 4.25-in.-diam × 33-in. Al canister	Unknown ^c	0.048	0.001	<0.0005
Various fuel scrap samples	UO ₂ , Zr-clad	In one 4.25-in.-diam × 33-in. Al canister	Unknown ^c	2.100	0.652	<0.0005
Total				100.960	1.278	<1.016

^aSee ref. 6.^bZr-clad = Zircaloy-clad.^cCurrently in underground storage tubes.^dMiscellaneous materials from periodic hot-cell cleanup.^eNegligible.^fCalculated assuming a contamination level of <0.5 g of plutonium per drum.

Table A.6. Miscellaneous radioactive materials inventory at the Oak Ridge National Laboratory, as of December 31, 1993^a

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)
				Total	²³⁵ U	²³³ U	
Belgium Reactor-3 (BR-3)	UO ₂ , Zr-clad	3/8-in.-diam × 6-in. fuel rod lengths	42,000	0.837	0.020		0.006
Consolidated Edison Uranium (CEU)	U ₃ O ₈ -CdO solid cake	In 401 3.5-in.-OD × 24-in. SS cans	c	1,042.58	796.3	101.14	
Dresden-1	UO ₂ , Zr-clad	Sheared fuel pins in two 1-qt paint cans	~24,000	5.00	0.024		0.020
		9/16-in.-diam × 8-in. fuel rod sections plus short lengths	20,000	0.930	0.005		0.006
General Electric Test Reactor (GETR)	UO ₂ , Zr-clad	9/16-in.-diam × 8-in. fuel test capsules	1,000-2,000	0.399	0.022		
H. B. Robinson	UO ₂ , Zr-clad	1/2-in.-diam × 12-in. fuel rod sections plus short lengths	30,000	1.00	0.005		0.004
Molten Salt Reactor Experiment ^d (MSRE)	LiF-BeF ₂ -ZrF ₄ -UF ₄	c	~5 × 10 ⁴ Ci total ^c	36.95	0.940	31.01	0.743
Monticello	UO ₂ , Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008
Oconee-1	UO ₂ , Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	38,000	1.00	0.005		0.005
ORNL Inventory Item Nos. AUA-67/AUA-70 from LANL	U metal chunks	In two 3.75-in.-OD × 18-in. SS cans	c	6.02		5.89	
CZA-91 from ANL	UO _x powder	In one 3.5-in.-OD × 13-in. SS can	c	0.881		0.856	
HUA-2A from HEDL	UO _x powder	In five 3.75-in.-OD × 7-in. SS cans	c	0.317		0.307	

Table A.6 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)
				Total	²³⁵ U	²³³ U	
ORNL Inventory Item Nos. (contd.)							
LAE-03 from Atomics International (AI)	Metal	In one 3-in.-OD × 10-in. SS can	c	0.01		0.01	
RCP-02 from SRS	UO ₂ powder	In thirty-two 3.5-in.-OD × 24-in. SS cans	c	11.14		10.72	
RCP-03 from SRS	UO ₂ powder	In 140 3.88-in.-OD × 10-in. SS cans	c	67.37		61.57	
RCP-04 from SRS	UF ₄ -LiF powder converted from UO ₂	In four 3.5-in.-OD × 24-in. SS cans	c	3.19		2.92	
RCP-06	U ₃ O ₈ -CdO solid cake	In twenty-seven 3.5-in.- OD × 24-in. SS cans	c	65.19		60.27	
RCP-20/JZBL from LANL	U metal chunks	In six 3.5-in.-OD × 24-in. SS cans	c	5.04		4.94	
Peach Bottom-2	UO ₂ , Zr-clad	9/16-in.-diam × 8-in. fuel rod sections plus short lengths	10,000	0.324	0.001		0.001
Quad City-1	UO ₂ , Zr-clad	1/2-in.-diam × 6-in. fuel rod sections plus short lengths	40,000	1.00	0.004		0.008
Total				1,250.178	797.300	279.63	0.801

^aSee refs. 7 and 8.^bZr-clad = Zircaloy-clad.^cNo information regarding the burnup of this fuel is available.^dThe Molten Salt Reactor Experiment was concluded in 1969, and the fuel has never been removed from the facility. A surveillance and monitoring program has been in force since shutdown. Decommissioning of the MSRE facility is an environmental restoration activity and is discussed in Chapter 6.^eSee ref. 8.

Table A.7. Miscellaneous radioactive materials inventory at the Pacific Northwest Laboratory, as of December 31, 1993^a

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg		Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U		
Calvert Cliffs	UO ₂ , Zr-clad	0.440-in. diam × 147 in.					
		(stored as 174 intact rods, 2 cut rods ^c)	30,000	370.5	2.6	5.3	
		(stored as 150 intact rods, 5 cut rods ^c)	45,000	293.5	1.7	7.7	
Cooper	UO ₂ , Zr-clad	Stored as 95 intact rods, 3 cuts rods ^c	28,000	365.9	2.5	3.1	
H. B. Robinson	UO ₂ , Zr-clad	Stored as 19 cut fuel rod sections ^c	28,000	35.1	0.3	0.3	
Miscellaneous scrap and fuel	Cut pieces, scrap	Stored in hot cells	Unknown	25.1	3.4	2.6	0.2
PNL Lot Numbers:							
	ATM-5	Glass mix			0.1	d	d
	ATM-6	Glass mix			0.1	d	d
Point Beach-1	UO ₂ , Zr-clad	Stored as 3 intact fuel assemblies, miscellaneous cut samples	33,000	1,164.5	10.3	10.6	6.7
Shippingport			24,000	3.6	d	d	
VBWR ^e	UO ₂ , Zr-clad	Stored as 6 rodlets and 160-in. fuel rod segments	7,500–33,000	8.3	0.1	0.1	
Total				2,266.7	20.9	29.7	6.9

^aSee ref. 9.

^bZr-clad = Zircaloy-clad.

^cStored are in a hot cell.

^dNegligible.

^eVallecitos boiling-water reactor.

Table A.8. Miscellaneous radioactive materials inventory at the Savannah River Site, as of December 31, 1993^a

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Civilian Development Programs materials inventory at SRS								
Canadian Deuterium Uranium Reactor (CANDU)	UO ₂ , Zr-clad	Rods in three 5.0-in.- diam × 14-ft cans; pieces three 3.5-in.-diam × 1-ft cans	6,500	50.07	0.231			
Carolinas-Virginia Tube Reactor	UO ₂ -Zr or SS-clad	One bundle of 34 rods in a 5.0-in.-diam × 14-ft can	Unknown	67.27	0.640		0.200	
Dresden	UO ₂ -ThO ₂ , SS-clad	Intact assemblies in 4.4-in. × 4.4-in. × 135-in. cans	4,000–10,000	684.00	37.545	15.391	1.879	1,857.0
Elk River Reactor (ERR)	UO ₂ -ThO ₂ , SS-clad	Assemblies 3.5 in. × 3.5 in. × 81.62 in.	Max. 50,000	224.29	186.159	14.722		4,818.6
H. B. Robinson	UO ₂ -PuO ₂ , Zr-clad, SS casing	Four 6- to 8-in.-long fragments in 4.5-in.- diam × 32-in.-long can	6,800–30,000	0.51	0.004		0.003	
Light-water reactor (LWR) samples	UO ₂ -PuO ₂ , SS- and Zr-clad	Fuel rod pieces in five 3.75-in.-diam × 32.5-in.- long cans	Unknown	12.631	0.192		0.109	
Nereide (a French experiment using DOE fuel)	UAl-Si _x , Al-clad	Materials Test Reactor plate-type fuel assembly 34.37 in. × 2.98 in. × 3.14 in.	600	35.42	7.015			
Saxton	UO ₂ -PuO ₂ , Zr- or SS-clad	567 rods in eight 5.0-in.- diam × 14-ft cans and 64 rods in one 3.75-in.- diam × 50-in. can	1,000	280.21	1.411		15.408	

Table A.8 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE/Civilian Development Programs materials inventory at SRS (continued)								
Saxton (continued)	UO ₂ , Zr-clad	Multiple pins in four 5.0-in.-diam × 14-ft cans and one bundle in one 12-in.-diam × 14-ft can	1,600	89.19	6.866		0.233	
Vallecitos boiling-water reactor (VBWR)	UO ₂ , Zr-clad	In four 3.5-in.-diam × 12-in. cans	1,500	11.93	1.243		0.003	
Subtotal				1,455.521	241.306	30.113	17.835	6,675.6
DOE plus other government agencies materials inventory at SRS								
B&W scrap	UO ₂ -PuO ₂ , SS-clad	In 3.5-in.-diam × 32-in. cans	6-54	0.025	0.013		0.0	48
Experimental boiling-water reactor (EBWR)	UO ₂ , SS-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	1.73	1.612			
	UO ₂ , Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	1,600.32	95.456			
	UO ₂ -Zr, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	7,482.73	73.967		9.092	
	UO ₂ -ZrO ₂ -CaO, Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	28.93	26.651			
	UO ₂ -PuO ₂ , Zr-clad	Assemblies 3.75 in. × 3.75 in. × 62.5 in.	1,600	917.72	2.087		13.940	
Experimental breeder reactor-2 (EBR-2)	UO ₂ -PuO ₂ , SS-clad (from ANL)	Eight rods in a 3.5-in.- diam × 30-in. can	120 kW total in 1975	0.44	0.376		0.114	

Table A.8 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE plus other government agencies materials inventory at SRS (continued)								
EBR-2 (continued)	UO ₂ -PuO ₂ , SS-clad	Rod segments in 0.5-in.- (from HEDL)	10,000–34,000 diam × 42-in. cans	2.04	1.624		0.680	
Experimental power reactor–1 (EPR–1)	PuO ₂ , SS-clad	Pieces in 4.5-in.-diam × 32-in. cans	Unknown				0.022	
Gas-cooled reactor experiment (GCRE)	UO ₂ or UO ₂ -BeO, Hastelloy-clad	Four 2-in.-diam × 32-in. Al cans of scrap pieces; two 1.5-in.-diam Al cans of plates; 66 pin-type assemblies		61.290	56.559			
Heavy-water components test reactor (HWCTR)	U and UO ₂ , Zr-clad	Intact assemblies 3 in. diam × 132 in. Pieces of assemblies in 3.5-in.- diam × 12-in. cans	6,200	1,051.376	9.470		0.565	
	U-Zr, Zr-clad			37.165	31.590			
High-temperature reactor experiment (HTRE)	UO ₂ -BeO, Nichrome- clad	Segments and pieces of fuel assemblies and test pieces in thirteen 4-in.- diam × 36-in. Al cans		4.039	3.423			
Mobile Low Power Plant No. 1 (ML–1)	UO ₂ and PuO ₂ -BeO, SS-clad	Sixty-eight 19-pin assemblies		58.575	54.478			
Oak Ridge National Laboratory (ORNL) SIW–1 rods	U, Zr-clad	Rods in three 4.5-in.- diam × 9.25-in. Al cans	Unknown but low	0.184	0.171			
Oak Ridge Reactor-low enriched uranium (ORR-LEU)	U ₃ Si ₂ , Al-clad	In fourteen 3.5-in. × 3.5-in. × 168-in. Al cans	15,600	95.006	14.960		0.537	

Table A.8 (continued)

Source of material	Composition ^b	Description	Estimated burnup (MWd/MTIHM)	U content, kg			Total Pu content (kg)	Total Th content (kg)
				Total	²³⁵ U	²³³ U		
DOE plus other government materials inventory at SRS (continued)								
ORNL mixed oxide	UO ₂ -PuO ₂ , Zr- or SS-clad	One 3.5-in.-diam × 15.12-in. can	Unknown but low	0.376	0.030		0.094	
Savannah River Site (SRS)	UO ₂ -PuO ₂ , Zr-clad	In one 12.0-in.-diam × 14-ft can	Unknown	69.87	0.304		0.161	
Shippingport	UO ₂ , Zr-clad	One 10.5-in.-diam × 15-in. container	18,000	16.000	0.023		0.108	
Sodium Reactor Experiment (SRE)	U, Th rods, SS-clad	3.5-in.-diam × 110.25-in. cans	10,000	154.934	143.410	1.045		1,972.6
	UC, SS-clad			44.324	4.344		0.016	
Special Power Excursion Reactor Test (SPERT-3)	UO ₂ , Zr-clad	Three 4.0-in.-diam × 12-ft cans	Unknown	9.739	0.603			
Subtotal				11,636.813	521.151	1.045	25.377	1,972.6
Total				13,092.334	762.457	31.158	43.212	8,648.2

^aSee refs. 10–12. The spent nuclear fuels listed in this table are not reprocessible in existing facilities.^bZr-clad = Zircaloy-clad.

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES

APPENDIX B. CHARACTERISTICS OF IMPORTANT RADIONUCLIDES

B.1 DISCUSSION

The following Table B.1 lists radionuclides whose characteristics are most often referenced in the variety of studies and evaluations discussed in Chapters 1–7. It includes isotopes for HLW, TRUW, LLW, and UMT as defined by EPA,¹ NRC,^{2,3} and DOE.^{4,5} The data in Table B.1 were obtained from refs. 6–9.

B.2 REFERENCES

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Table B.1. Characteristics of important radionuclides^a

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	$\gamma(X)$	(MeV/dis)	(W/Ci)		
³ H	1	1.233E+01 y	β		0.00568		5.68E-03	3.37E-05	9.650E+03	³ He
¹⁴ C	6	5.730E+03 y	β		0.0495		4.95E-02	2.93E-04	4.457	¹⁴ N
²⁶ Al	13	7.2E+05 y	EC		0.4451	2.6758	3.079	1.825E-02	1.91E-02	²⁶ Mg
³² Si	14	650 y	β		0.0647		2.10E-01	1.245E-03	1.719E+01	³² P
³² P	15	14.282 d	β		0.6947		6.95E-01	4.12E-03	2.853E+05	³² S
³⁵ S	16	87.51 d	β		0.0486		4.86E-02	2.88E-04	4.263E+04	³⁵ Cl
³⁶ Cl	17	3.01E+05 y	β (98.1%); EC (1.9%)		0.2460		2.460E-01	1.458E-03	3.299E-02	³⁶ Ar; ³⁶ S
⁴⁰ K	19	1.277E+09 y	β (89.33%); EC (10.67%)		0.4545	0.1559	6.104E-01	3.62E-03	6.983E-06	⁴⁰ Ca; ⁴⁰ Ar
⁴⁵ Ca	20	163.8 d	β		0.0770		7.70E-02	4.56E-04	1.780E+04	⁴⁵ Sc
⁴⁶ Sc	21	83.83 d	β	0.1120	2.0095		2.122	1.257E-02	3.381E+04	⁴⁶ Ti
⁵¹ Cr	24	27.704 d	EC		0.0031	0.0325	3.56E-02	2.11E-04	9.240E+04	⁵¹ V
⁵⁴ Mn	25	312.20 d	EC		0.0034	0.8360	8.394E-01	4.975E-03	7.738E+03	⁵⁴ Cr
⁵⁵ Fe	26	2.73 y	EC		0.0038	0.0016	5.4E-03	3.2E-05	2.500E+03	⁵⁵ Mn
⁵⁹ Fe	26	44.496 d	β		0.1174	1.1882	1.3056	7.741E-03	4.918E+04	⁵⁹ Co
⁵⁷ Co	27	271.77 d	EC		0.0176	0.1252	1.428E-01	8.464E-01	8.456E+03	⁵⁷ Fe
⁵⁸ Co	27	70.92 d	EC		0.0336	0.9758	1.0094	5.99E-03	3.181E+04	⁵⁸ Fe
⁶⁰ Co	27	5.271 y	β		0.0958	2.5058	2.6016	1.541E-02	1.131E+03	⁶⁰ Ni
^{60m} Co	27	10.47 min	IT (99.75%); β (0.25%)		0.0536	0.0066	6.02E-02	3.57E-04	2.993E+08	⁶⁰ Co; ⁶⁰ Ni
⁵⁹ Ni	28	7.5E+04 y	EC		0.0043	0.0024	6.72E-03	3.98E-05	8.079E-02	⁵⁹ Co
⁶³ Ni	28	1.001E+02 y	β		0.0171		1.71E-02	1.01E-04	6.168E+01	⁶³ Cu

Table B.1 (continued)

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ε	γ(X)	(MeV/dis)	(W/Ci)		
⁶⁵ Zn	30	244.1 d	EC		0.0066	0.5838	5.90E-01	3.51E-03	8.237E+03	⁶⁵ Cu
⁶⁷ Ga	31	3.261 d	EC		0.0333	0.1549	1.882E-01	1.115E-03	5.975E+05	⁶⁷ Zn
⁷⁵ Se	34	119.77 d	EC		0.0134	0.3924	4.06E-01	2.41E-03	1.453E+04	⁷⁵ As
⁷⁹ Se	34	<6.5E+04 y			0.0529		5.29E-02	3.13E-04	6.966E-02	⁷⁹ Br
⁸⁵ Kr	36	1.072E+01 y	β		0.2505	0.0022	2.53E-01	1.50E-03	3.923E+02	⁸⁵ Rb
⁸⁶ Rb	37	18.66 d	β		0.6670	0.0945	7.62E-01	4.52E-03	8.138E+04	⁸⁶ Sr
⁸⁹ Sr	38	50.55 d	β		0.5829	0.0001	5.83E-01	3.46E-03	2.905E+04	⁸⁹ Y
⁹⁰ Sr	38	2.85E+01 y	β		0.1958		1.96E-01	1.16E-03	1.364E+02	⁹⁰ Y
⁹⁰ Y	39	2.671 d	β		0.9332		9.33E-01	5.54E-03	5.441E+05	⁹⁰ Zr
⁹¹ Y	39	58.51 d	β		0.6039	0.0036	6.07E-01	3.60E-03	2.452E+04	⁹¹ Zr
⁹³ Zr	40	1.53E+06 y	β		0.0471	0.0018	4.89E-02	2.90E-04	2.513E-03	⁹³ Nb
⁹⁵ Zr	40	64.02 d	β		0.1200	0.7337	8.54E-01	5.06E-03	2.148E+04	⁹⁵ Nb
^{93m} Nb	41	1.36E+01 y	IT		0.0281	0.0018	2.99E-02	1.77E-04	2.826E+02	⁹³ Nb
⁹⁴ Nb	41	2.03E+04 y	β		0.1454	1.5715	1.7169	1.018E-02	1.873E-01	⁹⁴ Mo
⁹⁵ Nb	41	34.97 d	β		0.0435	0.7643	8.078E-01	4.788E-03	3.910E+04	⁹⁵ Mo
⁹³ Mo	42	3500 y	EC		0.0051	0.0107	1.58E-02	9.37E-05	1.10	⁹³ Nb
⁹⁹ Mo	42	2.748 d	β		0.4076	0.2723	6.799E-01	4.028E-03	4.796E+05	⁹⁹ Tc
⁹⁹ Tc	43	2.13E+05 y	β		0.0846		8.46E-02	5.01E-04	1.695E-02	⁹⁹ Ru
^{99m} Tc	43	6.006 h	IT		0.0142	0.1240	1.382E-01	8.186E-04	5.271E+06	⁹⁹ Tc
¹⁰³ Ru	44	39.254 d	β		0.1105	0.4851	5.96E-01	3.53E-03	3.227E+04	¹⁰³ Rh
¹⁰⁶ Ru	44	1.020 y	β		0.1004		1.004E-01	5.951E-04	3.346E+03	¹⁰⁶ Rh
^{103m} Rh	45	56.12 min	IT		0.0375	0.0017	3.92E-02	2.32E-04	3.253E+07	¹⁰³ Rh
¹⁰⁶ Rh	45	2.17 h	β		0.3144	2.8826	3.197	1.894E-02	3.560E+09	¹⁰⁶ Pd

Table B.1 (continued)

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	$\gamma(X)$	(MeV/dis)	(W/Ci)		
¹⁰⁷ Pd	46	6.5E+06 y	β			0.0093	9.3E-03	5.5E-05	5.143E-04	¹⁰⁷ Ag
¹¹⁰ Ag	47	24.6 s	β (99.70%); EC (0.30%)		1.1842	0.0316	1.216	7.208E-03	4.169E+09	¹¹⁰ Cd; ¹¹⁰ Pd
^{110m} Ag	47	249.76 d	β (98.64%); IT (1.36%)		0.0755	2.7392	2.815	1.669E-02	4.750E+03	¹¹⁰ Cd; ¹¹⁰ Ag
¹¹³ Cd	48	9.3E+15 y	β		0.0933		9.13E-02	5.412E-04	3.402E-13	¹¹³ In
^{113m} Cd	48	1.37E+01 y	β (99.9%); IT (0.1%)			0.1834	1.83E-01	1.08E-03	2.168E+02	¹¹³ In; ¹¹³ Cd
^{115m} Cd	48	44.6 d	β		0.6029	0.0329	6.36E-01	3.76E-03	2.546E+04	¹¹⁵ In
¹¹¹ In	49	2.807 d	EC		0.0340	0.4053	4.393E-01	2.604E-03	4.157E+05	¹¹¹ Cd
^{113m} In	49	1.658 h	IT		0.1340	0.2555	3.89E-01	2.31E-03	1.673E+07	¹¹³ In
^{114m} In	49	49.51 d	IT (95.7%); EC (4.3%)		0.1431	0.0943	2.37E-01	1.40E-03	2.313E+04	¹¹⁴ In; ¹¹⁴ Cd
¹¹³ Sn	50	115.09 d	EC		0.1394	0.2808	4.20E-01	2.48E-03	1.004E+04	¹¹³ In
^{117m} Sn	50	13.61 d	IT		0.1613	0.1580	3.19E-01	1.89E-03	7.969E+04	¹¹⁷ Sn
^{119m} Sn	50	293.0 d	IT		0.0783	0.0114	8.97E-02	5.32E-04	4.478E+03	¹¹⁹ Sn
^{121m} Sn	50	5.5E+01 y	IT (77.6%); β (22.4%)		0.0352	0.0050	4.02E-02	2.43E-04	5.912E+01	¹²¹ Sn; ¹²¹ Sb
¹²³ Sn	50	129.2 d	β		0.5222	0.0069	5.29E-01	3.14E-03	8.219E+03	¹²³ Sb
¹²⁵ Sn	50	9.64 d	β		0.8110	0.3124	1.123	6.656E-03	1.084E+05	¹²⁵ Sb
¹²⁶ Sn	50	~1E+05 y	β		0.1249	0.0573	1.82E-01	1.08E-03	2.837E-02	¹²⁶ Sb
¹²⁴ Sb	51	60.20 d	β		0.3897	1.8523	2.242	1.329E-02	1.749E+04	¹²⁴ Te
¹²⁵ Sb	51	2.73 y	β		0.1257	0.4434	5.69E-01	3.37E-03	1.032E+03	¹²⁵ Te
¹²⁶ Sb	51	12.4 d	β		0.3527	2.7496	3.102	1.839E-02	8.360E+04	¹²⁶ Te
^{126m} Sb	51	19.0 min	β (86%); IT (14%)		0.6323	1.5484	2.181	1.292E-02	7.854E+07	¹²⁶ Te; ¹²⁶ Sb
^{123m} Te	52	119.7 d	IT		0.1020	0.1482	2.502E-01	1.482E-03	8.870E+03	¹²³ Te
^{125m} Te	52	58 d	IT		0.1106	0.0361	1.467E-01	8.690E-04	1.801E+04	¹²⁵ Te
¹²⁷ Te	52	9.35 h	β		0.2248	0.0048	2.30E-01	1.36E-03	2.639E+06	¹²⁷ I

Table B.1 (continued)

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	$\gamma(X)$	(MeV/dis)	(W/Ci)		
^{127m} Te	52	109 d	IT (97.6%); β (2.4%)		0.0821	0.0111	9.32E-02	5.52E-04	9.432E+03	¹²⁷ Te; ¹²⁷ I
¹²⁹ Te	52	1.160 h	β		0.5422	0.0624	6.05E-01	3.58E-03	2.094E+07	¹²⁹ I
^{129m} Te	52	33.6 d	IT (64%); β (36%)		0.2663	0.0370	3.03E-01	1.80E-03	3.013E+04	¹²⁹ Te; ¹²⁹ I
¹²³ I	53	13.2 h	EC		0.0276	0.1729	2.005E-01	1.188E-03	1.940E+06	¹²³ Te
¹²⁵ I	53	60.14 d	EC		0.0179	0.0423	6.02E-02	3.57E-04	1.737E+04	¹²⁵ Te
¹²⁹ I	53	1.57E+07 y	β		0.0556	0.0248	8.04E-02	4.77E-04	1.765E-04	¹²⁹ Xe
¹³¹ I	53	8.040 d	β		0.1913	0.3826	5.74E-01	3.40E-03	1.240E+05	¹³¹ Xe
¹³³ Xe	54	5.245 d	β		0.1363	0.0459	1.82E-01	1.08E-03	1.872E+05	¹³³ Cs
¹³⁴ Cs	55	2.062 y	β		0.1639	1.5555	1.719	1.019E-02	1.294E+03	¹³⁴ Ba
¹³⁵ Cs	55	3.0E+06 y	β		0.0563		5.63E-02	3.32E-04	1.151E-03	¹³⁵ Ba
¹³⁷ Cs	55	3.017E+01 y	β (94.6%); β (5.4%)			0.1708	1.71E-01	1.01E-03	8.698E+01	^{137m} Ba; ¹³⁷ Ba
¹³³ Ba	56	1.054E+01 y	EC		0.0547	0.4045	4.592E-01	2.722E-03	2.500E+02	¹³³ Cs
^{137m} Ba	56	2.552 min	IT		0.0652	0.5991	6.64E-01	3.94E-03	5.379E+08	¹³⁷ Ba
¹⁴¹ Ce	58	32.50 d	β		0.1707	0.0770	2.48E-01	1.47E-03	2.848E+04	¹⁴¹ Pr
¹⁴⁴ Ce	58	284.9 d	β		0.0918	0.0192	1.11E-01	6.58E-04	3.190E+03	¹⁴⁴ Pr
¹⁴³ Pr	59	13.58 d	β		0.3156		3.16E-01	1.87E-03	6.731E+04	¹⁴³ Nd
¹⁴⁴ Pr	59	17.28 min	β		1.2091	0.0289	1.238	7.338E-03	7.555E+07	¹⁴⁴ Nd
^{144m} Pr	59	7.2 min	IT (99.96%); β (0.04%)		0.0464	0.0121	5.85E-02	3.43E-04	1.814E+08	¹⁴⁴ Pr; ¹⁴⁴ Nd
¹⁴⁶ Pm	61	5.53 y	EC (66.1%); β (33.9%)		0.0928	0.7542	8.47E-01	5.02E-03	4.428E+02	¹⁴⁶ Nd; ¹⁴⁶ Sm
¹⁴⁷ Pm	61	2.6234 y	β		0.6196		6.20E-02	3.67E-04	9.270E+02	¹⁴⁷ Sm
¹⁴⁸ Pm	61	5.370 d	β		0.7235	0.5747	1.298	7.691E-03	1.643E+05	¹⁴⁸ Sm
^{148m} Pm	61	41.29 d	β (95.4%); IT (4.6%)		0.1695	1.9861	2.156	1.278E-02	2.136E+04	¹⁴⁸ Sm; ¹⁴⁸ Pm

Table B.1 (continued)

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	$\gamma(X)$	(MeV/dis)	(W/Ci)		
¹⁵¹ Sm	62	9.0E+01 y	β		0.1251		1.25E-01	7.41E-04	2.631E+01	¹⁵¹ Eu
¹⁵² Eu	63	1.333E+01 y	EC (72.08%); β (27.92%)		0.1275	1.1628	1.290	7.646E-03	1.729E+02	¹⁵² Sm; ¹⁵² Gd
¹⁵⁴ Eu	63	8.8 y	β		0.2794	1.2531	1.532	9.081E-03	2.699E+02	¹⁵⁴ Gd
¹⁵⁵ Eu	63	4.96 y	β		0.0650	0.0633	1.28E-01	7.59E-04	4.651E+02	¹⁵⁵ Gd
¹⁵³ Gd	64	241.6 d	EC		0.0399	0.1015	1.414E-01	8.381E-04	3.526E+03	¹⁵³ Eu
¹⁵⁷ Tb	65	150 y	EC		0.0031	0.0050	8.10E-03	4.802E-05	1.519E+01	¹⁵⁷ Gd
¹⁵⁸ Tb	65	150 y	EC (82%) β (18%)				9.02E-01	5.347E-03	1.508E+01	¹⁵⁸ Gd; ¹⁵⁸ Dy
¹⁶⁰ Tb	65	72.3 d	β		0.2535	1.1271	1.381	8.186E-03	1.129E+04	¹⁶⁰ Dy
¹⁶⁹ Yb	70	32.02 d	EC		0.1117	0.3121	4.238E-01	2.512E-03	2.414E+04	¹⁶⁹ Tm
¹⁷⁵ Hf	72	70.0 d	EC		0.0439	0.3646	4.085E-01	2.422E-03	1.066E+04	¹⁷⁵ Lu
¹⁸¹ Hf	72	42.39 d	β		0.1943	0.5441	7.54E-01	4.47E-03	1.702E+04	¹⁸¹ Ta
¹⁸² Ta	73	115.0 d	β		0.2073	1.3011	1.508	8.940E-03	6.253E+03	¹⁸² W
¹⁸⁷ Re	75	4.6E+10 y	β		0.0007		2.59	1.535E-02	3.823E-08	¹⁸⁷ Os
¹⁹² Ir	77	73.831 d	β (95.4%); EC (4.6%)		0.2162	0.8137	1.030	6.105E-03	9.211E+03	¹⁹² Pt; ¹⁹² Os
²⁰¹ Tl	81	3.046 d	EC		0.0481	0.0924	1.40E-01	8.30E-04	2.132E+05	²⁰¹ Hg
²⁰⁷ Tl	81	4.77 min	β		0.4931	0.0022	4.95E-01	2.93E-03	1.904E+08	²⁰⁷ Pb
²⁰⁸ Tl	81	3.053 min	β		0.5979	3.3742	3.972	2.354E-02	2.945E+08	²⁰⁸ Pb
²⁰⁹ Pb	82	3.253 h	β		0.1980		1.98E-01	1.17E-03	4.544E+06	²⁰⁹ Bi
²¹¹ Pb	82	36.1 min	β		0.4523	0.0678	5.20E-01	3.083E-03	2.468E+07	²¹¹ Bi
²¹² Pb	82	10.64 h	β		0.1752	0.1453	3.20E-01	1.90E-03	1.389E+06	²¹² Bi
²¹¹ Bi	83	2.14 min	α (99.727%); β (0.273%)	6.5505	0.0099	0.0467	6.607	3.916E-02	4.184E+08	²⁰⁷ Tl; ²¹¹ Po

Table B.1 (continued)

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	$\gamma(X)$	(MeV/dis)	(W/Ci)		
²¹² Bi	83	1.0092 h	α (35.94%); β (64.06%)	2.1740	0.5025	0.1061	2.783	1.649E-02	1.465E+07	²⁰⁸ Tl; ²¹² Po
²¹³ Bi	83	45.59 min	α (2.16%); β (97.84%)	0.1268	0.4563	0.0825	6.66E-01	3.95E-03	1.934E+07	²⁰⁹ Tl; ²¹³ Po
²⁰⁹ Po	84	102 y	α (99.74%) EC (0.26%)				4.9645	2.943E-01	1.68E+01	²⁰⁵ Pb; ²⁰⁹ Bi
²¹² Po	84	2.98E-07 s	α	8.7844			8.784	5.207E-02	1.774E+17	²⁰⁸ Pb
²¹³ Po	84	4.2E-06 s	α	8.3757			8.375	4.964E-02	1.261E+16	²⁰⁹ Pb
²¹⁵ Po	84	1.780E-03 s	α	7.3864			7.386	4.378E-02	2.948E+13	²¹¹ Pb
²¹⁶ Po	84	1.50E-02 s	α	6.7785			6.779	4.018E-02	3.482E+11	²¹² Pb
²¹⁷ At	85	3.23E-02 s	α	7.0657		0.0002	7.066	4.189E-02	1.610E+12	²¹³ Bi
²¹⁹ Rn	86	3.96 s	α	6.8122	0.0064	0.0560	6.875	4.076E-02	1.301E+10	²¹⁵ Po
²²⁰ Rn	86	55.6 s	α	6.2878		0.0005	6.288	3.727E-02	9.223E+08	²¹⁶ Po
²²² Rn	86	3.825 d	α	5.4892		0.0004	5.490	3.255E-02	1.538E+05	²¹⁸ Po
²²¹ Fr	87	4.9 min	α	6.3571	0.0084	0.0277	6.393	3.789E-02	1.772E+08	²¹⁷ At
²²³ Fr	87	21.8 min	β		0.3805	0.0542	4.35E-01	2.85E-03	3.868E+07	²²³ Ra
²²³ Ra	88	11.43 d	α	5.6972	0.0731	0.1348	5.905	3.500E-02	5.121E+04	²¹⁹ Rn
²²⁴ Ra	88	3.66 d	α	5.6751	0.0022	0.0103	5.688	3.372E-02	1.593E+05	²²⁰ Rn
²²⁵ Ra	88	14.2 d	β		0.1057	0.0137	1.19E-01	7.08E-04	3.920E+04	²²⁵ Ac
²²⁶ Ra	88	1.600E+03 y	α	4.7741	0.0035	0.0067	4.784	2.836E-02	9.887E-01	²²² Rn
²²⁸ Ra	88	5.75 y	β		0.0116		1.16E-02	6.88E-05	2.340E+02	²²⁸ Ac
²²⁵ Ac	89	10.0 d	α	5.7501	0.0257	0.0176	5.793	3.434E-02	5.803E+04	²²¹ Fr
²²⁷ Ac	89	2.177E+01 y	β (98.62%); α (1.38%)	0.0673	0.0125	0.0002	8.00E-02	4.74E-04	7.233E+01	²²⁷ Th; ²²³ Fr
²²⁸ Ac	89	6.13 h	β		0.4292	0.9269	1.356	8.038E-03	2.242E+06	²²⁸ Th
²²⁷ Th	90	18.718 d	α	5.9022	0.0543	0.1113	6.068	3.597E-02	3.073E+04	²²³ Ra
²²⁸ Th	90	1.913 y	α	5.3992	0.0201	0.0034	5.423	3.214E-02	8.196E+02	²²⁴ Ra
²²⁹ Th	90	7.340E+03 y	α	4.8620		0.0343	4.896	2.902E-02	2.127E-01	²²⁵ Ra
²³⁰ Th	90	7.54E+04 y	α	4.6651		0.0004	4.665	2.765E-02	2.109E-02	²²⁶ Ra

Table B.1 (continued)

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	$\gamma(X)$	(MeV/dis)	(W/Ci)		
²³¹ Th	90	1.0633 d	β	0.1732		0.0295	2.03E-01	1.21E-03	5.316E+05	²³¹ Pa
²³² Th	90	1.405E+10 y	α	4.0056		0.0002	4.006	2.375E-02	1.097E-07	²²⁸ Ra
²³⁴ Th	90	24.10 d	β		0.0158	0.0094	2.52E-02	1.49E-04	2.316E+04	²³⁴ Pa
²³¹ Pa	91	3.276E+04 y	α	4.9230	0.0483	0.0399	5.011	2.970E-02	4.723E-02	²²⁷ Ac
²³³ Pa	91	27.0 d	β		0.1941	0.2042	3.98E-01	2.36E-03	2.075E+04	²³³ U
^{234m} Pa	91	1.17 min	β (99.87%); IT (0.13%)		0.8227	0.0121	8.35E-01	4.95E-03	6.868E+08	²³⁴ U; ²³⁴ Pa
²³² U	92	6.89E+01 y	α	5.3065		0.0002	5.307	3.146E-02	2.140E+01	²²⁸ Th
²³³ U	92	1.592E+05 y	α	4.8141	0.0055	0.0013	4.821	2.857E-02	9.680E-03	²²⁹ Th
²³⁴ U	92	2.454E+05 y	α	4.7732		0.0001	4.773	2.829E-02	6.248E-03	²³⁰ Th
²³⁵ U	92	7.037E+08 y	α	4.3785	0.0426	0.1561	4.577	2.713E-02	2.161E-06	²³¹ Th
²³⁶ U	92	2.342E+07 y	α	4.4793	0.0108	0.0015	4.492	2.662E-02	6.469E-05	²³² Th
²³⁸ U	92	4.468E+09 y	α	4.1945	0.0095	0.0013	4.205	2.492E-02	3.362E-07	²³⁴ Th
²³⁶ Np	93	1.550E+05 y	EC (91%); β (8.9%); α (0.20%)		0.1967	0.1411	3.38E-01	2.00E-03	1.317E-02	²³⁶ U; ²³⁶ Pu; ²³² Pa
²³⁷ Np	93	2.140E+06 y	α	4.7604	0.0640	0.0327	4.857	2.879E-02	7.049E-04	²³³ Pa
²³⁹ Np	93	2.355 d	β		0.2521	0.1740	4.26E-01	2.53E-03	2.320E+05	²³⁹ Pu
²³⁶ Pu	94	2.851 y	α	5.7521	0.0126	0.0020	5.767	3.418E-02	5.313E+02	²³² U
²³⁸ Pu	94	8.774E+01 y	α	5.4871	0.0099	0.0018	5.499	3.2593E-02	1.712E+01	²³⁴ U
²³⁹ Pu	94	2.411E+04 y	α	5.1011		0.0001	5.101	3.024E-02	6.216E-02	²³⁵ U
²⁴⁰ Pu	94	6.563E+03 y	α	5.1549			5.155	3.056E-02	2.279E-01	²³⁶ U
²⁴¹ Pu	94	1.44E+01 y	β	0.0001		0.0052	5.3E-03	3.2E-05	1.030E+02	²⁴¹ Am
²⁴² Pu	94	3.763E+05 y	α	4.8901	0.0081	0.0014	4.900	2.904E-02	3.818E-03	²³⁸ U
²⁴⁴ Pu	94	8.26E+07 y	α (99.875%); SPF (0.125%)	4.5751	0.0007	0.0001	4.576	2.712E-02	1.774E-05	²⁴⁰ U; (fission products)
²⁴¹ Am	95	4.327E+02 y	α	5.4801	0.0304	0.0287	5.539	3.283E-02	3.432	²³⁷ Np
²⁴² Am	95	16.01 h	β (82.7%); EC (17.3%)		0.1781	0.0180	1.96E-01	1.16E-03	8.084E+05	²⁴² Cm; ²⁴² Pu

Table B.1 (continued)

Nuclide	Atomic number	Half-life ^b	Principal mode(s) of decay ^c	Major radiation energies ^d (MeV/dis)			“Q” value ^e		Specific activity (Ci/g)	Daughter(s)
				α	ϵ	$\gamma(X)$	(MeV/dis)	(W/Ci)		
^{242m} Am	95	1.41E+02 y	IT (99.55%); α (0.45%)	0.0232	0.0403	0.0049	6.84E-02	4.05E-04	9.718	²⁴² Am; ²³⁸ Np
²⁴³ Am	95	7.380E+03 y	α	5.2656		0.0481	5.3137	3.1496E-02	1.993E-01	²³⁹ Np
²⁴² Cm	96	162.94 d	α	6.0434	0.0090	0.0018	6.0542	3.5886E-02	3.306E+03	²³⁸ Pu
²⁴³ Cm	96	2.85E+01 y	α (99.76%); EC (0.24%)	5.8380	0.1129	0.1316	6.083	3.605E-02	5.162E+01	²³⁹ Pu; ²⁴³ Am
²⁴⁴ Cm	96	1.811E+01 y	α	5.7965		0.0016	5.798	3.437E-02	8.090E+01	²⁴⁰ Pu
²⁴⁵ Cm	96	8.5E+03 y	α	5.3631	0.1342	0.1178	5.615	3.329E-02	1.717E-01	²⁴¹ Pu
²⁴⁶ Cm	96	4.73E+03 y	α	5.3764	0.0072	0.0014	5.385	3.192E-02	3.072E-01	²⁴² Pu
²⁴⁷ Cm	96	1.56E+07 y	α	4.9475		0.3152	5.263	3.119E-02	9.278E-05	²⁴³ Pu
²⁴⁸ Cm	96	3.40E+05 y	α (91.74%); SPF (8.26%)	4.6524			4.6524	2.7577E-02	4.251E-03	²⁴⁴ Pu; (fission products)
²⁵² Cf	98	2.645 y	α (96.908%); SPF (3.092%)	5.9308	0.0051	0.0011	5.9370	3.5191E-02	5.378E+02	²⁴⁸ Cm; (fission products)

^aBased on refs. 6–9.^by—years; d—days; h—hours; min—minutes; and s—seconds.^c α —alpha decay; β —negative beta decay; EC—electron capture; IT—*isomeric transition* (radioactive transition from one nuclear isomer to another of lower energy); and SPF—*spontaneous fission*.^d α —alpha decay; ϵ —total electron emissions; and $\gamma(X)$ —gamma and X-ray photons.^eThe sum of the average energies for different radiation types in MeV/disintegration or W/Ci (includes alpha and beta particles, discrete electrons, and photons). The “value” indicates the amount of energy (heat) that could be deposited in a radioactive material from each decay event if none of the radiation escaped from the material. Neutrinos are not included.

**APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS,
AND CHARACTERISTICS**

APPENDIX C. WASTE FLOWSHEETS, SOURCE TERMS, AND CHARACTERISTICS

C.1 DISCUSSION

In this report, a number of engineering estimates, assumptions, and ground rules are used to determine radioactive waste and spent nuclear fuel projections through the year 2030. Many of these involve parameters that characterize certain types of waste (e.g., see Table C.1). In other instances, estimates were made of the waste volume generated per unit of product throughput for each step in the fuel cycle. This appendix is a compilation of generic flowsheets and source terms used for making waste projections. Source terms are used to describe quantitative and qualitative characteristics of radioactive wastes. As used in this report, the source term for a particular waste is comprised of two components unique to that waste: (1) the number of curies of radioactivity expressed either per unit of facility production or per unit of waste volume or mass and (2) a listing of the relative radioactivity contributions of component radioisotopes.

The source terms used in the analysis of this report are based on reported historical data, engineering estimates, calculations, and/or experimental data. Documentation of the source terms and key waste-modeling parameters is provided in the following sets of figures and tables (based primarily on refs. 1 through 8). Detailed information on how these source terms and modeling parameters were derived is available, mainly in ref. 1 and its update (ref. 2). Figures C.1 and C.2 were adapted from refs. 3 and 4, respectively. The mass, radioactivity, and thermal power of the nuclides contained in all stored domestic commercial LWR spent nuclear fuel as of December 31, 1993, are listed in Table C.2.

Representative DOE LLW radionuclide compositions are described in Table C.3 (based on ref. 1). Average concentrations for representative radionuclides in LLW disposed of at commercial sites are given in Table C.4. Table C.5, which gives the radionuclide composition of saltstone at the Savannah River Site, summarizes information obtained from ref. 5. Table C.6 gives a summary of major sources and estimated characteristics of commercial greater-than-Class-C LLW (data from refs. 6 and 7). Information on the LLW to be incorporated in cement as a result of future operations by the West Valley Demonstration Project Radwaste Treatment System is presented in Table C.7, which is taken from ref. 8.

C.2 REFERENCES

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Fig. C.1. Boiling-water reactor decommissioning wastes per 1-MW(e) capacity.

Fig. C.2. Pressurized-water reactor decommissioning wastes per 1-MW(e) capacity.

Table C.1. Estimated representative unit activity and thermal power characteristics of various types of radioactive materials and wastes

Radioactive material/ waste type	Unit activity (Ci/m ³)	Unit thermal power (W/m ³)
Spent nuclear fuel^a		
BWR	1,000,000–10,000,000	3,500–40,000
PWR	2,000,000–20,000,000	7,500–65,000
High-level waste	1,500–15,000	5–50
Transuranic waste		
Remote-handled, stored	1,000	1–2
Contact-handled, stored	25–50	0.5–1.5
Buried	0.25–0.50	0.005–0.010
Low-level waste^b		
DOE sites	9–27	0.012–0.054
Commercial sites ^c	4.6–6.4	0.30–1.60
Class A	0.5–0.7	0.03–0.10
Class B	55–60	14–15
Class C	0.1–>7,000 ^d	0.003–115 ^d
GTCC ^e	>0.1–No limit	>0.003–No limit
Uranium mill tailings	0.010	0.00020

^aLower-bound levels are based on cumulative spent nuclear fuel discharged; upper-bound levels are based on annual discharges.

^bBased on 1986–1988 Solid Waste Information Management System (SWIMS) and the national Low-Level Waste Management Program (LLWMP) data access system, both of which were maintained by EG&G, Idaho, Inc., Idaho Falls, Idaho.

^cWaste classification is defined by the NRC in 10 CFR Part 61.55 on the basis of concentration of certain long- and short-lived radionuclides. The classification system is designed to minimize potential exposures in both the short and long term. The gross Ci/m³ shown above are representative of typical LLW shipped to commercial disposal sites. Nuclear power plant wastes account for most of the radioactivity (~96%) and include Class A, B, and C. Essentially all medical wastes are Class A. Industrial wastes are largely Class A, but they contain some Class B and C.

^dMaximum for ⁶³Ni in activated metal or ⁹⁰Sr. There is no limit on concentration of ³H, ⁶⁰Co, or nuclides with half-lives < 5 years. The maximum thermal power shown is based on the highest reported gross Ci/m³ analysis for irradiated core components (1986–1988) and assumes all the activity is due to ⁶⁰Co, which would yield the greatest heat output. If the activity is due to activation products, such as ⁵⁴Mn, ⁵⁸Co, etc., the Ci/m³ could be much higher for individual shipments, and the total W/m³ could exceed the value shown.

^eIn temporary storage. The concentration of actinides and ¹²⁹I determines the lower activity boundary. There is no limit on concentrations of ³H, ⁶⁰Co, or nuclides with half-lives < 5 years.

Table C.2. Mass, radioactivity, and thermal power of nuclides in domestic commercial LWR spent nuclear fuel at the end of calendar year 1993^a

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1	Hydrogen	Stable ^b	1.04E+04	1.33E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Hydrogen	3	1.97E+02	1.47E+03	1.90E+06	1.42E+07	6.41E+01	4.76E+02
2	Helium	Stable	6.56E+03	6.60E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	Lithium	Stable	2.46E+03	3.06E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	Beryllium	Stable	2.51E+00	2.56E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	Boron	Stable	2.27E+03	2.80E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Carbon	Stable	4.03E+05	5.02E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Carbon	14	1.08E+03	1.09E+04	4.82E+03	4.86E+04	1.41E+00	1.43E+01
7	Nitrogen	Stable	2.76E+05	3.46E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	Oxygen	Stable	3.04E+08	3.78E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	Fluorine	Stable	2.41E+04	3.00E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	Neon	Stable	1.03E+00	1.08E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	Sodium	Stable	3.37E+04	4.19E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Sodium	24	2.01E-04	2.01E-04	1.75E+03	1.75E+03	4.86E+01	4.86E+01
12	Magnesium	Stable	4.60E+03	5.70E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	Aluminum	Stable	1.89E+05	2.29E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14	Silicon	Stable	1.07E+06	1.34E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Phosphorus	Stable	5.34E+05	6.32E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15	Phosphorus	32	3.76E-01	3.76E-01	1.07E+05	1.07E+05	1.09E+03	1.09E+03
	Sulfur	Stable	5.90E+04	7.49E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	Chlorine	Stable	1.11E+04	1.39E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	Argon	Stable	9.78E+02	1.03E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19	Potassium	Stable	4.24E+00	4.44E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	Calcium	Stable	4.50E+03	5.60E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21	Scandium	Stable	2.77E-01	2.90E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	Titanium	Stable	1.95E+05	2.34E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	Vanadium	Stable	4.22E+04	4.76E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vanadium	50	1.36E+02	1.48E+03	2.43E-11	2.65E-10	2.67E-13	2.93E-12
24	Chromium	Stable	2.46E+07	3.06E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Chromium	51	9.29E+01	9.29E+01	8.59E+06	8.59E+06	1.84E+03	1.84E+03
25	Manganese	Stable	2.04E+06	2.56E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Manganese	54	2.07E+02	3.58E+02	1.60E+06	2.77E+06	7.96E+03	1.38E+04
26	Iron	Stable	7.46E+07	9.33E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Iron	55	5.76E+03	1.97E+04	1.44E+07	4.92E+07	4.87E+02	1.66E+03
	Iron	59	3.52E+00	3.53E+00	1.73E+05	1.74E+05	1.34E+03	1.34E+03

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
27	Cobalt	Stable	1.78E+05	2.21E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cobalt	58	1.06E+02	1.09E+02	3.36E+06	3.46E+06	2.01E+04	2.07E+04
	Cobalt	60	1.66E+04	8.40E+04	1.87E+07	9.50E+07	2.89E+05	1.46E+06
28	Nickel	Stable	2.34E+07	2.84E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Nickel	59	1.55E+05	1.51E+06	1.17E+04	1.15E+05	4.66E-01	4.55E+00
	Nickel	63	2.72E+04	2.48E+05	1.68E+06	1.53E+07	1.69E+02	1.54E+03
29	Copper	Stable	4.03E+04	4.95E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
30	Zinc	Stable	9.08E+04	1.13E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zinc	65	2.39E+01	3.65E+01	1.97E+05	3.01E+05	6.90E+02	1.05E+03
31	Gallium	Stable	8.12E+01	8.51E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
32	Germanium	Stable	1.54E+03	1.52E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
33	Arsenic	Stable	4.80E+02	4.80E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
34	Selenium	Stable	1.20E+05	1.18E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Selenium	79	1.44E+04	1.41E+05	1.00E+03	9.86E+03	2.49E-01	2.45E+00
35	Bromine	Stable	5.22E+04	5.15E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
36	Krypton	Stable	8.25E+05	8.06E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Krypton	81	5.83E-02	5.47E-01	1.23E-03	1.15E-02	1.51E-07	1.42E-06
	Krypton	85	5.62E+04	3.81E+05	2.21E+07	1.50E+08	3.31E+04	2.24E+05
	Rubidium	Stable	2.41E+05	2.35E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
37	Rubidium	86	4.08E+00	4.08E+00	3.32E+05	3.32E+05	1.50E+03	1.50E+03
	Rubidium	87	5.98E+05	5.83E+06	5.23E-02	5.10E-01	4.37E-05	4.26E-04
38	Strontium	Stable	8.56E+05	8.35E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Strontium	89	1.15E+04	1.16E+04	3.35E+08	3.37E+08	1.16E+06	1.16E+06
	Strontium	90	1.29E+06	1.09E+07	1.76E+08	1.48E+09	2.04E+05	1.72E+06
39	Yttrium	Stable	1.06E+06	1.02E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Yttrium	90	3.27E+02	2.73E+03	1.78E+08	1.49E+09	9.87E+05	8.23E+06
	Yttrium	91	2.09E+04	2.11E+04	5.12E+08	5.19E+08	1.84E+06	1.86E+06
40	Zirconium	Stable	7.56E+08	9.77E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Zirconium	93	2.02E+06	1.99E+07	5.08E+03	5.01E+04	5.91E-01	5.82E+00
	Zirconium	95	3.93E+04	4.01E+04	8.46E+08	8.62E+08	4.28E+06	4.37E+06
41	Niobium	Stable	1.20E+06	1.44E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Niobium	93m	1.72E+00	5.60E+01	4.87E+02	1.58E+04	8.62E-02	2.80E+00
	Niobium	94	1.63E+04	1.56E+05	3.05E+03	2.92E+04	3.11E+01	2.98E+02
	Niobium	95	3.34E+04	3.44E+04	1.31E+09	1.34E+09	6.27E+06	6.45E+06
	Niobium	95m	1.71E+01	1.74E+01	6.51E+06	6.63E+06	9.04E+03	9.21E+03
42	Molybdenum	Stable	8.76E+06	8.69E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Technetium	99	1.88E+06	1.88E+07	3.19E+04	3.18E+05	1.60E+01	1.60E+02

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
44	Ruthenium	Stable	5.35E+06	5.24E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Ruthenium	103	1.58E+04	1.58E+04	5.11E+08	5.12E+08	1.71E+06	1.71E+06
	Ruthenium	106	2.82E+05	5.37E+05	9.43E+08	1.80E+09	5.61E+04	1.07E+05
45	Rhodium	Stable	9.99E+05	1.03E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Rhodium	103m	1.42E+01	1.42E+01	4.61E+08	4.62E+08	1.06E+05	1.06E+05
	Rhodium	106	2.65E-01	5.05E-01	9.43E+08	1.80E+09	9.05E+06	1.72E+07
46	Palladium	Stable	2.55E+06	2.42E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Palladium	107	5.45E+05	5.42E+06	2.81E+02	2.79E+03	1.66E-02	1.65E-01
47	Silver	Stable	1.85E+05	1.89E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Silver	108	3.48E-09	2.21E-08	2.56E+00	1.63E+01	9.54E-03	6.06E-02
	Silver	108m	1.10E+00	7.00E+00	2.88E+01	1.83E+02	2.79E-01	1.77E+00
	Silver	110	2.17E-05	3.27E-05	9.06E+04	1.36E+05	6.51E+02	9.80E+02
	Silver	110m	1.43E+03	2.16E+03	6.81E+06	1.03E+07	1.14E+05	1.71E+05
	Silver	111	3.02E+01	3.02E+01	4.77E+06	4.77E+06	1.07E+04	1.07E+04
48	Cadmium	Stable	3.26E+05	3.31E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cadmium	109	8.37E-01	1.88E+00	2.16E+03	4.86E+03	2.51E-01	5.65E-01
	Cadmium	113m	6.24E+02	4.61E+03	1.35E+05	1.00E+06	2.28E+02	1.69E+03
	Cadmium	115m	2.69E+01	2.69E+01	6.84E+05	6.86E+05	2.55E+03	2.56E+03
49	Indium	Stable	2.81E+03	3.01E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Indium	114	8.81E-05	8.86E-05	1.21E+05	1.22E+05	5.78E+02	5.81E+02
	Indium	114m	5.48E+00	5.51E+00	1.27E+05	1.27E+05	1.79E+02	1.80E+02
	Indium	115	5.25E+03	6.32E+04	3.27E-08	3.93E-07	4.68E-11	5.64E-10
	Indium	115m	5.36E-02	5.36E-02	3.40E+05	3.40E+05	6.77E+02	6.77E+02
50	Tin	Stable	1.24E+07	1.60E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Tin	117m	1.74E+01	1.74E+01	1.39E+06	1.39E+06	2.58E+03	2.58E+03
	Tin	119m	3.53E+03	5.35E+03	1.58E+07	2.39E+07	8.18E+03	1.24E+04
	Tin	121m	5.65E+01	5.25E+02	3.34E+03	3.10E+04	6.69E+00	6.22E+01
	Tin	123	4.82E+02	5.61E+02	3.97E+06	4.61E+06	1.24E+04	1.44E+04
	Tin	125	1.27E+01	1.27E+01	1.38E+06	1.38E+06	9.13E+03	9.13E+03
	Tin	126	6.63E+04	6.65E+05	1.88E+03	1.89E+04	2.35E+00	2.35E+01
51	Antimony	Stable	5.06E+04	5.15E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Antimony	124	4.37E+01	4.44E+01	7.65E+05	7.76E+05	1.02E+04	1.03E+04
	Antimony	125	3.53E+04	1.28E+05	3.65E+07	1.32E+08	1.14E+05	4.13E+05
	Antimony	126	1.60E+00	1.60E+00	1.34E+05	1.34E+05	2.47E+03	2.47E+03
	Antimony	127	1.32E+01	1.32E+01	3.53E+06	3.53E+06	2.09E+04	2.09E+04
52	Tellurium	Stable	1.14E+06	1.13E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Tellurium	123	3.05E+01	2.75E+02	8.86E-09	8.00E-08	8.98E-13	8.11E-12

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
53	Tellurium	123m	2.96E+00	3.32E+00	2.63E+04	2.95E+04	3.83E+01	4.29E+01
	Tellurium	125m	4.78E+02	1.77E+03	8.61E+06	3.19E+07	7.24E+03	2.68E+04
	Tellurium	127	5.92E+00	6.43E+00	1.56E+07	1.70E+07	2.11E+04	2.29E+04
	Tellurium	127m	1.33E+03	1.47E+03	1.25E+07	1.39E+07	6.73E+03	7.46E+03
	Tellurium	129	4.26E-01	4.26E-01	8.93E+06	8.93E+06	3.19E+04	3.19E+04
	Tellurium	129m	4.38E+02	4.38E+02	1.32E+07	1.32E+07	2.31E+04	2.32E+04
	Tellurium	132	1.19E+02	1.19E+02	3.62E+07	3.62E+07	7.16E+04	7.16E+04
	Iodine	Stable	1.30E+05	1.30E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Iodine	129	4.37E+05	4.37E+06	7.71E+01	7.72E+02	3.57E-02	3.57E-01
	Iodine	131	5.26E+02	5.26E+02	6.53E+07	6.53E+07	2.22E+05	2.22E+05
54	Xenon	Stable	1.28E+07	1.26E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Xenon	129m	4.30E-03	4.30E-03	5.44E+02	5.44E+02	7.61E-01	7.61E-01
	Xenon	131m	2.12E+01	2.12E+01	1.78E+06	1.78E+06	1.71E+03	1.71E+03
	Xenon	133	5.21E+02	5.21E+02	9.75E+07	9.75E+07	1.04E+05	1.04E+05
55	Cesium	Stable	2.71E+06	2.71E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cesium	134	2.59E+05	7.29E+05	3.36E+08	9.44E+08	3.42E+06	9.61E+06
	Cesium	135	8.22E+05	7.64E+06	9.47E+02	8.80E+03	3.16E-01	2.94E+00
	Cesium	136	8.09E+01	8.09E+01	5.93E+06	5.93E+06	8.09E+04	8.09E+04
	Cesium	137	2.90E+06	2.47E+07	2.53E+08	2.15E+09	2.79E+05	2.38E+06
56	Barium	Stable	3.39E+06	3.27E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Barium	136m	3.63E-06	3.63E-06	9.78E+05	9.78E+05	1.18E+04	1.18E+04
	Barium	137m	4.44E-01	3.78E+00	2.39E+08	2.03E+09	9.38E+05	7.98E+06
	Barium	140	2.34E+03	2.34E+03	1.71E+08	1.71E+08	4.77E+05	4.77E+05
57	Lanthanum	Stable	2.99E+06	2.93E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lanthanum	138	1.34E+01	1.37E+02	2.57E-07	2.62E-06	1.88E-09	1.92E-08
	Lanthanum	140	3.55E+02	3.55E+02	1.98E+08	1.98E+08	3.32E+06	3.32E+06
58	Cerium	Stable	2.99E+06	2.91E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cerium	141	1.47E+04	1.47E+04	4.19E+08	4.19E+08	6.14E+05	6.14E+05
	Cerium	142	2.77E+06	2.72E+07	6.65E-02	6.52E-01	0.00E+00	0.00E+00
	Cerium	144	5.46E+05	9.02E+05	1.74E+09	2.88E+09	1.16E+06	1.91E+06
59	Praseodymium	Stable	2.65E+06	2.59E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Praseodymium	143	2.54E+03	2.54E+03	1.71E+08	1.71E+08	3.19E+05	3.19E+05
	Praseodymium	144	2.31E+01	3.81E+01	1.74E+09	2.88E+09	1.28E+07	2.12E+07
	Praseodymium	144m	1.15E-01	1.90E-01	2.09E+07	3.45E+07	7.15E+03	1.18E+04
60	Neodymium	Stable	6.51E+06	6.46E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Neodymium	144	2.78E+06	3.07E+07	3.29E-06	3.63E-05	0.00E+00	0.00E+00
	Neodymium	147	7.02E+02	7.02E+02	5.64E+07	5.64E+07	1.36E+05	1.36E+05

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
61	Promethium	147	2.85E+05	1.03E+06	2.64E+08	9.59E+08	9.48E+04	3.44E+05
	Promethium	148	7.62E+01	7.62E+01	1.25E+07	1.25E+07	9.64E+04	9.64E+04
	Promethium	148m	4.77E+02	4.78E+02	1.02E+07	1.02E+07	1.29E+05	1.29E+05
62	Samarium	Stable	1.04E+06	1.05E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Samarium	147	1.89E+05	4.09E+06	4.29E-03	9.29E-02	5.88E-05	1.27E-03
	Samarium	148	4.39E+05	3.96E+06	1.32E-07	1.19E-06	1.58E-09	1.43E-08
	Samarium	149	6.41E+03	7.74E+04	1.54E-09	1.86E-08	0.00E+00	0.00E+00
	Samarium	151	2.97E+04	3.16E+05	7.83E+05	8.32E+06	9.18E+01	9.76E+02
63	Europium	Stable	2.63E+05	2.58E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Europium	152	7.83E+01	5.91E+02	1.36E+04	1.02E+05	1.02E+02	7.74E+02
	Europium	154	9.70E+04	5.75E+05	2.62E+07	1.55E+08	2.34E+05	1.39E+06
	Europium	155	3.37E+04	1.59E+05	1.57E+07	7.40E+07	1.14E+04	5.38E+04
	Europium	156	5.57E+02	5.57E+02	3.07E+07	3.07E+07	3.17E+05	3.17E+05
64	Gadolinium	Stable	1.34E+06	1.78E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Gadolinium	152	7.49E+01	2.42E+03	1.63E-09	5.28E-08	2.13E-11	6.87E-10
	Gadolinium	153	1.79E+02	2.78E+02	6.32E+05	9.82E+05	5.71E+02	8.87E+02
65	Terbium	Stable	2.38E+04	2.67E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Terbium	160	2.00E+02	2.06E+02	2.25E+06	2.32E+06	1.84E+04	1.89E+04
	Terbium	161	1.55E+00	1.55E+00	1.82E+05	1.82E+05	3.64E+02	3.64E+02
81	Thallium	Stable	2.56E-09	2.29E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Thallium	206	7.81E-22	7.81E-22	1.70E-13	1.70E-13	1.54E-15	1.54E-15
	Thallium	207	7.49E-12	3.95E-10	1.43E-03	7.53E-02	4.19E-06	2.21E-04
	Thallium	208	1.13E-08	4.64E-07	3.33E+00	1.37E+02	7.84E-02	3.22E+00
	Thallium	209	2.23E-14	1.39E-13	9.11E-06	5.67E-05	1.51E-07	9.42E-07
82	Lead	Stable	2.22E+03	2.76E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lead	204	3.10E+01	3.85E+02	3.88E-13	4.83E-12	5.98E-15	7.44E-14
	Lead	205	7.94E-02	8.32E-01	4.62E-06	4.84E-05	1.34E-10	1.41E-09
	Lead	209	2.38E-10	7.22E-10	1.08E-03	3.28E-03	1.24E-06	3.78E-06
	Lead	210	1.15E-07	1.45E-05	8.75E-06	1.11E-03	2.03E-09	2.57E-07
	Lead	211	5.80E-11	3.06E-09	1.43E-03	7.55E-02	4.29E-06	2.26E-04
	Lead	212	6.67E-06	2.74E-04	9.27E+00	3.80E+02	1.77E-02	7.24E-01
	Lead	214	1.90E-12	2.33E-10	6.24E-05	7.64E-03	1.99E-07	2.44E-05
83	Bismuth	Stable	9.01E+02	1.12E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Bismuth	208	1.28E-02	1.34E-01	6.00E-05	6.24E-04	9.44E-07	9.82E-06
	Bismuth	210	1.58E-05	1.58E-05	1.96E+00	1.96E+00	4.53E-03	4.53E-03
	Bismuth	210m	7.55E-02	7.91E-01	4.28E-05	4.49E-04	1.34E-06	1.41E-05
	Bismuth	211	3.42E-12	1.80E-10	1.43E-03	7.55E-02	5.71E-05	3.01E-03

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
84	Bismuth	212	6.33E-07	2.60E-05	9.27E+00	3.80E+02	1.58E-01	6.47E+00
	Bismuth	213	2.18E-11	1.36E-10	4.22E-04	2.63E-03	1.77E-06	1.10E-05
	Bismuth	214	1.41E-12	1.73E-10	6.24E-05	7.64E-03	7.99E-07	9.79E-05
	Polonium	210	9.91E-03	1.18E-02	4.45E+01	5.30E+01	1.43E+00	1.70E+00
	Polonium	211	4.20E-17	2.21E-15	4.01E-06	2.11E-04	1.80E-07	9.51E-06
	Polonium	212	3.35E-17	1.37E-15	5.94E+00	2.44E+02	3.15E-01	1.29E+01
	Polonium	213	3.27E-20	2.04E-19	4.13E-04	2.57E-03	2.09E-05	1.30E-04
	Polonium	214	2.54E-19	2.39E-17	8.16E-05	7.66E-03	3.79E-06	3.56E-04
	Polonium	215	4.85E-17	2.56E-15	1.43E-03	7.55E-02	6.39E-05	3.37E-03
	Polonium	216	2.66E-11	1.09E-09	9.26E+00	3.80E+02	3.79E-01	1.56E+01
85	Polonium	218	2.21E-13	2.70E-11	6.24E-05	7.64E-03	2.26E-06	2.77E-04
	Astatine	217	2.62E-16	1.63E-15	4.22E-04	2.63E-03	1.80E-05	1.12E-04
86	Radon	218	1.30E-17	1.30E-17	1.92E-05	1.92E-05	8.26E-07	8.26E-07
	Radon	219	1.10E-13	5.80E-12	1.43E-03	7.55E-02	5.94E-05	3.13E-03
	Radon	220	1.00E-08	4.12E-07	9.26E+00	3.80E+02	3.52E-01	1.44E+01
	Radon	222	4.05E-10	4.97E-08	6.24E-05	7.64E-03	2.07E-06	2.53E-04
87	Francium	221	2.38E-12	1.48E-11	4.22E-04	2.63E-03	1.63E-05	1.01E-04
	Francium	223	5.52E-13	2.73E-11	2.14E-05	1.06E-03	5.55E-08	2.75E-06
88	Radium	222	1.43E-14	1.43E-14	1.92E-05	1.92E-05	7.60E-07	7.60E-07
	Radium	223	2.79E-08	1.47E-06	1.43E-03	7.55E-02	5.10E-05	2.69E-03
	Radium	224	5.81E-05	2.39E-03	9.26E+00	3.80E+02	3.18E-01	1.31E+01
	Radium	225	9.84E-09	6.61E-08	3.86E-04	2.59E-03	2.71E-07	1.82E-06
	Radium	226	6.36E-05	7.74E-03	6.29E-05	7.66E-03	1.82E-06	2.21E-04
	Radium	228	3.66E-11	4.55E-09	8.58E-09	1.06E-06	6.61E-13	8.20E-11
	Radium	225	7.26E-09	4.52E-08	4.22E-04	2.63E-03	1.47E-05	9.17E-05
89	Actinium	227	2.14E-05	1.06E-03	1.55E-03	7.67E-02	7.50E-07	3.71E-05
	Actinium	228	6.45E-12	6.92E-12	1.45E-05	1.55E-05	1.25E-07	1.34E-07
	Actinium	228	6.45E-12	6.92E-12	1.45E-05	1.55E-05	1.25E-07	1.34E-07
90	Thorium	226	7.15E-13	7.15E-13	1.92E-05	1.92E-05	7.34E-07	7.34E-07
	Thorium	227	4.73E-08	2.44E-06	1.45E-03	7.49E-02	5.31E-05	2.73E-03
	Thorium	228	1.11E-02	4.61E-01	9.14E+00	3.78E+02	2.99E-01	1.24E+01
	Thorium	229	1.57E-03	1.19E-02	3.33E-04	2.54E-03	1.02E-05	7.78E-05
	Thorium	230	3.71E+00	1.34E+02	7.50E-02	2.71E+00	2.12E-03	7.67E-02
	Thorium	231	8.27E-05	9.55E-04	4.40E+01	5.08E+02	2.47E-02	2.85E-01
	Thorium	232	6.36E-01	2.39E+01	6.97E-08	2.63E-06	1.69E-09	6.36E-08
	Thorium	233	1.32E-11	1.32E-11	4.83E-04	4.83E-04	1.22E-06	1.22E-06
	Thorium	234	3.08E-02	3.87E-01	7.13E+02	8.95E+03	2.89E-01	3.63E+00
	Thorium	234	3.08E-02	3.87E-01	7.13E+02	8.95E+03	2.89E-01	3.63E+00

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
91	Protactinium	231	7.64E-01	8.30E+00	3.61E-02	3.92E-01	1.09E-03	1.18E-02
	Protactinium	232	1.42E-05	1.42E-05	6.09E+00	6.09E+00	3.98E-02	3.98E-02
	Protactinium	233	3.82E-02	3.50E-01	7.93E+02	7.27E+03	1.80E+00	1.65E+01
	Protactinium	234	4.70E-07	5.83E-06	9.40E-01	1.17E+01	1.35E-02	1.67E-01
	Protactinium	234m	1.04E-06	1.30E-05	7.13E+02	8.95E+03	3.53E+00	4.43E+01
	Protactinium	235	7.07E-17	7.07E-17	2.35E-09	2.35E-09	6.55E-12	6.55E-12
92	Uranium	230	7.02E-10	7.02E-10	1.92E-05	1.92E-05	6.81E-07	6.81E-07
	Uranium	231	6.70E-09	6.70E-09	9.02E-04	9.02E-04	7.46E-07	7.46E-07
	Uranium	232	1.49E+00	2.36E+01	3.18E+01	5.05E+02	1.02E+00	1.62E+01
	Uranium	233	3.22E+00	5.33E+01	3.12E-02	5.16E-01	9.08E-04	1.50E-02
	Uranium	234	4.09E+05	4.81E+06	2.56E+03	3.01E+04	7.37E+01	8.66E+02
	Uranium	235	1.69E+07	2.32E+08	3.66E+01	5.01E+02	9.60E-01	1.31E+01
	Uranium	236	9.58E+06	9.42E+07	6.20E+02	6.10E+03	1.68E+01	1.65E+02
	Uranium	237	6.33E+02	6.33E+02	5.17E+07	5.17E+07	9.77E+04	9.78E+04
	Uranium	238	2.12E+09	2.66E+10	7.13E+02	8.95E+03	1.81E+01	2.27E+02
	Uranium	239	2.04E-02	2.04E-02	6.84E+05	6.84E+05	1.84E+03	1.84E+03
93	Uranium	240	2.74E-04	2.74E-04	2.54E+02	2.54E+02	2.08E-01	2.08E-01
	Neptunium	235	8.03E-03	1.52E-02	1.13E+01	2.14E+01	6.55E-04	1.24E-03
	Neptunium	236	1.01E+00	8.73E+00	1.33E-02	1.15E-01	2.68E-05	2.32E-04
	Neptunium	236m	1.19E-04	1.19E-04	7.03E+01	7.03E+01	5.56E-02	5.56E-02
	Neptunium	237	1.13E+06	1.03E+07	7.94E+02	7.28E+03	2.43E+01	2.22E+02
	Neptunium	238	2.69E+01	2.69E+01	6.99E+06	6.99E+06	3.35E+04	3.35E+04
	Neptunium	239	1.75E+03	1.75E+03	4.05E+08	4.06E+08	9.79E+05	9.80E+05
	Neptunium	240	4.42E-04	4.42E-04	5.33E+03	5.33E+03	5.65E+01	5.65E+01
94	Neptunium	240m	2.45E-06	2.45E-06	2.59E+02	2.59E+02	1.50E+00	1.50E+00
	Neptunium	241	1.78E-13	1.78E-13	8.69E-06	8.69E-06	2.43E-08	2.43E-08
	Plutonium	236	2.68E+00	8.81E+00	1.42E+03	4.68E+03	4.96E+01	1.63E+02
	Plutonium	237	2.28E-02	2.29E-02	2.75E+02	2.76E+02	1.02E-01	1.02E-01
	Plutonium	238	3.77E+05	3.10E+06	6.46E+06	5.31E+07	2.14E+05	1.76E+06
	Plutonium	239	1.13E+07	1.36E+08	7.00E+05	8.44E+06	2.16E+04	2.60E+05
	Plutonium	240	5.33E+06	5.70E+07	1.21E+06	1.30E+07	3.78E+04	4.05E+05
	Plutonium	241	2.85E+06	2.29E+07	2.93E+08	2.36E+09	9.10E+03	7.31E+04
	Plutonium	242	1.19E+06	1.13E+07	4.53E+03	4.30E+04	1.34E+02	1.27E+03
	Plutonium	243	2.44E-01	2.44E-01	6.34E+05	6.34E+05	7.32E+02	7.32E+02
	Plutonium	244	7.32E+01	6.03E+02	1.30E-03	1.07E-02	3.77E-05	3.10E-04
	Plutonium	245	2.84E-06	2.84E-06	3.43E+00	3.43E+00	8.13E-03	8.13E-03
	Plutonium	246	6.30E-07	6.30E-07	3.08E-02	3.08E-02	2.59E-05	2.59E-05

Table C.2 (continued)

Atomic number	Element	Mass number of nuclide	Mass, g		Radioactivity, Ci		Thermal power, W	
			Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
95	Americium	239	4.36E-09	4.36E-09	4.81E-03	4.81E-03	1.16E-05	1.16E-05
	Americium	240	1.89E-05	1.89E-05	4.86E+00	4.86E+00	3.18E-02	3.18E-02
	Americium	241	1.49E+05	9.57E+06	5.12E+05	3.29E+07	1.70E+04	1.09E+06
	Americium	242	6.34E-01	8.06E-01	5.13E+05	6.52E+05	5.82E+02	7.40E+02
	Americium	242m	1.75E+03	1.61E+04	1.70E+04	1.57E+05	6.70E+00	6.19E+01
	Americium	243	2.50E+05	2.16E+06	4.99E+04	4.31E+05	1.61E+03	1.39E+04
	Americium	244	1.80E-02	1.80E-02	2.30E+04	2.30E+04	1.20E+02	1.20E+02
	Americium	244m	1.85E-04	1.85E-04	5.50E+03	5.50E+03	1.66E+01	1.66E+01
	Americium	245	6.68E-07	6.68E-07	4.13E+00	4.13E+00	7.66E-03	7.66E-03
	Americium	246	1.01E-09	1.01E-09	3.09E-02	3.09E-02	2.49E-04	2.49E-04
96	Curium	242	1.67E+04	2.08E+04	5.53E+07	6.88E+07	2.04E+06	2.54E+06
	Curium	243	9.88E+02	7.09E+03	5.10E+04	3.66E+05	1.87E+03	1.34E+04
	Curium	244	7.87E+04	5.03E+05	6.37E+06	4.07E+07	2.23E+05	1.42E+06
	Curium	245	3.12E+03	2.34E+04	5.37E+02	4.02E+03	1.78E+01	1.34E+02
	Curium	246	4.49E+02	3.07E+03	1.38E+02	9.43E+02	4.51E+00	3.09E+01
	Curium	247	4.77E+00	3.04E+01	4.43E-04	2.82E-03	1.41E-05	9.01E-05
	Curium	248	2.85E-01	1.68E+00	1.21E-03	7.16E-03	1.51E-04	8.92E-04
Totals			3.45E+09	4.33E+10	1.32E+10	2.77E+10	5.50E+07	1.05E+08

^aIncludes contributions from nuclides in the fuel, cladding, and fuel assembly structural material.

^bThe term *stable* represents a group of nonradioactive nuclides of a particular element.

Table C.3. Representative DOE LLW radionuclide composition by percent activity^a

Uranium/thorium		Fission product		Induced activity		Alpha, <100 nCi/g		Other	
Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition
²⁰⁸ Tl	0.0017	⁶⁰ Co	0.08	⁵¹ Cr	4.95	²³⁸ Pu	2.62	³ H	1.22
²¹² Pb	0.0045	⁹⁰ Sr	7.77	⁵⁴ Mn	38.10	²³⁹ Pu	0.20	¹⁴ C	0.06
²¹² Bi	0.0045	⁹⁰ Y	7.77	⁵⁸ Co	55.40	²⁴⁰ Pu	0.70	⁵⁴ Mn	6.76
²¹² Po	0.0029	⁹⁵ Zr	1.27	⁵⁹ Fe	0.49	²⁴¹ Pu	96.4	⁵⁸ Co	6.24
²¹⁶ Po	0.0045	⁹⁵ Nb	2.83	⁶⁰ Co	0.87	²⁴¹ Am	0.004	⁶⁰ Co	18.03
²²⁴ Ra	0.0045	⁹⁹ Tc	0.02	⁶⁵ Zn	0.19	²⁴² Cm	0.056	⁹⁰ Sr	8.48
²²⁸ Ra	0.0269	¹²⁵ Sb	2.93			²⁴⁴ Cm	0.020	⁹⁰ Y	8.48
²²⁸ Ac	0.0269	^{125m} Tc	0.73		100.00			⁹⁹ Tc	0.12
²²⁸ Th	0.0045	¹⁰⁶ Ru	6.39				100.000	¹³⁴ Cs	13.98
²³¹ Th	0.0259	¹⁰⁶ Rh	6.39					¹³⁷ Cs	18.45
²³² Th	0.273	¹³⁴ Cs	0.38					^{137m} Ba	17.45
²³⁴ Th	33.197	¹³⁷ Cs	17.31					²³⁸ U	0.73
^{234m} Pa	33.197	^{137m} Ba	16.38						
²³⁴ Pa	0.0034	¹⁴⁴ Ce	14.67						100.00
²³⁵ U	0.0258	¹⁴⁴ Pr	14.67						
²³⁸ U	33.197	¹⁴⁷ Pm	0.06						
		¹⁵¹ Sm	0.11						
	100.0000	¹⁵² Eu	0.09						
		¹⁵⁴ Eu	0.09						
		¹⁵⁵ Eu	0.06						
			100.00						

^aBased on ref. 1.

Table C.4. Average concentrations for representative radionuclides in LLW at commercial disposal sites^a

Radionuclide	Half-life ^b	Concentration (Ci/m ³)
³ H	1.228E+01 y	1.083E+00
¹⁴ C	5.730E+03 y	5.079E-03
²⁶ Al	7.300E+05 y	2.980E-10
³² Si	1.000E+02 y	3.725E-11
³² P	1.428E+01 d	9.292E-04
³⁵ S	8.751E+01 d	2.208E-03
³⁶ Cl	3.010E+05 y	6.143E-06
⁴⁰ K	1.280E+09 y	1.766E-07
⁵¹ Cr	2.770E+01 d	7.137E-02
⁵⁴ Mn	3.122E+02 d	3.895E-01
⁵⁵ Fe	2.730E+00 y	3.112E+00
⁵⁹ Fe	4.445E+01 d	5.081E-03
⁵⁸ Co	7.092E+01 d	2.047E-01
⁶⁰ Co	5.271E+00 y	2.242E+00
⁵⁹ Ni	7.500E+04 y	1.364E-03
⁶³ Ni	1.001E+02 y	2.692E-01
⁶⁵ Zn	2.441E+02 d	1.174E-01
⁸⁵ Kr	1.072E+01 y	8.147E-04
⁸⁹ Sr	5.055E+01 d	6.032E-03
⁹⁰ Sr	2.850E+01 y	6.987E-02
⁹⁰ Y	2.671E+01 d	6.987E-02
⁹¹ Y	5.851E+01 d	8.859E-03
⁹⁵ Zr	6.402E+01 d	1.036E-02
⁹⁴ Nb	2.030E+04 y	1.659E-05
⁹⁵ Nb	3.497E+01 d	1.916E-02
⁹³ Mo	3.500E+03 y	9.273E-12
⁹⁹ Tc	2.130E+05 y	1.949E-04
¹⁰³ Ru	3.925E+01 d	5.900E-04
^{108m} Ag	1.300E+02 y	5.534E-06
^{110m} Ag	2.498E+02 d	3.600E-02
¹¹³ Cd	9.000E+15 y	4.223E-12
¹²⁴ Sb	6.020E+00 d	2.621E-03
¹²⁵ Sb	2.730E+00 y	1.901E-02
¹²³ Te	1.300E+13 y	5.710E-07
¹²⁵ I	6.014E+00 d	4.570E-04
¹²⁹ I	1.570E+07 y	2.101E-05
¹³¹ I	8.040E+00 d	5.299E-03
¹³⁴ Cs	2.062E+00 y	8.661E-02
¹³⁵ Cs	3.000E+06 y	1.105E-05
¹³⁷ Cs	3.017E+01 y	2.431E-01
^{137m} Ba	2.552E+00 min	2.300E-01
¹⁴¹ Ce	3.250E+01 d	1.649E-03
¹⁴⁴ Ce	2.849E+02 d	1.463E-02

Table C.4 (continued)

Radionuclide	Half-life ^b	Concentration (Ci/m ³)
¹⁴⁴ Pr	1.728E+01 min	1.463E-02
¹⁴⁴ Nd	2.100E+15 y	1.689E-10
¹⁴⁷ Pm	2.623E+00 y	1.317E-02
¹⁵⁷ Tb	1.100E+02 y	1.012E-10
¹⁵⁸ Tb	1.800E+02 y	3.768E-10
¹⁷⁵ Hf	7.000E+01 d	1.427E-03
¹⁸¹ Hf	4.240E+01 d	3.235E-03
¹⁸⁷ Re	4.100E+10 y	1.772E-11
²⁰⁹ Po	3.253E+00 h	1.284E-10
²²⁶ Ra	1.600E+03 y	2.852E-04
²²⁹ Th	7.340E+03 y	1.310E-10
²³⁰ Th	7.540E+04 y	1.721E-08
²³² Th	1.405E+10 y	8.482E-03
²³¹ Pa	3.276E+04 y	1.016E-10
²³³ U	1.592E+05 y	2.308E-07
²³⁴ U	2.454E+05 y	5.368E-05
²³⁵ U	7.037E+08 y	3.179E-05
²³⁶ U	2.432E+07 y	7.886E-07
²³⁸ U	4.468E+09 y	9.970E-03
²³⁷ Np	2.140E+06 y	2.210E-07
²³⁹ Pu	2.413E+04 y	1.021E-05 ^c
²⁴⁰ Pu	6.563E+03 y	2.504E-06 ^c
²⁴² Pu	3.763E+05 y	6.148E-07 ^c
²⁴¹ Am	4.322E+02 y	4.053E-05
²⁴³ Am	7.380E+03 y	1.398E-08
²⁴⁸ Cm	3.400E+05 y	6.220E-07
Total		8.380E+00

^aTaken from the report by G. W. Roles, *Characteristics of Low-Level Radioactive Waste Disposed During 1987 Through 1989*, NUREG-1418, December 1990.

^by = years; d = days; h = hours; min = minutes; and s = seconds.

^cIsotopes of plutonium are omitted when this list is applied to waste disposed at Barnwell, South Carolina, because this site has not permitted disposal of plutonium (even though traces of plutonium could have entered with other wastes).

Table C.5. Projected composition of LLW saltstone at SRS^{a,b}

End of calendar year	Radioactivity fraction of radionuclide ^c																Total ^d
	³ H	⁸⁹ Sr	⁹⁰ Sr	⁹⁰ Y	⁹¹ Y	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru	¹⁰⁶ Rh	¹²⁵ Sb	¹³⁷ Cs	^{137m} Ba	¹⁴⁴ Ce	¹⁴⁴ Pr	¹⁴⁷ Pm	
1996	0.02	0.00	0.11	0.11	0.00	0.00	0.00	0.01	0.01	0.01	0.06	0.02	0.02	0.00	0.00	0.65	1.00
1997	0.02	0.00	0.20	0.20	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.47	1.00
1998	0.03	0.00	0.24	0.24	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.04	0.03	0.00	0.00	0.38	1.00
1999	0.04	0.00	0.27	0.27	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.04	0.04	0.00	0.00	0.30	1.00
2000	0.05	0.00	0.29	0.29	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.05	0.04	0.00	0.00	0.24	1.00
2001	0.06	0.00	0.31	0.31	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.05	0.05	0.00	0.00	0.20	1.00
2002	0.06	0.00	0.32	0.32	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.05	0.05	0.00	0.00	0.16	1.00
2003	0.07	0.00	0.33	0.33	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.05	0.05	0.00	0.00	0.13	1.00
2004	0.07	0.00	0.34	0.34	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.06	0.05	0.00	0.00	0.11	1.00
2005	0.08	0.00	0.35	0.35	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.06	0.05	0.00	0.00	0.09	1.00
2006	0.09	0.00	0.35	0.35	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.07	1.00
2007	0.09	0.00	0.36	0.35	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.06	1.00
2008	0.09	0.00	0.36	0.36	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.05	1.00
2009	0.09	0.00	0.36	0.36	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.04	1.00
2010	0.10	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.03	1.00
2011	0.11	0.00	0.36	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.02	1.00
2012	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.02	1.00
2013	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.02	1.00
2014	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2015	0.11	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2016	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2017	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.01	1.00
2018	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2019	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2020	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2021	0.12	0.00	0.37	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2022	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2023	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2024	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2025	0.12	0.00	0.36	0.36	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00

Table C.5 (continued)

End of calendar year	Radioactivity fraction of radionuclide ^c																
	³ H	⁸⁹ Sr	⁹⁰ Sr	⁹⁰ Y	⁹¹ Y	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru	¹⁰⁶ Rh	¹²⁵ Sb	¹³⁷ Cs	^{137m} Ba	¹⁴⁴ Ce	¹⁴⁴ Pr	¹⁴⁷ Pm	Total ^d
2026	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2027	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2028	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2029	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00
2030	0.12	0.00	0.36	0.35	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	1.00

^aTaken from ref. 5.

^bChemical composition (wt %): fly ash, 46.0; water, 30.2; cement, 11.5; NaNO₃, 6.0; NaOH, 1.9; NaNO₂, 1.5; NaAl(OH)₄, 1.3; Na₂SO₄, 0.7; and other, 0.9.

^cThe radionuclide composition at the end of a year is expressed in terms of the fraction of each significant nuclide making up an average unit of radioactivity in all saltstone collected from the beginning of the operation of the saltstone plant to the end of the year indicated.

^dFor some years the total may not equal the sum of components because of independent rounding.

Table C.6. Estimated sources and characteristics of commercial Greater-Than-Class-C LLW^a

Waste source	Physical form	Primary isotopes of concern for disposal
Utilities		
Reactor operations	Activated metals, instruments, filters, ion-exchange resins, sludges	⁵⁹ Ni, ⁶³ Ni, ⁹⁴ Nb, and TRU isotopes
Reactor decommissioning	Activated metals	⁵⁹ Ni, ⁶³ Ni, and ⁹⁴ Nb
Fuel testing labs		
Burnup lab operation	Solidified liquids, metal cuttings, glassware, equipment, ion-exchange resins	⁹⁰ Sr and TRU isotopes
Burnup lab decommissioning	Solidified liquids, metals, glassware, equipment	⁹⁰ Sr and TRU isotopes
Sealed sources		
Manufacturer operations	Trash, metal, foils	¹⁴ C, ⁹⁰ Sr, ¹³⁷ Cs, ²⁴¹ Am, and Pu isotopes
Manufacturer decommissioning	Trash, metal, foils	¹⁴ C, ⁹⁰ Sr, ¹³⁷ Cs, ²⁴¹ Am, and Pu isotopes
Sources designated as waste	Sealed sources	¹³⁷ Cs, ²³⁸ Pu, ²³⁹ Pu, and ²⁴¹ Am
Other		
¹⁴ C users	Solidified process liquids	¹⁴ C
Test and research reactors	Activated metals	⁵⁹ Ni, ⁹⁴ Nb, and TRU isotopes
Other	Soil, trash	²⁴¹ Am

^aGleaned from information given in refs. 6 and 7.

Table C.7. Historical and projected number and volume of drums and classes of LLW incorporated in cement to be generated in the WVDP Low-Level Radwaste Treatment System^{a,b,c,d}

End of calendar year	Number of drums			Total volume of drums (m ³)
	Class A ^e	Class B	Class C ^e	
1987	726 ^f	g	—	189
1988	—	g	2,009	523
1989	—	g	4,523	1,177
1990 ^h	—	g	3,862	1,055
1991	—	g	0	0
1992	1,268	g	268	399
1993	2,387	g	1,298	959
1994	—	g	3,373	878
Total number	4,381	g	15,333	
Total volume, m ³	1,140	g	3,990	5,130

^aThe so-called square drums used are parallelepipeds of square cross section (~0.6 m × 0.6 m × 0.8 m) with a volume of 71 gal (0.27 m³).

^bThe classes are in accordance with the Classes (A, B, or C) as set by requirements of the NRC in 10 CFR Part 61.55.

^cTaken from ref. 8.

^dAlkaline HLW liquid is processed (see Chapter 2) to yield a loaded ion-exchange material (zeolite), which is HLW, and an effluent, which is LLW. This effluent is solidified with cement.

^eStored in a shielded drum cell.

^fGenerated in 1987 during equipment testing campaigns.

^gNo Class-B LLW is expected to be generated with the effluent mentioned in footnote d.

^hProcessing of alkaline HLW liquid was completed in November 1990, leaving a 1,090-m³ heel of liquid in the alkaline HLW waste (liquid plus sludge) storage tank.

APPENDIX D. REFERENCE SITES AND FACILITIES

APPENDIX D. REFERENCE SITES AND FACILITIES

This appendix provides information on the major DOE and commercial sites and facilities discussed in this report. The DOE operations and special site offices are identified in Table D.1, along with the sites for which they have responsibility. This is followed by Table D.2, which lists DOE Naval Reactors Program (NE-60) offices and sites. Table D.3 lists major DOE sites and facilities referred to in this report, and major commercial radioactive waste disposal sites are given in Table D.4. For each site or facility listed in Tables D.3 and D.4, additional information is provided, including reference symbol or label, location, operations contractor, and, for DOE sites, the supervisory DOE operations and area office.

Table D.1. DOE operations and special site offices

DOE office	Symbol/label	General mailing address (Phone number) ^a	Radioactive waste sites for which DOE office has responsibility
Albuquerque Operations Office ^b	DOE/AL	P.O. Box 5400 Albuquerque, NM 87115-5400 (505/845-4154)	Grand Junction Projects Office sites Inhalation Toxicology Research Institute Kansas City Plant Los Alamos National Laboratory Pantex Plant Pinellas Plant Sandia National Laboratories/California Sandia National Laboratories/New Mexico Uranium Mill Tailings Remedial Action Program sites Waste Isolation Pilot Plant
Chicago Operations Office ^c	DOE/CH	Building 201 9800 South Cass Avenue Argonne, IL 60439 (708/252-2001)	Ames Laboratory Argonne National Laboratory-East Argonne National Laboratory-West Battelle Columbus Laboratories Decommissioning Project Brookhaven National Laboratory Fermi National Accelerator Laboratory Princeton Plasma Physics Laboratory
Idaho Operations Office	DOE/ID	785 DOE Place Idaho Falls, ID 83402 (208/526-0111)	Argonne National Laboratory-West Idaho National Engineering Laboratory
Nevada Operations Office	DOE/NV	P.O. Box 98518 Las Vegas, Nevada 89193-8518 (702/295-1212)	Nevada Test Site
Oakland Operations Office	DOE/OAK	1301 Clay Street Oakland, CA 94612-5208 (510/273-6383)	Energy Technology Engineering Center (Santa Susana Field Laboratory) Laboratory for Energy-Related Health Research (Institute of Toxicology and Environmental Health) Lawrence Berkeley Laboratory Lawrence Livermore National Laboratory Stanford Linear Accelerator Center

Table D.1 (continued)

DOE office	Symbol/label	General mailing address (Phone number) ^a	Radioactive waste sites for which DOE office has responsibility
Oak Ridge Operations Office ^d	DOE/OR	P.O. Box 2001 Oak Ridge, TN 37831 (615/576-5454)	Formerly Utilized Sites Remedial Action Program (FUSRAP) sites Oak Ridge Institute for Science and Education Oak Ridge K-25 Site Oak Ridge National Laboratory Oak Ridge Y-12 Plant Paducah Gaseous Diffusion Plant Portsmouth Gaseous Diffusion Plant Weldon Spring Site Remedial Action Project
Ohio Field Office	DOE/OH	P.O. Box 3020 Miamisburg, OH 45343-3020 (513/865-3977)	Fernald Environmental Management Project Mound Plant West Valley Demonstration Project
Richland Operations Office	DOE/RL	P.O. Box 550 825 Jadwin Avenue Richland, WA 99352 (509/376-7411)	Hanford Site Pacific Northwest Laboratory
Rocky Flats Office	DOE/RF	P.O. Box 928 Golden, CO 80401-0928 (303/966-7000)	Rocky Flats Plant
Savannah River Operations Office	DOE/SR	P.O. Box A Aiken, SC 29802 (803/725-6211)	Savannah River Site

^aAccess to main organizations.

^bThe Albuquerque Operations Office also has the following area offices (monitoring activities of the sites indicated) under its purview: Amarillo (Pantex Plant), Grand Junction (Grand Junction Projects Office), Kansas City (Kansas City Plant), Los Alamos (Los Alamos National Laboratory), and Pinellas (Pinellas Plant).

^cThe Chicago Operations Office has the following area offices (monitoring activities of the sites indicated) under its purview: Argonne (Argonne National Laboratory-East), Batavia (Fermi National Accelerator Laboratory), Upton (Brookhaven National Laboratory), and Princeton (Princeton Plasma Physics Laboratory).

^dThe Oak Ridge Operations Office has a separate site office located at the following: Oak Ridge K-25 Site, Oak Ridge National Laboratory, Oak Ridge Y-12 Plant, Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, and the Weldon Spring Site Remedial Action Project.

Table D.2. DOE Naval Reactors Program offices and sites

DOE office	Symbol/label	General mailing address (Phone number) ^a	Radioactive waste sites for which DOE office has responsibility
DOE/HQ, Office of Naval Reactors	DOE/HQ/NE-60	Route Symbol NE-60 2521 Jefferson Davis Hwy Arlington, VA 22202 (703/603-7321)	Oversees Pittsburgh and Schenectady area offices and their sites; oversees the following shipyards: <ul style="list-style-type: none"> • Charleston Naval Shipyard, Charleston, SC • Mare Island Naval Shipyard, Mare Island, CA • Norfolk Naval Shipyard, Norfolk, VA • Pearl Harbor Naval Shipyard, Pearl Harbor, HI • Portsmouth Naval Shipyard, Portsmouth, ME • Puget Sound Naval Shipyard, Puget Sound, WA
Pittsburgh Naval Reactors Offices	DOE/PNRO	P.O. Box 109 West Mifflin, PA 15122-0109 (412/476-5000)	Bettis Atomic Power Laboratory Naval Reactors Facility (Idaho Falls, ID)
Schenectady Naval Reactors Office	DOE/SNRO	P.O. Box 1069 Schenectady, NY 12301-1069 (518/395-4000)	Knolls Atomic Power Laboratory

^aAccess to main organizations.

Table D.3. Major DOE sites and facilities referred to in this report

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^a	DOE operations office (Phone number) ^a
Ames Laboratory	AMES	Iowa State University Spedding Hall Pammel Drive Ames, IA 50011-3020 (515/294-2680)	Chicago (708/252-2001)
Argonne National Laboratory—East	ANL—E	University of Chicago 9700 South Cass Avenue Argonne, IL 60439 (708/252-2000)	Chicago Argonne Area Office (708/252-2001)
Argonne National Laboratory—West ^b	ANL—W	University of Chicago Idaho Site P.O. Box 2528 Idaho Falls, ID 83403-2528 (208/533-7000)	Idaho (208/526-0111)
Battelle Columbus Laboratories Decommissioning Project	BCLDP	Battelle Memorial Institute 505 King Avenue Columbus, OH 43201-2693 (614/424-3989)	Chicago (708/252-2001)
Brookhaven National Laboratory	BNL	Associated Universities, Inc. 16 South Railroad Street Upton, NY 11973-2310 (516/282-2123)	Chicago Brookhaven Area Office (516/282-3427)
Colonie Interim Storage Site	CISS	Bechtel National, Inc. P.O. Box 5169 Albany, NY 12205 (518/482-0237)	Oak Ridge (615/576-5454)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^a	DOE operations office (Phone number) ^a
Energy Technology Engineering Center (Santa Susana Field Laboratory)	ETEC (SSFL)	Rockwell International Rocketdyne Division 6633 Canoga Avenue P.O. Box 1449 Canoga Park, CA 91304 (818/586-5326)	Oakland (510/273-6383)
Fermi National Accelerator Laboratory	FNAL	University Research Association P.O. Box 500 Batavia, IL 60510 (708/840-3000)	Chicago Batavia Area Office (708/840-3281)
Fernald Environmental Management Project	FEMP	Fluor Daniels Fernald Environmental Restoration Management Corporation P.O. Box 398704 7400 Wiley Road Cincinnati, OH 45239-8704 (513/738-6200)	Ohio Field Office Fernald Area Office (513/648-3119)
Grand Junction Projects Office	GJPO	Chem-Nuclear Geotech, Inc. P.O. Box 14000 Grand Junction, CO 81502-5504 (303/248-6200)	Albuquerque (505/845-4154)
Hanford Site	HANF	Westinghouse Hanford Company, Inc. P.O. Box 1970 Richland, WA 99352 (509/376-7511)	Richland (509/376-7411)
Idaho National Engineering Laboratory	INEL	Lockheed Idaho Technologies Company P.O. Box 1625 Idaho Falls, ID 83415-4201 (208/526-0111)	Idaho (208/526-0111)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^a	DOE operations office (Phone number) ^a
Inhalation Toxicology Research Institute	ITRI	Lovelace Biomedical and Environmental Research Institute, Inc. P.O. Box 5890 Albuquerque, NM 87185 (505/845-1037)	Albuquerque (505/845-4154)
Kansas City Plant	KCP	Allied-Signal Aerospace Company Kansas City Division Bannister Federal Complex Kansas City, MO 64141 (816/997-2000)	Albuquerque Kansas City Area Office (816/997-3348)
Laboratory for Energy-Related Health Research (Institute of Toxicology and Environmental Health)	LEHR (ITEH)	University of California-Davis Old Davis Road Davis, CA 95616-8615 (916/752-1340)	Oakland (510/273-6383)
Lawrence Berkeley Laboratory	LBL	University of California One Cyclotron Road Berkeley, CA 94720 (510/486-4000)	Oakland Lawrence Berkeley Laboratory Site Office (510/486-4363)
Lawrence Livermore National Laboratory	LLNL	University of California 7000 East Avenue P.O. Box 808, L-1 Livermore, CA 94550 (510/422-1100)	Oakland (510/273-6383)
Los Alamos National Laboratory	LANL	University of California P.O. Box 1663 Los Alamos, NM 87545 (505/667-5061)	Albuquerque Los Alamos Area Office (505/667-5061)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^a	DOE operations office (Phone number) ^a
Mound Plant	MOUND	EG&G Mound Applied Technologies P.O. Box 3000 Miamisburg, OH 45343-0987 (513/865-4020)	Ohio Field Office Miamisburg Area Office (513/865-3271)
Naval Reactors Program Facilities Bettis Atomic Power Laboratory	BAPL	Westinghouse Electric Corporation P.O. Box 79 West Mifflin, PA 15122-0079 (412/476-5000)	DOE/HQ Office of Naval Reactors (NE-60) Pittsburgh Naval Reactors Office (412/476-5000)
Knolls Atomic Power Laboratory	KAPL	General Electric Company P.O. Box 1072 Schenectady, NY 12301-1072 (518/395-4000)	DOE/HQ Office of Naval Reactors (NE-60) Schenectady Naval Reactors Office (518/395-4000)
Naval Reactors Facility (INEL)	NRF	Westinghouse Electric Corporation P.O. Box 2068 Idaho Falls, ID 83403-2068 (208/526-5526)	DOE/HQ Office of Naval Reactors (NE-60) Pittsburgh Naval Reactors Office (412/476-5000)
Nevada Test Site	NTS	Reynolds Electrical & Engineering Company, Inc. P.O. Box 98521 Mail Stop 738 Las Vegas, NV 89193-8521 (702/295-9060)	Nevada (702/295-1212)
Oak Ridge Institute for Science and Education	ORISE	Oak Ridge Associated Universities 246 Laboratory Road P.O. Box 117 Oak Ridge, TN 37831-0117 (615/576-3000)	Oak Ridge (615/576-5454)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^a	DOE operations office (Phone number) ^a
Oak Ridge K-25 Site	K-25	Martin Marietta Energy Systems, Inc. P.O. Box 2003 Oak Ridge, TN 37831-7358 (615/576-5454)	Oak Ridge (615/576-5454)
Oak Ridge National Laboratory	ORNL	Martin Marietta Energy Systems, Inc. P.O. Box 2008 Oak Ridge, TN 37831-6235 (615/576-5454)	Oak Ridge (615/576-5454)
Oak Ridge Y-12 Plant	Y-12	Martin Marietta Energy Systems, Inc. P.O. Box 2009 Oak Ridge, TN 37831-8010 (615/576-5454)	Oak Ridge (615/576-5454)
Pacific Northwest Laboratory ^c	PNL	Battelle Memorial Institute Battelle Boulevard P.O. Box 999 Richland, WA 99352 (509/375-2121)	Richland (509/376-7411)
Paducah Gaseous Diffusion Plant	PAD	Martin Marietta Energy Systems, Inc. P.O. Box 1410 Paducah, KY 42001 (502/441-6000)	Oak Ridge Paducah Site Office (502/441-6800)
Pantex Plant	PANT	Mason & Hanger—Silas Mason Company, Inc. P.O. Box 30020 Amarillo, TX 79177 (806/477-3000)	Albuquerque Amarillo Area Office (806/477-3000)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^a	DOE operations office (Phone number) ^a
Pinellas Plant	PINELLAS	Martin Marietta Specialty Components, Inc. P.O. Box 2908 Largo, FL 34649-2908 (813/541-8001)	Albuquerque Pinellas Area Office (813/541-8196)
Portsmouth Gaseous Diffusion Plant	PORTS	Martin Marietta Energy Systems, Inc. P.O. Box 628 Piketon, OH 45661 (614/897-2331)	Oak Ridge Portsmouth Site Office (614/897-2331)
Princeton Plasma Physics Laboratory	PPPL	Princeton University P.O. Box 451 Princeton, NJ 08543 (609/243-2000)	Chicago Princeton Area Office (609/243-3700)
Reactive Metals, Inc. Extrusion Plant	RMI	RMI Titanium Company P.O. Box 579 Ashtabula, OH 44004 (216/992-7442)	Fernald Ashtabula Area Office (216/992-7442)
Rocky Flats Plant	RFP	EG&G Rocky Flats, Inc. P.O. Box 464 Golden, CO 80401-0464 (303/966-7000)	Rocky Flats Office (303/966-7000)
Sandia National Laboratories California	SNL/CA	Martin Marietta Sandia Corporation P.O. Box 969 Livermore, CA 94551-0969 (510/294-3000)	Albuquerque (505/845-4154)
New Mexico	SNL/NM	Martin Marietta Sandia Corporation P.O. Box 5800 Albuquerque, NM 87185-5800 (505/844-5678)	Albuquerque (505/845-4154)

Table D.3 (continued)

Site/facility	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^a	DOE operations office (Phone number) ^a
Savannah River Site	SRS	Westinghouse Savannah River Company P.O. Box 616 Aiken, SC 29802 (803/725-6211)	Savannah River (803/725-6211)
Stanford Linear Accelerator Center	SLAC	Stanford University P.O. Box 4349 Palo Alto, CA 94309 (415/926-3300)	Oakland Stanford Site Office (415/926-3208)
Three Mile Island—Unit 2 Reactor	TMI—Unit 2	General Public Utilities P.O. Box 480 Middletown, PA 17057 (717/944-7621)	Idaho Three Mile Island Site Office (717/944-7621)
Waste Isolation Pilot Plant	WIPP	Westinghouse Electric Corporation WIPP Project Office P.O. Box 2078 Carlsbad, NM 88221 (505/885-7500)	Albuquerque WIPP Project Office (505/887-8115)
Weldon Spring Site Remedial Action Project	WSSRAP	Jacobs Engineering Group, Inc. MK-Ferguson Company 7295 Highway 94 South St. Charles, MO 63304 (314/441-8978)	Oak Ridge Weldon Spring Site Office (314/441-8978)
West Valley Demonstration Project	WVDP	Westinghouse Electric Corporation West Valley Nuclear Services Company, Inc. 10282 Rock Springs Road P.O. Box 191 West Valley, NY 14171-0191 (716/942-3235)	Ohio Field Office West Valley Area Office (716/942-4313)

^aPhone number for access to main organization.^bPart of the Idaho National Engineering Laboratory.^cPart of the Hanford Site.

Table D.4. Major commercial radioactive waste disposal sites included in this report^a

Site	Symbol/label	Principal contractor(s) for site operations and mailing address (Phone number) ^b
Barnwell	BARN	Chem-Nuclear Systems, Inc. 140 Stoneridge Drive Columbia, SC 29210 (803/256-0450)
Beatty	BETY	U.S. Ecology, Nuclear P.O. Box 578 Beatty, NV 89003 (702/553-2203)
Maxey Flats	MFKY	Commonwealth of Kentucky ^c Department of Environmental Protection/Superfund Branch Maxey Flats Project 14 Reilly Road Frankfort, KY 40601-1190 (502/564-6716) <u>Site address:</u> Maxey Flats Project Route 2 P.O. Box 238A Hillsboro, KY 41049 (606/784-6612)
Richland	RICH	U.S. Ecology, Nuclear P.O. Box 638 Richland, WA 99352 (509/377-2411)
Sheffield	SHEF	U.S. Ecology, Nuclear P.O. Box 158 Sheffield, IL 61361 (815/454-2342)
West Valley	WVNY	Westinghouse Electric Corporation West Valley Nuclear Services Company, Inc. 10282 Rock Springs Road P.O. Box 191 West Valley, NY 14171-0191 (716/942-3235) New York State Energy Research and Development Authority 2 Rockefeller Plaza Albany, NY 12223 (518/465-6251)

^aDoes not include uranium mill tailings sites. See Table 5.2.^bPhone number for access to main organizations.^cThe Commonwealth of Kentucky assumed operating contractor responsibilities for the Maxey Flats site in 1992.

APPENDIX E. INTEGRATED DATA BASE READER COMMENT FORM

APPENDIX E. INTEGRATED DATA BASE READER COMMENT FORM

To maintain an updated distribution list for this report, the Integrated Data Base (IDB) is asking its readership to supply the information requested on the Reader Comment Form provided in the front of this report. When filling out this form, please respond to the questions in Items 1-11 (note that some require two answers). Item 12 requests some personal information (please type or print your complete name and mailing address). To be eligible for future updates of this report, please fold, attach stamp, and mail the completed Reader Comment Form to the Integrated Data Base Program at the mailing address given on the back of the form (and listed below) at your earliest convenience. Also, please notify the IDB Program of any corrections or future changes in your mailing address. Your cooperation and assistance are greatly appreciated.

Integrated Data Base Program
Oak Ridge National Laboratory
105 Mitchell Road, Mail Stop 6495
P.O. Box 2008
Oak Ridge, TN 37831-6495
Phone(s): 615/574-6823
615/576-7575
Fax: 615/576-0327

GLOSSARY OF TERMS

This glossary gives definitions of some terms commonly used in the main body of this report. A more detailed glossary of waste terms, applicable to the DOE complex, is being developed by the DOE Office of Environmental Management and will be issued for use by DOE and its contractors in the near future.

Actinides: Elements with atomic numbers from 89 (actinium) or 90 (thorium) to 103 (lawrencium) inclusive.

Activation product: A radioactive material produced by bombardment with neutrons, protons, or other nuclear particles.

Agreement State: A state that has entered into an agreement with the U.S. Nuclear Regulatory Commission (as specified by the Atomic Energy Act of 1954) and has authority to regulate the disposal of low-level radioactive waste under such an agreement. This term is used in the Low-Level Radioactive Waste Policy Act (Public Law 99-240).

Alpha decay: Radioactive decay in which an alpha particle (^4He nucleus) is emitted.

Beta decay: Radioactive decay in which a beta particle (negative or positive electron) is emitted.

Borosilicate glass: A type of glass containing at least 5% boric oxide. It is used in glassware that resists heat and is a leading candidate for use in high-level waste immobilization and disposal.

Branching ratio: In branching radioactive decay, the fraction of nuclei that disintegrates in a specific way. (It is usually expressed as a percentage.)

Burnup, specific: The total energy released per initial unit mass of reactor fuel as a result of the fission process occurring. The unit commonly used for specific burnup is megawatt-days per metric ton of initial heavy metal, MWd/MTIHM.

By-product material: (1) Any radioactive material (except special nuclear material) yielded in, or made

radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear material. For purposes of determining the applicability of the Resource Conservation and Recovery Act of 1976 to any radioactive waste, the term "any radioactive material" refers only to the actual radionuclides dispersed or suspended in the waste substance. The nonradioactive hazardous waste component of the waste substance will be subject to regulation under the Resource Conservation and Recovery Act; (2) the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. Ore bodies depleted by uranium solution extraction operations and which remain underground do not constitute by-product material.

Calcine: A form of high-level waste produced from defense reactor fuel reprocessing waste (at the Idaho Chemical Processing Plant) by heating to a temperature below the melting point to bring about loss of moisture and nonradioactive volatile oxides, thus producing a chemically stable granular powder.

Canister: A metal container used for the storage or disposal of heat-producing, solid, high-level radioactive waste.

Capacity factor, plant: The ratio of the electrical energy actually supplied by a power plant in a given time interval to the electrical energy that could have been produced at continuous full-power operation during the same time period.

Capsules: Encapsulated strontium and cesium high-level wastes produced from defense reactor fuel reprocessing at the Hanford Site. For purposes of this report, inventories of encapsulated strontium and cesium are included in a separate table in the high-level waste section (Chapter 2).

Cladding: A corrosion-resistant tube (commonly aluminum, zirconium alloy, or stainless steel) surrounding the reactor fuel pellets which provides protection from a chemically reactive environment and containment of fission products.

Code of Federal Regulations: A documentation of the general rules by the executive departments of the federal government. The code is divided into 50 titles that represent broad areas subject to federal regulation. Each title is divided into chapters that usually bear the name of the issuing agency. Each chapter is further subdivided into parts covering specific regulatory areas.

Control rod: A movable part of the reactor core that is adjusted to regulate the degree of fuel fissioning in the core.

Conversion, fuel: Chemical treatment of yellowcake (U_3O_8) to uranium hexafluoride (UF_6) in preparation for enrichment.

Core, nuclear reactor: That part of the reactor which contains the nuclear fuel and in which most or all of the nuclear fissions occur.

Daughter product(s): The nuclide(s) formed by the radioactive decay of the parent radionuclide.

Decay, radioactive: The transition of a nucleus from one energy state to a lower one, usually involving the emission of a photon, electron, neutron, or alpha particle.

Decay chain, radioactive: A series of nuclides in which each member decays to the next member of the chain through radioactive decay until a stable nuclide has been formed.

Decommissioning: Activities taken to reduce the potential health and safety impacts of commercial and DOE-contaminated facilities, including removing a unit from operation, decontamination, entombment, dismantlement, or conversion of the site to another use.

Decommissioning wastes: Wastes (generally low-level) collected or resulting from facility decommissioning activities.

Decontamination: Activities taken to remove unwanted (typically radioactive) material from facilities, soils, or equipment by washing, chemical action, mechanical cleaning, or other (treatment) techniques.

Deep bed plant: A boiling-water reactor facility using a demineralizer vessel for water purification which contains an ion-exchange resin that is 3 ft or more deep.

Disintegration energy (Q-value): The amount of energy released in a particular nuclear disintegration. This is usually expressed in MeV/disintegration.

DOE waste: Radioactive waste produced from activities supported by the Department of Energy and/or U.S. government defense programs.

Double-shell tank wastes: High-level wastes, generated from defense reactor fuel reprocessing at Hanford, which are stored in double-shelled tanks. These wastes consist of a mixture of liquid and suspended solids referred to as slurry. See also "single-shell tank wastes."

Electron capture: Radioactive decay in which an orbital electron is captured by the nucleus of the radionuclide.

Enrichment, fuel: A nuclear fuel cycle process which increases the concentration of fissionable uranium (i.e., ^{235}U) in uranium ore above its natural level of 0.71%. (The method currently used in the United States is gaseous diffusion.)

Environmental Impact Statement: A report that documents the information required to evaluate the environmental impact of a project. Such a report informs decision-makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the environment.

Environmental restoration: Cleanup and restoration of sites contaminated with radioactive and/or hazardous substances during past production, accidental releases, or disposal activities.

Equilibrium cycle: An assumed nuclear fuel cycle in which the feed and waste materials of a facility have constant compositions. In a reactor this condition typically results after the third or fourth fuel-loading schedule.

Fabrication, fuel: Conversion of enriched uranium hexafluoride (UF_6) into pellets of ceramic uranium dioxide (UO_2). These pellets are then sealed into corrosion-resistant tubes of zirconium alloy or stainless steel. The loaded tubes, called fuel elements or rods, are then mounted into special assemblies for loading into the reactor core.

Fertile nuclide: A nuclide capable of being transformed into a fissile nuclide by neutron capture.

Filter/demineralizer plant: A facility that combines filtration and ion-exchange processing using non-regenerable powered resins.

Fissile nuclide: A nuclide capable of undergoing nuclear fission with thermal neutrons.

Fission, nuclear: The division of a heavy atomic nucleus into two or more isotopes, usually accompanied by the emission of neutrons and gamma radiation.

Fission products: Nuclides produced either by fission or by the subsequent decay of the nuclides thus formed.

Fission, spontaneous: Nuclear fission that occurs without the addition of particles or energy to the nucleus.

Formerly utilized site: A site contaminated with radioactive wastes which was previously used for supporting nuclear activities of the DOE's predecessor agencies, the Manhattan Engineer District (Manhattan Project) and the Atomic Energy Commission.

Fuel assembly: A grouping of nuclear fuel rods that remains integral during the charging and discharging of a reactor core.

Fuel cycle, nuclear: The complete series of steps involved in supplying fuel for nuclear reactors. It includes mining, refining, UF_6 conversion, enrichment, fabrication of fuel elements, use in a reactor, and management of radioactive waste. It may also involve chemical processing to recover the fissionable material remaining in the spent nuclear fuel, reenrichment of the fuel material, and/or refabrication of new fuel elements.

Generation (electricity): The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, commonly expressed in kilowatt-hours (kWh) or megawatt-years [MW(e)-years].

Generation (gross): The total amount of electric energy produced by the generating units in a generating station or stations, measured at the generator terminals.

Generation (net): Gross generation less the electric energy consumed at the generating station for station use.

Generation (waste): The origination of new wastes from various facility operations (including production, rework, decontamination and decommissioning, and environmental restoration), including the recovery of pre-1970 transuranic-produced wastes, should their recovery be determined necessary.

Glass frit: A fusible ceramic mixture used to make glass for use in the immobilization and disposal of high-level wastes.

Greater-than-Class-C low-level waste: Waste from commercial sources containing concentrations of radionuclides that exceed U.S. Nuclear Regulatory Commission limits for Class C low-level radioactive waste, as defined in 10 CFR Part 61.55.

Grout: A mortar or cement mixture used to immobilize radioactive wastes.

Half-life, radioactive: For a single radioactive decay process, the time required for the activity to decrease to one-half of its initial value by that process.

Hazardous waste: Nonradioactive waste that has at least one of the following characteristics: (1) is listed as a hazardous waste in Subpart D of 40 CFR Part 261, (2) exhibits any of the characteristics identified in Subpart C of 40 CFR Part 261, or (3) contains PCB-containing wastes subject to regulation under the Toxic Substances Control Act and 40 CFR Parts 702-799.

High-level waste: As defined by the Nuclear Waste Policy Act, high-level waste is (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including the liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations and (2) other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule to require permanent isolation.

Hydrofracture: A process formerly used for permanent disposal of low-level (approximately 0.25 Ci/L) liquid waste at the Oak Ridge National Laboratory. The process involved mixing the waste with a blend of cement and other additives with the resulting grout being injected into shale at a depth of 200 to 300 m. The injected grout hardened into thin, horizontal sheets several hundred meters wide.

Industrial waste: Commercial low-level waste resulting from nonnuclear fuel cycle sources. These include the commercial producers of radiochemicals and radiopharmaceuticals, luminous dial manufacturers, and instruments that incorporate sealed source components (e.g., smoke detectors).

Institutional waste: Commercial low-level waste resulting from bioresearch, medical, and certain nonbioresearch sources. Bioresearch wastes include wastes from animal studies at universities. Medical wastes include those generated from diagnostic and therapeutic procedures on humans at hospitals. Nonbioresearch wastes include research reactor wastes; small-volume, sealed radiation sources; and accelerator targets.

Leaching: The process of removal or separation of soluble components from a solid by percolating water or other liquids through the solid.

Low-level waste: As specified in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (Public Law 99-240), radioactive waste not classified as high-level waste, spent nuclear fuel, or by-product material specified as uranium or thorium tailings and waste.

Mill tailings, uranium: Earthen residues that remain after the extraction of uranium from ores. Tailings may also contain other minerals or metals not extracted in the process.

Mixed low-level waste: Waste that satisfies the definition of low-level radioactive waste (LLW) in the Low-Level Radioactive Waste Policy Amendments Act of 1985 and that contains hazardous waste that has at least one of the following characteristics: (1) is listed as a hazardous waste in Subpart D of 40 CFR Part 261, (2) exhibits any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261, or (3) contains PCB-containing wastes subject to regulation under the Toxic Substances Control Act and 40 CFR Parts 702-799.

Mixed-oxide fuel: Nuclear reactor fuel composed of plutonium and uranium in oxide form.

Mixed waste: Waste that includes concentrations of both radionuclides and hazardous chemicals.

Moderator: A material used to reduce neutron energy (for fissioning if in a reactor) by elastic scattering.

MRS facility: A proposed facility for the monitored retrievable storage of spent nuclear fuel from commercial power plants. Such a facility would permit continuous monitoring, management, and maintenance of these wastes and provide for their ready retrieval for further processing or disposal.

Naturally occurring or accelerator-produced radioactive material: Any radioactive material that can be considered naturally occurring and is not source, special nuclear, or by-product material or that is produced in a charged particle accelerator.

Neutron activation: The process of irradiating a material with neutrons so that the material itself is transformed into a radioactive nuclide.

Nonfuel components: Nuclear reactor core parts and hardware, excluding the nuclear fuel itself. Such components include shrouds, control rods, fuel channels, in-core chambers, support tubes, and dummy fuel rods.

Parent: A radionuclide that upon decay yields a specified nuclide (the daughter) either directly or as a later member of a radioactive decay series.

Pressure vessel, reactor: A strong-walled container housing the core of most types of power reactors. It usually also contains other core components such as the moderator and control rods.

PUREX™ process: A solvent extraction process that may be used in the reprocessing of uranium/plutonium-based nuclear fuels.

Radioactivity: The property possessed by certain nuclides of spontaneously emitting alpha or beta particles and, sometimes, gamma radiation by the disintegration of atomic nuclei. The units for the rate of decay of radioactive nuclides are the curie, Ci (3.7×10^{10} disintegrations per second exactly), or, in SI units, the becquerel, Bq (1 disintegration per second).

Reactor, boiling-water: A light-water reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam is used directly to drive a turbine.

Reactor, breeder: A reactor that produces more fissionable fuel than it consumes. The new fissionable material is created by a process (breeding) in which fission neutrons are captured in fertile materials.

Reactor, fast flux: A reactor in which fission is induced predominantly by fast neutrons.

Reactor, high-temperature, gas-cooled: A nuclear reactor that uses an inert gas (helium) as the primary coolant and graphite as the moderator.

Reactor, light-water: A nuclear reactor that uses light water (H_2O) as the primary coolant and moderator and slightly enriched uranium as the fuel. There are two types of commercial light-water reactors: boiling-water and pressurized-water.

Reactor, naval propulsion: A reactor used to power a U.S. Navy vessel.

Reactor, pressurized-water: A light-water reactor in which heat is transferred from the core to a heat exchanger via water kept under high pressure, so that high temperatures can be maintained in the primary coolant system without boiling the water. Steam is generated in a secondary circuit.

Reactor, production: A reactor whose primary purpose is to produce fissile or other materials or to perform irradiations on an industrial scale. Unless otherwise specified, the term usually refers to either a tritium- or plutonium-production facility used to produce materials for nuclear weapons.

Reactor, research: A reactor whose nuclear radiations are used primarily as a tool for basic or applied research. Typically, it has a thermal power of 10 MW(t) or less and may include facilities for testing reactor materials.

Reactor, test: A reactor associated with an engineering-scale test program conducted to develop basic design information or demonstrate safety characteristics of nuclear reactor systems.

Reinserted fuel: Irradiated reactor fuel that is discharged in one cycle and inserted into the same reactor during a subsequent refueling. In a few cases, fuel discharged from one reactor has been used to fuel a different reactor.

Repository, geologic: A facility that has an excavated subsurface system for the permanent disposal of spent nuclear fuel and high-level waste.

Reprocessing, fuel: The chemical/mechanical processing of irradiated nuclear reactor fuel to remove fission products and recover fissile and fertile material.

Salt cake: A salt form of high-level waste stored in tanks, which is produced from neutralizing acidic liquid waste from defense reactor fuel reprocessing with an alkaline agent (caustic soda).

Saltstone: A low-level waste by-product from the solidification of high-level waste at the Savannah River Site. Saltstone is retained in trenches at the Savannah River Site.

Sea-bed disposal: Placement of waste packages in deep ocean sediments.

Sea dumping (disposal): The practice of periodically dumping shiploads of drummed, solidified waste into the ocean at specified locations. (No longer performed.)

Separative work unit: The standard measure of enrichment services. The separative work unit (SWU) is expressed as a unit of mass. For example, 1 kilogram of separative work is expressed as 1 kg SWU.

Single-shell tank wastes: High-level wastes, generated from defense reactor fuel reprocessing at Hanford, which are stored in single-shelled tanks that contain liquid, sludge, and salt cake. See also "double-shell tank wastes."

Slurry, high-level waste: A watery mixture of highly radioactive, insoluble matter.

Solvent extraction: The separation of materials of different chemical types by exploiting the relative chelating ability of different chemicals which preferentially dissolve in one of the two phases. In spent nuclear fuel reprocessing, liquid-liquid contact of two immiscible solvents (one aqueous, one organic) permits recovery and separation of uranium and plutonium in one phase and fission products in the other phase.

Source term (IDB Program usage): A set of qualitative and quantitative features used to describe the origin and concentration of radioactive waste. The qualitative features include a flowchart of waste streams generated by a facility or an activity. Quantitative features include (1) the number of curies of radioactivity expressed either per unit of facility production or per unit of waste volume or mass and (2) a listing of the relative concentrations of component radioisotopes per curie of waste activity.

Special nuclear material: Plutonium or uranium enriched to a higher-than-natural assay.

Spent nuclear fuel: Nuclear fuel that has been permanently discharged from a reactor after it has been irradiated. Typically, spent nuclear fuel is measured in terms of either the number of discharged fuel assemblies or the quantity of discharged fuel mass. The latter is measured either in metric tons of heavy metal (i.e., only the heavy-metal content of the spent nuclear fuel is considered) or in metric tons of initial heavy metal (essentially, the initial heavy-metal mass of the fuel before irradiation). The difference between these two quantities is the weight of the fission products produced during irradiation.

Thermal power: A measure of the rate of heat-energy emission that results from the radioactive decay of a material. A unit of thermal power commonly used is the watt (W).

THOREX process: A solvent extraction process developed to reprocess thorium-based nuclear fuels.

Transuranic waste: As defined and used by the U.S. Department of Energy (DOE Order 5820.2A), radioactive waste that, at the time of assay, contains more than 100 nCi/g of alpha-emitting isotopes with atomic numbers greater than 92 and half-lives greater than 20 years.

Transuranic waste acceptance criteria: A set of conditions established for permitting transuranic wastes to be disposed at the Waste Isolation Pilot Plant.

Transuranic waste certification: The process for verifying that a suspect radioactive waste is transuranic.

Transuranic waste, contact-handled: Transuranic waste with a surface dose rate of less than 200 mrem/h and minimal heat generation to permit handling by contact methods.

Transuranic waste nondestructive assay/nondestructive examination: Nondestructive test procedures performed on suspect transuranic wastes to determine their transuranic isotope concentration. From these tests such wastes can be properly classified (certified) as transuranic or low-level.

Transuranic waste, remote-handled: Transuranic waste with a surface dose rate of greater than 200 mrem/h and/or heat generation to require remote handling and/or shielding.

Vitrification: The conversion of high-level waste materials into a glassy or noncrystalline solid for subsequent disposal.

Waste Isolation Pilot Plant: A facility, located near Carlsbad, New Mexico, to be used for demonstrating the safe disposal of transuranic wastes from DOE activities.

Yellowcake: A uranium oxide concentrate that results from milling (concentrating) uranium ore. It typically contains 80 to 90% U_3O_8 .

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