3. WASTE

Hanford "Tank Farm." The million-gallon double-walled carbon steel tanks buried here hold high-level nuclear waste from Hanford's plutonium production program. The double-walled tanks have replaced Hanford's older, single-walled tanks which have leaked approximately one million gallons of high-level radioactive waste into Hanford soil. *200 Area, Hanford Site, Washington. July 12, 1994.*

OVERVIEW

The term "waste" in this report refers to solids and liquids that are radioactive, hazardous, or both. These materials have, in the past, been disposed of by shallow burial, sea burial, or by deep underground injection.[1] Waste not yet disposed of or which await a decision on their method of disposal, are accumulated in containers, tanks, silos, buildings, and other structures. Also awaiting disposal are previously disposed waste that have been retrieved in site cleanups and are currently in storage.

Waste is measured in terms of its volume (cubic meters) and its radioactivity content (curies).[2] Waste from nuclear weapons production managed by the Department of Energy includes 24 million cubic meters of waste containing about 900 million curies. DOE manages another 12 million cubic meters of waste containing 110 million curies which has resulted from nonweapons activities. The total from both sources is 36 million cubic meters and about one billion curies.[3] Some key information about the waste

[1] *Hydrofracture (an underground injection disposal technology) and sea disposal of radioactive waste have been discontinued.*

[2] *A curie is a unit of radioactivity expressed in terms of nuclear disintegrations per second. It provides a measure of the immediate radioactive emission of the radionuclides in the waste, but it does not take into account the type of particles or amount of energy released per disintegration or the shielding effect of the waste's physical matrix. The number of curies will decrease over time at a rate that depends on the particular isotopes in the waste.*

[3] *By contrast, commercial spent nuclear fuel is estimated to contain 29 billion curies.*

legacy is provided in the text box. The methodology section of this chapter further describes the data sources and documents used in the process to determine the volume, characteristics, and sources of the waste legacy.

DEFINITIONS AND CATEGORIES

This chapter identifies and describes the major categories of waste in the nuclear weapons legacy and provides information on the volume of waste and amount of radioactivity in each category, the location of the waste, and the activities that generated the waste. The waste legacy includes seven major categories:

- High-level waste
- Transuranic waste
- Low-level waste
- Mixed low-level waste
- 11e(2) byproduct material
- Hazardous waste
- Other waste

This categorization takes into account the radioactive and chemically hazardous properties of the waste and is the primary factor used by the Department in determining how a waste should be managed. These categories correspond to distinct waste classes subject to external federal or state requirements or DOE's internal system of orders. Waste is classified as *radioactive* if it contains, or is presumed to contain (based on available data), radioactive source, special nuclear, or byproduct material regulated under the Atomic Energy Act (AEA). Some naturally-occurring and accelerator-produced radioactive materials are also managed as radioactive waste, although they are not subject to the AEA. Waste that does not contain hazardous or radioactive constituents or that contains them at below regulated levels does not appear in this report. This waste does not require long-term monitoring or care and does not pose the same risks as waste in the other categories.

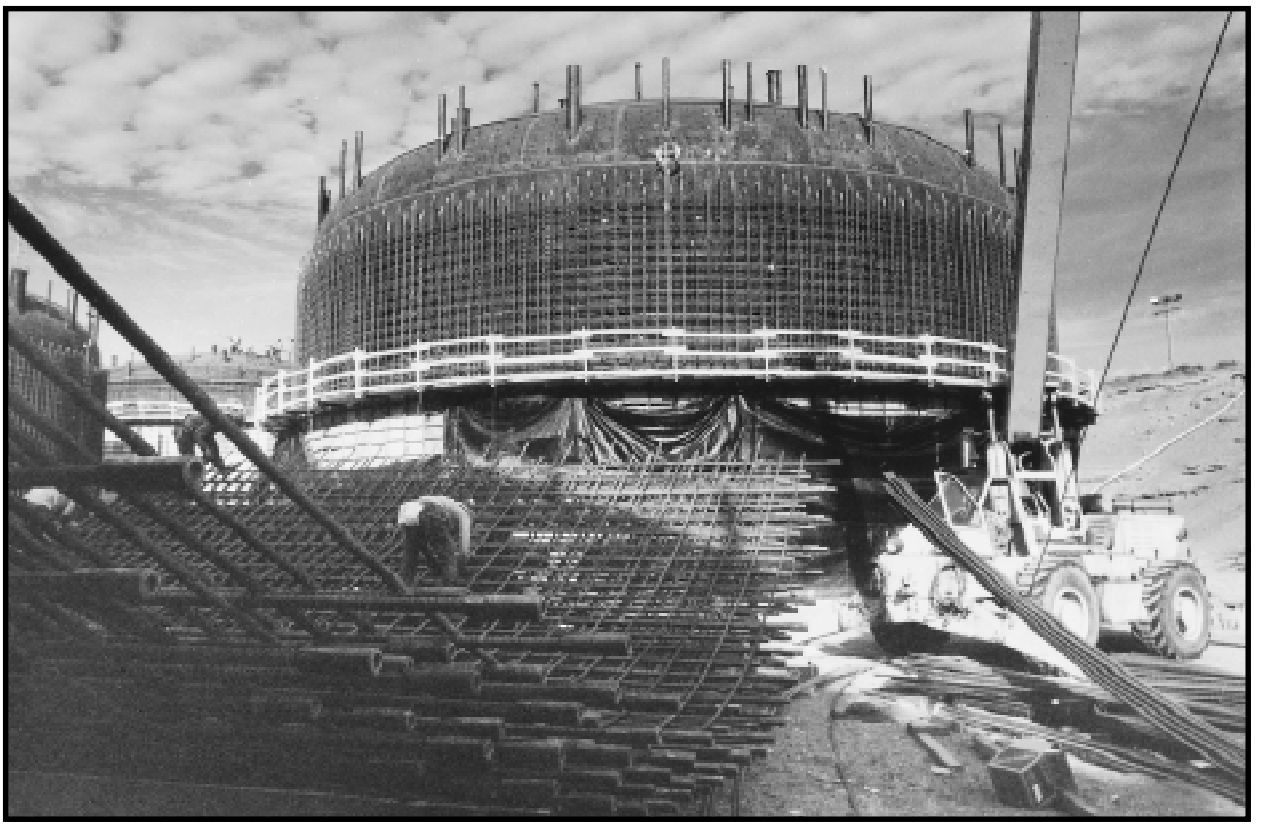
Key Information about the Waste Legacy

- Uranium mining, milling, and refining generated the largest volume of weapons waste (61 percent by volume). The largest volume of this waste is disposed 11e(2) byproduct material (i.e., uranium mill tailings). States with the largest volumes of waste from weapons production are Colorado, Utah, New Mexico, and Texas.
- Weapon operations produced the smallest volume of waste (less than1%).
- Most of the radioactivity in the waste legacy is contained in high-level waste, attributed to the chemical separation process. All high-level waste remains in storage, except for about one million gallons that has leaked from storage tanks at Hanford, Washington. Most of the high-level waste is located at the three DOE sites performing chemical separation for weapons production located in Idaho, South Carolina, and Washington. Because of differences in the materials processed, the age of the waste, and waste management practices, the radioactive content of the Department's high-level waste (in curies per cubic meter) varies greatly from site to site.
- Radioactivity in waste from uranium mining, milling, and refining; enrichment; and fuel and target fabrication is due generally to natural radioactivity (e.g., uranium, thorium, and their daughter products). Radioactivity in waste from the other processes is due primarily to reactor-generated fission products and transuranic isotopes.
- Portions of all waste categories, except high-level waste, have been disposed. However, much of this waste was originally disposed of under conditions considered inadequate by today's standards.
- The Office of Waste Management oversees much greater quantities of radioactivity than the Office of Environmental Restoration. This radioactivity is contained primarily in high-level waste. The Office of Environmental Restoration, however, manages a larger volume of waste than the Office of Waste Management.

High-level Waste

High-level waste is the highly radioactive waste resulting from the chemical processing of spent nuclear fuel and irradiated target assemblies. It includes liquid waste produced directly, and any solid waste derived from the liquid, that contains a combination of transuranic elements and fission products in concentrations that require permanent isolation.[4] High-level waste also includes some other radioactive waste that is combined with high-level waste from fuel reprocessing. The intense radioactivity primarily

[4] *The definition and management requirements for high-level waste are set forth in DOE Order 5820.2A, the Nuclear Waste Policy Act, and numerous NRC regulations.*



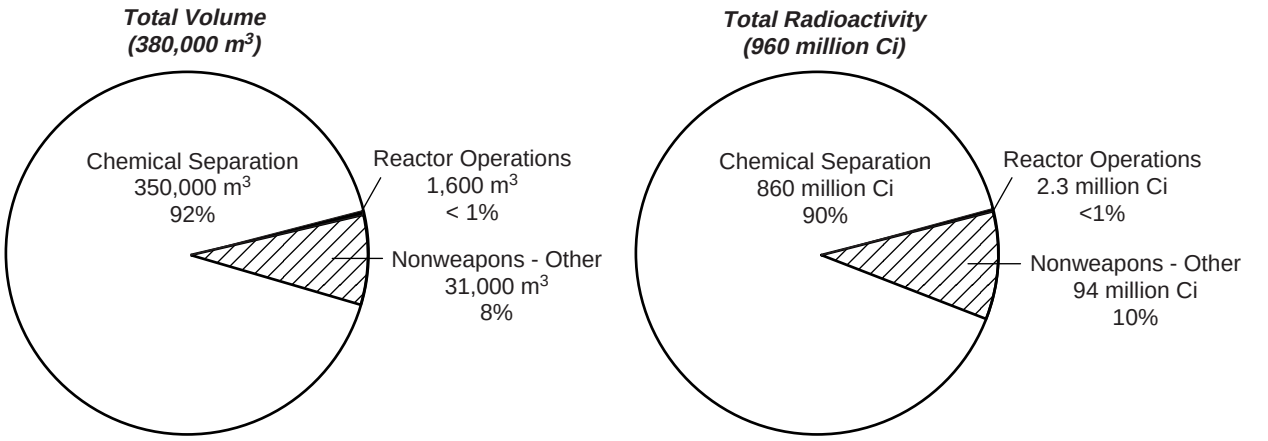
Million-gallon double-walled carbon-steel tank under construction. A total of 149 single-shell tanks and 28 double-shell tanks like this one contain high-level radioactive waste from Hanford's plutonium production operations. This tank design supercedes Hanford's older single-walled tanks, many of which have leaked. Some one million gallons of waste are believed to have leaked from the older single-shell tanks. The new double-walled tanks are expected to last for 50 years. By that time, the Department of Energy anticipates that a sucessful long-term solution for the disposal of high-level waste will have been developed. *200 Area Tank Farm, Hanford Site, Washington. November 16, 1984.*

determines how high-level waste is managed. However, the presence of hazardous constituents and the regulatory status of the waste are also important factors in high-level waste management decisions. Much of the Department's high-level waste also is either known or presumed to contain hazardous constituents subject to regulation under Subtitle C of the Resource Conservation and Recovery Act (RCRA) and is regulated as mixed waste.

High-level waste is formally defined in the Nuclear Waste Policy Act; in Title 10 of the Code of Federal Regulations (CFR), Part 60; and in DOE Order 5820.2A, which governs the Department's management of radioactive waste. By virtue of these definitions, nearly all high-level waste resulting from nuclear weapons production included in the legacy is attributed to chemical separations. Spent fuel from commercial nuclear power reactors is not included in the definition of high-level waste in the Nuclear Waste Policy Act or 10 CFR Part 60. The Department categorizes spent fuel, including fuel and targets from weapons production reactors, research reactors, and some power reactors, as materials in inventory rather than waste. Spent fuel is discussed in Chapter 6 of this report.

The radioactivity in high-level waste comes from fission fragments and their daughter products resulting chiefly from the splitting of uranium-235 in production reactor fuel. These fission fragments and their daughter products are collectively known as "fission products." Although radiation levels and health risks caused by short-lived fission products decrease dramatically in a few hundred years, risks attributable to long-lived isotopes in high-level waste will not change over thousands of years. During most of the initial decay period, most of the radioactivity is caused by cesium-137, strontium-90, and their short-lived daughter products. After the radioactivity from fission products decays to lower levels, radioactiv-

Figure 3-1. High-level Waste Radioactivity Categorized by Process



Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995. (See Endnotes a, k, and q).
(2) Waste category assignments are made in accordance with the process set forth in Endnote r.
(3) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnote s.

ity from long-lived isotopes, including plutonium, americium, uranium, daughter products from these elements, technetium-99, and carbon-14, becomes the dominant component and will pose the largest long-term potential risk.

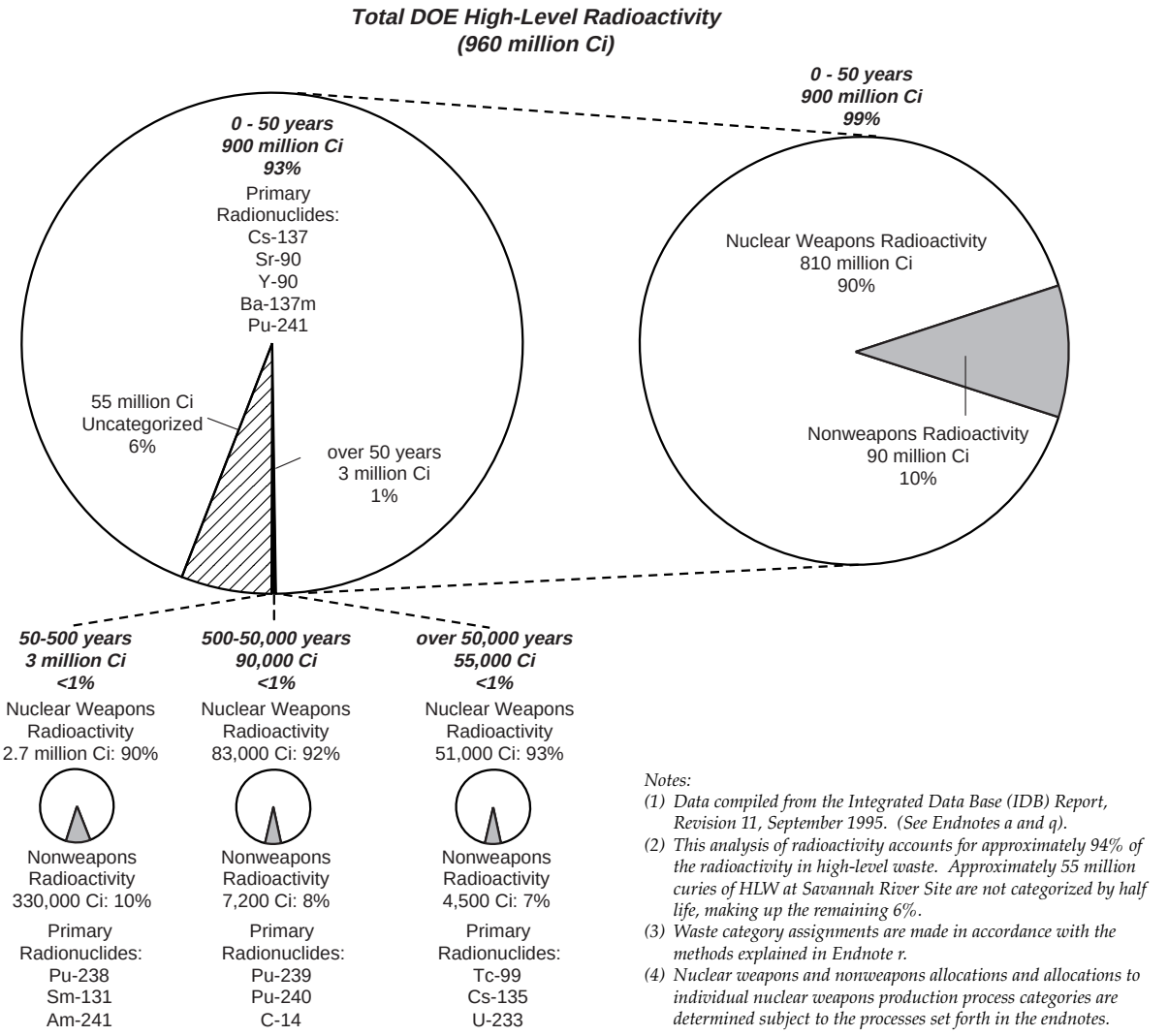
Most of the Department's liquid high-level waste is stored in either a highly acidic or a highly caustic solution, or as a saltcake or sludge. Most of the liquids, sludges, and other forms of high-level waste also contain toxic heavy metals, and some of the high-level waste also contains organic solvents (e.g., hexone, tributyl phosphate) and cyanide compounds.

Of the total volume of 380,000 cubic meters, about 92 percent (350,000 cubic meters) of the Department's high-level waste is the result of weapons production and 8 percent is the result of nonweapons activities. None of the high-level waste is attributed to DOE activities supporting the Naval Nuclear Propulsion Program (NNPP). Of a total radioactive content of 960 million curies, about 90 percent is from weapons production and 10 percent was generated by nonweapons activities (Figure 3-1). Nearly all high-level waste, both weapons and nonweapons, was produced by chemical separation activities, and a small amount of high-level waste is attributed to reactor operation; no high-level waste resulted from the other six weapons production process categories.[5] All high-level waste at Idaho National Engineering Laboratory is attributed to weapons production because it resulted from the reprocessing of spent nuclear fuel to recover highly-enriched uranium for the nuclear weapons program. A portion of the high-level waste at Hanford and the Savannah River Site and all of the high-level waste at West Valley Demonstration Project is attributed to nonweapons activities. Most nonweapons high-level waste resulted from Hanford and West Valley Demonstration Project reprocessing of spent fuel from the Hanford N Reactor to produce fuel grade plutonium for civilian power reactor programs. Additional nonweapons high-level waste was the result of commercial reprocessing of spent fuel from electric utility power reactors conducted at West Valley Demonstration Project.

Over 99 percent of the radioactivity now present in high-level waste is from radionuclides with half-lives of less than 50 years (Figure 3-2). Longer-lived radionuclides make up the remaining fraction of one percent of the current radioactivity. After several hundred years, the short-lived radionuclides will have decayed and will no longer comprise most of the radioactivity.

[5] *High-level waste attributed to reactor operation consists of ion exchange resins used to remove radionuclides from spent nuclear fuel storage basins containing corroded fuel and sludge from the bottom of these pools at Hanford.*

Figure 3-2. High-level Waste Radioactivity Categorized by Half-life



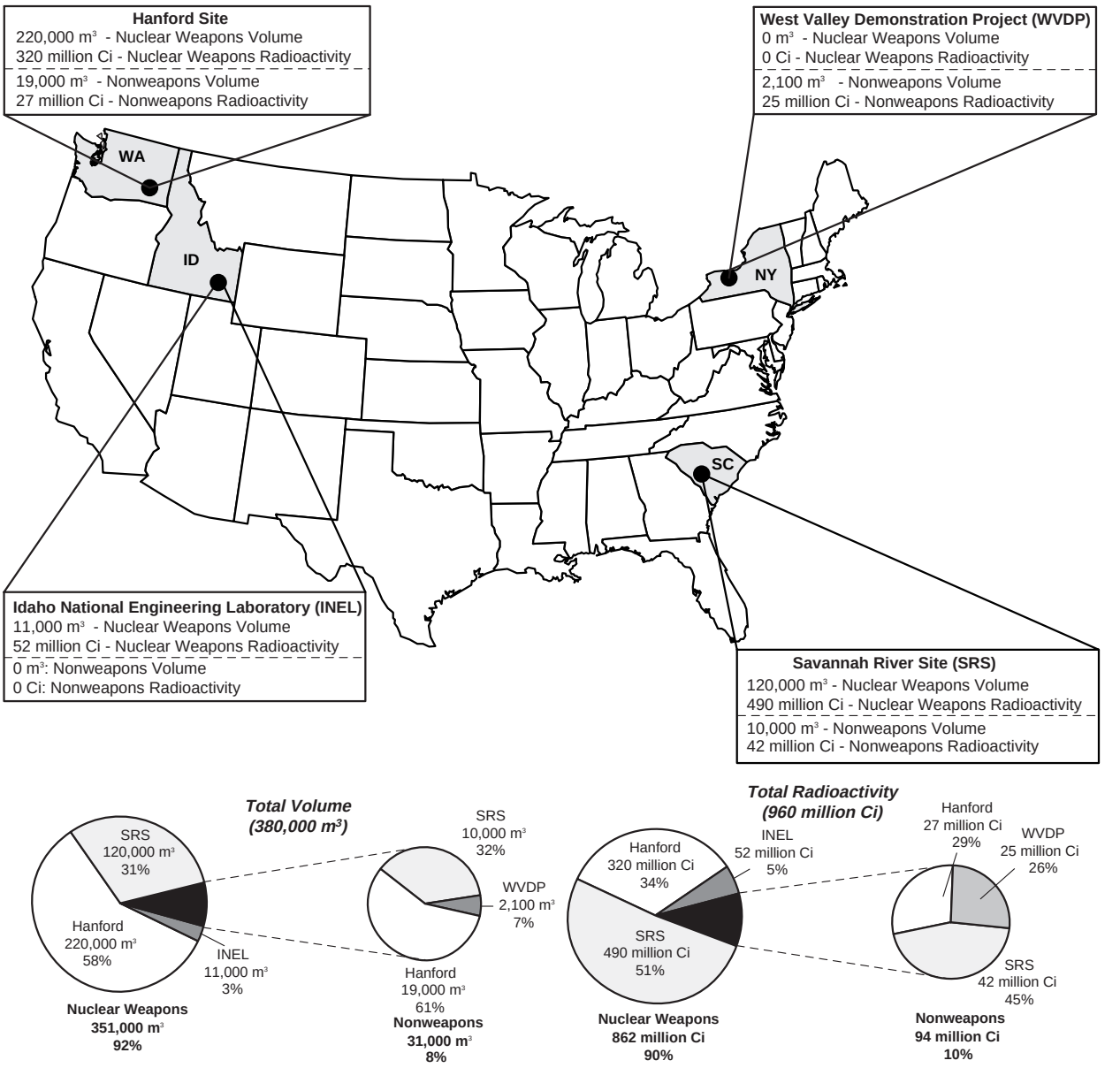
Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995. (See Endnotes a and q).
(2) This analysis of radioactivity accounts for approximately 94% of the radioactivity in high-level waste. Approximately 55 million curies of HLW at Savannah River Site are not categorized by half life, making up the remaining 6%.
(3) Waste category assignments are made in accordance with the methods explained in Endnote r.
(4) Nuclear weapons and nonweapons allocations and allocations to individual nuclear weapons production process categories are determined subject to the processes set forth in the endnotes.

The Office of Environmental Management manages all of the Department's high-level waste at the four sites where it was originally generated: Hanford Site, Idaho National Engineering Laboratory, the Savannah River Site, and West Valley Demonstration Project.[6] Hanford manages the largest volume of high-level waste; but a larger amount of radioactivity in high-level waste is located at the Savannah River Site (Figure 3-3). The Department has begun to vitrify the high-level waste at the Savannah River Site and West Valley Demonstration Project.

Hanford – At Hanford, high-level waste alkaline liquid, salt cake, and sludge are stored in 149 single-shell underground tanks and 28 double-shell underground tanks. Some transuranic waste and low-level waste is also stored in the tanks but all tank waste is classified at Hanford and managed as high-level waste. The Department is currently processing Hanford tank waste by evaporation to reduce its volume and is transferring pumpable liquids from the single-shell tanks to the double-shell tanks. Some single-shell high-level waste tanks have leaked, releasing approximately one million gallons of waste to the environment. During the 1940s, a relatively small amount of high-level waste was discharged directly to the soil.

[6] *West Valley Demonstration Project is a nonweapons site, owned by New York State and managed by DOE.*

Figure 3-3. Four Sites Managing High-level Waste



Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995. (See Endnotes a, k, and q).
(2) Waste Category asssignments are made in accordance with the process explained in Endnote r.
(3) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnote s.

Hanford high-level tank waste liquids and solids both contain an average of about 800 curies per cubic meter (Ci/m³).

Hanford also manufactured approximately 2,200 highly radioactive capsules containing concentrated cesium and strontium salts. Some of these high-level waste capsules had been leased for use offsite, and are being returned to Hanford. They are the most highly radioactive high-level waste managed by the Department containing tens of millions of curies per cubic meter. The capsules contain over 40 percent of the high-level waste radioactivity at Hanford, in a volume of less than four cubic meters. Nearly 300

Worker with empty cesium capsule. Between 1968 and 1983, Hanford recovered and encapsulated cesium-137 and strontium-90 from high-level radioactive waste. DOE and its predecessors leased many of these capsules as intense radiation sources for industrial applications. The capsules deteriorated over time, and the last one was returned to DOE in 1996. The capsules are stored in Hanford's B Plant, the World War II chemical separations plant that produced them. *Waste Encapsulation and Storage Facility, B Plant, 200 Area, Hanford, Washington. November 16, 1984.*

capsules have been dismantled, while the remainder are being stored, pending selection of an appropriate stabilization method prior to disposal.

Savannah River Site – High-level waste at the Savannah River Site is composed of alkaline liquid, salt cake, sludge, and precipitate, and is stored in double-shell underground tanks. The volume of high-level tank waste at the Savannah River Site is only about half as large as Hanford tank waste, but it contains about one and one-half times the amount of radioactivity. Hanford tank waste is less radioactive than the tank waste at the Savannah River Site because much of the radioactive cesium and strontium has been removed and concentrated in the capsules, the waste is older and has had more time to decay, and the waste has been mixed with other waste. Savannah River Site high-level tank waste liquids and solids each contain an average of about 4,000 Ci/m^3.

Idaho National Engineering Laboratory – High-level waste at Idaho National Engineering Laboratory is composed of acidic liquid and calcined solids. The acidic liquids are stored in underground tanks and include actual high-level waste as well as sodium-bearing waste that is managed as high-level waste. High-level waste calcine is an interim solid waste form made by processing the liquid waste. The calcine is stored in bins. More than 90 percent of the radioactivity in Idaho National Engineering Laboratory

[7] *Of the 640 tons of spent fuel reprocessed at West Valley Demonstration Project, 380 tons came from the Hanford N Reactor. West Valley Demonstration Project reprocessing produced about 530 kilograms of plutonium from the N Reactor spent fuel. Nearly 900 kilograms of plutonium from commercial spent fuel were sent from West Valley Demonstration Project to Hanford as well. However, nearly all of the plutonium produced was fuel-grade, rather than weapons-grade, and was intended for nonweapons purposes. Most of the plutonium was used in breeder reactor and zero-power reactor programs. Even though most of the spent fuel came from DOE, the commercial reactor fuel generally had a higher "burn up," and as a result, most of the radioactivity in West Valley Demonstration Project high-level waste came from reprocessing commercial fuels.*

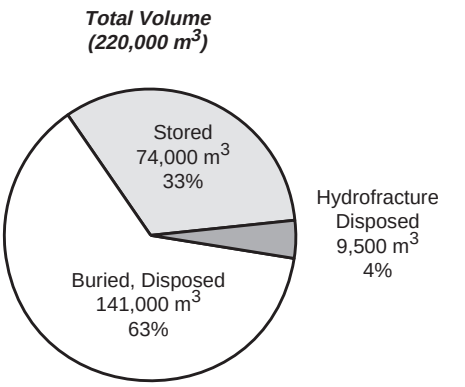
high-level waste is present in the calcine, which contains an average of about 12,000 curies/cubic meter. Liquid high-level waste from Idaho National Engineering Laboratory only contains about 300 Ci/m^3.

West Valley Demonstration Project – Unlike high-level waste managed at Hanford, Idaho National Engineering Laboratory, and the Savannah River Site, the high-level waste at West Valley Demonstration Project was not generated by DOE and is not attributed to weapons production.[7] West Valley Demonstration Project, which operated from 1966 to 1972, was the site of the only commercial nuclear fuel reprocessing plant operated in the United States. In accordance with the 1980 West Valley Demonstration Project Act , DOE is responsible for demonstrating high-level waste solidification at the facility. New York State currently owns both the site and the waste.

In terms of both volume and radioactivity, the amount of high-level waste at West Valley Demonstration Project is much less than that at Hanford, the Savannah River Site, or Idaho National Engineering Laboratory. This high-level waste is stored in tanks and consists of alkaline liquid, sludge, and ion-exchange resin. The high-level waste at West Valley Demonstration Project is similar to that at Idaho National Engineering Laboratory in that the radioactivity in the former's high-level waste is present primarily in the solid high-level waste (i.e., sludge and resin). Although nearly 90 percent of the volume of West Valley Demonstration Project high-level waste is in liquid form (containing about 1,700 Ci/m^3), over 90 percent of its radioactivity is present in the waste that is in solid form (containing 150,000 Ci/m^3).

Under federal law, DOE high-level waste will eventually be disposed of in geologic repositories after it has been treated to produce solid waste forms acceptable for disposal, and repository facilities become available. The DOE Office of Civilian Radioactive Waste Management is responsible for characterizing the Yucca Mountain repository site in Nevada, constructing a repository, and disposing of DOE high-level waste, DOE nuclear spent fuel, and commercial spent nuclear fuel in accordance with the Nuclear Waste Policy Act. The only planned offsite transfers of high-level waste are those from the current storage sites to the repository. At all four sites, the Department is currently pretreating some high-level waste to reduce its volume and produce solid waste forms acceptable for safer long-term storage. At two of these sites, treatment to produce final waste forms for repository disposal is underway. The Defense Waste Processing Facility at the Savannah River Site began producing vitrified final waste forms in May 1996. A facility for vitrifying high-level waste at West Valley Demonstration Project began operations in July 1996. Final treatment of high-level waste at Hanford and Idaho National Engineering Laboratory is now in the planning stage.

Figure 3-4. Transuranic Waste Volume Categorized by Disposition



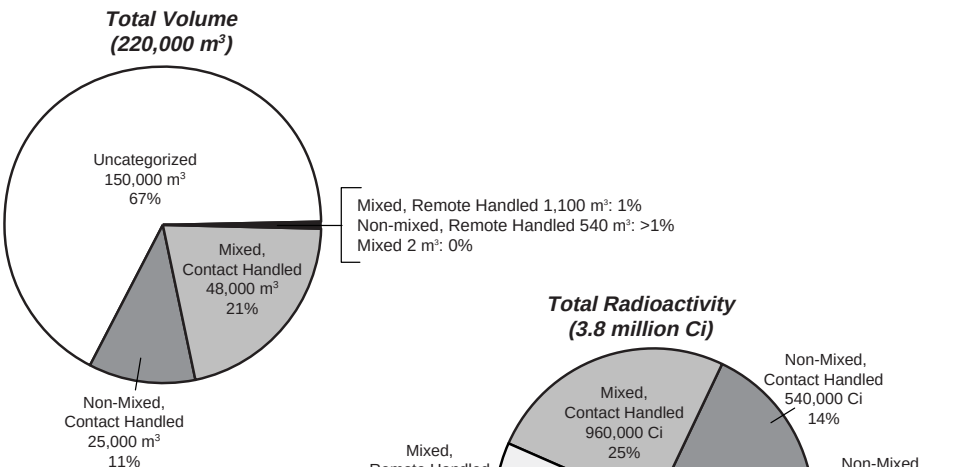
Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996.
(2) Waste category asssignments are made in accordance with the methods explained in Endnote r.
(3) Waste volumes are calculated subject to the limitations listed in Endnotes f, h, and k.

The Department is currently generating, and expects to generate, relatively small quantities of new high-level waste. Generation of this waste decreased substantially during the late 1980s and early 1990s when the Department stopped reprocessing spent nuclear fuel. In the future, new high-level waste will continue to be generated from several sources, including the maintenance and eventual deactivation and decommissioning of the chemical separation facilities and processing of some nuclear fuel and target elements at the Savannah River Site. However, the quantity of new high-level waste is expected to be small in comparison to the currently stored inventories. In addition, the Department is seeking to develop alternative technologies capable of stabilizing nuclear materials without generating additional waste. Only the new waste from nuclear fuel and target processing (i.e., chemical separation) actually meets the high-level waste definition, but new waste from other sources is managed as high-level waste because it contains very high concentrations of radionuclides.

[8] *Transuranic elements are those with atomic numbers greater than 92, heavier than uranium. All are artificially produced by neutron irradiation, and all are part of the actinide group of elements.*

Transuranic waste storage. A radiological control technician scans the ground for contamination at a transuranic waste storage facility in Idaho. Beneath each concrete plug is a vault for storing three or four drums of remote handled transuranic waste. Most of the vaults are currently empty. Waste stored in these vaults is mostly from nonweapons research at the nearby Argonne National Laboratory-West. *Intermediate Level Transuranic Waste Storage Facility, Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho. March 17, 1994.*

Figure 3-5. Transuranic Waste Volume and Activity Categorized by Handling Type (Nuclear Weapons and Nonweapons Transuranic Waste Combined)



Notes:

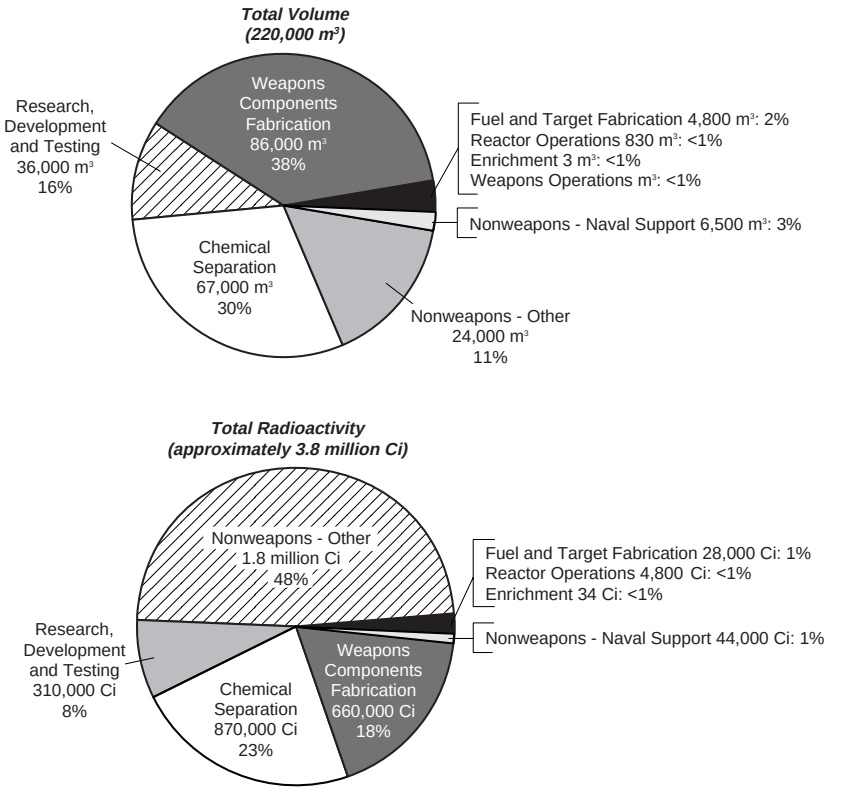
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996. (See Endnotes a and c).

(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, h, and k.

(3) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, and q.

(4) Waste category assignments are made in accordance with the methods explained in Endnote r.

Figure 3-6. Transuranic Waste Volume and Radioactivity Categorized by Process



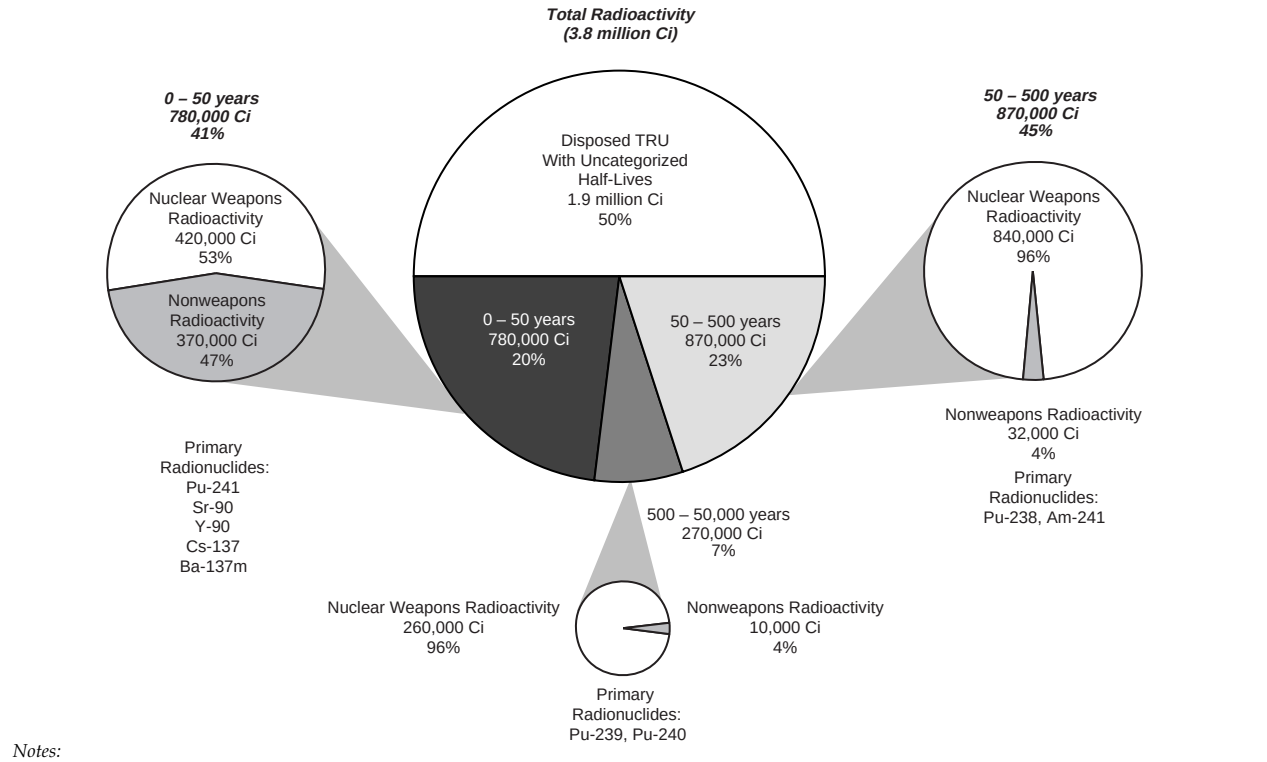
Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996. (See Endnotes a and c).
(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, h, and k.
(3) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, and q.
(4) Waste category assignments are made in accordance with the methods explained in Endnote r.
(5) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the limitations explained in Endnotes t and u.

Transuranic (TRU) Waste

Transuranic (TRU) waste is waste that contains alpha-emitting transuranic elements[8] with half-lives greater than 20 years whose combined activity level is at least 100 nanocuries per gram of waste at the time of assay. Like high-level waste, TRU waste is formally defined in DOE Order 5820.2A. TRU waste is further categorized according to its external surface radiation dose rates. Waste with dose rates exceeding 200 millirem per hour requires special handling and is classified as remote-handled TRU waste. TRU waste below this level is called contact-handled TRU waste. Because of the long half-lives of many TRU isotopes, TRU waste can remain radioactive for hundreds of thousands of years. Some of the common TRU radionuclides present in TRU waste include plutonium-239, -240, -241, -238, and -242; americium-241; and curium-244. Other important radionuclides that can be present in TRU waste, primarily remote-handled TRU waste, are fission products, reactor activation products, and their resulting daughter products, including strontium-90, yttrium-90, cesium-137, barium-137, cobalt-60, and europrium-152, -154, and -155.

Most TRU waste is the result of the weapons production process and contains plutonium. TRU waste from weapons production results almost exclusively from fabrication of plutonium weapons components, recycling plutonium from production scrap, residues, or retired weapons, and chemical separation of plutonium. Considerable amounts of TRU waste also contains hazardous constituents subject to regulation under RCRA (mixed TRU waste), and some contains polychlorinated biphenyls (PCBs) subject to the Toxic Substances Control Act. TRU, mixed-TRU, and PCB-TRU waste have been combined in this analysis because the primary factor used to determine how the waste will be managed is the concentration of TRU radionuclides in the waste rather than the waste's chemical composition. However, the

Figure 3-7. Transuranic Waste Radioactivity Categorized by Half-life (Stored Waste Only)



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996. (See Endnotes a and c).
(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, h, and k.
(3) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, and q.
(4) Waste category assignments are made in accordance with the methods explained in Endnote r.
(5) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the limitations explained in Endnotes t and u.
(6) Data excludes TRU waste that is buried.

presence of hazardous constituents and the regulatory status of the waste are also important factors that affect TRU waste management decisions.

AEC first managed TRU waste as a separate category of radioactive waste in 1970. Prior to that time, TRU waste and low-level waste were usually combined and managed as a single waste type and were disposed of in shallow burial trenches. Recognizing the need to isolate TRU waste more permanently from the environment, AEC discontinued shallow burial of TRU waste in 1970. Since that time, the Department has placed TRU waste in retrievable storage, typically in metal drums or boxes either on above- or below-grade soil-covered storage pads or in buildings or tanks. Some TRU waste has been disposed of by hydrofracture, which is a form of underground injection used at Oak Ridge National Laboratory. About two-thirds of the TRU waste managed by the Department has been disposed of and the remaining one-third is in storage (Figure 3-4). The Department plans to dispose of stored post-1970 defense TRU waste in a geologic repository. However, TRU waste will continue to be stored until the planned repository, the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, becomes operational, and the waste is appropriately treated, packaged, and certified for disposal. During transport to the repository, the waste will be packaged in special overpack containers known as TRUPACs.

In 1984, the Department revised the definition for TRU waste, raising the minimum concentration of TRU radionuclides from 10 to 100 nanocuries per gram. Since that time, all newly-generated radioactive waste and a portion of the TRU waste in retrievable storage has been categorized according to the revised standard. However, the concentration of TRU radionuclides in some of the Department's current inventory of TRU waste may be below the revised standard. As the waste is prepared for disposal in WIPP, the Department will reevaluate the TRU content of some of this waste and may reclassify some of it as low-level waste.

Table 3-1. Transuranic Waste Storage and Disposal Sites (Resulting from Nuclear Weapons Production)

Stored TRU Waste

Site	Nuclear Weapons Volume (m^3)	Nuclear Weapons Radioactivity (Ci)	Nonweapons Volume (m^3)	Nonweapons Radioactivity (Ci)
Idaho National Engineering Laboratory, ID	32,000	340,000	2,700	29,000
Savannah River Site, SC	15,000	560,000	0	0
Los Alamos National Laboratories, NM	11,000	210,000	0	0
Hanford, WA	8,100	210,000	1,300	34,000
Rocky Flats Environmental Technology Site, CO	1,100	86,000	0	0
Nevada Test Site, NV	620	3,500	0	0
Mound, OH	260	910	0	0
Lawrence Livermore National Laboratory, CA	220	2,000	0	0
Oak Ridge National Laboratory, TN	53	11,000	1,700	350,000
Sandia National Laboratory, NM	8	0	0	0
Paducah Gaseous Diffusion Plant, KY	3	34	2	22
Pantex, TX	1	0	0	0
Nonweapons Sites	0	0	570	130,000

Buried and Disposed TRU Waste

Site	Nuclear Weapons Volume (m^3)	Nuclear Weapons Radioactivity (Ci)	Nonweapons Volume (m^3)	Nonweapons Radioactivity (Ci)
Hanford, WA	55,000	150,000	8,800	24,000
Idaho National Engineering Laboratory, ID	53,000	230,000	4,500	20,000
Los Alamos National Laboratories, NM	14,000	5,600	0	0
Savannah River Site, SC	4,900	31,000	0	0
Oak Ridge National Laboratory, TN	5	7	170	233
Sandia National Laboratory, NM	1	1	0	0
Nonweapons Sites	0	0	1,350	652,000

Hydrofracture Disposed TRU Waste

Site	Nuclear Weapons Volume (m^3)	Nuclear Weapons Radioactivity (Ci)	Nonweapons Volume (m^3)	Nonweapons Radioactivity (Ci)
Oak Ridge National Laboratory, TN	290	20,000	9,200	660,000

Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996. (See Endnotes a and c).

(2) Waste volumes are calculated subject to the limitations listed in Endnotes i and k.

(3) Waste category assignments are made in accordance with the process explained in Endnote o.

(4) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the method set forth in Endnotes t and u.

A small percentage of the Department's TRU waste exhibits high direct radiation exposure hazards; it is referred to as "remote-handled" TRU waste. The majority of TRU waste emits low levels of direct radiation, it is referred to as "contact-handled" TRU waste. The handling category of TRU waste that has already been disposed of was not documented at the time of disposal, but the Department believes that much of that waste is contact handled. The chief hazard from contact-handled waste is caused by the alpha-emitting TRU elements they contain. Inhalation and, to a lesser degree, ingestion of these substances is the exposure pathway of concern. Alpha particles emitted by TRU radionuclides cannot penetrate the skin, but they can cause serious localized tissue damage when they are emitted inside the body. When inhaled, TRU elements tend to accumulate in the lungs; soluble TRU materials migrate through the circulatory system and accumulate primarily in the liver and bone marrow. Figure 3-5 shows the volume and radioactivity distribution of stored and disposed TRU waste by handling type. This figure also shows the distribution of TRU waste volume and radioactivity according to whether it contains a hazardous component subject to RCRA. This waste is classified as mixed TRU waste by the Department.

Unlike high-level waste, which is generated from only a few specific processes and has a narrow range of physical matrices and chemical characteristics, TRU waste exists in many forms and can contain a broad spectrum of hazardous chemical constituents. Cleaning, maintenance, and production processes involving plutonium and other transuranic radionuclides generate TRU waste. In the future, deactivation and decommissioning of chemical separations facilities will produce TRU waste. Environmental restoration, and treatment and handling of high-level and low-level waste, also generate TRU waste.

By volume, about 86 percent of TRU waste is the result of weapons production, three percent is the result of DOE activities supporting the NNPP, and 11 percent is the result of other nonweapons activities (Figure 3-6). About 38 percent of all TRU waste is from nuclear weapon component fabrication, including plutonium recycling, 30 percent from chemical separation, and 18 percent from the other weapons production processes. No TRU waste resulted from uranium mining, milling, and refining or from weapon operations. By radioactivity content, about 51 percent of TRU waste came from weapons production, one percent from activities supporting the NNPP, and 48 percent from other nonweapons activities. About 23 percent of the radioactivity in TRU waste is present in waste from chemical separation, 18 percent in waste from component fabrication, and 10 percent in waste from the other weapons production processes. The remaining 48 percent of the radioactivity is in TRU waste from nonweapons activities.

Radionuclides with half-lives of less than 500 years, including plutonium-241 and -238, amiricium-241, and several fission products, 86 percent of the radioactivity in stored transuranic waste. As shown in Figure 3-7, the distribution of radionuclides in transuranic waste from weapons production differs from that from nonweapons activities. Nonweapons TRU waste (primarily from Oak Ridge National Laboratory) contains a much higher proportion of short-lived (less than 50-year half-lives) radionuclides. The stored inventory of transuranic waste contains about 160,000 curies of plutonium-239, equivalent to about 2,600 kilograms of plutonium.

Data on the radioactive content of disposed TRU waste is more limited. However, the Department's Nuclear Materials Management and Safeguards System indicates that a total of about 3,400 kilograms of plutonium are present in combined DOE-stored and -disposed waste, primarily at Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory, and the Savannah River Site. This implies that 800 kilograms of plutonium are in the buried TRU waste.

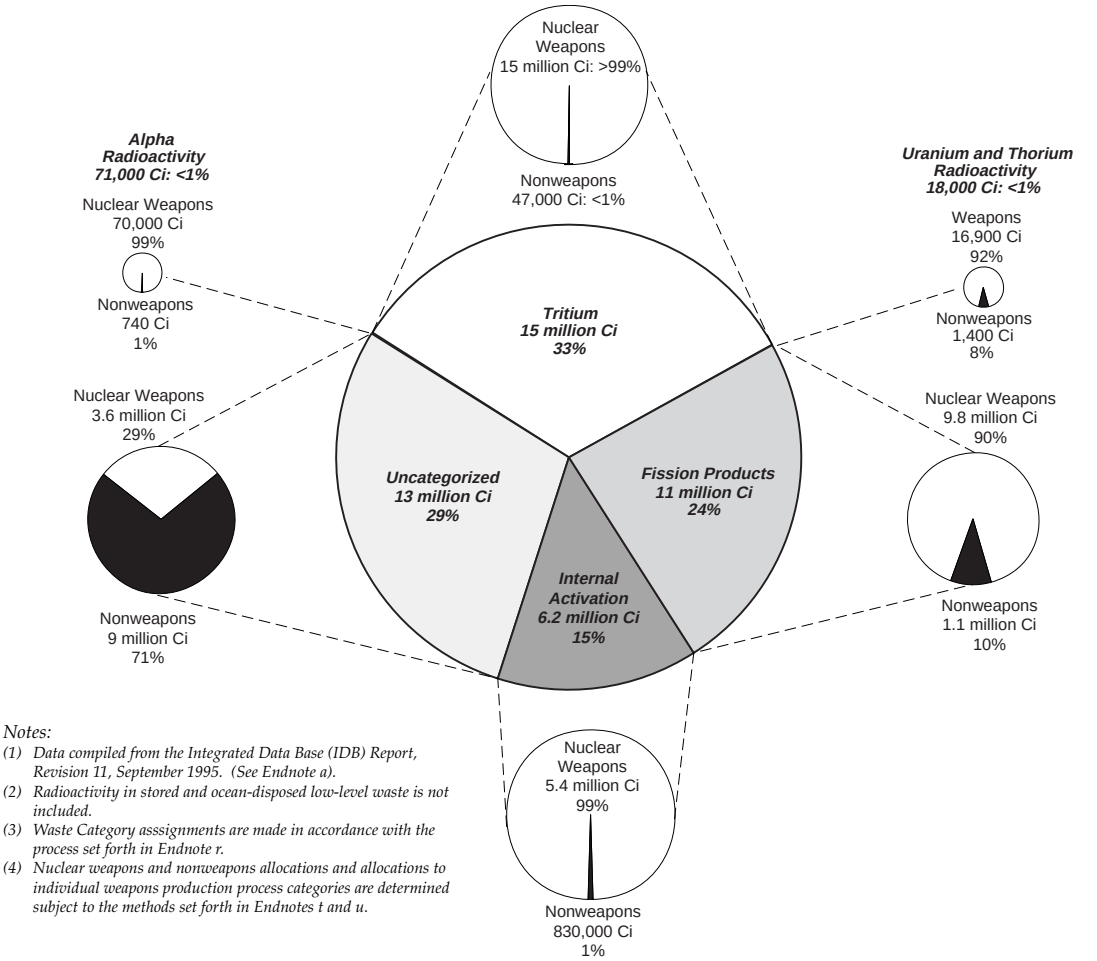
TRU waste includes aqueous and organic solutions, glass, filters, sludges, salts, resins, incinerator ash, leaded rubber gloves, combustibles, ceramics, low-grade oxides, sand, slag, crucibles, alloys, miscellaneous compounds, scrub alloy, and anode heels. Some TRU waste does include organic and halogenated organic solvents, toxic metals, PCBs, acids, and caustics; although, a large portion of TRU waste does not contain chemically hazardous constituents.

Some TRU waste requires special management because it was not produced from weapons production activities or because it cannot be certified for disposal at the planned repository. Nonweapons TRU waste includes filters, resins, neutron sources, reactor vessels, demineralizer systems, and waste from fuel fabrication facilities. Uncertifiable TRU waste includes materials from decontamination and decommissioning of hot cells, waste from nuclear weapons accidents, DoD waste, certain sludges, large metal parts, and remotely-handled items.

TRU waste is managed at 21 sites, including 12 sites where TRU waste from weapons production is managed (Table 3-1). Most stored TRU waste has resulted from weapons production activities at six sites: Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Rocky Flats Plant (now the Rocky Flats Environmental Technology Site), and the Savannah River Site. Smaller amounts of TRU waste are stored or generated at 15 other sites, including a number of sites that produce TRU waste solely from nonweapons activities.

Prior to 1970, TRU waste from weapons production was buried at Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratories, Oak Ridge National Laboratory, the Savannah River Site, and Sandia National Laboratories/New Mexico (SNL/NM). The largest amounts of stored and disposed TRU waste are at Idaho National Engineering Laboratory. Much of the TRU waste at Idaho National Engineering Laboratory was originally generated by plutonium component fabrication activities at DOE's Rocky Flats Plant, including debris from major fires in 1957 and 1969. Sites at which TRU waste was generated predominantly or entirely by nonweapons activities include nonweapons research sites (Argonne National Laboratory-East and -West, Battelle Columbus Laboratories, Energy Technology Engineering Center, Lawrence Berkeley National Laboratory, and the Missouri University Research

Figure 3-8. Types of Radioactivity in Disposed Low-level Waste



Reactor); NNPP sites (Knolls Atomic Power Laboratory); and sites supporting the commercial nuclear power industry (e.g., Paducah Gaseous Diffusion Plant and West Valley Demonstration Project).

Low-level Waste

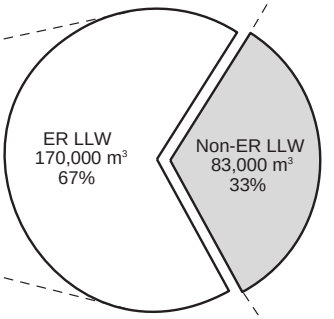
Low-level waste is composed of all radioactive waste not classified as high-level waste, TRU waste, spent nuclear fuel, or natural uranium and thorium byproduct material defined under section 11e(2) of the AEA.

Like high-level waste and TRU waste, low-level waste is defined in DOE Order 5820.2A. It is also defined in the Energy Policy Act of 1992. DOE low-level waste is segregated into remote-handled and contact-handled categories. Some low-level waste contains alpha-emitting transuranic radionuclides in concentrations below the 100 nanocurie per gram minimum concentration established in the TRU waste definition. Low-level waste containing hazardous waste or PCBs is categorized as mixed low-level waste and is presented separately from other low-level waste in this analysis. In addition, the Department manages some naturally-occurring or accelerator-produced radioactive material as low-level waste.

Low-level waste comes from many sources and is present at many DOE sites. The facilities that process, create, or otherwise handle radioactive materials, perform chemical conversions or separations, and fabricate nuclear components, all generate low-level waste. Low-level waste is generated from many of the support activities (e.g., wastewater treatment and equipment maintenance) associated with both weapons production and nonweapons activities. Some low-level waste is also derived from the pretreatment of high-level waste and the management of chemical separation facilities. Finally, low-level waste

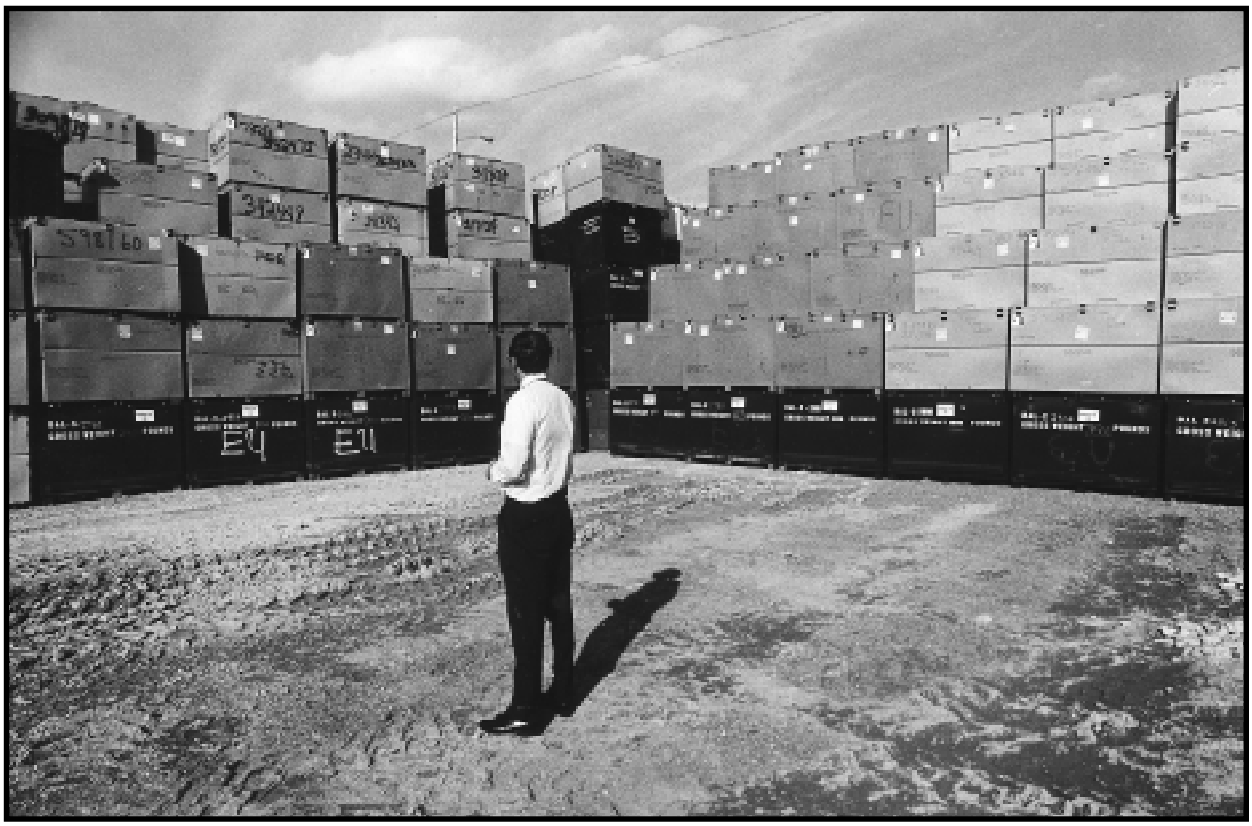
Figure 3-9. Physical Matrices of Low-level Waste from Environmental Restoration and Non-Environmental Restoration Activities (Stored Waste Only – Nuclear Weapons and Nonweapons Waste Combined)

Physical Matrix	Volume (m^3)	Percent
Other Solid	140,000	83
Soil	28,000	17
Rubble/Debris	410	<1
Paper/Cloth	370	<1
Residues	180	<1
Sludge	130	<1
Liquid	100	<1
TOTAL	170,000	100



Physical Matrix	Volume (m^3)	Percent
Other	37,000	44
Debris, noncombustible and combustible, mixed	14,000	17
Contaminated metal, equipment, & hardware	11,000	13
Solidified sludges and resins	7,400	9
Debris, combustible	5,700	7
Soil, sediment, and rubble	1,600	2
Other inorganic pariculates	1,600	2
Activated metal, equipment, & hardware	1,600	2
Solidified liquids, chelates, and oils	1,300	2
Biological waste and carcasses	710	1
Filter media	680	1
Debris, noncombustible and compactible	270	<1
Incinerator ash	170	<1
Salt waste	160	<1
Activated carbon	82	<1
Sources (sealed sources, devices, and gauges)	4	<1
Paint waste	1	<1
TOTAL	83,000	100

Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996. (See Endnotes a and c).
(2) Waste volumes are calculated subject to the limitations listed in Endnotes h, i, and k.
(3) Waste category asssignments are made in accordance with the process explained in Endnote r.



Boxes containing low-level radioactive waste lie in a shallow land burial trench at the Savannah River Site. Alternative methods for the disposal of low-level waste are being developed by the Department. *Savannah River Site, South Carolina. January 7, 1994.*

can be generated from environmental restoration, facility deactivation and decommissioning, and the treatment and handling of TRU waste and mixed low-level waste.

Of the 3.3 million cubic meters of low-level waste managed by DOE, about 85 percent is from weapons production, approximately one percent from activities supporting the NNPP, and 14 percent from other nonweapons activities (Figure 3-10). Low-level waste is attributed to all eight process categories, but most resulted from research, development, and testing (RD&T, 25 percent), fuel and target fabrication (21 percent), chemical separation (17 percent), and uranium mining, milling, and refining (14 percent). By radioactive content, about 72 percent of the Department's low-level waste is from weapons production, less than one percent from activities supporting the NNPP, and 28 percent from other nonweapons activities.

The radioactive content of disposed low-level waste is composed of the following six distinct types of radionuclides that indicate how the radioactivity originated or the level of radioactive hazard: fission products, tritium, internal activation products, alpha radioactivity, uranium and thorium, and uncategorized radioactivity (Figure 3-8). By curie content, more than 99 percent of the tritium, internal activation products, and alpha radioactivity, 90 percent of the fission products, and 92 percent of the uranium and thorium come from weapons production. Nonweapons activities are responsible for 71 percent of the uncategorized radioactivity.

Low-level waste is composed of a wide variety of materials generally similar to those in TRU waste. Recently generated low-level waste (except for low-level waste from environmental restoration activities) is classified into 18 physical forms (Figure 3-9). Low-level waste resulting from environmental restoration activities is classified into categories similar to non-Environmental Restoration low-level waste (Figure 3-9).

Certain low-level waste, known as special case waste, requires special handling and is not suitable for disposal in shallow land burial facilities because of its high radioactive content. This waste includes certain resins, sludges, filter media, radioisotope thermoelectric generators, equipment, demineralizer systems, gauges and dials, waste from hot cells, and other materials.

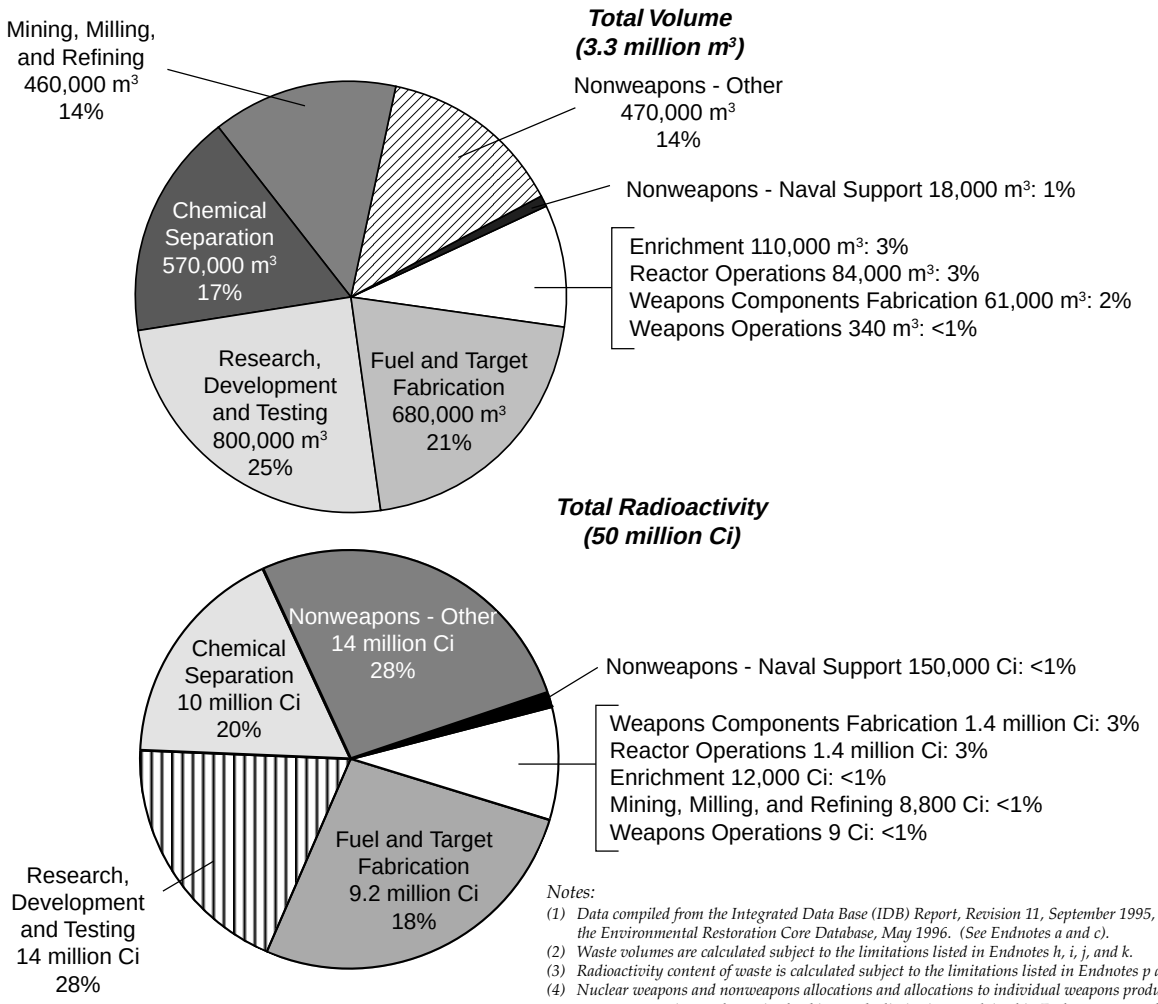
Low-level waste contains a broad spectrum of radionuclides, including nearly all of those found in high-level waste and TRU waste. Most low-level waste contains much lower concentrations of radionuclides than high-level waste and TRU waste, and thus exhibits far lower direct radiation and inhalation/ingestion hazards. A small amount of low-level waste, such as irradiated reactor parts and some of the special-case waste described above, presents much greater radiation hazards and is managed separately from the bulk of low-level waste. Some low-level waste containing uranium enriched in the uranium-235 isotope also can present criticality hazards and must be stored in geometric configurations that are considered criticality safe.

Hazardous constituents generally are not present in waste identified in this report as "low-level waste" since any low-level waste containing RCRA- or TSCA-regulated substances above regulatory levels is classified in this report mixed low-level waste or radioactive PCB waste, respectively. Radioactive asbestos waste has also been classified separately. Low-level waste containing these hazardous constituents has been separated from other low-level waste in this analysis because the presence of RCRA- or TSCA-regulated chemical constituents in the waste is a major factor affecting how the waste will be managed.

The Department did not generally apply RCRA and TSCA standards to low-level waste disposed of the 1980s. An unknown portion of this waste could be classified as mixed low-level waste if current regulatory standards were applied.

At sites that managed both TRU waste and low-level waste before 1970, an unknown amount of the pre-1970 low-level waste was commingled and disposed of with TRU waste. This waste is currently inventoried as TRU waste but some could be considered low-level waste by today's standards. The Department is characterizing some of the buried pre-1970 waste and has made some projections of the TRU, low-

Figure 3-10. Low-level Waste Volume and Radioactivity Categorized by Process



Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996. (See Endnotes a and c).
(2) Waste volumes are calculated subject to the limitations listed in Endnotes h, i, j, and k.
(3) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes p and q.
(4) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the limitations explained in Endnotes t, u, and w.

Table 3-2. Low-level Waste Resulting from Nuclear Weapons Production

Stored Low-Level Waste (260,000 m³)

Site	Nuclear Weapons Volume (m^3)	Nonweapons Volume (m^3)
Fernald Environmental Management Project (OH)	140,000	0
Latty Avenue Properties (MO)	24,000	0
Portsmouth Gaseous Diffusion Plant (OH)	15,000	10,000
K-25 Site (TN)	9,400	4,700
Mound Plant (OH)	8,800	0
Rocky Flats Environmental Technology Site (CO)	5,300	0
Idaho National Engineering Laboratory (ID)	3,200	9,500
Reactive Metals Incorporated, Ashtabula (OH)	2,900	0
Paducah Gaseous Diffusion Plant (KY)	2,700	1,800
Savannah River Site (SC)	1,600	0
Y-12 Plant (TN)	720	0
Lawrence Livermore National Laboratory (CA)	600	0
Nevada Test Site (NV)	270	0
Pantex Plant (TX)	210	0
Oak Ridge National Laboratory (TN)	110	3,400
Pinellas Plant (FL)	66	0
Hanford (WA)	47	0
Sandia - California (CA)	27	0
Kansas City Plant (MO)	9	0
Nonweapons Sites	0	18,000

Currently Active Low-Level Waste Disposal (2.4 million m³)

Site	Nuclear Weapons Volume (m^3)	Nonweapons Volume (m^3)
Savannah River Site (SC)	680,000	0
Hanford Site (WA)	560,000	53,000
Nevada Test Site (NV)	480,000	0
Los Alamos National Laboratory (NM)	220,000	0
Idaho National Engineering Laboratory (ID)	37,000	110,000
Oak Ridge National Laboratory (TN)	6,800	220,000

Historic Low-Level Waste Disposal (620,000 m³)

Site	Nuclear Weapons Volume (m^3)	Nonweapons Volume (m^3)
Fernald Environmental Management Project (OH)	340,000	0
Y-12 Plant (TN)	150,000	0
K-25 Site (TN)	54,000	27,000
Lawrence Livermore National Laboratory (CA)	9,100	0
Portsmouth Gaseous Diffusion Plant (OH)	7,300	4,800
Paducah Gaseous Diffusion Plant (KY)	4,600	3,000
Sandia National Laboratories/New Mexico (NM)	3,200	0
Pantex Plant (TX)	130	0
Nonweapons Ocean Diposal	0	19,000

Notes:
(1) Data compiled from the Mixed Waste Inventory Report (MWIR) Data System, October 1995.
(2) Waste category asssignments are made in accordance with the methods explained in Endnote r.
(3) Mixed waste inventories not recorded in the MWIR, including some waste resulting from the DOE Environmental Restoration Program, are not included in the physical matrix analysis.

Disposal of DOE Waste at Maxey Flats

Some of the waste legacy from nuclear weapons production is located at the Maxey Flats Disposal Site. This site is included on the Environmental Protection Agency's National Priorities List of hazardous waste sites compiled under the Comprehensive Environmental Response Compensation and Liability Act. DOE has been identified as a potentially responsible party for Maxey Flats.

The Nuclear Engineering Company (now U.S. Ecology) operated Maxey Flats, located in Fleming County, Kentucky, about 65 miles northeast of Lexington, Kentucky, as a low-level radioactive waste disposal site between 1963 and 1977.

A total of 125,000 cubic meters of radioactive waste is estimated to have been buried at the Maxey Flats site during its operation. During its operating period, nearly 54,000 cubic meters of low-level waste from 29 former Atomic Energy Commission contractors was disposed of at Maxey Flats. About 44 percent of this waste came from the Mound Plant, a weapons component fabrication site in southwestern Ohio, and another 1 percent came from other nuclear weapons production sites. The balance of the DOE waste was generated by nonweapons programs, including sites supporting the nuclear navy program.

The commonwealth of Kentucky is managing cleanup of the site. DOE is responsible for funding about 40 percent of the cleanup; the balance is provided by over 800 other responsible parties.

Data on the waste legacy at Maxey Flats is not aggregated with other DOE waste because DOE is not responsible for managing the cleanup of the site.

level, and mixed low-level waste that would be generated from remedial actions at the burial sites. However, these projections are not included in this report.

Similarly, a portion of the Department's waste now classified as TRU waste was placed into storage between 1970 and 1984 and contains between 10 and 100 nanocuries per gram of TRU radionuclides. Upon future recharacterization, some of this TRU waste may be reclassified as low-level waste.

The Department disposes of most solid low-level waste in shallow-land burial facilities. While the Department currently disposes of low-level waste at six sites (Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Nevada Test Site, Oak Ridge National Laboratory, and the Savannah River Site), buried low-level waste is present at eight other sites that have either conducted onsite disposal in the past or have experienced past radioactive releases resulting in buried low-level waste (Table 3-2).

Much low-level waste is treated prior to disposal to either stabilize the waste form (e.g., by solidifying low-level waste containing free liquid or particulates) or reduce the disposal volume (e.g, by incineration or compaction). Treatment is usually conducted onsite but in some cases waste is transported offsite for treatment and then returned to the Department. The waste is then stored onsite until it is either disposed onsite or transported to another DOE site for disposal. Nineteen sites involved in nuclear weapons production currently store low-level waste, typically in metal drums or metal or plywood boxes. Larger items are wrapped in plastic. Prior to disposal, the waste is certified to ensure that no mixed low-level waste or other prohibited materials (e.g., free liquids that could leak out) are present. Low-level waste emitting high levels of gamma radiation is stored in heavily shielded containers prior to disposal. Low-level waste containing alpha-emitting radionuclides at levels at or above 10 nanocuries per gram are sometimes managed separately from low-level waste containing lower concentrations of alpha-emitters. Because of the potential inhalation hazard, high-alpha low-level waste require special procedures to limit possible inhalation hazards to workers.

In addition to disposing of low-level waste at DOE sites, the Department and its predecessor agencies disposed of some low-level waste at commercial facilities (e.g., Maxey Flats), by underground injection (e.g., hydrofracture at Oak Ridge National Laboratory), or by sea burial. DOE low-level waste recently disposed of at commercial facilities is not included in this report because it is outside the scope of the Department's Environmental Management Program. However, DOE low-level waste disposed of at commercial disposal sites many years ago is included in cases where remedial action is necessary at the disposal site (e.g., at the Maxey Flats, Kentucky, Superfund Site.) Some low-level waste, such as sealed radioactive sources and irradiated reactor parts, is too radioactive for shallow-land disposal; some has been disposed of at greater confine-

[9] *Material at sites managed under DOE's Uranium Mill Tailings Remedial Action (UMTRA) Project and other Environmental Restoration Program sites is defined as residual radioactive material under Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA). Since this material has the same physical and radioactive properties as 11e(2) byproduct material, it is included with 11e(2) byproduct material for reporting purposes in this document. UMTRCA specifies the requirements under which residual radioactive material at UMTRA sites will be remediated.*

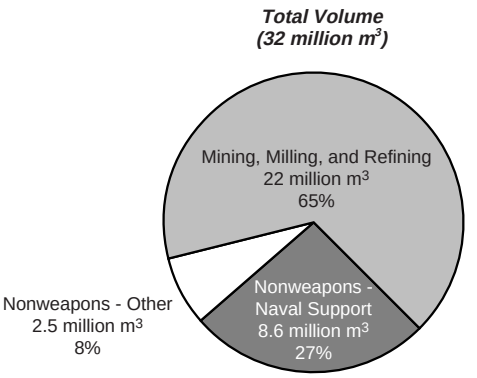
Table 3-3. Commercial Sites Managing 11e(2) Byproduct Material Resulting from AEC Purchases

State	Commercial Site	Volume (m^3)
CO	Cotter Corp., Canon City Mill Site	200,000
CO	UMETCO Mineral Corp., Uravan Mill Site	3,600,000
IL	Kerr-McGee Chemical Corp., West Chicago Thorium Mill Site	20,000
NM	Quivira Mining Company, Ambrosia Lake Mill Site	6,300,000
NM	Homestake Mining Company, Grants Mill Site	880,000
NM	Atlantic Richfield Company, Blue Water Mill Site	5,500,000
SD	Tennessee Valley Authority, Edgemont Mill Site	1,000,000
UT	Atlas Corp., Moab Mill Site	3,700,000
WA	Dawn Mining Company, Ford Mill Site	730,000
WY	Union Carbide Corp., East Gas Hills Mill site	1,300,000
WY	American Nuclear Corp., Gas Hills Mill Site	1,400,000
WY	Western Nuclear, Inc., Split Rock Mill Site	2,100,000
WY	Pathfinder Mines Corp., Lucky MC Mine	1,800,000
WY	Petrotomics Company, Shirley Basin Mill Site	450,000
TOTAL		29,000,000

Source:
Federal Register, May 23, 1994; Reimbursement for Costs of Remedial Action at Active Uranium and Thorium Processing Sites.
Notes:
(1) All sites are former uranium processing facilities except for the West Chicago Thorium Mill.
(2) Volumes only include amount of 11e(2) material resulting from other uranium or thorium sales.
(3) The site owners and operators are responsible for management of all materials at these sites. The sites are not managed by DOE and are not included in the analysis of the waste legacy.
(4) Volumes based on a mass-to-volume conversion of 1.6 dry short tons/cubic meter.

Corroded waste drums. Drums that contain radioactive waste can become radioactive waste themselves, as seen here at the Hazelwood Interim Storage Site outside St. Louis. These 55 gallon steel drums originally held uranium-contaminated 11e(2) byproduct material from the uranium refinery in downtown St. Louis. Once the drums lost their structural integrity, workers transferred their contents and cut up the corroded drums in preparation for disposal. *Hazelwood Interim Storage Site, Latty Avenue, Hazelwood, Missouri. January 29, 1994.*

Figure 3-11. 11e(2) Byproduct Material Volume Categorized by Process



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, the Environmental Restoration Core Database, May 1996; and GAO/RCED-96-37. (See Endnotes a,c, and d).

(2) Waste volumes are calculated subject to the limitations listed in Endnotes g, i, and k.

(3) Waste category asssignments are made in accordance with the process explained in Endnote r.

(4) Nuclear weapons and nonweapons allociations to individual weapons production process categories are determined subject to the methods set forth in Endnote v.

ment facilities, but most of this waste will remain in storage until treatment and disposal decisions are made and facilities become available.

The Office of Environmental Restoration manages the largest volume of DOE low level waste. Much of the low-level waste generated within the Department is transferred to the Office of Waste Management for further management. In recent years, the quantity of waste resulting from remediation activities (e.g., excavating and treating contaminated soil) and building deactivation and decommissioning has increased. In some cases, this waste is transferred to the Office of Waste Management for further disposition. In other cases, the Office of Environmental Restoration disposes the waste onsite or ships it to commercial disposal facilities.

11e(2) Byproduct Material

11e(2) byproduct material is the Department's term for the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material (i.e., uranium or thorium) content. Like mixed waste, which is defined under RCRA, 11e(2) byproduct material is defined by law, under Section 11e(2) of the AEA as amended by Title II of the Uranium Mill Tailings Radiation Control Act of 1978. [9] (All radioactive materials discussed in this report fall under the definitions of source, special nuclear, or byproduct materials in section 11 of the AEA. There are two types of byproduct material defined in subpart C of Section 11, referred to as 11e(1) byproduct material and 11e(2) byproduct material.)

A few processes associated with the initial milling and refining of uranium ore generate almost all 11e(2) byproduct material. These processes include large-volume ore processing steps to physically separate U_3O_8 from natural ore as well as smaller scale supporting activities such as laboratory analysis and research. The vast majority of 11e(2) byproduct material is composed of homogenous sand- or clay-like particles. After the recoverable uranium is removed from ore, the resulting residues, known as mill tailings, still contain much of their original radioactivity in the form of alpha-emitting uranium, thorium-230, radium-226, and daughter products of radium-226 decay. The total radioactivity levels present in mill tailings can exceed 1,000 picocuries per gram. Radon gas (Rn-222) that is released to the environment as the radium-226 decays causes one hazard associated with the tailings. Because daughter products from radon gas can adhere to dust and other particles in the air, they can present a hazard in enclosed spaces where they can be inhaled, become trapped in the lungs, and cause cell damage as their radioactive decay continues. Toxic heavy metals such as chromium, lead, molybdenum, and vanadium are also present in 11e(2) byproduct material in low concentrations.[10]

DOE manages approximately 32 million cubic meters of 11e(2) byproduct material. Overall, about 65 percent of this amount is attributed to nuclear weapons production, 27 percent is from activities supporting the NNPP, and 8 percent is the result of other nonweapons activities (Figure 3-11). Both the nuclear weapons and nonweapons portions of the 11e(2) byproduct material inventory resulted from mining, milling, and refining. The uranium initially produced at the mines and mills was used for many products, including nuclear weapon components and fuel for plutonium and tritium production reactors,

[10] *The toxic heavy metals and other hazardous constituents in 11e(2) byproduct material are exempt from RCRA. Unlike the other source, special nuclear and byproduct materials under section 11e(1) of the AEA which consist solely of radioactive constituents, 11e(2) byproduct material as defined by the AEA includes both radioactive and nonradioactive components. Thus, 11e(2) material is exempt from RCRA even though it may contain hazardous constituents. When byproduct material is mixed with hazardous waste, however, the mixture becomes a mixed waste subject to RCRA. Data on the relatively small amount of mixed 11e(2) material managed by DOE is presented later in this chapter under the heading of "Other Waste."*

naval reactors, research reactors, and commercial power plants. The apportionment of 11e(2) byproduct material into weapons and nonweapons categories is an estimate based on the amount of uranium used for various nuclear weapons and nonweapons purposes.

The amount of radium-226 present in the 11e(2) byproduct material managed by DOE is about 27,000 curies. Using the allocation method described in the text box, about 73 percent of the radioactivity in the 11e(2) byproduct material resulted from production of uranium for weapons, 21 percent from uranium subsequently used by the NNPP, and 6 percent from uranium used by the government for other nonweapons purposes. Uranium, thorium, radon, and radon daughter products are not included in this total. Detailed data on the inventories of these radionuclides in 11e(2) byproduct material are available at a number of the sites managing the 11e(2) byproduct material, but the data have not been compiled on a nationwide basis.

Mill tailings are typically generated as a slurry and are initially placed in large ponds. The liquid portion of the tailings, which either evaporates or infiltrates out of the ponds, can contain radioactivity levels up to 7,500 pCi/L of radium-226, 22,000 pCi/L of thorium-230, and 0.01 percent uranium. The dry tailings contain about 85 percent of the radioactivity present in unprocessed uranium ore. Dry tailings are periodically removed from the ponds and stored in large aboveground piles. When mill tailings sites are remediated, the dry tailings from ponds and other holding areas, and windblown tailings are typically collected and stabilized in large above grade disposal cells which are capped to prevent future dispersion of the tailings by erosion. This contrasts with the other waste types that, except for unusually large items and environmental restoration waste which is handled in bulk, is typically put in containers for both storage and disposal. Of the 32 million cubic meters of 11e(2) byproduct material managed by DOE, nearly 27 million cubic meters (82 percent)

Three Types of Sites Managing 11e(2) Byproduct Material

- **Sites subject to Title I of the Uranium Mill Tailings Radiation Control Act:** This category is composed of 24 inactive uranium milling sites that had ceased operation by 1978. These sites produced uranium concentrate, the overwhelming majority of which was sold to AEC in support of weapons production, nuclear fuel production for the NNPP, and other AEC programs. Although all of these sites were commercially operated, the law assigns the responsibility for performing environmental restoration at 22 of these sites to the Department. In addition, DOE has designated two more sites, and the vicinity properties of a third site, for restoration under the UMTRA program (Table 3-3). The Department is remediating these sites under the UMTRA Project managed by the Office of Environmental Restoration. Stabilization of the mill tailings has been completed at all but five of the sites. The Department has identified about 8,000 potential vicinity properties associated with these sites. Cleanup has been completed at nearly 97 percent of the 5,275 properties requiring further action.
- **Sites subject to Title II of the UMTRCA and Title X of the Energy Policy Act of 1992:** This category includes 13 commercial uranium mill sites and one commercial thorium mill site that were licensed to operate on or after January 1, 1978 (Table 3-4). For these sites, the *proportion* of uranium (or thorium) sales made to the government to support weapons, naval, and R&D programs is smaller than that for sites in the UMTRCA Title I category. However, most of the sites initially operated to supply uranium to the Atomic Energy Commission and the total amount of uranium provided by these sites is more than that provided by the UMTRCA Title I sites. Beginning in the 1970s, the private sector purchased much of the uranium from these sites to produce fuel for commercial nuclear power reactors and some other applications. For these sites, the mill owners are responsible for cleanup, and the Department is responsible for reimbursing site owners for the portion of decontamination, decommissioning, reclamation, and other remedial action costs determined to be attributable to uranium (and thorium) sales to the Federal Government. Because the Department is not conducting restoration of these sites, the waste (and contaminated media) at these sites is not aggregated with the waste volumes presented in this report. However, the quantities are listed in Table 3-4.
- **Other Sites:** This category is composed of eight sites that stored or processed uranium and thorium ore or concentrates, or were used to store the resulting residues, but that do not fall into the other two categories. This includes six sites that managed uranium for nuclear weapons production (Table 3-3). None of these sites is still active as part of the nuclear weapons production process. Some sites were owned by the AEC and others were owned and operated by AEC contractors during the Manhattan Project and the early part of the Cold War. The Department is responsible for remediating the waste, contaminated media, and facilities at the DOE-owned sites in this category. At the non-DOE-owned sites, the Department is responsible for remediating only some of the waste and contamination attributed to work performed for AEC. The Office of Environmental Restoration is remediating these sites, and several are in the Formerly Used Sites Remedial Action Program (FUSRAP).

Attributing 11e(2) Byproduct Material to Nuclear Weapons Production

Between 1942 and 1971, domestic uranium mines and mill sites supplied about half of the uranium purchased by the Manhattan Project and the Atomic Energy Commission (AEC). Initially, only AEC could legally own processed uranium, or "source material," and nearly all of the uranium it purchased was used for weapons production. Some uranium was enriched to produce weapons components and other enriched and natural uranium was used in reactors to produce plutonium. Later, small amounts of uranium were used in reactors for research, powering naval vessels, and generating electric power. The AEA was amended in 1954 to allow private ownership of nuclear facilities, and again in 1964 to allow private ownership of enriched uranium and plutonium. During the 1960s and 1970s, use of uranium for nonweapons purposes increased, and use of uranium for nuclear weapons production declined. Much uranium also was recycled. For example, uranium used in nuclear weapons production reactors and naval reactors was reprocessed, blended, fabricated into fuel, and reused in the production reactors.

More than 200 pounds of 11e(2) byproduct material are typically produced for each pound of natural (unenriched) uranium product. Because the uranium from the mills was used for both nuclear weapons and nonweapons purposes, the resulting 11e(2) byproduct material is allocated into both nuclear weapons and nonweapons categories. The material is allocated according to how much uranium was used, overall, for various purposes (nuclear weapons program, naval fuel, research reactors or commercial reactors), taking into account all historic AEC uranium purchases (including uranium purchases from sites where DOE is responsible for remediation, other U.S. mill tailing sites, and foreign mill tailing sites). In this analysis, the same allocation is applied to all mill tailing sites, regardless of when the mills operated. This allocation is accurate to within ten percent. It does not take into account that some uranium was recycled for other purposes.

Table 3-4. 11e(2) Byproduct Material Resulting from Nuclear Weapons Production

Remediation Complete

Site	State	Type	Nuclear Weapons (m^3)	Nonweapons (m^3)	Total (m^3)
Falls City	TX	UMTRA	2,900,000	1,500,000	4,400,000
Grand Junction Mill Tailing Site	CO	UMTRA	2,300,000	1,200,000	3,600,000
Old Rifle & New Rifle (2 sites)	CO	UMTRA	2,100,000	1,100,000	3,200,000
Ambrosia Lake	NM	UMTRA	1,900,000	1,000,000	2,900,000
Mexican Hat	UT	UMTRA	1,400,000	750,000	2,100,000
Salt Lake City	UT	UMTRA	1,400,000	720,000	2,100,000
Durango	CO	UMTRA	1,300,000	670,000	1,900,000
Riverton	WY	UMTRA	900,000	480,000	1,400,000
Shiprock	NM	UMTRA	800,000	420,000	1,200,000
Monument Valley	AZ	UMTRA	470,000	250,000	720,000
Lakeview	OR	UMTRA	460,000	250,000	710,000
Tuba City	AZ	UMTRA	390,000	210,000	600,000
Gunnison	CO	UMTRA	360,000	190,000	550,000
Naturita	CO	UMTRA	270,000	150,000	420,000
Green River	UT	UMTRA	190,000	100,000	290,000
Spook	WY	UMTRA	160,000	84,000	240,000
Canonsburg	PA	UMTRA	110,000	60,000	170,000
Lowman	ID	UMTRA	64,000	34,000	98,000

Remediation Not Complete

Site	State	Type	Nuclear Weapons (m^3)	Nonweapons (m^3)	Total (m^3)
Maybell	CO	UMTRA	1,700,000	930,000	2,700,000
Monticello Remedial Action Project	UT	Non-UMTRA	1,300,000	690,000	2,000,000
Slick Rock Union Carbide & North Continent (2 sites)	CO	UMTRA	320,000	120,000	440,000
Niagara Falls Storage Site	NY	Non-UMTRA	200,000	0	200,000
Weldon Spring Site	MO	Non-UMTRA	160,000	0	160,000
Bowman	ND	UMTRA	64,000	34,000	98,000
Belfield	ND	UMTRA	29,000	15,000	44,000
Middlesex Sampling Plant	NJ	Non-UMTRA	17,000	9,300	27,000
Edgemont Vicinity Properties *	SD	UMTRA	15,000	8,000	23,000
Fernald Environmental Management Project	OH	Non-UMTRA	11,000	0	11,000
Grand Junction Projects Office	CO	Non-UMTRA	690	370	1,000
Other Nonweapons Sites	N/A	Non-UMTRA	0	56,000	56,000

** DOE is responsible for vicinity properties only; the Tennessee Valley Authority owns and remediated the former uranium mill site in Edgemont in the late 1980s.*

Notes:

(1) Data compiled from the Environmental Restoration Core Database, May 1996 and GAO/RCED-96-37. (See Endnotes c and d).

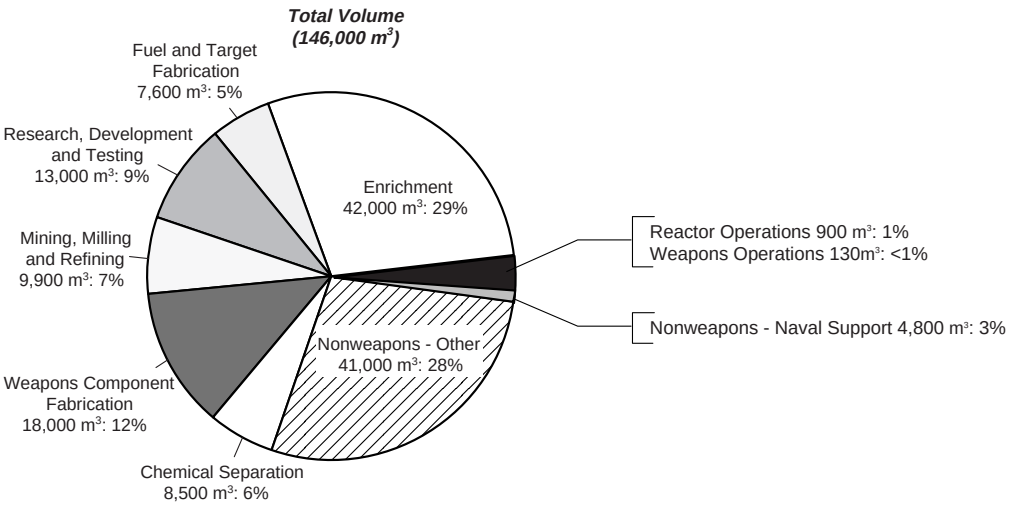
(2) Waste volumes are calculated subject to the limitations listed in Endnotes g, i, and k.

(3) Waste category asssignments are made in accordance with the methods explained in Endnote r.

(4) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnote v.

(5) Status indicates whether remedial actions at the site have been completed. For UMTRA Project sites, "Complete" signifies only that surface cleanup is finished.

Figure 3-12. Mixed Low-level Waste Volume Categorized by Process



Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; the Environmental Restoration Core Database, May 1996; and GAO/RCED-96-37. (See Endnotes a, c, and d).
(2) Waste volumes are calculated subject to the limitations listed in Endnotes g, i, and k.
(3) Waste category asssignments are made in accordance with the processes explained in Endnote r.
(4) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the methods set forth in Endnote v.

has been stabilized. The remaining 11e(2) byproduct material is scheduled to be stabilized in the next few years.

In the past, uranium mill tailings were considered useful as a construction material and were used extensively on public and private property in many communities near the ore processing sites. These locations where tailings were used for construction purposes or where they were carried by wind or water are known as "vicinity properties."

In addition to mill tailings, 11e(2) byproduct materials resulted from the processing of imported high-grade pitchblende ores. These ores, containing uranium at concentrations 100 times greater than domestic ores, produced a smaller volume of residues. However, these residues contain much higher concentrations of radium-226, thorium-230, radon, and other radionuclides than those from processing domestic ores.

The mining, milling, and refining sites managing 11e(2) byproduct material are typically different from those involved in the other seven weapons process categories. The facilities and processes used are similar to those in other mining operations and involve large-scale outdoor facilities. Most sites managing 11e(2) byproduct material were not originally owned by the Department or its predecessors. Instead, they were owned and operated by companies that processed either government-owned or company-owned uranium and uranium ore. The 11e(2) byproduct materials are present at government and privately-owned uranium and thorium refining plants and ore storage and waste disposal sites in several western states as well as in Ohio, Missouri, New York, New Jersey, and Pennsylvania.

Private companies manage 11e(2) byproduct material at sites subject to Title X of the Energy Policy Act of 1992. Electric companies purchased much of the uranium (and thorium) produced at these sites for commercial nuclear power generation. However, the Atomic Energy Commission (AEC) also purchased some from Title X sites for weapons production and other purposes. DOE established the portion of 11e(2) byproduct material attributed to AEC purchases in accordance with the Energy Policy Act of 1992. This volume of 11e(2) byproduct material is not included in the total volumes presented in Table 3-3 because DOE is not managing it. However, it is comparable in size to the volume managed by DOE (see Table 3-4).

During the active production cycle of the nuclear weapons complex, DOE predecessors purchased between two and three times as much uranium from the Title X sites as was purchased from sites in the UMTRA Project.

Mixed Low-level Waste

Mixed waste is waste that contains both hazardous waste subject to RCRA, and source, special nuclear, or byproduct material subject to the AEA.[11] Although mixed waste was formally defined by statute in 1992, regulators recognized that it required special management many years earlier. The Department first started managing mixed low-level waste as a separate waste type in the 1980s.

Some mixed waste is addressed in the high-level waste and TRU subsections. However, mixed low-level waste is considered separately from other low-level waste because the presence of RCRA-regulated constituents is a major factor in determining how it is managed. In contrast, decisions for treatment and disposal of high-level waste and TRU are based primarily on radiological rather than chemically hazardous characteristics.

Mixed low-level waste is generated during a broad spectrum of processes and activities including equipment maintenance, materials production, cleaning, environmental restoration, facility deactivation and decommissioning, and the treatment or handling of low-level waste and other waste types.

Table 3-5. Mixed Low-level Waste by Matrix

Physical Matrix	Volume (m^3)
Inorganic Sludges	27,000
Solidified Homogeneous Solids	25,000
Soil/Gravel	13,000
Metal Debris	9,000
Organic Debris	9,000
Heterogeneous Debris	7,800
Aqueous Liquids/Slurries	5,100
Inorganic Particulates	3,500
Unknown/Other Solids	3,200
Organic Liquids	2,000
Unknown/Other Debris	2,000
Elemental Hazardous Metals	1,000
Inorganic Nonmetal Debris	900
Unknown/Other Inorganic Homogeneous Solids	820
Lab Packs	480
Reactive Metals	410
Salt Waste	370
Organic Sludges	170
Unknown/Other Inorganic Debris	130
Organic Particulates	120
Batteries	110
Unknown/Other Matrix	100
Paint Waste	86
Unknown/Other Organic Homogenous Solids	64
Final Waste Forms	34
Compressed Gases/Aerosols	31
Elemental Mercury	11
Unknown/Other Liquids	11
Organic Chemicals	4
Beryllium Dust	3
Inorganic Chemicals	2
Unknown/Other Homogeneous Solids	1
Explosives/Propellants	<1

Notes:
(1) Data compiled from the Mixed Waste Inventory Report (MWIR) Data System, October 1995.
(2) Waste category asssignments are made in accordance with the processes explained in Endnote r.
(3) Mixed waste inventories not recorded in the MWIR, including some waste resulting from the DOE Environmental Restoration Program, are not included in the physical matrix analysis.

The Department manages about 146,000 cubic meters of mixed low-level waste. About 69 percent is from weapons production activities, 3 percent from NNPP support activities, and 28 percent from other nonweapons activities (Figure 3-12). The weapons production process categories that produced the most mixed low-level waste are enrichment (29 percent of the Department's mixed low-level waste), component fabrication (12 percent), and weapons RD&T (9 percent). About 20 percent of the Department's mixed low-level waste is attributed to the other five weapons production process categories.

The radioactive component of mixed low-level waste is similar to the component in low-level waste. This waste is generally much less radioactive than high-level and TRU waste and can contain a broad spectrum of radionuclides, depending on the source of the waste. Based on the radioactive content of low-level waste managed at the same sites where mixed low-level waste is managed, it is likely that fewer than 2.4 million curies are present in DOE mixed low-level waste. Although DOE sites generally maintain more detailed data on the radioactive content of the mixed low-level waste inventory, this data has not been compiled at a nationwide level.

DOE tracks the composition of mixed low-level waste by assigning each waste stream to one or more of over 100 treatability groups. The groups take into account the physical matrix of the waste form, the presence of hazardous constituents and characteristics, and the radiological characteristics of the waste.

[11] *Mixed waste is defined in the Federal Facility Compliance Act, a 1992 amendment to RCRA.*

Twenty-eight thousand drums of low-level mixed waste await treatment in a storage yard at the K-25 Plant. These drums contain sludge from settling ponds that received waste from a plating facility that served the uranium enrichment plant. The drums corroded prematurely when a 1987 waste-stabilization project failed to follow guidelines for combining low-level mixed waste with cement. *K-1417 Drum Storage Yards, Pond Waste Management Project, Oak Ridge, Tennessee. January 10, 1994.*

Table 3-6. Mixed Low-level Waste Resulting from Nuclear Weapons Production

Site	State	Nuclear Weapons Volume (m^3)	Nonweapons Volume (m^3)
K-25 Site	TN	26,000	13,000
Rocky Flats Environmental Technology Site	CO	14,000	0
Y-12 Plant	TN	14,000	0
Portsmouth Gaseous Diffusion Plant	OH	11,000	7,000
Savannah River Site	SC	7,300	0
Los Alamos National Laboratory	NM	6,600	0
Paducah Gaseous Diffusion Plant	KY	6,400	0
Idaho National Engineering Laboratory	ID	6,400	19,000
Hanford Site	WA	5,900	490
Fernald Environmental Management Project	OH	3,500	0
Lawrence Livermore National Laboratory	CA	460	0
Nevada Test Site	NV	300	0
Pantex Plant	TX	130	0
Mound Plant	OH	110	0
Oak Ridge National Laboratory	TN	91	2,900
Sandia National Laboratories/New Mexico	NM	75	0
Reactive Metals Incorporated, Ashtabula	OH	67	0
Sandia National Laboratories/California	CA	1	0
Nonweapons Sites	Various	0	900

Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; the Environmental Restoration Core Database, May 1996; and GAO/RCED-96-37. (See Endnotes a, c, and d).

(2) Waste volumes are calculated subject to the limitations listed in Endnotes i and k.

(3) Waste category asssignments are made in accordance with the processes explained in Endnote r.

(4) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the methods set forth in Endnotes t and u.

The major categories of treatability groups, which identify the physical waste matrix, are presented in Table 3-5.

Hazardous constituents present in mixed low-level waste include toxic heavy metals, organic and halogenated organic chemicals, cyanides, inorganic chemicals and elements, explosive compounds, and corrosive chemicals and solutions. Some mixed low-level waste contains both RCRA-regulated hazardous constituents and PCBs regulated under TSCA.

The storage, treatment, and disposal of mixed low-level waste is subject to state and federal RCRA regulations. Mixed low-level waste generally is not disposed of at DOE sites. Instead, DOE stores mixed low-level waste at its sites, and the waste is treated either at DOE or commercial sites. Some mixed low-level waste has been disposed of commercially. (The commercially disposed mixed low-level waste is not included in the totals presented in this report.) Decisions for the future disposal of mixed low-level waste at DOE sites have not yet been made.

In the past several years, mixed low-level waste has been generated or stored at approximately 40 sites. The number of sites varies because some sites sporadically generate small quantities that are promptly treated to render the waste nonhazardous, thereby eliminating the need for storage. Mixed low-level waste from weapons production is managed at 18 sites in 11 states. Six of the weapons production sites also manage mixed low-level waste from nonweapons activities. Nonweapons sites managing mixed low-level waste include ten sites managed under the NNPP, and several small sites and laboratories that play small or no roles in weapons production (Table 3-6).

Hazardous Waste

Hazardous waste is defined under RCRA, its implementing regulations in 40 CFR Parts 260 to 279, and corresponding state regulations. A material is a hazardous waste under RCRA only if it meets the definition of a solid waste. A solid waste is considered to be hazardous if it is either listed in the regulations as a hazardous waste or exhibits a characteristic of corosivity, ignitability, reactivity, or toxicity.

Hazardous waste is managed differently from other waste types handled by DOE. Because hazardous waste does not contain a radioactive component, the Department can more easily release it for private-sector treatment and disposal. After release by DOE, this waste is treated, if necessary, by incineration and other technologies, and the residues, which sometimes are no longer hazardous, are disposed of in landfills. Some DOE hazardous waste is also recycled. This waste is not considered a legacy from nuclear weapons production because no long-term monitoring or management of the waste by the Department is expected.

Prior to offsite release, the Department stores and characterizes hazardous waste to comply with RCRA regulations and to verify that it does not contain radioactive material. The Department also recycles some hazardous waste into usable products. In either case, DOE generally does not store hazardous waste for a long time.

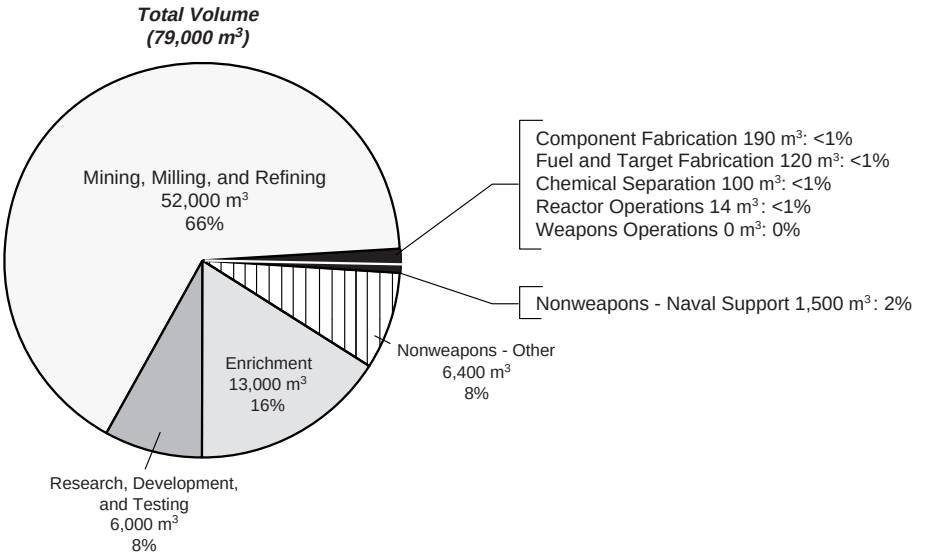
The Department began handling hazardous waste as a distinct waste type in the 1980s. Prior to the regulation of hazardous waste, DOE disposed of some waste at its production sites. Hazardous waste disposal sites are part of the legacy of environmental contamination managed by the Department described in Chapter 4.

Other Waste

Some DOE waste does not fit into one of the previously defined categories because of its chemical and radiological composition. The following waste has been included in this category:

- PCBs and PCBs mixed with radioactive waste, that are subject to TSCA but are not also subject to RCRA. (Some of this waste is classified as mixed low-level waste if it contains other RCRA-regulated hazardous constituents or because it is managed in a state where polychlorinated biphenyls are subject to state RCRA programs.)

Figure 3-13. Other Wastes Managed by DOE Categorized by Process



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; the Environmental Restoration Core Database, May 1996; and GAO/RCED-96-37. (See Endnotes a, c, and d).

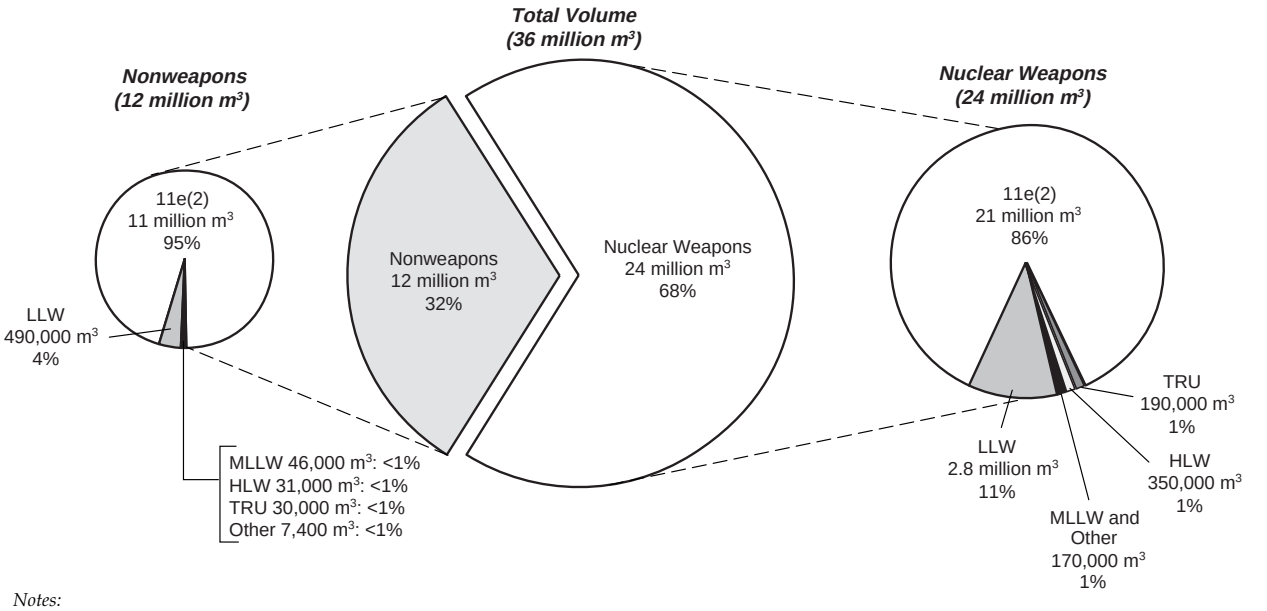
(2) Waste volumes are calculated subject to the limitations listed in Endnotes g, i, and k.

(3) Waste category asssignments are made in accordance with the processes explained in Endnote r.

(4) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the methods set forth in Endnote v.

Radioactively-contaminated asbestos removed from buildings that processed uranium for the Manhattan Project. *Downtown St. Louis FUSRAP site, Missouri. January 29, 1994.*

Figure 3-14. Total DOE Waste Volume Categorized by Waste Type



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; Mixed Waste Inventory Report (MWIR) Data System, October 1995; Environmental Restoration Core Database, May 1996; GAO/RCED-96-37; and Contaminated Media/Waste Database, 1993. (See Endnotes a, b, c, d, and e).

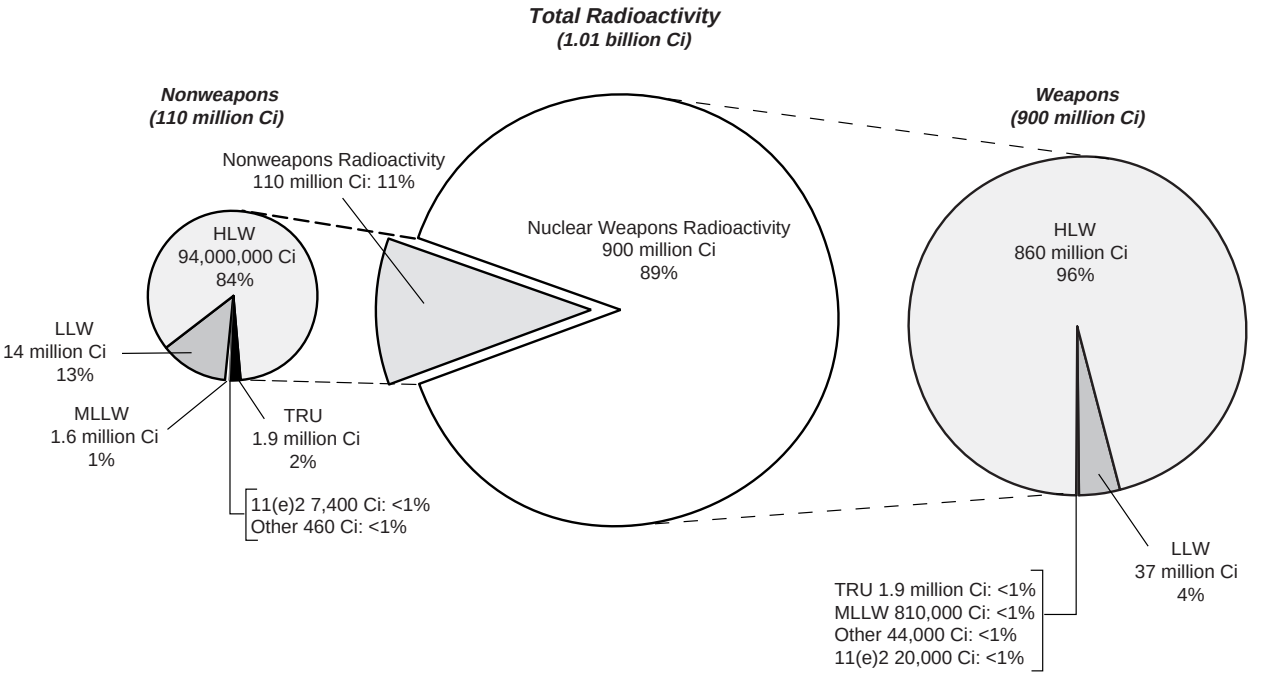
(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, g, h, i, j, and k.

(3) Eadioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, p, and q.

(4) Waste category assignments are made in accordance with the methods outlined in Endnote r.

(5) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnotes t and u.

Figure 3-15. Total DOE Waste Radioactivity Categorized by Waste Type



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; Mixed Waste Inventory Report (MWIR) Data System, October 1995; Environmental Restoration Core Database, May 1996; GAO/RCED-96-37; and Contaminated Media/Waste Database, 1993. (See Endnotes a, b, c, d, and e).

(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, g, h, i, j, and k.

(3) Eadioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, p, and q.

(4) Waste category assignments are made in accordance with the methods outlined in Endnote r.

(5) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnotes t and u.

Table 3-7. Other Category Wastes Resulting from Nuclear Weapons Production

Type	Site	State	Nuclear Weapons Volume (m^3)	Nonweapons Volume (m^3)
Asbestos	Reactive Metals Incorporated, Ashtabula	OH	16	0
Mixed 11e(2)	Middlesex Sampling Plant	NJ	24,000	0
	Weldon Spring Site Remedial Action Project	MO	20,000	0
PCB	Kansas City Plant	MO	24	0
Radioactive Asbestos	Weldon Spring Site Remedial Action Project	MO	7,500	0
	Los Alamos National Laboratory	NM	3,900	0
	K-25 Site	TN	900	450
	Paducah Gaseous Diffusion Plant	KY	260	170
	Savannah River Site	SC	140	0
	Y-12 Plant	TN	110	0
	Portsmouth Gaseous Diffusion Plant	OH	98	64
	Rocky Flats Environmental Technology Site	CO	41	0
	Mound Plant	OH	16	0
	Pantex Plant	TX	3	0
	Lawrence Livermore National Laboratory	CA	1	0
	Sandia National Laboratories/New Mexico	NM	<1	0
	Sandia National Laboratories/California	CA	<1	0
	Nevada Test Site	NV	<1	0
	Nonweapons Sites	Various	0	62
Radioactive PCBs	K-25 Site	TN	5,400	2,700
	Paducah Gaseous Diffusion Plant	KY	4,500	3,000
	Portsmouth Gaseous Diffusion Plant	OH	2,100	1,400
	Los Alamos National Laboratory	NM	2,100	0
	Y-12 Plant	TN	150	0
	Hanford Site	WA	88	8
	Rocky Flats Environmental Technology Site	CO	71	0
	Grand Junction Projects Office	CO	46	0
	Lawrence Livermore National Laboratory	CA	1	0
	Nonweapons Sites	Various	0	87

Notes:
(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995, and the Environmental Restoration Core Database, May 1996. (See Endnotes a and c).
(2) Waste volumes are calculated subject to the limitations listed in Endnotes i and k.
(3) Waste category asssignments are made in accordance with the processes explained in Endnote o.
(4) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the methods set forth in Endnotes t and u.

- Asbestos and low-level waste asbestos that is not subject to RCRA. (Some of this waste is classified as mixed low-level waste if it contains other RCRA-regulated hazardous constituents or because it is managed in a state where asbestos is subject to state RCRA programs.)
- 11e(2) byproduct material that has been mixed with a hazardous waste subject to RCRA (known as mixed 11e(2) byproduct material).

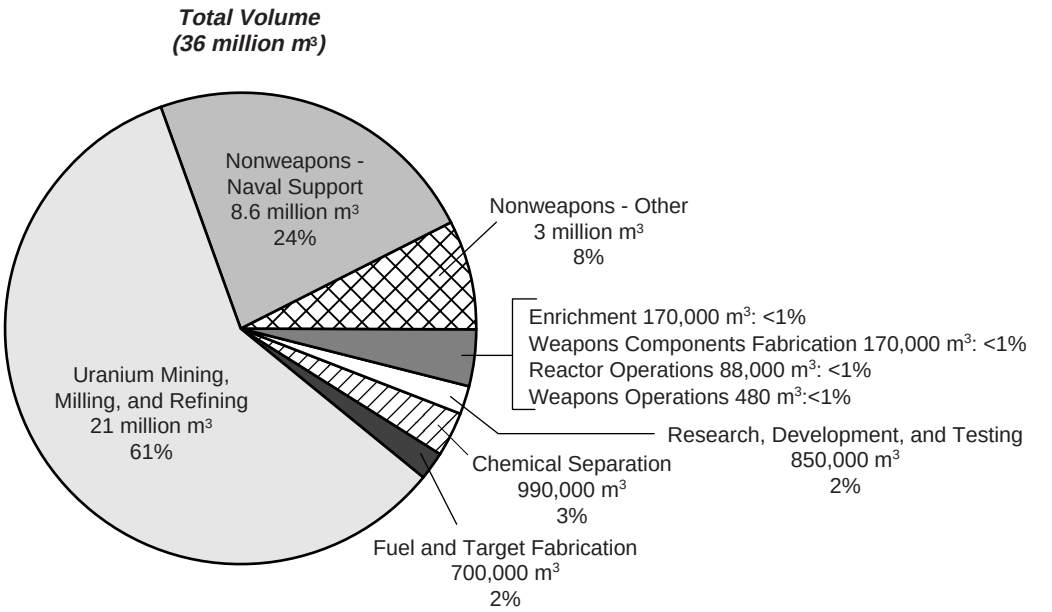
DOE manages about 79,000 cubic meters of these types of waste at about 30 sites, including 19 sites involved in weapons production. This includes 14,000 cubic meters of radioactive asbestos, 22,000 cubic meters of radioactive PCBs, and 44,000 cubic meters of mixed 11e(2) byproduct material.[12] A small amount (40 cubic meters) of nonradioactive asbestos and PCBs also is included in this category. All of the nonradioactive waste and mixed 11e(2) byproduct material is the result of weapons production. The mixed 11e(2) byproduct material is attributed entirely to uranium mining, milling, and refining.

About 94 percent of the radioactive asbestos and 67 percent of the radioactive PCBs also are the result of nuclear weapons production (Table 3-7). When combined, about 16 percent of this waste is the result of enrichment, 66 percent from uranium mining, milling, and refining, eight percent from RD&T, two percent from activities supporting the NNPP, and eight percent from other nonweapons activities (Figure 3-13).

The two sites where mixed 11e(2) material is located are the Middlesex Sampling Plant and Weldon Spring Site (Table 3-7). The radioactive asbestos is located primarily at Weldon Spring Site and Los Alamos National Laboratory. The radioactive PCBs are located primarily at the three uranium enrich-

[12] *See footnote 10.*

Figure 3-16. Total DOE Waste Volume Categorized by Process



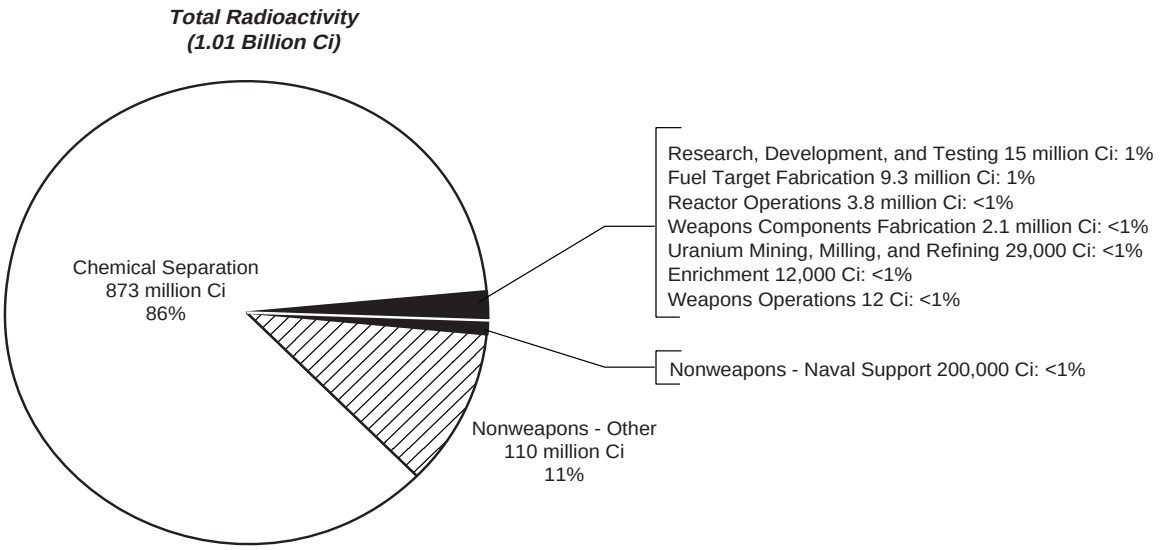
Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; Mixed Waste Inventory Report (MWIR) Data System, October 1995; Environmental Restoration Core Database, May 1996; GAO/RCED-96-37; and Contaminated Media/Waste Database, 1993. (See Endnotes a, b, c, d, and e).

(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, g, h, i, j, and k.

(3) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnotes s, t, u, v, and w.

Figure 3-17. Waste Radioactivity Categorized by Process



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; Mixed Waste Inventory Report (MWIR) Data System, October 1995; Environmental Restoration Core Database, May 1996; GAO/RCED-96-37; and Contaminated Media/Waste Database, 1993. (See Endnotes a, b, c, d, and e).

(2) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, p, and q.

(3) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnotes s, t, u, v, and w.

ment sites (Paducah, Portsmouth, and K-25) and Los Alamos National Laboratory. The portion of this waste that resulted from nuclear weapons production is presented in Table 3-7.

Results

Figures 3-14 and 3-15 present the relative volumes of the major waste categories and amounts of radioactivity they contain. They show that the largest volume is 11e(2) byproduct material (Figure 3-14), whereas most of the radioactivity is in the high-level waste (Figure 3-15).

The total DOE waste legacy includes 36 million cubic meters of waste. Overall, 89 percent of the volume of the DOE waste legacy is 11e(2) byproduct material and 9 percent is low-level waste; the remaining waste categories only comprise about 2 percent of the waste legacy. The distribution of radioactivity in the waste, however, is very different. Radioactivity in high-level waste is 94 percent, 5 percent in low-level waste, and only about 1 percent of the radioactivity is found in the remaining waste categories.

Approximately two-thirds of the legacy of waste managed by the Department was generated from nuclear weapons production. Some waste has been generated as a result of other DOE programs in basic research, nuclear power research, and other applied research and development activities. Additionally, some waste was generated as a result of producing nuclear fuel for the NNPP (or was directly produced by the NNPP)[13] and commercial nuclear power reactors.

By volume, about 68 percent of the 36 million cubic meter waste legacy is due to nuclear weapons production activities, and the remaining 32 percent to nonweapons activities (Figure 3-16). By volume, 61 percent of the waste legacy came from uranium mining, milling, and refining for weapons production.

Advanced waste water treatment facility under construction. *Fernald Environmental Management Project, Ohio. December 28, 1993.*

[13] *Of the waste attributed to supporting the NNPP program, only a small fraction has actually been generated directly by the NNPP. The majority came from supporting activities, such as uranium mining, milling, refining, and enriching uranium. Most mining and milling occurred at commercially-owned and -operated sites that were later transferred to DOE for cleanup. The enrichment took place at the DOE gaseous diffusion plants.*

Table 3-8. Waste Volume and Radioactivity (Stored and Disposed)

Site Name	State	Nuclear Weapons Volume (m^3)	Nuclear Weapons Radioactivity (Ci)	Nonweapons Volume (m^3)	Nonweapons Radioactivity (Ci)
Falls City	TX	2,900,000	870	1,500,000	460
Grand Junction Mill Tailing Site	CO	2,300,000	2,500	1,200,000	1,300
Old Rifle & New Rifle	CO	2,000,000	1,700	1,100,000	890
Ambrosia Lake	NM	1,900,000	1,600	1,000,000	880
Maybell	CO	1,700,000	310	930,000	160
Mexican Hat	UT	1,400,000	990	746,000	530
Salt Lake City	UT	1,400,000	1,100	720,000	610
Monticello Remedial Action Project	UT	1,300,000	1,300	690,000	710
Durango	CO	1,300,000	1,300	670,000	680
Riverton	WY	900,000	300	480,000	160
Hanford Site	WA	850,000	330,000,000	83,000	28,000,000
Savannah River Site	SC	820,000	500,000,000	10,000	42,000,000
Shiprock	NM	800,000	580	420,000	310
Fernald Environmental Management Project	OH	490,000	8,100	0	0
Nevada Test Site	NV	480,000	9,800,000	0	0
Monument Valley	AZ	470,000	35	250,000	20
Lakeview	OR	460,000	82	250,000	43
Tuba City	AZ	390,000	350	210,000	190
Gunnison	CO	360,000	170	190,000	90
Slick Rock Union Carbide & North Continent	CO	320,000	58	120,000	21
Naturita	CO	270,000	20	150,000	10
Los Alamos National Laboratory	NM	260,000	1,800,000	0	0
Niagara Falls Storage Site	NY	200,000	2,200	0	0
Weldon Spring Site Remedial Action Project	MO	190,000	unavailable	0	0
Green River	UT	190,000	22	100,000	12
Y-12 Plant	TN	170,000	11,000	0	0
Spook	WY	160,000	104	84,000	55
Idaho National Engineering Laboratory	ID	140,000	56,000,000	150,000	11,000,000
Canonsburg	PA	110,000	360	60,000	190
K-25 Site	TN	100,000	69	48,000	34
Bowman	ND	64,000	3	34,000	2
Lowman	ID	64,000	16	34,000	8
Middlesex Sampling Plant	NJ	51,000	unavailable	0	0
Portsmouth Gaseous Diffusion Plant	OH	36,000	64	23,000	42
Belfield	ND	29,000	3	15,000	1
Latty Avenue Properties	MO	24,000	unavailable	0	0
Rocky Flats Environmental Technology Site	CO	20,000	86,000	0	0
Paducah Gaseous Diffusion Plant	KY	16,000	77	10,000	50
Edgemont Vicinity Properties	SD	15,000	unavailable	8,000	unavailable
Lawrence Livermore National Laboratory	CA	10,000	19,000	0	0
Mound Plant	OH	9,200	1,400,000	0	0
Oak Ridge National Laboratory	TN	7,400	130,000	240,000	4,300,000
Sandia National Laboratories/New Mexico	NM	3,300	9,300	0	0
Reactive Metals Incorporated, Ashtabula	OH	2,900	30	0	0
Grand Junction Projects Office	CO	780	unavailable	370	unavailable
Pantex Plant	TX	480	12	0	0
Pinellas Plant	FL	66	30,000	0	0
Kansas City Plant	MO	33	1	0	0
Sandia National Laboratories/California	CA	27	13	0	0
Nonweapons Sites	Various	0	0	98,000	26,000,000
	TOTAL	24,000,000	900,000,000	12,000,000	110,000,000

Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; Mixed Waste Inventory Report (MWIR) Data System, October 1995; Environmental Restoration Core Database, May 1996; GAO/RCED-96-37; and Contaminated Media/Waste Database, 1993. (See Endnotes a, b, c, d, and e).

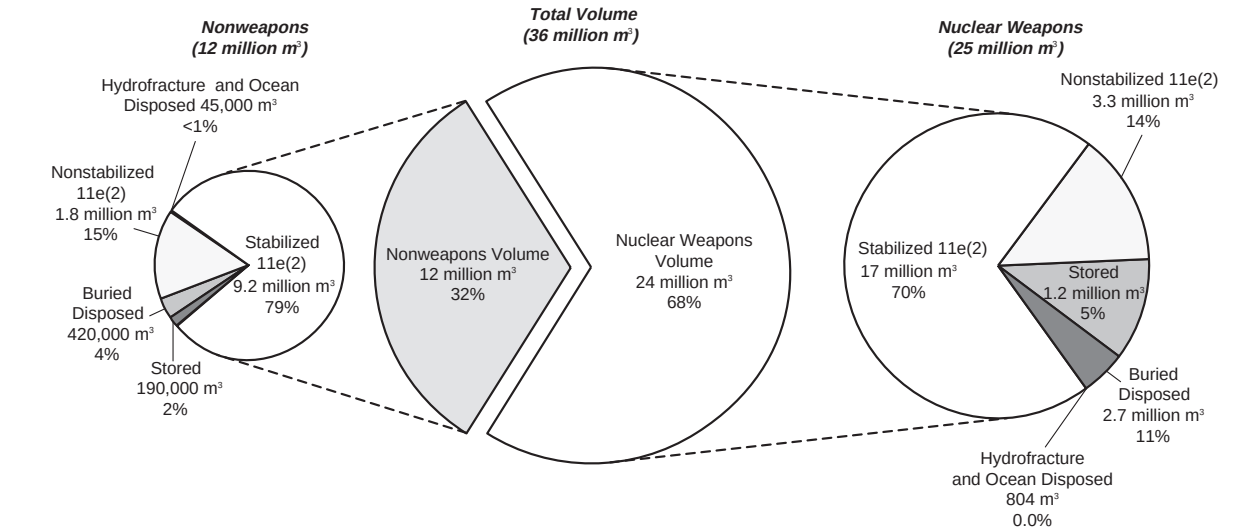
(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, g, h, i, j, and k.

(3) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes j, k, l, m, n, o, p, and q.

(4) Waste category assignments are made in accordance with the process explained in Endnote r.

(5) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the process set forth in Endnotes s, t, u, v, and w.

Figure 3-18. Waste Volume Categorized by Disposition



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; Mixed Waste Inventory Report (MWIR) Data System, October 1995; Environmental Restoration Core Database, May 1996; GAO/RCED-96-37; and Contaminated Media/Waste Database, 1993. (See Endnotes a, b, c, d, and e).

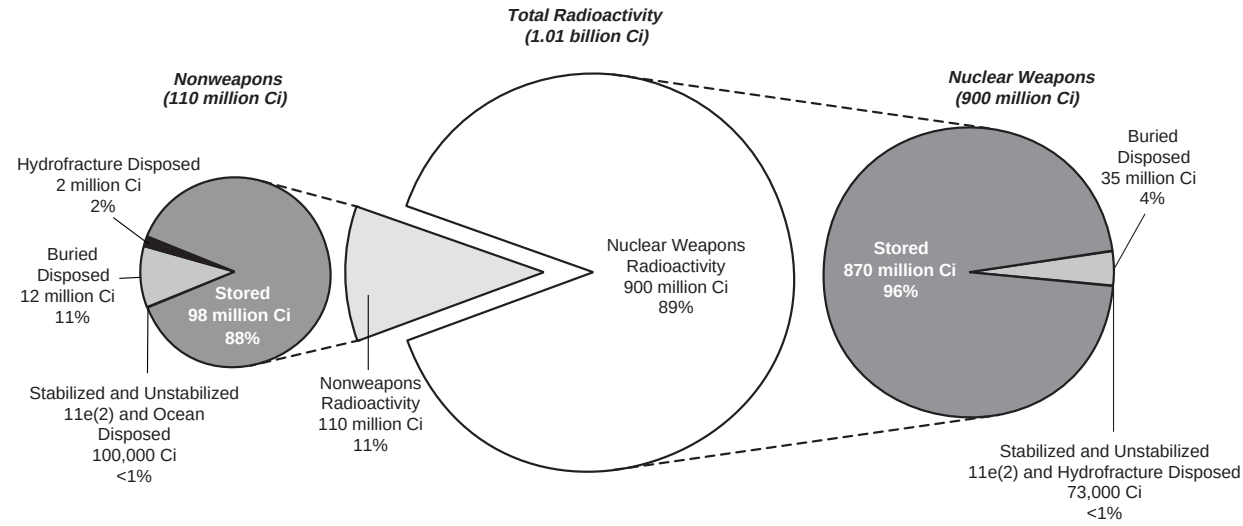
(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, g, h, i, j, and k.

(3) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, p, and q.

(4) Waste category assignments are made in accordance with the process explained in Endnote r.

(5) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the methods set forth in Endnotes t and u.

Figure 3-19. Waste Radioactivity Categorized by Disposition



Notes:

(1) Data compiled from the Integrated Data Base (IDB) Report, Revision 11, September 1995; Mixed Waste Inventory Report (MWIR) Data System, October 1995; Environmental Restoration Core Database, May 1996; GAO/RCED-96-37; and Contaminated Media/Waste Database, 1993. (See Endnotes a, b, c, d, and e).

(2) Waste volumes are calculated subject to the limitations listed in Endnotes f, g, h, i, j, and k.

(3) Radioactivity content of waste is calculated subject to the limitations listed in Endnotes l, m, n, o, p, and q.

(4) Waste category assignments are made in accordance with the process explained in Endnote r.

(5) Nuclear weapons and nonweapons allocations and allocations to individual weapons production process categories are determined subject to the methods set forth in Endnotes t and u.

Activities supporting the NNPP attributed for 24 percent. The remaining fifteen percent is attributed to nonweapons activities (8 percent); nuclear weapons production resulted primarily from chemical separation (3 percent), RD&T (2 percent), and fuel and target fabrication (2 percent).

The waste legacy from nuclear weapons production is found at 49 sites in 22 states (Table 3-8). The largest volumes are found in Colorado (35 percent), Utah (18 percent), New Mexico (12 percent), and Texas (12 percent). Nonweapons waste also is managed at 32 of the nuclear weapons sites and 30 additional sites. The sites where the largest waste legacy volumes are located are Falls City, Texas; Grand Junction, Colorado; and Rifle, Colorado. These sites were commercially-owned and -operated uranium mining and milling sites that were closed and later transferred to the Department for cleanup.

Overall, the waste legacy contains 1.01 billion curies. By radioactive content, 89 percent of the waste legacy is due to nuclear weapons production, less than 1 percent to activities supporting the NNPP, and 11 percent is attributed to other nonweapons programs (Figure 3-17). By radioactive content, 86 percent of the waste came from chemical separations for nuclear weapons production. The remaining 3 percent attributed to weapons production resulted primarily from RD&T (1.4 percent), and fuel and target fabrication (0.9 percent).

The largest amounts of radioactivity in the waste legacy are found at the DOE sites that performed chemical separation: 54 percent at Savannah River Site in South Carolina, 35 percent at Hanford site in Washington, seven percent at Idaho National Engineering Laboratory in Idaho and two percent West Valley Demonstration Project in New York. The radioactivity at West Valley Demonstration Project is attributed to nonweapons activities. (Table 3-8).

More than 81 percent of the waste volume has already been disposed or stabilized, and about 18 percent is in storage or is unstabilized (Figure 3-18). In contrast, approximately 96 percent of the radioactivity is contained in stored waste (Figure 3-19).

METHODOLOGY AND DATA

Data Sources

Data on the waste legacy were gathered primarily from previously compiled data sources; new data collection was limited to verifying existing data. The data were collected from the following sources:

- *Integrated Data Base Report – 1994: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, U.S. Department of Energy, DOE/RW-0006, Rev. 11, September 1995 ("1995 IDB"). The 1995 IDB was used as a basis for determining the volumes and radioactivity levels of all high-level waste, and much of the Department's TRU waste, low-level waste, mixed low-level waste, 11(e)2 byproduct material, and other waste. The IDB is updated annually.
- *1995 National Mixed Waste Inventory Report Data System* (electronic data), October 25, 1995 ("1995 MWIR"). This database was originally issued in a report in response to the Federal Facility Compliance Act, a 1992 amendment to RCRA that granted states the authority to enforce hazardous waste management regulations against federal agencies and required the Department to coordinate mixed waste treatment planning with the states. Since its creation, the database has been updated twice, in May 1994 and October 1995. MWIR data was used as a basis for determining the weapons process category or nonweapons activity for much mixed low-level waste, low-level waste, TRU waste, and high-level waste and was used as a source of some mixed low-level waste volume data not included in the IDB.
- *Uranium Mill Tailings Cleanup Continues but Future Costs are Uncertain*, (GAO/RCED-96-37), U.S. General Accounting Office, December 1995. The Department of Energy provided the data used in this report. It contains estimates of the quantities of 11e(2) byproduct material present at the 24 inactive uranium milling sites managed by DOE under UMTRCA Title I.

Methodology for Attributing Uranium Enrichment Waste

The uranium enrichment plants at K-25, Paducah, and Portsmouth were constructed and initially operated to produce enriched uranium for nuclear weapons. The plants produced highly enriched uranium for weapons components as well as low enriched uranium for use in plutonium production reactors. (Only Portsmouth and K-25 produced highly enriched uranium.) Beginning in the 1950s, small amounts of enriched uranium were used for other purposes such as naval propulsion reactors, research reactors, and nuclear power plants. In the 1960s, production of highly enriched uranium for nuclear weapons was discontinued and production shifted to serve other needs. During the 1970s and 1980s, the vast majority of the enrichment was conducted for commercial nuclear power reactors and smaller amounts were produced for naval reactors and research reactors.

Waste and contamination at the enrichment plants began to accumulate in the 1940s and 1950s and continued into the 1980s when the plants became subject to current environmental standards. However, some waste and contamination resulted from discrete activities over known time periods. Because most waste and contamination at the plants was the result of activities supporting many purposes, but the plants might never have existed if not for the weapons program, the portion of the uranium enrichment environmental legacy attributable to nuclear weapons production is difficult to calculate. Many factors should be considered, and there is no single "correct" approach. The allocation used in this report is only an estimate; it is similar to the approach developed to allocate the costs for decontamination and decommissioning of the plants.

Under this approach, waste or contaminated media that resulted from enrichment or plant support activities performed solely for nuclear weapons purposes are allocated entirely to weapons production. Waste and contamination resulting from activities performed for both nuclear weapons production and nonweapons purposes are divided, and a portion is allocated to each category. The allocation is based on two factors: the amount of separative work units used to enrich the uranium for each purpose (separative work units are a measure of plant output) and the timing of the activity. Timing is accounted for by attributing a larger portion of the waste and contamination legacy to the earlier years of plant operation. This is intended to account for the period during which plant operation is on a "learning curve" and may have more inadvertent waste generation and releases. It also recognizes that the cost to clean up initial waste and contamination is greatest, while the cost to clean up additional waste and contamination is only incremental. The "weighting" of waste and contamination to early operations is determined by assuming a "half-life" of seven years. The seven-year half-life approach allocates 50 percent of the contamination to the first seven years of plant operation, 25 percent to the next seven years, 12.5 percent to the next seven years, etc. (A seven-year period was selected for this analysis because it was the median value used as an example in the enrichment plant decontamination and decommissioning cost allocation study. Other half-life values would result in different allocations, but in most cases, most waste and media would still be allocated to nuclear weapons production.)

This allocation approach has some weaknesses. It considers the output over the entire operating life of the plant. In fact, releases resulting in incremental contamination decreased greatly during the 1980s as the plants became subject to current environmental regulations. Additionally, this approach does not take into account that some releases may have occurred or increased as facilities aged. The effect of incorporating these factors into the approach has not been determined, but they would tend to offset each other. Another weakness of the approach is that some waste or contamination resulted from discrete releases rather than releases over the life of the plant.

While the allocation used in this report has a reasonable basis and is adequate for this analysis, it is only an estimate. Further study or more refined assumptions could improve its accuracy.

- *Environmental Restoration Core Database*, U.S. Department of Energy, revised May 1996 (Core Database). The Department uses this database as an internal management tool. The database contains information on the quantity and composition of stored waste managed by the Office of Environmental Restoration. It also contains information on facility deactivation and decommissioning activities conducted by the Office of Environmental Restoration.

In addition to these sources, some data on the radioactive content of 11e(2) byproduct material at some sites was compiled from DOE's Environmental Restoration Contaminated Media/Waste Database, a precursor to the Core Database currently used to monitor activities in the Environmental Restoration program. To supplement and verify the data from these sources, several other sources were used. However, the 1995 IDB, the MWIR, and Core Database were the primary data sources.

Data Issues and Assumptions

The primary data sources for waste are the IDB, Rev.11, September 1995; the MWIR, October 1995; the Environmental Restoration Core Database, May 1996; a GAO report on the UMTRA Project (GAO/RCED-96-37), December 1995; and the Environmental Restoration Contaminated Media/Waste Database.

Some volumes of disposed waste are also counted as environmental media. Waste not managed by DOE, including tailings at UMTRCA Title II sites and disposed waste at Maxey Flats, has not been included in the analysis. Remediation waste classified as sanitary, demolition debris, or "NA" also is excluded.

Much of the radioactivity in waste containing relatively low levels of radioactivity was not included in the curie inventory. This waste includes most environmental restoration waste, and some stored low-level waste, mixed low-level waste, 11e(2) byproduct material, and "other" waste. Furthermore, only certain radionuclides have been included for TRU waste and 11e(2) byproduct material. Radioactive decay in disposed TRU waste has not been accounted for. Remote-handled TRU waste mixed with contact-handled mixed waste is classified as remote-handled.

Allocations of high-level waste to nuclear weapons programs are based on the eventual use of the products resulting from the reprocessing.

Allocations of mixed low-level waste, TRU waste, and low-level waste at multipurpose sites production are based on, or extrapolated from, waste stream descriptions in the MWIR.

Allocations of waste from uranium milling and enrichment are estimated based on the various uses of the uranium products. Ocean-disposed waste is assumed to have resulted from nonweapons activities.

Limitations, Uncertainties, and Assumptions

Several important gaps are present in the waste data sources that are currently available. In some cases, these data exist, but the Department has not compiled them in a uniform format at a national level. In other cases, the data have not yet been developed. To fill some of the data gaps, reasonable assumptions were made where possible. In some cases, the quality of data was inadequate even for reasonable assumptions. No attempt was made to quantify such portions of the waste legacy. The assumptions were made in four general areas:

• *Waste Categories* – Criteria used by the Department to categorize waste today are different from criteria used in the past. As criteria changed, the Department and its predecessors recharacterized disposed and stored waste according to the new criteria in only a limited number of cases. In this analysis, the Department classified waste according to how the waste is counted in existing inventory data. That is, no collection or reevaluation of detailed waste characterization data were attempted. For some of these wastes, data on the presence of hazardous constituents are incomplete, and data on the concentrations of TRU radionuclides are often not sufficient to determine whether the total TRU concentration is above or below the current 100 nanocurie per gram threshold. The inventory amounts of stored waste also do not always recognize that some containers are partially empty, and some remote-handled TRU waste is stored in containers combined with contact-handled waste (rendering the entire container remote-handled). Because of the relatively large volume of TRU and low-level waste categorized according to old criteria, the volume of waste that could fall under another category under current categorization criteria also could be large and could affect the results of this analysis.

• *Radioactive Content of Waste* – Data on the radioactive content of much TRU waste, low-level waste, 11e(2) byproduct material, mixed low-level waste, and other waste are incomplete. For TRU waste, some radioactivity data did not take into account radionuclide decay or included only certain isotopes. The radioactive content of some waste, including some low-level waste, mixed low-level waste, and other waste, was not available and was estimated on a site-by-site basis using data on the radioactive content of other low-level waste at the sites. Where comparative data on the radioactive content were not available, the radioactive content of the waste was set at zero. The radioactive content of environmental restoration waste was not estimated except for mill tailings and certain other 11e(2) byproduct materials. For these materials, only data on the radium-226 present was available. Because the vast majority of radionuclides in DOE-managed waste are found in high-level waste, the concentrations assigned to waste in the other categories are relatively small and these assumptions did not significantly affect the results of the analysis.

• *Nuclear Weapons Production Process Categories and Nonweapons Activities* – Only limited data were available to determine whether a given waste was the result of weapons production, NNPP

Waste Isolation Pilot Plant. In southwestern New Mexico, DOE has dug a waste repository deep into a 200-million-year-old rock salt formation. Chambers 2,150 feet below the surface will store transuranic waste from chemical separations, pit manufacturing, and plutonium recycling if the Environmental Protection Agency approves disposal in this repository. *WIPP Site, near Carlsbad, New Mexico. February 25, 1994.*

support, or other DOE activities and, if appropriate, to determine the nuclear weapons production process category responsible for waste generation. The key information used to make weapons-nonweapons determinations and to determine which nuclear weapons production process category resulted in the generation of waste was the historical mission of each site where waste was generated. Since most sites performed activities in only a single process category or a few process categories, information on the site's mission was often adequate to determine, with reasonable certainty, how the waste was generated. However, for those sites performing more than one activity (e.g., Hanford, Savannah River Site, and Y-12 Plant), a more detailed analysis was performed that considered other available information, including the location or building in which the waste was generated and the presence of certain signature chemical and radioactive contaminants, from which information on the waste generating process was inferred. For waste at some sites such as Idaho National Engineering Laboratory and Oak Ridge National Laboratory, a generic sitewide allocation was used. At Idaho National Engineering Laboratory, it was assumed that 75 percent of the low-level waste was from nonweapons activities and at Oak Ridge National Laboratory, 97 percent of the waste was assumed to result from nonweapons activities. Special assumptions were made for waste generated at the uranium mill sites and uranium enrichment sites to attribute the waste to weapons production and nonweapons activities. The same estimate of waste was made for all uranium milling, refining and enrichment sites based on how the uranium products from these sites were used. It was assumed that all low-level waste that was disposed at sea resulted from nonweapons activities.

- *Disposed Waste also Counted as Contaminated Environmental Media* – Some volumes of low-level waste and TRU waste disposed of years ago and the soils that surrounded them are now being assessed under the Department's Environmental Restoration Program. Double-counted materials include much of the disposed TRU waste at Idaho National Engineering Laboratory; low-level waste at

Hanford, Savannah River Site, Fernald Environmental Management Project, Los Alamos National Laboratories and Y-12 Plant; and smaller amounts of waste at other sites. DOE sites maintain information on the amounts of material that have been double-counted, but these data have not been compiled on a nationwide basis. The double-counted materials are further described in Chapter 4 (Contaminated Environmental Media). While much of the low-level and TRU waste historically disposed of at DOE sites is being assessed under the environmental restoration program, this material and the surrounding contaminated environmental media associated with the disposal sites make up only a small portion of all contaminated environmental media being assessed by the Environmental Restoration Program.

Information on these and other assumptions, data sources used in cataloging the waste legacy, and other data issues is presented in the endnotes to this chapter, and is summarized here.

SUMMARY

The Department of Energy's waste legacy includes seven fundamental waste categories: high-level waste, TRU waste, low-level waste, mixed low-level waste, 11e(2) byproduct material, hazardous waste, and "other" waste. The waste legacy was generated at numerous sites throughout the complex, primarily at DOE sites. While much of the waste legacy volume has been disposed of or stabilized, much of the radioactivity still must be addressed. Most of the radioactivity in the waste legacy is in the high-level waste from chemical separation and is managed by the Office of Waste Management. The Office of Environmental Restoration manages most of the waste volume in the form of 11e(2) byproduct material from uranium mining and milling.

Much more is known about the waste legacy than the other legacy elements because the quality of data available to quantify the waste legacy are better than those available to quantify other legacy elements. However, there is uncertainty about the characteristics of waste disposed of many years ago.

ENDNOTES

a. *Integrated Data Base Report—1994: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics* (IDB), Rev.11 (DOE/RW-0006), was used as a source for volume data for high level waste, TRU waste, low-level waste, radioactive PCB waste, and some mixed low-level waste managed by the Office of Waste Management, and radioactivity content data for high level waste, TRU waste, and low-level waste managed by the Office of Waste Management. Data on the volume and activity content of stored and disposed low-level waste was compiled from backup tables for the IDB. The current volume and radioactivity content of waste at most sites has changed, in some cases substantially, since these data were compiled but the total amount across all sites has not changed appreciably.

b. *1995 National Mixed Waste Inventory Report System* (electronic data), October 1995, was used as a source for volume data for some mixed low-level waste.

c. Environmental Restoration Core Database, updated as of May 1996, was used as a source for volume data of TRU waste, low-level waste, radioactive PCB waste, mixed low-level waste, non-UMTRA 11e(2) byproduct material, and mixed 11e(2) byproduct material managed by the Office of Environmental Restoration, and radioactivity content data for some UMTRA Project 11e(2) mill tailings. The volume and waste type data were provided to the Core Database from DOE sites and other field locations. These data are subject to revision as data on environmental restoration wastes continue to be compiled.

d. *Uranium Mill Tailings Cleanup Continues, but Future Costs Are Uncertain* (GAO/RCED-96-37) was used as a source for volume data of 11e(2) byproduct material at UMTRA sites. (The Environmental Restoration Core Database, has been revised to include these data.)

e. Office of Environmental Restoration Contaminated Media/Waste Database was used as a source for radioactivity content of 11e(2) mill tailings at the Monument Valley and Shiprock UMTRA sites, the Monticello Mill Site, and the Grand Junction Project Office Site. (The Environmental Restoration Core Database has been revised to include these data.)

f. Stored TRU waste volume data, as compiled in the IDB, measures the total volume of waste packages, not the volume of waste inside the packages. The difference between package volumes and waste volumes is small compared to the total volume of stored TRU waste.

g. Waste volumes do not include 11e(2) byproduct material at UMTRCA Title II commercial mill tailing sites. Waste resulting from weapons production activities is located at these sites, but the sites and waste are not managed by DOE.

h. Some volumes of historically disposed TRU and low-level waste are double-counted as both waste and contaminated environmental media. The waste volumes come from the IDB and correspond to records on the volume of waste buried; the media volumes (in Chapter 4) come from the Environmental Restoration Core Database. The media volumes are estimates of the amount of contaminated material associated with the buried waste.

i. Waste volumes from the Environmental Restoration Core Database that are classified as sanitary, demolition debris, or "NA" are not included because they do not require special management due to their chemical and radiological content.

j. The volume of low-level waste disposed at sea is estimated based on the approximate number of containers and the assumption that all containers were 55-gallon drums.

k. Waste volume figures are rounded. Because of rounding, some numbers may not appear to add correctly.

l. Radioactivity in waste from environmental restoration activities is not included except for the radium-226 content of mill tailings at UMTRA Project sites and K-65 residues at Fernald Environmental Management Project and Niagara Falls Storage Site. (K-65 residues are a specific type of 11e(2) byproduct material.)

m. Some TRU waste packages classified as remote handled contain a mixture of contact-handled and remote-handled waste. Separating such waste into contact- and remote-handled inventories would reduce the amount of remote-handled waste and increase the volume of contact-handled waste.

n. Radioactivity in disposed TRU waste, as compiled in the Integrated Data Base (IDB), does not include buried TRU at Los Alamos National Laboratories and includes the undecayed amount (i.e., amount prior to disposal) of curies in buried TRU at Idaho National Engineering Laboratory, Oak Ridge National Laboratory, and West Valley Demonstration Project. The radioactivity of TRU waste disposed by hydrofracture at Oak Ridge National Laboratory also is undecayed. The current amount of radioactivity in these wastes is less than the undecayed amount reported.

o. Stored TRU waste radioactivity data, as compiled in the IDB, includes selected isotopes which comprise over 99 percent of the radioactivity. Isotope data for contact-handled TRU waste include uranium-238, -235, and -233; plutonium-239, -240, and -242; and thorium-230. Isotope data for remote-handled TRU waste includes strontium-90; yttrium-90; cesium-137; barium-137; europium-152, -154, and -155; cobalt-60; plutonium-241; and curium-244. Other radioisotopes also are present.

p. Radioactivity content of stored mixed low-level waste and some stored low-level waste managed by the Office of Waste Management are extrapolated from other low-level waste radioactivity content data in the IDB. The radioactivity content of some low-level and waste mixed low-level waste is not included where it could not be extrapolated from other site-specific data.

q. Waste radioactivity inventory values are rounded. Because of rounding, some numbers may not appear to add correctly.

r. Waste categorized as high-level waste includes both mixed high-level waste (i.e., high-level waste that contains a hazardous component subject to RCRA) and non-mixed high-level waste. The TRU waste category includes mixed TRU waste, TRU waste containing polychlorinated biphenyls, and TRU waste whose nonradioactive component is not hazardous. Low-level waste containing asbestos or PCBs is categorized as "other" waste, unless there is a hazardous component present in the waste regulated under RCRA. Material at UMTRA Project sites defined as residual radioactive material under Title I of the Uranium Mill Tailings Radiation Control Act of 1978 has the same physical and chemical properties as 11e(2) byproduct material and is categorized as 11e(2) byproduct material. 11e(2) byproduct material that has been mixed with a RCRA-regulated hazardous waste (mixed 11e(2) byproduct material) is categorized as "other" waste.

s. For high-level waste resulting from fuel reprocessing, allocations are based on the eventual use of the products of reprocessing. For example, high-level waste resulting from reprocessing spent Naval fuel to recycle highly enriched uranium for weapons production is allocated to weapons production. For other waste managed as high-level waste, allocations are based on the process (e.g., decontamination) that generated the waste.

t. For TRU waste, low-level waste, mixed low-level waste, and "other" waste, allocations are based on the mission of the site where the waste was generated. For some multiple purpose sites, allocations of TRU waste and mixed low-level waste are based on waste stream descriptions in the MWIR Data System. Allocations of low-level waste and "other" waste are extrapolated from mixed low-level waste allocations. For much waste at Idaho National Engineering Laboratory and Oak Ridge National Laboratory, generic allocations were applied based on the approximate level of historical activities at the sites. For low-level waste at Idaho National Engineering Laboratory, 25 percent of the waste is attributed to nuclear weapons production and 75 percent is attributed to nonweapons activities. For TRU and low-level waste at Oak Ridge National Laboratory, 3 percent of the waste was attributed to nuclear weapons production and 97 percent to nonweapons activities.

u. Waste at uranium enrichment sites is allocated according to the amounts of enriched uranium produced for various purposes (nuclear weapons program, naval reactor fuel, research reactors, commercial reactors), as measured by separative work units, and taking into account when uranium was enriched. The allocation does not take into account that some uranium was recycled for other purposes. (For example, some uranium initially used as Naval fuel was recycled for weapons production.) Historic records may also be available that would allow waste to be allocated based on the specific causes of waste generation. (The amount of waste generated from uranium enrichment and attributed to supporting the NNPP is managed by DOE at the sites where it was generated, stored, and disposed. The NNPP did not generate or manage this waste.)

v. 11e(2) byproduct material at mill tailings sites is allocated according to how much uranium was used, overall, for various purposes (nuclear weapons program, naval reactor fuel, research reactors, commercial reactors), taking into account all Atomic Energy Commission uranium purchases (including uranium purchases from sites where DOE is responsible for remediation, other U.S. mill tailing sites, and foreign mill tailing sites). The same allocation is applied to all mill tailing sites, regardless of when they operated. This allocation does not take into account that some uranium was recycled for other purposes or that uranium produced at different times at certain sites may have been directed to specific weapons or nonweapons programs. (The amount of waste generated from uranium mining and milling and attributed to supporting the NNPP is managed by DOE at the sites where it was generated, stored, and disposed. The NNPP did not generate or manage this waste.)

w. Waste disposed at sea is assumed to have resulted from nonweapons activities. Ocean disposal has been discontinued.